

# Maturity Indices Color Chart and Quality Assessment of Mango (*Mangifera indica* cv. *Mallika*)

<sup>1</sup>Jaman, M. J., <sup>2</sup>Hasan, M. F., <sup>1</sup>Robbani, M., <sup>1</sup>Masumbillah, T. R., <sup>1</sup>Ferdous, K., and <sup>2</sup>Rajib, M. M. R.

<sup>1</sup>Department of Horticulture, Patuakhali Science and Technology University, Bangladesh.

<sup>2</sup>Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh.

DOI: 10.29322/IJSRP.12.07.2022.p12728

<http://dx.doi.org/10.29322/IJSRP.12.07.2022.p12728>

Paper Received Date: 10th June 2022

Paper Acceptance Date: 27th June 2022

Paper Publication Date: 6th July 2022

**Abstract-** Conspicuous color, quality, taste and flavor highly depend on maturity stages of mango which differ with varieties. Both farmers and consumers confused to determine the exact stages with visual estimation due to nonexistence of pricy and arduous colorimeter. An android based mobile software “On Color Measure” (developed by PotatotreeSoft, Version 3.0) was experienced to detect fruit color for maturity indices of “Mallika” mango with physiochemical quality assessment. The dark olive green peel color was marked as earliest physiological maturity (stage-1), while the subsequent maturity stages determined at 2-days intervals as stage-2 (olive), stage-3 (apple green), stage-4 (brown), stage-5 (saddle brown) and stage-6 (dark golden rod color). Fruit quality was measures on physical (peel color, firmness and weight loss) and biochemical (anthocyanin content, titratable acidity, pH, total soluble solids, ascorbic acid, reducing sugar, non-reducing sugar and total sugar) parameters for each stage. At stage-6 (dark golden rod color), pH (4.54), anthocyanin content (470 mg/100g), TSS (23.97%), reducing sugar (5.03%), non-reducing sugar (7.76%) and total sugar (10.80%) were significantly the highest, while titratable acidity (0.45%), ascorbic acid (29.08 mg/100g) were significantly the highest in stage-1 (dark olive green). Firmness and ascorbic acid (Vitamin C) diminished gradually whenever the flesh color turned dark olive green to dark golden rod with the progress of ripening. Total soluble solids and total sugar increased while TA gradually decreased with maturity. Significant relationship between fruit quality and fruit peel color was exhibited. Therefore, stage-1 (dark olive green) might be suitable for the harvesting and stages-6 (dark golden rod color) for the consumption. Moreover, android software along with mobile device could be used by farmers and consumers to detect the deserve maturity of Mallika mango.

**Index Terms-** Color chart, mallika mango, maturity indices, physiochemical quality

## I. INTRODUCTION

Mango (*Mangifera indica* L.) under the family Anacardiaceae is familiar as “king of fruits” (Nunes et al., 2007). It is believed to be originated in South East Asia, Indo Burma region (Mukherjee, 1997; Kothiyal et al., 2021). More than 80 countries

of the world grow 69 species of *Mangifera* genus and mostly restricted to tropical Asia (Gulcin et al., 2004). The leading mango producing countries of the world were India, Pakistan, Mexico, Brazil, Haiti, Philippines and Bangladesh (Ara et al., 2014). In 2020-2021 fiscal year, Bangladesh became the 7<sup>th</sup> largest mango producer country in the world having produced nearly 1.5 million tons (Ahmad, 2022). But the export earning is only 50 thousand US dollar through exporting only 791 tons which is much beyond the top earning countries like Thailand and India (734 and 137 million US dollar, respectively). Several quality assurances are to be emphasize to address boost exporting of mango.

In Bangladesh mango is considered to be the best among indigenous fruits having excellent flavour, attractive fragrance and color, delicious taste and nutritional value (Roy et al., 2011). Mango fruit has a greater health benefit due to the high nutritional value as well as important components. These components are grouped into macronutrients (carbohydrates, proteins, amino acids, lipids, fatty, and organic acids), micronutrients (vitamins and minerals), and phytochemicals (phenolic, polyphenol, pigments, and volatile constituents) by Maldonado-Celis et al. (2019). One cup of mango (225 gm) contains 105 calories, 16.9% CHO, 24% soluble sugar, 76% vitamin C, 25% vitamin A, 11 % vitamin B6, 9 % copper, 7% potassium, 4% magnesium, considerable amount of carotene (the precursor of vit. A), niacin, riboflavin, iron and others (Nilish & Banik, 2005). Although fruit consumed from green to maturity stages, nutritional value varies from variety to variety and developmental stages including mature and ripened stage (Leghari et al., 2013). Being a climacteric fruit, generally mango harvested at mature green stage and ripens up during the marketing as well as export process (transport, storage etc.). Sometimes, these desirous harvesting for higher economic return may result in loss in fruit yield due to earlier harvesting of underdeveloped fruits (Kour et al., 2018). The reduction in post-harvest losses, suitable harvesting stage of fruit (maturity) and optimum ripening conditions to have the best quality and longer shelf life has not been recognized in developing countries (Baloch & Bibi, 2012). However, these maturity indices for harvesting, ripening for quality mango varied with variety to variety (Ara et al., 2014). Determination of exact maturity indices of mango almost difficult due to the “biological variability” between

mangoes from the same batch as mentioned by Penchaiya et al. (2020).

The color of the fruit peel is an important factor of mango maturation indices and quality, which changes from green to orange, yellow, or red flush, depending on the type of cultivar. This green color attributed to chlorophylls (Sudhakar et al., 2016; Nelson & Cox, 2017), where blue-green for chlorophyll a and yellow-green for chlorophyll b in a 3:1 ratio (Medlicott et al., 1986; Saengnil & Kaewlublae, 1997; Lee & Schwartz, 2005). Hunter (L\*, a\*, b\*) is most commonly used color system for measuring color (Manasa et al., 2019), which is illusory in farmers and consumers' level. Therefore, based on our previous study on Amrapali mango variety (Jaman et al., 2017), we also practiced android based mobile application software namely "On Color Measure" (developed by PotatotreeSoft, Version 3.0) to measure different maturity stages along with physiochemical quality of fruits as to develop a standard maturity color chart of 'Mallika' mango varieties.

## II. MATERIALS AND METHODS

### 2.1 Experimental site

The experiment was carried out at the Postharvest laboratory of Horticulture, Patuakhali Science and Technology University (PSTU), Patuakhali, Bangladesh.

### 2.2 Atmospheric conditions of the laboratory

A digital thermo hygrometer (THERMO, TFA, Germany) was used to regular monitoring of the storage temperature and relative humidity during study. The average minimum of 24.0°C and maximum of 33.0°C were recorded during study. The minimum and maximum relative humidity were 82% and 90%, respectively.

### 2.3 A brief description of plant materials

Mallika is a hybrid from a cross of Neelum and Dashehari. Its fruit is medium large in size, oblong elliptical in shape and cadmium yellow in colored fruit having good keeping quality. Average fruit weight is 410 g. It is a mid-season variety.

### 2.4 Selection of the fruits

Uniform size, shape and colored 100 healthy fruits were selected from a tree of Mallika located at the residential area of PSTU.

### 2.5 Fruit harvesting

Fruits were harvested when they attained in light green color with uniform size and shape having apparently no defect. These were cut off with a sharp knife keeping about 2 cm stalk intact and carefully transferred to the Horticulture Laboratory.

### 2.6 Experimental design

Completely randomized design (CRD) with three replications was followed to conduct this study.

### 2.7 Determination of physical characteristics

#### Weight loss

Fruit weight was measured in every alternative day by weighing individual fruit with a top pan electronic balance (Model-668ALED, RFL). Weight loss was intended using the following formula:

$$\text{Citric acid (\%)} = \frac{\text{Titre (mL)} \times \text{NaOH normality (0.1 M)} \times \text{Vol. made up (50 mL)} \times \text{Citric acid eq. weight (64 g)} \times 100}{\text{Volume of sample for titrate (5 mL)} \times \text{Weight of sample taken (10 g)} \times 1000}$$

$$\text{Weight loss (\%)} = \frac{F_1 - F_2}{F_1} \times 100$$

Where,  $F_1$  = Initial weight of the fruit

$F_2$  = Weight of fruits at various ripening stages

#### External peel color

The peel color of fruits was determined using an Android based Software namely "On Color Measure" (developed by "PotatotreeSoft", Version 3.0) with an aim pointer equipped. "On Color Measure" is an amazing way to recognize color by using the camera of mobile device. It affords to store the color information in the easiest way. Color sensed at the stem end, equatorial region and blossom end of each face of the fruit and mean value was calculated. Detected peel color was stored in chromaticity values of Red (R\*), Green (G\*) and Blue (B\*). The camera was aimed and cross hair pointer clicked to capture the target point with little movement. The information displayed to dashboard was captured with Grab button. All detailed color information including RGB, HSV, color names, hex code and screen image was saved for the future enquiry.

#### Firmness

Firmness of mango was sensed by the method mentioned by Hassan (2006). Touch feeling was rated as 1-5, where, 5= mature hard, 4= sprung, 3= between sprung and eating ripe, 2= eating ripe and 1= over ripe.

### 2.8 Determination of chemical characteristics

#### Anthocyanin content

The total anthocyanin content of peel and the carotenoid content of pulp were determined by the method of Sims & Gamon (2002). Five gram of pulp were properly homogenized with 10 ml (1:2) 80% cold acetone (80:20 vol:vol, pH = 7.8) and then centrifuged at 800 rpm at 4°C for 4 min. The supernatant was diluted with additional acetone to make the volume of 5 ml. The absorbance of the extract was perceived 529 nm and 650 nm wave length with double beam spectrophotometer (Dynamica HALO-DB-20S UV-VIS Double Beam Spectrophotometer). Content of anthocyanin was counted by using the following formula:

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

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

Where,  $A_x$  is the absorbance of the extract solution at respective wave length.

#### Titratable acidity

Titratable acidity (TA) was determined according to the method by Ranganna (1979). Ten gram of pulp tissue was homogenized with 40 ml of distilled water using a kitchen blender for two minutes and filtered through a Whatman filter paper No.2. Five milliliters of the filtrate was transferred into a 100 ml conical flask with 1% phenolphthalein indicator solution (two drops). The sample was titrated with 0.1 M sodium hydroxide (NaOH) solution until the color changed to pink and persistent at least 15 seconds. The titre volume was recorded and the result was expressed as percentage citric acid by using Ranganna (1979) formula:

## pH

The remaining filtrates after TA estimation was used to sense the pH of the fruit pulp. A glass electrode pH meter (PHS-25 Precision pH/mV meter, LIDA Instrument) was used for the purpose. 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.

## Total soluble solids concentration (TSS)

With the help of a digital refractometer (BOE 32195, BOECO Germany) remaining filtrates from TA estimation was used to measure the TSS. The refractometer was calibrated with distilled water each time before any measurement. Only 1-2 drops filtrate was placed on the prism glass and noted the refractometer reading as TSS, which multiplied by dilution factor to obtain an original % TSS. To overcome error from temperature, each reading was standardized to a temperature of 20°C by adding 0.28% to obtain % TSS at 27°C.

## Ascorbic acid (Vitamin C)

Ascorbic acid was determined with dye method as expressed by Ranganna (1979). Ten gram of pulp tissue was homogenized with 40 mL of 3% cold metaphosphoric acid (HPO<sub>3</sub>) using a blender for two minutes and filtered through Whatman filter paper no. 2. Five milliliters of aliquot was titrated with the indicator dye 2, 6-dichlorophenol-indophenol (DCIP or DPIP) until the filtrate changed to pink color at least for 15 seconds persistency. The titre volume of dye solution used was recorded and ascorbic acid content was calculated as follows:

$$\text{Ascorbic acid (mg /100 g)} = \frac{\text{Titre (mL)} \times \text{dye factor} \times \text{vol. made up} \times 100}{\text{Aliquot used for estimation (5 mL)} \times \text{sample weight (10 g)}}$$

Five milliliter standard ascorbic acid solution + 5 ml of 3% cold HPO<sub>3</sub> together was incorporated to standardize the dye. Then titrated with DICP as to convert into pink color at least for 15 seconds. The dye factor was calculated as follows:

$$\text{Dye factor} = \frac{0.5}{\text{Titre (mL)}}$$

## Total sugar

Sugar content of fruit was estimated by the following procedures described by the Lane & Eynon (1923).

## Standardization of Fehling's solution

Fehling's solution A and B was mixed together to 50 ml volume in a beaker. From this mixture, only ten milliliter was taken into a 250ml conical flask and 25ml distilled water was added to it. A burette was loaded with standard sugar. On the other hand, mixed solution in conical flask was heated on a hot plate until fully boiled. Then three drops of methylene blue indicator solution were added to mixed solution and titrated by standard sugar solution. We stopped whenever decolorization of the indicator occurred. Fehling's factor was calculated as below:

$$\text{Fehling's factor (g of sugar)} = \frac{\text{Titre} \times 2.5}{100}$$

## Preparation of sample

Mixing of 50 ml fruit juice + 100 ml of distilled water + 5ml of neutral led acetate solution was then kept for ten minutes for homogenized. Then the intermingled was transferred to a 250 ml volumetric flask and filled up to the mark with distilled water. The solution was then filtered.

## Estimation of reducing sugar

Ten ml of mixed Fehling's solution was intermingled with distilled water to reach the volume up to 250 ml in a conical flask. Filtrated pure juice was loaded into a burette, while conical flask was on a hot plate for boiling. Whenever boiling started, 3-5 drops of methylene blue indicator dropped into the boiled solution and titrated with burette juice. Decolorization of indicator was the end point of titration. Percent reducing sugar was expressed as follows:

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

Where, F= Fehling's solution  
D= Dilution  
T= Titre,  
W= and Weight of sample

## Estimation of total invert sugar

Fifty ml of filtrated pure solution + 5 ml citric acid + 50 ml distilled water poured into a 250 ml capacity conical flask which was boiled for inversion of sucrose and cooled. Consequently, transferred to a 250 ml capacity volumetric flask to neutralized with 1N NaOH using an indicator namely phenolphthalein. Additional distilled water was added to fulfill up to the mark of flask. Then the mixed Fehling's solution was titrated with previously revealed procedure of invert sugar (reducing sugar). Finally, total invert sugar was projected as follows:

## Estimation of non-reducing sugar

Non-reducing sugar was estimated by using the following formula:

$$\text{Non-reducing sugar (\%)} = \text{Total invert sugar (\%)} - \text{Reducing sugar (\%)}$$

## Statistical analysis

By implementing a statistical programme MSTAT-C recorded data on different parameters were analyzed following CRD with 3 replications (Gomez & Gomez, 1984). All means were envisioned and the analysis of variances (ANOVA) were compared using Duncan's Multiple Range Test (DMRT) at 1% levels of significance.

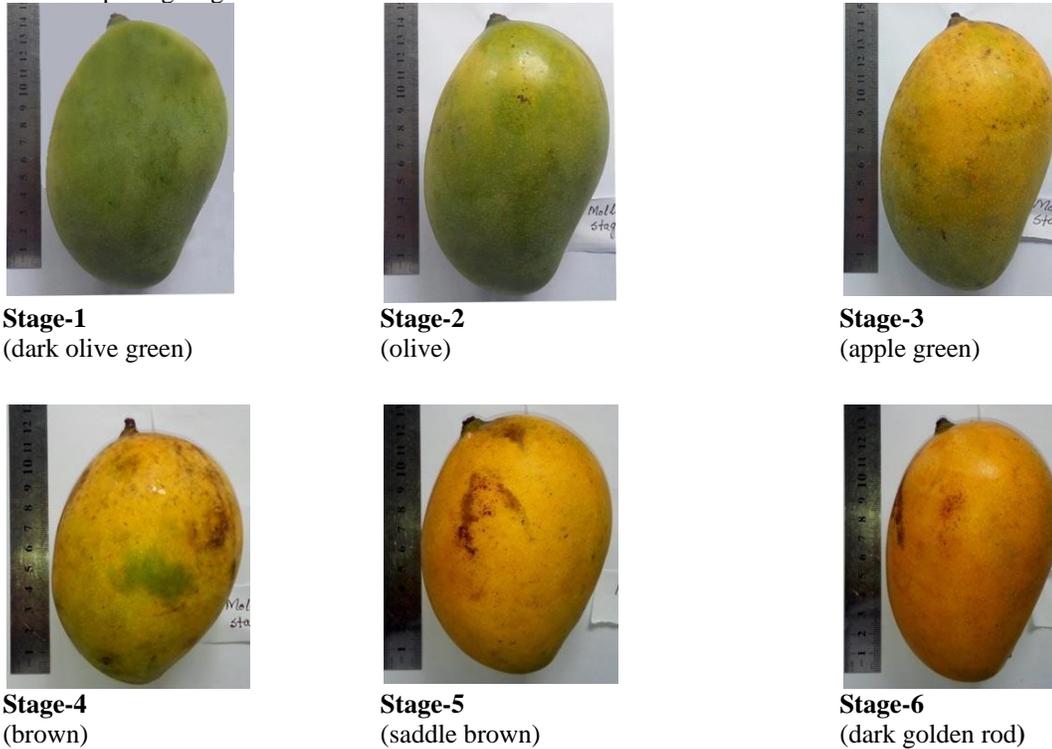
## III. RESULTS AND DISCUSSIONS

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

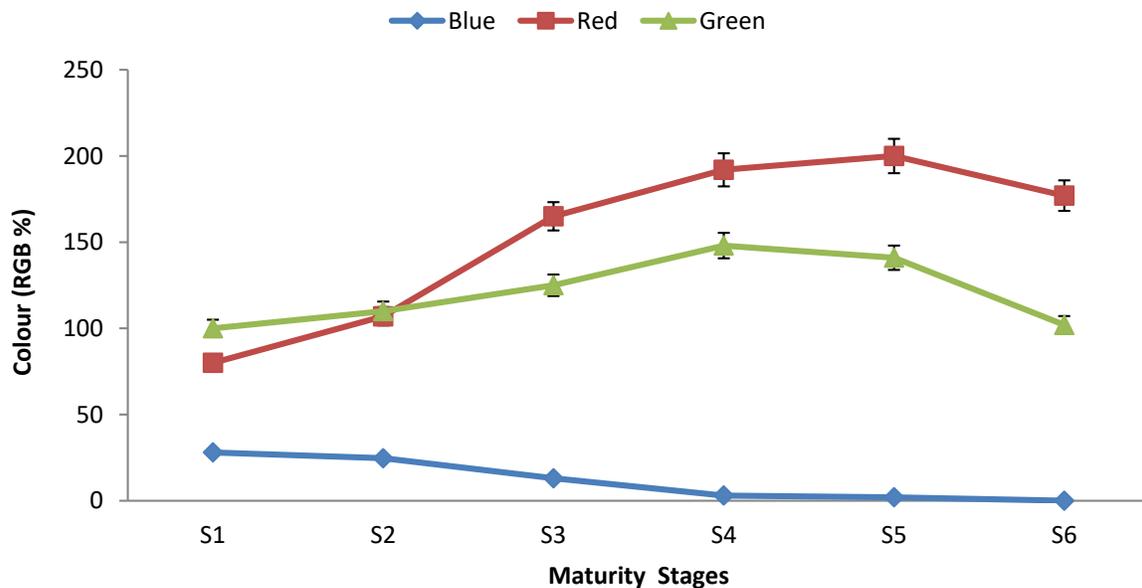
#### Peel color

Color is one of the most important criteria of quality of most fruits. The changes in color of mango peel dark olive green to dark

golden rod are the most obvious changes which occur during different ripening stages of fruits.



**Figure 1. Different maturity stages of Mallika mango**



**Figure 2. Colour (RGB %) of Mallika at different maturity stages.**

At early stage, green (G) color is prominent and gradually decreased with maturity. At stage-1, RGB % was 80, 100 and 28 respectively. The red (R) color contain was highest at stage-5 (RGB %- 200, 141, 2). Then value of RGB % was decreasing due to deterioration of color pigment.

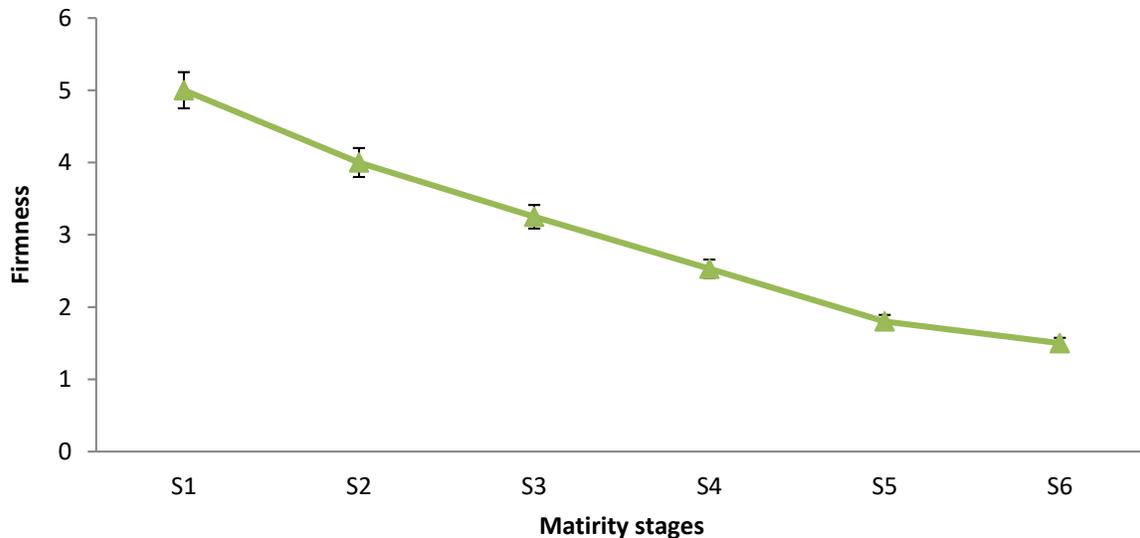
At stage-1, an abundance of chlorophyll masks the carotenoids expressing dark olive green. These carotenoids are unmasked when chlorophyll degraded during ripening leading to

yellow appearance (Charoenchongsuk et al., 2015). Chlorophyll degradation is attributed to ethylene, which up-regulates the de novo synthesis of the enzyme chlorophyllase in the peel during ripening (Mir et al., 2001; Choo, 2018). Besides, the peroxidase activity able to open the porphyrin ring, oxidative system, pH change may loss the green color (Kato & Shimizu, 1985, Doreyappy-Gowda & Huddar, 2001).

### Firmness

Hardness considered as important post-harvest quality of fruits at storage. The firmness is changed obviously during storage of mango. These changes in firmness were witnessed from stage-

1 to stage-6 which afflicted the pulp become softer and sweeter as a consequence of starch conversion to sugar in a higher ratio with pleasant aroma and color.



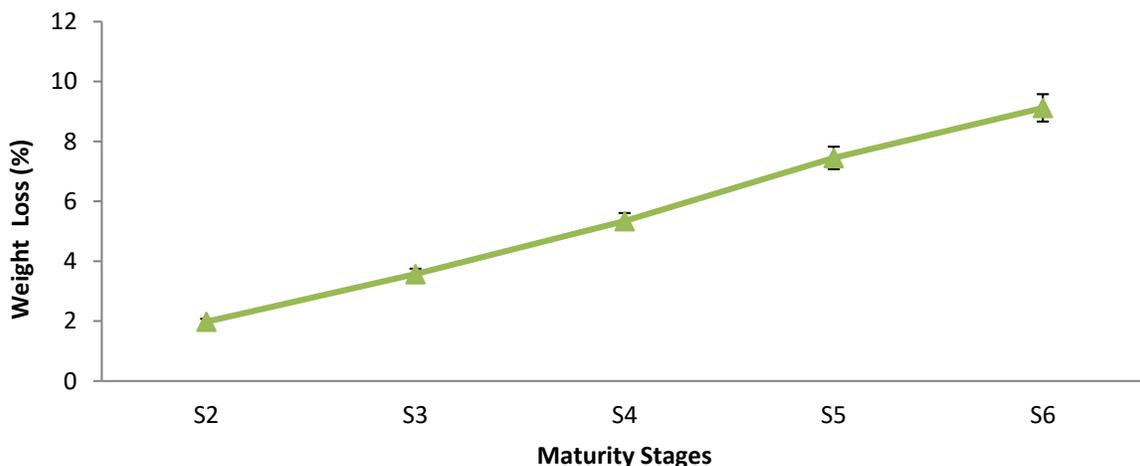
**Figure 3. Firmness at different maturity stages of Mallika mango.**

Significant variation was comprehended relating to firmness of mango pulp at different stages (Figure 3). The highest firmness was recorded at stage-1 (5), then the firmness of mango was decreased may be due to deviations in cell wall composition, pectin, cellulose and hemicellulose along with carbohydrates structures (Goncalves et al. 2006). The cell wall digested by pectinesterase, polygalacturonase, and other enzymes (Narain et al., 1998). The trend of decrease in firmness might be also due to loss of moisture by transpiration and respiration, conversion of

organic and inorganic metabolites. As a consequence, middle lamella of cell wall, its strength and degrade cell to cell bonding led to cellular swell as well as reduce puncture force of firmness (Sogvar et al., 2016; Arnon et al., 2014).

### Weight loss

The changes in weight loss are one of the important indicators for maintaining the quality of fruits. The weight loss is shown in Figure 4. Weight loss of fruits were varied from 1.98 – 9.12%, which increased with the time being (ripening).



**Figure 4. Percent weight loss of Mallika mango was perceived at different maturity stages**

The highest weight loss was 9.12% at their stage-6. The weight loss of the fruits was befallen due to the upshot of water

loss from the fruits, microbial dwindling and harsh storage environment like uncomplimentary temperature and humidity.

High temperature boosted the weight loss but low temperature declined it during ripening and storage. Such weight loss during ripening might be from water loss consequences of the fruits through various metabolic processes alike respiration and transpiration (Kour et al., 2018).

### 3.2 Biochemical characteristics at different stages of the fruits

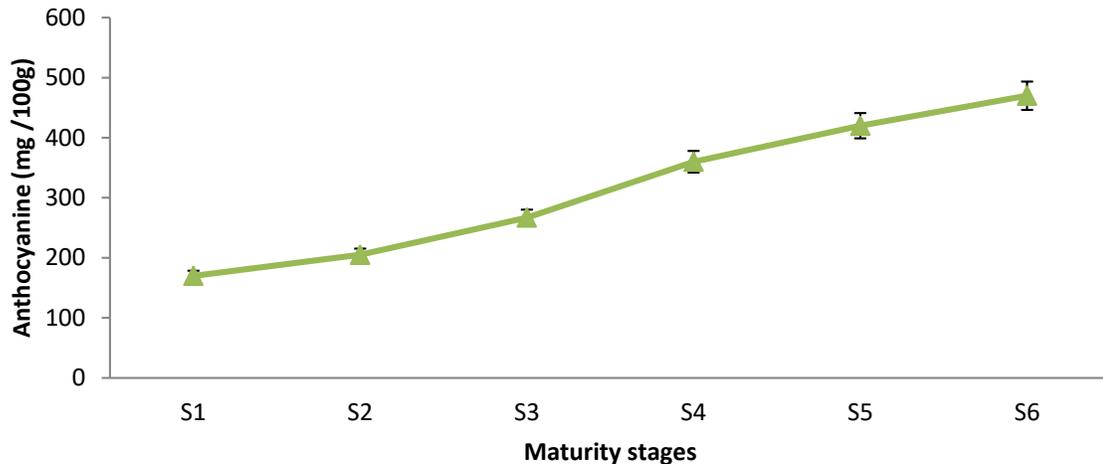


Figure 5. Anthocyanin content in Amrapali and Mallika mango varieties

Mango fruits rich in carotenoid compounds. These molecules are lipid-soluble stains contributing to yellow-orange colors of mango fruit and red colors when mango is ripe, although the reddish color of peel in several varieties is due to anthocyanins (Masibo & Qian, 2008; Sivankalyani et al., 2016). Anthocyanins are a group of phenolic compounds in the plant kingdom and they exhibit good antioxidant properties (Takeoka & Dao, 2002). Chromoplast is the place where carotenoids are sited which sometime masked by chlorophyll and non-photosynthetic plant tissues (Tanaka et al., 2008; Choo, 2018). Meanwhile, carotenoids harvest light as a accessory pigment and as in the chloroplast antioxidants converting the triplet chlorophyll to the singlet ground state in the chloroplast (Arafat, 2005; Alcaíno et al., 2016). This transition of chlorophyll during ripening stages increases carotenoids in mango which varied from variety to variety (Ellong et al., 2015; Haque et al., 2015).

#### Titratable acidity

The titratable acidity content of fruits significantly diverse among the maturity stages during study period (Table 1). At earlier maturity stage-1, the highest titratable acidity was encountered (0.45%), which was followed by stage- 2 (0.42%) and stage-3 (0.40%). Then the titratable acidity was declined towards completely ripen. Subsequently, the lowest titratable acidity (0.26%) was discovered from stage-6. A gradual decrease in titratable acidity with the advancement of maturity might be due to the transformation of citric acid into sugars and their additional deployment in metabolic process (Velez-Rivera et al. 2014;). A similar result was also reported by Kour et al. (2018) which is the corroboration of this study.

#### pH of fruit juice

#### Total anthocyanin content

Anthocyanin increased with ripening stages. Ripe mango peel gratified more anthocyanin at stage-6 and that was 470 mg/100 g. Meanwhile, it was only 170 mg/100g in early maturity stage-1 (Figure 5).

The pH of the fruit pulp under the study varied from 3.96-4.54 contingent on maturity stages (Table 1). The lowest pH (2.80) came across at earlier green stage-1, which was followed by stage-2 (2.90) and stage-3 (3.08). Then pH was amplified with the maturity progress and ripening and significantly the highest pH (4.09) was noted at stage-6. This variation of pulp pH was mainly due to the alteration of citric acid and ascorbic acid into sugar and other products during ripening physiology (Rathore et al., 2007; Baloch & Bibi, 2012).

#### TSS of fruit juice

The TSS content of fruit under the study varied from 15.52-23.97% contingent on maturity stages (Table 1). The lowest TSS (15.52%) was documented at early green stage-1, which was followed by olive green stage- 2 (16.50%) and apple green stage-3 (18.63%). Then the TSS was increased up to the highest maturity stage-6 and the highest TSS (23.97%) was recorded at stage-6. Ripened mango fruit is a major source of sugars (glucose, fructose, and sucrose) and other carbohydrates such as starch and pectins (Bello-Pérez et al., 2007). Starch remains in higher quantity during green stage which hydrolyzed to glucose (Derese et al., 2017). On the other hand, pectin also remains in abundant quantity in green mango which loss molecular weight during ripening (Saleem-Dar et al., 2016). As a consequence of phosphorylation, glucose phosphate enters the hexose phosphate pool and fuels a “futile cycle” of sucrose synthesis and degradation (Geigenberger & Stitt, 1991). that controls the content of glucose, fructose, and sucrose (Moscatello et al., 2011). Thus, glucose, fructose, and sucrose generally increase during ripening (Bernardes et al., 2008). Several researchers also exhibited increased monosaccharides and disaccharides during maturation in different cultivars (Tasneem, 2004; Yashoda et al., 2005).

**Ascorbic acid**

The ascorbic acid within the fruit was varied from 10.19-29.08 mg/100g unlikely to different maturity stages (Table 1). At stage-1, the highest ascorbic acid (29.08 mg) was logged, which was followed by olive green stage- 2 (25.50 mg/100g) and apple green stage-3 (23 mg/100g). Then the ascorbic acid was lessened towards wholly ripening stage-6 and which was the lowest (10.19 mg/100g). Presence of higher amount of vitamin C in less ripen fruit exhibited by Matheyambath et al. (2016) and Hu et al. (2018). These decreased rate with ripening may be due to the involvement of different metabolic pathways such as ethylene, oxalate, and tartrate biosynthesis because vitamin C is a coenzyme of their respective enzymes (Singh et al., 2011).

**Reducing sugar**

The reducing sugar was also varied from 1.90-5.03% as per different maturity stages (Table 1). The lowest reducing sugar (1.90%) was note down from dark olive-green stage-1, which was followed by olive green stage- 2 (2.03%) and apple green stage-3 (4.90%). Then the reducing sugar was boosted abundantly to completely ripen stage-6 where it was chronicled as the highest (5.03%). This steady accumulation of reducing sugar with the advancement of ripening maturity might be due to numerous enzymatic activities.

**Non reducing sugar**

Similar increasing trend in respect of non-reducing sugar was also noticed as the maturity increased which varied from 2.50-

6.20% (Table 1). The lowest non reducing sugar (2.50%) was also tested from dark olive-green stage-1, which was followed by olive green stage- 2 (3.16%) and apple green stage-3 (3.60%). Then the non-reducing sugar was abundant towards complete ripening stage-6 and significantly the highest non reducing sugar (6.20%) was verified at stage-6.

**Total sugar**

The total sugar was fluctuated from 4.40-11.37% based on the progress of maturity toward ripening (Table 1). At dark olive-green stage-1, the lowest total sugar (4.40%) was detected followed by olive green stage- 2 (6.83%) and apple green stage-3 (8.13%). Then the total sugar was encountered enormous in completely ripen stage-6. The highest total sugar (11.37%) was prominent in stage-6. Conversion of all carbohydrates and acids into sugar might be reason of increased total sugar in fully ripen mango. Taste of mango is the combination of sugar and acids where increased sugar with reduced acids is always desired (Kays, 1991; Malundo et al., 2001). Hydrolysis of polysaccharides into soluble sugar for climacteric mango fruits during ripening might be another reason of such higher quantity of total sugar. “Transition of chlorophyll into carotenoids, biochemical conversions of starch into sugar, insoluble protopectin into pectin and loss of organic acid through oxidation altogether are responsible for the increase in sugar and carotenoids” (Campestre et al., 2002; Kays, 1991; Martinez et al., 1997)

**Table 1. Biochemical characteristics at different maturity stages of Mallika**

Maturity stages	TA	TSS	AC	pH	RS	Non-RS	TS
Stage-1	0.45a	15.52d	29.08a	2.79f	1.90d	2.50e	4.40e
Stage-2	0.42ab	16.50cd	25.50b	2.89e	2.03cd	3.16de	5.19de
Stage-3	0.40ab	18.63c	23.00b	3.00d	2.40bc	3.60cd	6.00cd
Stage-4	0.33abc	21.50b	17.00c	3.38c	3.12b	4.13c	7.26c
Stage-5	0.28bc	23.40ab	11.92d	3.91b	4.42a	5.63b	10.06b
Stage-6	0.26c	23.97a	10.13de	4.09a	5.03a	6.20a	10.80a
LSD <sub>(0.01)</sub>	0.084	1.32	2.45	0.02	0.81	0.63	1.42
CV%	13.29	2.87	4.79	8.26	7.55	6.23	13.43
Level of Sig.	**	**	**	**	**	**	**

Means in a column followed by the same letter(s) are not significantly differently at 1% level of DMRT, \*\*= Significant at 1% level of probability, TSS= Total soluble solids concentration, AC=Ascorbic acid, TA= Titratable acidity, RS= Reducing sugar, Non-RS= Non reducing sugar, TS= Total sugar

**IV. CONCLUSIONS**

The physical quality such as color, firmness and percent weight loss were the highest at earlier maturity stage-1 (dark olive green). This stage is suitable for harvesting as to transportation, marketing and exportation purpose from the farmers point of view. All biochemical parameters such as TSS, pH, reducing, non-reducing as well as total sugar content were found promising with decreased TA, vitamin C and increased carotenoids as well as anthocyanins. Therefore, stage-6 (dark golden rod colour) is the

most suitable for consumption. Android based mobile software like “PotatotreeSoft”, Version 3.0 could be alternative of expensive colorimeter for farmers and consumers both. More android software along with different varieties of mango might be practiced in future for the maturity indices for harvesting, transportation, marketing and consumption.

**REFERENCES**

[1] Ahmad, R. 2022 (June 24). “Bangladesh 7th largest mango producer in the world”. Dhaka Tribune: E-Paper. Retrieved from <https://archive.dhakatribune.com/business/economy/2021/07/18/bangladesh-is-top-10-in-global-mango-exporters>

[2] Alcaino, J., Baeza, M., & Cifuentes, V. 2016. “Carotenoid distribution in nature,” in Carotenoids in nature, subcellular biochemistry. Ed. C. Stange. (Switzerland: Springer International Publishing Switzerland, 79, 3–35. doi: 10.1007/978-3-319-39126-7\_1

- [3] Ara, R., Motalab, M., Uddin, M. N., Fakhruddin, A. N. M., & Saha, B. K. 2014. Nutritional evaluation of different mango varieties available in Bangladesh. *International Food Research Journal*, 21(6), 2169-2174.
- [4] Arafat, L. A. 2005. Chilling injury in mangoes. [Ph. D. thesis]. Netherlands: Wageningen University, 227.
- [5] Arnon, H., Zaitsev, Y., Porat R., & Poverenov, E. 2014. Effects of carboxymethyl cellulose and chitosan bilayer edible coating on postharvest quality of citrus fruit. *Postharvest Biology and Technologist*, 87, 21–26.
- [6] Baloch, M.K., & F. Bibi, F. 2012. Effect of harvesting and storage conditions on the post harvest quality and shelf life of mango (*Mangifera indica* L.) fruit. *South African Journal of Botany*, 83: 109–116. <https://doi.org/10.1016/j.sajb.2012.08.001>
- [7] Bello-Pérez, L. A., García-Suárez, F. J., & Agama-Acevedo, E. 2007. Mango carbohydrates. *Food* 1 (1), 36–40.
- [8] Bernardes, S. A. P., do Nascimento, J. R. O., Lajolo, F. M., & Cordenunsi, B. R. 2008. Starch mobilization and sucrose accumulation in the pulp of Keitt mangoes during postharvest ripening. *J. Food Biochem.*, 32, 384–395. doi: 10.1111/j.1745-4514.2008.00175.x
- [9] Campestre, C., Marsilio, V., Lanza, B., Iezzi, C., & Bianchi, G. 2002. Phenolic compounds and organic acids change in black oxidized table olives. *ISHS Acta Hort.* 586: IV International Symposium on Olive Growing. ISBN: 978- 90-66057-56-2.
- [10] Charoengchongsuk, N., Ikeda, K., Itai, A., Oikawa, A., & Murayama, H. 2015. Comparison of the expression of chlorophyll-degradation-related genes during ripening between stay-green and yellow-pear cultivars. *Sci. Hortic.*, 181, 89–94. doi: 10.1016/j.scienta.2014.10.005
- [11] Choo, W. S. 2018. "Fruit pigment changes during ripening in reference module," in *Food Science (Switzerland: Elsevier)*, 1–7.
- [12] Derese, S., Guantai, E. M., Souaibou, Y., & Kuete, V. 2017. "Chapter 21 *Mangifera indica* L (Anacardiaceae)," in *Medicinal spices and vegetables from Africa: therapeutic potential against metabolic, inflammatory, infectious and systemic diseases (Switzerland: Elsevier)*, 451–483. doi: 10.1016/B978-0-12-809286-6.00021-2
- [13] Doreyappu-Gowda, I.N.D., & Huddar, A.G. 2001. Studies on ripening changes in mango (*Mangifera indica* L.) fruits. *Journal of Food Science and Technology Mysore* 38, 135–137.
- [14] Ellong, E. N., Adenet, S., & Rochefort, K. 2015. Physicochemical, nutritional, organoleptic characteristics and food applications of four mangos (*Mangifera indica* L.) varieties. *Food Nutr. Sci.*, 6, 242–253. doi: 10.4236/fns.2015.62025
- [15] Geigenberger, P., & Stitt, M. 1991. A futile cycle of sucrose synthesis and degradation is involved in regulating partitioning between sucrose, starch and respiration in cotyledons of germinating *Ricinus communis* L. seedlings when phloem transport is inhibited. *Planta* 185, 81–90. doi: 10.1007/BF00194518
- [16] Gomez, K. A., & Gomez, A. A. 1984. *Statistical Procedures for Agric. Res.* John Wiley and Sons, New York. p. 680.
- [17] Goncalves, B., Moutinho-Pereira, J., Santos, A., Silva, A. P., Bacelar, E., Correia, C., & Rosa, E. 2006. Scion–Rootstock interaction effect the physiology and fruit quality of sweet cherry. *Tree Physiol.*, 26:93.
- [18] Gulcin, I., Uguz, M.T., Oktay, M., Beydemir, S., & Kufrevioglu, O.I. 2004. Evaluation of the antioxidant and antimicrobial activities of Clary Sage (*Slaviasclarea* L.). *Turkey Journal of Agricultural Forestry*, 28: 25-33.
- [19] Haque, S., Begum, P., Khatun, M., & Nazrul Islam, S. 2015. Total carotenoid content in some mango (*Mangifera indica*) varieties of Bangladesh. *Inter. J. Pharm. Sci. Res.*, 6, 4875–4878. doi: 10.13040/IJPSR.0975-8232.6(11).4875-78
- [20] Hassan, M. K. 2006. Final Report: Postharvest loss Assessment: A Study to Formulate Policy for Postharvest Loss Reduction of fruits and Vegetables and Socio-Economic Uplift of the Stakeholders. pp. 188.
- [21] Hu, K., Dars, A. G., Liu, Q., Xie, B., & Sun, Z. 2018. Phytochemical profiling of the ripening of Chinese mango (*Mangifera indica* L.) cultivars by real-time monitoring using UPLC–ESI–QTOF–MS and its potential benefits as prebiotic ingredients. *Food Chem.*, 256, 171–180. doi: 10.1016/j.foodchem.2018.02.014
- [22] Kato, M., & Shimizu, S. 1985. Chlorophyll metabolism in higher plant. VI. Involvement of peroxidase in chlorophyll degradation. *Plant Cell Physiol.*, 26, 1291–1301. doi: 10.1093/oxfordjournals.pcp.a077029
- [23] Kays, S.J. 1991. *Post harvest Phys. of Perishable Plant Products.* Vas Nostr and Rein Hold Book. AVI Publishing Co., pp. 149–316.
- [24] kothiyal, K., Singh, A. K., Singh, K. P., & Pratibha. 2021. Effect of pre-harvest application of eco-friendly chemicals and fruit bagging on yield and fruit quality of mango. *Pantnagar Journal of Research*, 19 (3), 447-451.
- [25] Kour, R., Singh, M., Gill, P. P. S., & Jawandha, S. K. 2018. Ripening quality of Dusehri mango in relation to harvest time. *J. Food Sci. Technol.*, 55(7), 2395–2400. <https://doi.org/10.1007/s13197-018-3156-4>
- [26] Lane, J. H., & Eynon, L. (1923). Method for determination of reducing and non-reducing sugars. *J. Soc. Chem. Ind.*, 42:32-37.
- [27] Lee, J. H., & Schwartz, S. J. 2005. "Pigments in plant foods," in *Handbook of food science, technology, and engineering*, vol. 1. Eds. Y. H. Hui and F. Sherkat (Boca Raton, FL: CRC Press), 1–13. doi: 10.1201/b15995-16
- [28] Leghari, M.S., Sheikh, S.A., Memon, N., Soomro, A.H., & Khooharo, A.A. 2013. Quality attributes of immature fruit of different mango varieties. *Journal of Basic and Applied Sciences* 9, 52-56.
- [29] Maldonado-Celis, M. E., Yahia, E. M., Bedoya, R., Landázuri, P., Loango, N., Aguillón, J., Beatriz Restrepo, B., & Ospina, J. C. G. 2019. Chemical composition of mango (*Mangifera indica* l.) fruit: nutritional and phytochemical compounds. *Front. Plant Sci.*, 10:1073 <https://doi.org/10.3389/fpls.2019.01073>
- [30] Malundo, T.M.M., Shewfelt, R.L., Ware, G.O., & Baldwin, E.A. 2001. Sugars and acids influence flavor properties of mango (*Mangifera indica* L.). *Journal of the American Society for Horticulture Science* 126, 115–121.
- [31] Manasa, B., Jagadeesh, S. L., Thammaiah, N., & Nethravath. 2019. Colour measurement of ripening mango fruits as influenced by pre-harvest treatments using L\* a\* b\* coordinates. *Journal of Pharmacognosy and Phytochemistry*, 8(1), 2466-2470.
- [32] Martinez, B.E., Guevara, C.G., Contreras, J.M., Rodriguez, J.R., Lavi, U., 1997. Preservation of mango Azucar variety (*Mangifera indica* L.) at different storage stages: Proceedings of the fifth international mango symposium (Tel Aviv, Israel, 1996), 2, 747–754.
- [33] Masibo, M., & Qian, H. (2008). Major mango polyphenols and their potential significance to human health. *Compr. Rev. Food Sci. Food Saf.* 7, 309–319. doi: 10.1111/j.1541-4337.2008.00047.x
- [34] Matheyambath, A. C., Subramanian, J., & Paliyath, G. (2016). "Mangoes reference module in food science," in *Encyclopedia of food and health*. Eds. B. C. Paul and F. F. Told (Switzerland: Elsevier), 641–645. doi: 10.1016/B978-0-12-384947-2.00442-6
- [35] Medicott, A. P., & Thompson, A. K. 1985. Analysis of sugar and organic acids in ripening mango fruit (*Mangifera indica* var Keitt) by high performance liquid chromatography. *J. Sci. Food Agric.*, 36, 561–566. doi: 10.1002/jsfa.2740360707
- [36] Mir, N. A., Curell, E., Khan, N., Whitaker, M., & Beaudry, R. M. 2001. Harvest maturity, storage temperature, and 1-MCP application frequency alter firmness retention and chlorophyll fluorescence of 'Redchief Delicious' apples. *J. Amer. Soc. Hortic. Sci.*, 126, 618–624. doi: 10.21273/JASHS.126.5.618
- [37] Moscatello, S., Famiani, F., Proietti, S., Farinelli, D., & Battistelli, A. 2011. Sucrose synthase dominates carbohydrate metabolism and relative growth rate in growing kiwifruit (*Actinidia deliciosa*, cv Hayward). *Sci. Hortic.*, 128 (3), 197–205. doi: 10.1016/j.scienta.2011.01.013
- [38] Mukherjee, K. U. 1997. Introduction: Botany and Importance. In: *The Mango: Botany, Production and Uses*. 1 Edition (R. E. Litz. Ed.), CAB International, Wallingford UK 1-19.
- [39] Narain, N., Bora, P.S., Narian, R., & Shaw, P. 1998. Mango. In: Shaw, P.E., Chan, H.T., Nagy, S. (Eds.), *Tropical and Subtropical Fruits*. Agriscience, Inc., Auburndale, FL, pp. 1–77.
- [40] Nelson, D. L., & Cox, M. M. 2017. "Lehninger," in *Principles of biochemistry*. Eds. D. L. Nelson and M. M. Cox (United States, NY: W. H. Freeman). doi: 10.1007/978-3-662-08289-8
- [41] Nilesb, B., & Banik, B.C. 2005. Yield and physico-chemical properties of some mango cultivars in new alluvial zone of West Bengal. *Environment and Ecology*. Calcutta, India: MKK Publication 23:503-506.
- [42] Nunes, C.N., Emond, J.P., Bredcht, J.K., Dea, S., & Proulx, E., 2007. Quality curves for mango fruit stored at chilling and non chilling temperatures. *Journal of Food Quality* 30, 104–120.
- [43] Penchaiya, P., Tijskens, L.M., Uthairatanakij, A., Srilaong, V., Tansakul, A., & Kanlayanarat, S. 2020. Modelling quality and maturity of 'Namdokmai Sithong' mango and their variation during storage. *Postharvest Biol. Technol.*, 159, 111000

- [44] Jaman, M. R., Hassan, M. F., Rabbani, M., Suvo, T. P., & Ahmed, M. R. 2017. Response of physical quality and biochemical characteristics to different maturity stages of *Mangifera indica* (cv. Amrapali). *Journal of Bioscience and Agricultural Research*, 15 (2), 1279-1286. <https://doi.org/10.18801/jbar.150217.158>
- [45] Ranganna, S. 1979. *Manual of Analysis of Fruit and vegetable products*. Tata Mc Graw Hill publishing company Ltd., New Delhi. p. 634.
- [46] Rathore, H.A., Masud, T., Sammi, S., & Soomro, A.H. 2007. Effect of storage on physico-chemical composition and sensory properties of Mango (*Mangifera indica* L.) variety Dosehri. *Pakistan Journal of Nutrition* 6, 143–148.
- [47] Roy, R., Rahim, M. A., & Alam, M. S. 2011. Effect of Wrapping Papers on Physiological Changes and Shelf-life of Mango cv. Langra. *J. Environ. Sci. & Natural Resources*, 4(2), 99-103.
- [48] Saleem-Dar, M., Oak, P., Chidley, H., Deshpande, A., Giri, A., & Gupta, V. 2016. "Nutrient and flavor content of mango (*Mangifera indica* L.) cultivars: an appurtenance to the list of staple foods," in *Nutritional composition of fruit cultivars*, Chap. 19. Eds. M. S. J. Simmonds and V. R. Preedy (Switzerland), 445–468. doi: 10.1016/B978-0-12-408117-8.00019-2
- [49] Saengnil, S., & Kaewlublae, M. 1997. Changes in red colour and pigment content of attached mango fruit skin with and without bagging. *Food Agric. Organ U Nations* 19 (2), 173–180 <http://agris.fao.org/agris-search/search.do?recordID=TH2001002309>.
- [50] Sims, G. K., & Gamon, D. S. 2002. Changes in anthocyanin synthesis as an index of maturity in red apple varieties. *J. Hort. Sci.*, 48, 387–392.
- [51] Singh, R. K., Ali, S. A., Nath, P., & Sane, V. A. 2011. Activation of ethylenesensitive phydroxyphenylpyruvate dioxygenase leads to increased tocopherol levels during ripening in mango. *J. Exp. Bot.*, 44, 1254–1263. doi: 10.1093/jxb/err006
- [52] Sivankalyani, V., Feygenberg, O., Diskin, S., Wright, B., & Alkan, N. 2016. Increased anthocyanin and flavonoids in mango fruit peel are associated with cold and pathogen resistance. *Postharvest Biol. Technol.*, 111, 132–139. doi: 10.1016/j.postharvbio.2015.08.001
- [53] Sogvar O. B., Koushesh Saba, M., Emamifar, A. 2016. Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. *Postharvest Biology and Technology*, 114, 29–35.
- [54] Sudhakar, P., Latha, P., & Reddy, P. V. 2016. "Plant pigments," in *Phenotyping crop plants for physiological and biochemical traits* (New York, FL: CRC Press), 121–127. doi: 10.1016/C2015-0-01450-2
- [55] Takeoka, F. R., & Dao, F. D. 2002. Red colour distribution in the skin of 'Gala' apple and some of its sports. *N. Z. J. Agric. Res.*, 29, 695–698.
- [56] Tanaka, Y., Sasaki, N., & Ohmiya, A. 2008. Biosynthesis of plant pigments: anthocyanins, betalains and carotenoids. *Plant J.*, 54, 733–749. doi: 10.1111/j.1365-313X.2008.03447.x
- [57] Tasneem, A. 2004. *Postharvest treatments to reduce chilling injury symptoms in stored mangoes* [master's thesis]. Canada: University of McGill.
- [58] Velez-Rivera, N., Blasco, J., Chanona-Perez, J., Calderon-Dominguez, G., de Jesus Perea-Flores, M., Arzate-Vazquez, I., Cubero, S., & FarrereRebollo, R. 2014. Computer vision system applied to classification of manila mangoes during ripening process. *Food Bioprocess Technol* 7, 1183–1194.
- [59] Yashoda, H. M., Prabha, T. N., & Tharanathan, R. N. 2005. Mango ripening: changes in cell wall constituents in relation to textural softening. *J. Sci. Food Agric.*, 86, 713–721. doi: 10.1002/jsfa.2404

#### AUTHORS

**First Author** –Md. Rajibullah Jaman, MS student, Department of Horticulture, Patuakhali Science and Technology University, Bangladesh.

**Second Author** – Md. Fakhrul Hasan, Professor, Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh. [hasanpstu@yahoo.com](mailto:hasanpstu@yahoo.com)

**Third Author** – Mahbub Robbain, Professor, Department of Horticulture, Patuakhali Science and Technology University, Bangladesh. [mrobbani@pstu.ac.bd](mailto:mrobbani@pstu.ac.bd)

**Fourth Author** – T. R. Masumbillah, MS student, Department of Horticulture, Patuakhali Science and Technology University, Bangladesh.

**Fifth Author** – K. Ferdous, MS student, Department of Horticulture, Patuakhali Science and Technology University, Bangladesh.

**Correspondence Author** – Md. Mijanur Rahman Rajib, Associate Professor, Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh. [mmrrajib@bsmrau.edu.bd](mailto:mmrrajib@bsmrau.edu.bd), [rajibaghort32@gmail.com](mailto:rajibaghort32@gmail.com), +8801716081532.