*American Journal of Food Science and Technology, 2014, Vol. 2, No. 3, 80-87*
Available online at http://pubs.sciepub.com/ajfst/2/3/1

DOI:10.12691/ajfst-2-3-1

# Nutritional Composition of Culinary Musa ABB at Different Stages of Development

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*Received March 24, 2014; Revised April 11, 2014; Accepted May 09, 2014*

**Abstract** Culinary banana (*Musa* ABB) is an important ingredient of several dishes and is yet to be scientifically studied its nutritional and other biochemical compositions at different stages of development. It is one of the important nutritionally riches *Musa* sp and is a part of a balanced diet in Northeast India. Variations in nutritional and biochemical compositions associated with growth were studied at 20 (stage I), 35 (stage II), 50 (stage III), 65 (stage IV) and 80 (stage V) days after emergence (DAE) of banana inflorescence. Ash (7.03 g/100 g), protein (10.56 g/100 g), fat (1.50 g/100 g), phenol content (307.99 mg/100 g), radical scavenging activity (59.12% SA), linoleic acid (2.081 mg/100 g) and linolenic acid (1.210 mg/100 g) gradually declined with maturity. A rise in starch content from 12.36 to 22.66 g/100 g was observed with the maturity of banana. Maximum total carbohydrate was observed at stage III (32.15 g/100 g) and declined gradually. Out of 8 minerals tested, magnesium (Mg) was recorded the highest followed by potassium (K) and zinc (Zn) irrespective of the developmental stages of banana. Essential amino acids were found to be present at all the stages of development. The carotenoids (0.130 - 0.159 mg/100 g), vitamin A (0.028 - 0.038 mg/100 g) and thiamine (0.002 – 0.032 mg/100 g) were recorded at various stages of development of culinary banana. Pulp to peel ratio and total soluble sugars suggest that 50 DAE is the optimum stage of harvesting for culinary banana. However, young stages are rich in antioxidants, amino acids and fatty acids.

***Keywords:*** *Culinary Musa ABB, biochemical compositions, days after emergence of inflorescence, developmental stages*

**Cite This Article:** P. Khawas, A. J. Das, N. Sit, L. S. Badwaik, and S. C. Deka, "Nutritional Composition of Culinary Musa ABB at Different Stages of Development." *American Journal of Food Science and Technology*, vol. 2, no. 3 (2014): 80-87. doi: 10.12691/ajfst-2-3-1.

## 1. Introduction

Banana plants are the world's biggest herbs, grown in many countries. Culinary bananas, often called as plantains, are mostly evolved from the edible varieties of two species *Musa acuminata* (genome "A")and *Musa balbisiana* (genome "B") (Stover and Simmonds, 1987). Considering the nutritional aspect, plantains and bananas are the world's 4$^{th}$ leading agricultural crop (Ganapathi *et al.*, 1999). Plantains and cooking bananas look almost similar to unripe dessert bananas, but they are larger in size, more fleshy and starchy (Emaga *et al.,* 2008). The cooking type banana is a major staple food in some countries (Seenappa *et al.,* 1986). They are considered to be one of the most important sources of energy and starchy staple food for the people of tropical humid regions (Onwuka and Onwuka, 2005). According to Doymaz (2010) bananas and plantains are rich in nutrients, starch, sugar and vitamins A and C, potassium, calcium, sodium and magnesium. Plantains are nutritionally low protein food material but relatively high in carbohydrates, vitamins and minerals (Offem and Njoku, 1993).

Compared to culinary banana, most available reports are on changes in chemical composition of dessert banana cultivars during ripening (Emaga *et al.,* 2008; Cheirsilp and Umsakul, 2008; Yang and Hoffman, 1984; Marriott *et al.,* 1981).Culinary bananas are rich source of nutrients and the biochemical composition varies with growth stage and maturity (Emaga*et al.,* 2008). The *Musa* ABB culinary banana (locally called *kachkal*) found only in Northeast India, and is used as a vegetable in preparing various traditional dishes (Khawas *et al*., 2014). However, till today no scientific effort has been undertaken for its complete nutritional studies at various stages of development. The nutritional studies will be useful for exploitation of the crop at different stages of growth to obtain value added products. Therefore, the present work was undertaken to study the nutritional and biochemical compositions at various developmental stages of banana *Musa* ABB which can be exploited for developing value added products.

## 2. Methods

### 2.1. Sample Collection and Preparation

Samples were collected from the experimental plot of Tezpur University, Assam, India. The fingers were harvested at growth stages of 20 days after emergence

(DAE) (stage I) of banana inflorescence, 35 DAE (stage II), 50 DAE (stage III), 65 DAE (stage IV), and 80 DAE (stage V). Samples were washed thoroughly under running water followed by distilled water and spread out on absorbent tissue papers to remove surface moisture. The pulp and peel samples were separated using a stainless steel knife. The pulp samples were cut into 5 mm thick slices and dried in a tray drier (IK-112, IKON Instruments, Delhi, India) at 40°C for 12 h. Dried samples were ground, sieved and stored at room temperature (25±2°C) in air tight containers till the time of analyses.

## 2.2. Chemical Analysis

The initial moisture, ash, protein, and crude fat contents at various stages of development were determined according to methods described in AOAC (2010). Ash content was determined by ignition in a muffle furnace (Optic Ivymen System, SNOL 8, 2/1100, Utena, Lithuania) at 550°C for 6 h. Nitrogen content was determined using the Kjeldahl apparatus (KelPlus, Pelican Equipment, Chennai, India) and the amount of nitrogen was multiplied by a factor 6.25. Crude fat was determined using the Soxhlet extractor (Socs Plus, Pelican Equipment, Chennai, India) with n-hexane as solvent. Crude fiber was determined following the acid and alkali treatment as described by Maynard (1970) and Sadasivam and Manikam (2008).The total carbohydrate content was measured by hydrolyzing the polysaccharides (acid hydrolysis) into simple sugars and estimating the resulting monosaccharide by anthrone method (Hodge and Hofreiter, 1962).

The pH of samples was measured by blending 10 g of pulp with 40 mL of deionized water (AOAC, 2010) and the mixture was shaken at 5 min intervals for 15 min and centrifuged at 3000 rpm for 15 min in refrigerated centrifuge (SIGMA Laborzentrifugen, 3-18 KS, Osterode, Germany). The supernatant was decanted and determined its pH (pH 510, Eutech, Ayer Rajah Crescent, Singapore). Ascorbic acid and titratable acidity of samples were determined using the method of Ranganna (2008). Cellulose content was estimated by reacting with acetic-nitric reagent and measured the absorbance at 630 nm. Lignin content was estimated by extraction in NaOH solution and aliquot samples were adjusted to pH 7.0 and 12.3. The absorbance of aliquots was measured at 245 and 350 nm. The amount of lignin content was calculated by difference between $A_{245}$ (pH 7.0) and $A_{350}$ (pH 12.3) (Stafford, 1960).

Starch and amylose contents were determined with the methods of Hodge and Hofreiter (1962) and Sadasivam and Manikam (2008), respectively. Soluble sugars were extracted from 1 g of sample in 80% ethanol (hot) and sugar contentwas quantified by the phenol-sulphuric acid method (Dubois *et al.*, 1956). The reducing sugar content was estimated by the Nelson-Somogyi method (Somogyi, 1952). The amount of non-reducing sugars was determined by subtracting the amount of reducing sugars from the amount of total sugars in the sample.

Pectin content was determined by extraction and saponification (Ranganna, 2008) followed by precipitation as calcium pectate by calcium chloride. After removal of chloride ions, the precipitate was dried and weighed. Tannin content was determined by Folin-Denis method (Schanderi, 1970) in which tannin like compounds reduces phosphotungstomolybdic acid in alkaline solution to produce a densely blue solution, and the intensity was measured spectrophotometrically (Spectrascan UV-2600, Thermo Fisher Scientific, Nasik, India). Phytic acid content was estimated by extracting phytate with trichloroacetic acid and precipitating as ferric salt (Wheeler and Ferrel, 1971).

Total phenolic content was determined with the Folin-Ciocalteu (F.C.) colorimetric method (Malick and Singh, 1980) where 0.5 mL extract was mixed with 0.5 mL F.C. reagent. The contents were mixed by manual shaking for 15-20 s. After 3 min, 2 mL of saturated sodium carbonate solution was added to each tube. The reaction mixturewas placed in a boiling water bath for 1 min, cooled and the absorbance was measured at 650 nm against deionized water using a dual beam UV-Visible spectrophotometer (Spectrascan UV-2600, Thermo Fisher Scientific, Nasik, India).

The DPPH radical scavenging activity was measured with the method of Brand-Williams *et al.* (1995) and the assay is based on the ability of antioxidant to scavenge the DPPH cation radical. This method determines the hydrogen donating capacity of molecule and does not produce oxidative chain reactions or react with free radical intermediates. Scavenging activity (SA) was calculated as per cent inhibition relative to control, using the equation: SA% (30 min) = control absorbance at 517 nm - extract absorbance at 517 nm/control abs at 517 nm × 100. Carotenoids were extracted and partitioned in organic solvents on the basis of their solubility. The amount of carotenoids present in the sample was measured spectrophotometrically (Spectrascan UV-2600) at 450 nm against concentrations of high purity β-carotene (Sadasivam and Manickam, 2008). Vitamin A content was measured by a rapid colorimetric method of Bayfield and Cole (1980). Thiamine content was estimated by a flurometric method (Sadasivam and Manickam, 2008).

The mineral contents were estimated by inductively coupled plasma optical emission spectrometry (ICP-OES) (Optima 2100 DV, Bridgeport, USA) following the methods of Naozuka *et al.* (2011). Concentrations were determined in the aqueous solution of acid digest. Powdered samples (1 g) were added to 30 mL concentrated nitric acid and 5 mL concentrated hydrochloric acid. The vessels were immediately closed after addition of oxidants. Samples were digested on a hot plate at 100°C. At the end of the digestion process, digests were cooled and diluted up to 50 mL with distilled water.

Gas liquid chromatography (GLC) (CP-3800, Varian, USA) was used for analysis of fatty acid profiles. Fatty acids can occur in small amounts in free form, but in general, they are combined in complex molecules through ester or amide bonds. Before GLC analysis non-reactive derivatives of fatty acids methyl esters were prepared (Luddy *et al.*, 1968). Samples were treated with 0.4 N sodium methylate and shaken vigorously at water bath for 2-3 min at 65°C followed by addition of 1 mL carbon disulphide and shaken for 1-2 min and filtered through activated charcoal. The filtrate constituted all methyl esters of fatty acids and were separated by chromatography (Varian) equipped with a flame ionization detector (FID) and electron capture detector (ECD). The column temperature was 190°C and flow of

the nitrogen carrier gas was maintained at 35 mL· $min^{-1}$. Peaks were identified by comparison of retention times to those of standard fatty acid esters.

Amino acid analysis was done by hydrolyzing with 6 N HCl and measured by ion exchange chromatography using ninhydrin post-column derivatization. Samples equivalent to 5 mg protein were placed in a 20 mL glass ampoule, kept on dry ice to avoid clumps forming and 10 mL 6 N HCl was added. Nitrogen gas was flushed to remove oxygen from the ampoule for 1 min and closed with para-film. Samples were kept in oven at 110°C for 22 h for hydrolysis. After hydrolysis, samples were removed and allowed to equilibrate at room temperature. The neck of the ampoule was broken and samples transferred to 25 mL volumetric flasks. Volume was made up to 25 mL with distilled water and mixed thoroughly and filtered through nitrogen free Whatman No. 1 filter paper. The aliquot (0.5 mL) was evaporated at 45-50°C and after complete drying, 5 mL deionized water was added and evaporated again. Drying and evaporation of samples were repeated 4 times. Crude dried samples were dissolved with 2.5 mL of sodium citrate loading buffer (pH 2.2). Samples were filtered using a syringe driven filter (0.45 µm) and kept in an auto sampler. Standards (100 p mol) and samples were run in an automated amino acid analyzer (Model 119 CL, Beckman, Palo Alto, California).

The colour measurement of samples at different growth stages was analyzed in a Hunter Lab Color Quest (Model Ultrascan Vis-Model, Virginia, USA).

### 2.3. Determination of Pulp to Peel Ratio

Following the method described by Adao and Gloria (2005) the pulp-to-peel ratio was determined by weighing the parts of individual sample in an analytical balance and the results were expressed as percent pulp relative to peel weights.

### 2.4. Statistical Analysis

Experiments were carried out in 4 replicates. The Origin 8.5 (Origin Lab Corporation, Northampton, USA) software was used for statistical analysis. Data were subjected to ANOVA and Fisher's Least Significant Difference (LSD) was used to separate means.

## 3. Results and Discussion

### 3.1. Proximate Compositions

Moisture content (Table 1)decreased gradually from stage I (59.49 g/100 g) to stage III (57.02 g/100 g) and then increased at stages IV (61.07 g/100 g) and V (66.83 g/100 g). There was a significant difference in moisture content in all states except in stages I and II. This might be attributed to respiratory breakdown of starches into sugars and migration of moisture from peel to pulp. Increase in moisture content at stage V might be due to softening tissue texture as ripening progresses (Onwuka and Onwuka, 2005). An increase of water content in pulp of two cooking banana hybrids with progress in maturity was attributed to utilization of carbohydrates during breathing and osmotic transfer from peel to pulp (Sakyi-Dawson *et al.*, 2008). Ash content decreased as plant's maturity progresses and the highest content was recorded at the stage I (7.03 g/100 g) which decreased gradually at the fully matured stage (3.05 g/100 g). Adeyemi and Oladiji (2009) reported that ash content of ripening plantain is affected by developmental stage and unripe plantain contains higher ash compared to ripe ones. Another reason for variation in ash might be due to differential absorption capacity of minerals at different stages of development. Gradual decrease in protein content as plants matured and decreased from stage I (10.56 g/100 g) to stage V (2.01 g/100 g). Goswami and Borthakur (1996) observed a decline in protein content in culinary banana with maturity and attributed to protein breakdown and the resulting amino acids being utilized in gluconeogenesis. The samples contained a relatively low amount of fat, which varied from stage I (1.50 g/100g) to stage V (0.63 g/100 g) and results are in agreement with Goswami and Borthakur (1996) who reported that fat content (0.8 – 1.2 %) in culinary banana was higher during early developmental stages and gradually decreased with increasing maturity. Fiber content also gradually increased as maturity progresses, indicating there were differences due to stage and the highest amount was recorded at stage IV (1.66 g/100 g). Egbebi and Bademosi (2012) reported crude fiber content in unripe and ripe plantain (0.7 – 1.11 %) and increased significantly with progress of maturity. The increase in fiber content at matured stage over tender stage might be due to increase in soluble and insoluble dietary fractions. Total carbohydrates content increased from stage I (21.32 g/100 g) to III (32.15 g/100 g) and de creased at stage V (27.63 g/100 g) with significant difference among the stages except in stages III and IV. The variation in carbohydrate contents during growth might be due to degradation of starch for synthesis of sugars (Sakyi-Dawson *et al.*, 2008).

**Table 1. Effect of different stages of development on proximate composition of *Musa* ABB (g/100 g)**

| Stage | Moisture content | Ash | Protein | Fat | Crude fiber | Total carbohydrate |
|---|---|---|---|---|---|---|
| I | 59.49±0.80b[a] | 7.03±0.35[d] | 10.56±0.86[d] | 1.50±0.11[d] | 0.61±0.01[a] | 21.32±0.05[a] |
| II | 55.84±0.42[a] | 6.11±0.73[c] | 8.61±0.96[c] | 1.27±0.08[c] | 0.99±0.08[b] | 28.04±0.29[b] |
| III | 57.02±0.5[a] | 4.03±0.49[b] | 5.56±0.84[c] | 0.94±0.05[b] | 1.50±0.02[c] | 32.15±0.20[d] |
| IV | 61.07±0.77[c] | 2.72±0.20[a] | 3.99±0.57[b] | 0.58±0.06[a] | 1.66±0.05[d] | 30.93±0.06[c] |
| V | 66.83±1.02[d] | 3.05 ±0.92[a] | 2.01±0.87[a] | 0.63±0.08[a] | 0.54±0.87[a] | 27.63±0.87[c] |

[a]Means in columns followed by the same letter are not significantly different at p< 0.05; values represent mean± SD, n=4

### 3.2. pH, Browning Potential and Titratable Acidity

The pH (Table 2) was the lowest at stage I (5.01) and highest at stage V (5.76). A gradual variation in pH of culinary banana during ripening stages has been reported (Sakyi-Dawson *et al.*, 2008). Titratable acidity was the lowest during early developmental stage I (0.16 g/100 g) and recorded highest at stage IV (0.32 g/100 g). There was no differences between stages I and II and stages III and V; however, stages II and III were different. Acids play an important role in the post-harvest quality of vegetables, as

taste is mainly a balance between sugar and acid contents which is important in evaluation of fruit taste (Bainbridge *et al.*, 1996). Sakyi-Dawson *et al.* (2008) reported changes in titratable acidity and pH of cooking banana and indicating a general increase in titratable acidity during plantain ripening. Ascorbic acid content (Table 2) varied with stages of development and ranged from 0.74 – 1.12 mg/100 g. Sakyi-Dawson *et al.* (2008) reported that ascorbic acid content in cooking banana varied with maturity with regular decreasing pattern. The present results are in agreement with the report of Segung and Kader (2000), in case of fluctuation in ascorbic acid content of horticultural crops with maturity. The lowest amount of ascorbic acid in fully matured tomato is reported by Moneruzzaman *et al.* (2008). Developmental stage affects the cellulose content (Table 2) and the highest value was recorded at stage IV (1.06 mg/100 g). Komolka *et al.* (2012) reported relatively low amount of cellulose compared to other fruits and vegetables. Lignin content gradually increased with maturity and was the highest at stage IV (1.57 mg/100 g). There was no significant difference between stages I and II; however, differences were observed in stages II, III and IV. This might be due to the lignifications of cell wall constituents resulted an increase in other dietary fiber fractions (Punna and Paruchuri, 2004).

**Table 2. Effect of different stages of development on pH, browning potential and titratable acidity of *Musa* ABB**

| Stage | pH | Titratable acidity (g/100g) | Ascorbic acid (mg/100g) | Lignin (mg/100g) | Cellulose (mg/100g) |
|---|---|---|---|---|---|
| I | 5.03±0.15b[a] | 0.16±0.01[a] | 1.12±0.02[e] | 0.56±0.08[a] | 0.04±0.01[a] |
| II | 5.01±0.09[a] | 0.19±0.02[a] | 0.86±0.02[d] | 0.68±0.10[a] | 0.25±0.01[b] |
| III | 5.12±0.17[a] | 0.23±0.03[b] | 0.83±0.03[c] | 1.25±0.12[b] | 0.32±0.02[c] |
| IV | 5.25±0.37[a] | 0.32±0.02[c] | 0.91±0.11[b] | 1.57±0.09[c] | 1.06±0.05[d] |
| V | 5.76±0.87[b] | 0.25±0.05[b] | 0.74±0.90[a] | 0.54±0.75[a] | 0.28±0.06[b] |

[a]Means in columns followed by the same letter are not significantly different at p<0.05; values represent mean± SD, n=4

## 3.3. Starch, Amylose, Sugar and Pectin Contents

Starch, amylose and sugar contents varied with maturity (Table 3). Present study revealed that starch is the major storage form of carbohydrates in cooking bananas. The starch content increased from stage I (12.36 g/100 g) to stage III (22.66 g/100 g) and then declined at stage V (11.21 g/100 g). Starch accumulation led to the higher weight in matured plantain (Kudachikar *et al.*, 2004). Carbohydrate in the form of starch is the major chemical change which occurs throughout growth and development in cooking bananas and plantains (Sakyi-Dawson *et al.*, 2008). Amylose content was affected by stages of development and increased from stage I to stage IV (3.77 to 8.81 g/100 g) with maturity. An increase in total carbohydrates content might be correlated with active synthesis of starch with growth however, with maturity of cooking banana starch content decreased and total soluble sugars increased significantly. Marriott *et al.*(1981) also reported similar results in ripening banana and plantains. Total soluble sugars content (Table 3) increased very marginally from stage I (0.64 g/100 g) to stage III (1.35 g/100 g) and thereafter sharp increase from stage IV (2.01 g/100 g) and in stage V (4.65 g/100 g) and this evinces that starch degrades with more maturity. Ogazi (1996) reported that sugars comprise only about 1.30 g/100 g of total drymatter in unripe plantain which corroborates the present findings. Reducing and nonreducing sugars (Table 3) increased with maturity. Nonreducing sugars (0.37 – 3.72 g/100 g) was higher than reducing sugars (0.16 – 1.08 g/100 g). Sakyi-Dawson *et al.* (2008) reported a similar trend of nonreducing sugar contents in plantain and cooking banana. There was significant difference in pectin content among stages and it increased from stage I (0.92 mg/100 g) to stage III (1.37 mg/100 g) which thereafter declined at stage V (0.81 mg/100 g). The reason for increase in pectin content with the advancement of growth up to stage III might be due to less interaction between the pectin and the other cellular components and as a consequence the pectin was more available for extraction. On the other hand, decrease at stage IV and V might be due to the degradation of pectin under the action of pecticenzymes, such as polygalacturonase (PG), pectin methyl esterase (PME) or pectatelyase (PL). The increase of pectin content up to a certain stage and then decrease was also observed by Lohani *et al.* (2004).

**Table 3. Effect of different stages of development on starch, amylose, total soluble, reducing, nonreducing sugars and pectin content of *Musa* ABB**

| Stage | Starch (g/100 g) | Amylose (g/100 g) | Total soluble sugars (g/100 g) | Reducing sugars (g/100 g) | Nonreducing sugars (g/100 g) | Pectin (mg/100 g) |
|---|---|---|---|---|---|---|
| I | 12.36±0.17a[a] | 3.77±0.51[a] | 0.64±0.03[a] | 0.16±0.02[a] | 0.37±0.08[a] | 0.92±0.15[a] |
| II | 18.47±0.10[b] | 5.84±0.48[b] | 0.72±0.05[b] | 0.29±0.06[b] | 0.48±0.04[b] | 1.27±0.10[b] |
| III | 22.66±0.61[c] | 7.25±0.62[c] | 1.35±0.03[c] | 0.41±0.01[c] | 0.63±0.01[c] | 1.37±0.05[b] |
| IV | 20.32±0.99[d] | 8.81±0.52[d] | 2.01±0.06[d] | 0.54±0.04[d] | 1.57±0.07[d] | 1.26±0.04[b] |
| V | 11.21±0.9[5] | 6.65±0.75[b] | 4.65±0.97[e] | 1.08±0.07[e] | 3.72±0.15[e] | 0.81±0.13[a] |

[a]Means in columns followed by the same letter are not significantly different at p<0.05; values represent mean±SD, n=4

**Table 4. Effect of different stages of development on tannin and phytic acid content of *Musa* ABB**

| Stage | Tannin (mg/100 g) | Phytic acid (mg/100 g) |
|---|---|---|
| I | 0.59± 0.01[e] | 15.50± 0.39[b] |
| II | 0.51± 0.02[d] | 24.15± 0.95[e] |
| III | 0.34± 0.06[c] | 20.05± 1.50[d] |
| IV | 0.27± 0.03[b] | 18.88± 0.97[c] |
| V | 0.21± 0.06[a] | 11.96± 1.05[a] |

[a]Means in columns followed by the same letters are not significantly different at p<0.05; values represent mean± SD, n=4

## 3.4. Tannin and Phytic Acid Contents

The tannin content (Table 4) of samples differed significantly with stages of development and the highest amount was recorded at stage I (0.59 mg/100 g) which declined with maturity (0.21 mg/100 g). The decrease in tannin content with advancement of growth reduces the astringency property. Mendoza *et al.*(1992) reported the tannin content in cooking bananas of Philippians (1.03-5.66 mg tannic acid equivalent/g) which is relatively

higher than the present values. As culinary banana attains maturity the astringency property gets reduced which is related to insolubilization and polymerization of polyphenols with other constituents of pulp. The variation might be due to differences in cultivar, growth condition and environmental factors. Fruits and vegetables normally exhibit astringency when it is young and gradually losses this characteristic property with maturity and becomes palatable for exploitation (Mendoza *et al.*, 1992). The stages of development also affect phytic acid content (Table 4) and recorded the highest values at stage II (24.15 mg/100 g) and lowest at stage V (11.96 mg/100 g). The amount of phytic acid was low compared to other starchy foods like cassava (95-135 mg/g) (Charles *et al.*, 2005).

## 3.5. Total Polyphenols, DPPH Radical Scavenging Activity, Total Carotenoids, Vitamin A and Thiamine Contents

Wide variations in total polyphenols (91.87 - 307.99 mg GAE/100 g dry matter), DPPH radical scavenging activity (39.64 – 59.12 % SA), total carotenoids (0.130 - 0.159 mg/100 g), vitamin A (0.029 - 0.038 mg/100 g) and thiamine (0.019 - 0.032 mg/100 g) contents at different stages of development were observed (Table 5). Total polyphenols were found higher at stage I compared to the other stages. Bananas have been classified as one of the prominent antioxidant foods by Kanazawa and Sakakibara (2000). The highest DPPH radical scavenging activity was observed in stage I and lowest at stage V and it decreased with maturity. Decreasing trend in scavenging activity of papaya with respect to crop maturity was also observed by Zuhair *et al.* (2013). A gradual increase in total carotenoids, vitamin A from stage I to stage V was observed and recorded the highest at stage V. Increase in thiamine content up to stage IV was observed but declined at stage V. Total carotenoid contents in fruits and vegetables increases during ripening because the chlorophyll undergoes degradation and carotenogenesis takes place resulting in synthesis of greater amount of individual carotenoid compounds at chromoplast rather than the chloroplast (Gross, 1991).

**Table 5. Effect of different stages of development on total polyphenols, DPPH radical scavenging activity, total carotenoids, vitamin A and thiamine contents of *Musa* ABB**

| Stage | Total polyphenols (mg GAE/100 g dry matter [a]) | DPPH radical scavenging activity (% SA) | Total carotenoids (mg/100 g) | Vitamin A (mg/100 g) | Thiamine (mg/100 g) |
|---|---|---|---|---|---|
| I | 307.99± 2.86e [b] | 59.12± 0.73[d] | 0.130± 0.07[a] | 0.029± 0.01[a] | 0.002± 0.01[a] |
| II | 261.22± 2.29[d] | 55.60± 1.16[c] | 0.142± 0.05[b] | 0.028± 0.03[a] | 0.019± 0.01[b] |
| III | 178.72± 2.60[c] | 52.66± 2.47[c] | 0.147± 0.01[c] | 0.030± 0.02[a] | 0.027± 0.03c |
| IV | 160.96± 2.40[b] | 46.96± 4.20[b] | 0.153± 0.09[d] | 0.033± 0.02[b] | 0.032± 0.03[d] |
| V | 91.87± 2.07[a] | 39.64± 1.75[a] | 0.159± 0.02[e] | 0.038± 0.01[c] | 0.021± 0.07[b] |

[a]GAE= gallic acid equivalent.

[b]Means in each column followed by the same letters are not significantly different at p<0.05; Values represent mean± SD, n=4.

## 3.6. Minerals Content

Results of mineral contents are presented in Table 6. Out of all the minerals Mg was recorded the highest (0.961 - 1.183 mg/100 g) in all stages with significant difference. The highest concentrations of Fe (0.385 mg/100 g), Cu (0.009 mg/100 g), and Ca (0.542 mg/100 g) were recorded at stage II; however, Zn concentration recorded the highest (0.417 mg/100 g) at stage IV. Significant variations of K (0.498 - 1.273 mg/100 g), Ca (0.241 - 0.542 mg/100 g), Fe (0.173 - 0.385 mg/100 g) and Na (0.115 - 0.167 mg/100 g) were observed at all stages of development. The variation in mineral contents at the growth stages is mainly attributed to preferential absorbance and this might be due to cultivar and/or soil, climate, agricultural practice and the quality of water for irrigation (Rop *et al.*, 2010). Most of the minerals are very crucial in many enzymes activities, protecting cells from free radicals attack, regulation of glucose homeostasis etc. (Garg*et al.*, 2005; Anhwange, 2008).

**Table 6. Effect of different stages of development on mineral contents of *Musa* ABB (mg/100g)**

| Stage | Na | K | Fe | Cu | Mn | Zn | Mg | Ca |
|---|---|---|---|---|---|---|---|---|
| I | 0.115±0.87[a] | 0.889±0.75[c] | 0.302±0.91d [a] | 0.008±0.01[a] | 0.005±0.27[a] | 0.350±0.04[b] | 0.961±0.65[a] | 0.432±3.11[d] |
| II | 0.127±1.34[b] | 1.038±0.98[d] | 0.385±1.71[e] | 0.009±0.31[e] | 0.013±0.66[c] | 0.389±1.09[d] | 1.020±1.71[c] | 0.542±4.92[e] |
| III | 0.139±1.28[c] | 1.273±0.97[e] | 0.210±0.46[b] | 0.005±0.03[d] | 0.014±0.16[d] | 0.353±1.50[c] | 1.183±0.37[e] | 0.345±6.56[c] |
| IV | 0.167±0.99[e] | 0.723±0.96[b] | 0.240±1.25[c] | 0.004±0.03[c] | 0.017±0.32[e] | 0.417±1.28[e] | 1.109±0.19[d] | 0.274±2.03[b] |
| V | 0.164±1.29[d] | 0.498±0.98[a] | 0.173±1.05[a] | 0.002±0.06[b] | 0.011±0.89[b] | 0.312±1.75[a] | 1.024±0.96[b] | 0.241±3.67[a] |

[a]Means in each column followed by the same letters are not significantly different at p< 0.05; values represent mean±SD, n=4.

## 3.7. Fatty Acids Composition

Results (Table 7) revealed that the major saturated fatty acids are palmitic acid (0.267 - 1.678 mg/100 g) and stearic acid (0.061 - 0.091 mg/100 g). The palmitic acid content decreased from stage I to stage V whereas stearic acid decreased from stage I to stage III and was absent at subsequent stages. Lauric (0.006 - 0.092 mg/100 g) and myristic (0.008 - 0.019 mg/100 g) acids were recorded in minor quantities during early stages of development, which gradually decreased towards maturity. Among unsaturated fatty acids the most predominant were linoleic (0.329 - 2.081 mg/100 g) and linolenic acids (0.139 - 1.210 mg/100 g). These essential fatty acids were the highest during early developmental stages. The oleic acid (0.128 - 0.651 mg/100 g) was recorded the highest at stage II and it indicates involvement of lipids to metabolic changes during development. The linoleic acid has nutritional benefits due to its metabolism at tissue levels which produces hormone like compound prostaglandins (Ramadan and Morsel, 2002). The role of α-linolenic acid has been reported in disease prevention (Simopoulos, 1999). The early rise in linoleic acid appeared to be associated with glycolipid and is a unique component in chloroplast of young plantains. Presence of these

unsaturated fatty acids in a reasonable amount enhances nutritional value of this crop.

**Table 7. Effect of different stages of development on fatty acid (mg/100g) profile of *Musa* ABB**

| Stage | Lauric acid | Myristic acid | Palmitic acid | Palmitoleic acid | Stearic acid | Oleic acid | Linoleic acid | Linolenic acid |
|---|---|---|---|---|---|---|---|---|
| I | 0.013± 1.54b [a] | 0.019± 0.97[b] | 1.678± 1.52[e] | 0.059± 1.22[b] | 0.091± 0.82[c] | 0.128± 10.51[a] | 2.081± 8.49[e] | 1.210± 10.91[d] |
| II | 0.006± 1.01[b] | 0.008± 0.50[a] | 0.988± 1.84[d] | 0.027± 0.53[a] | 0.061± 0.81[a] | 0.651± 6.1[c] | 1.386± 5.39[d] | 0.670± 11.66[c] |
| III | 0.092± 1.04[c] | 0.013± 1.41[c] | 0.593± 1.32[c] | ND | 0.068± 1.18[b] | 0.524± 6.76[b] | 0.387± 6.05[b] | 0.139± 5.16[a] |
| IV | ND [1] | ND | 0.422± 0.37[b] | ND | ND | ND | 0.603± 7.58[c] | 0.213± 6.30[b] |
| V | ND | ND | 0.267± 0.75[a] | ND | ND | ND | 0.329± 3.76[a] | ND |

[a]Means in columns followed by the same letters are not significantly different at p<0.05; values represent mean± SD, n=4.
[1]ND = Not detected.

## 3.8. Amino Acids Composition

Results (Table 8) revealed that all the essential amino acids viz., histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine are present in the culinary banana. Amino acids content decreased from stage I to stage V of growth and development (Table 8) of culinary banana. The predominant amino acids are glutamic acid (0.75 - 3.12 g/100 g), aspartic acid (0.05 - 1.08 g/100 g) and alanine (0.19 - 0.45 g/100 g) and declined with maturity. Deka and Harmine (1997) also reported the presence of all the essential and non-essential, amino acids in cultivar: Borjahaji (AAA) banana. The limiting amino acid methionine (0.017 - 0.048 g/100 g) was recorded in fewer amounts as compared to other amino acids. In plants ethylene plays a key role in fruit ripening and it is synthesized from methionine (Yang and Hoffman, 1984). There is a marked variation in most of the amino acid contents among all stages except for proline, leucine, tyrosine and phenylalanine. Decrease in amino acids level with advancement in maturity has been previously reported in tomato (Sorrequieta *et al.*, 2013).

**Table 8. Effect of different stages of development on amino acid composition (g/100g protein) of *Musa* ABB**

| Stage | Tryptophan | Aspartic acid | Threonine | Serine | Glutamic acid | Proline | Glycine | Alanine | Cystine | Valine | Methionine | Isoleucine | Leucine | Tyrosine | Phenylalanine | Histidine | Lysine | Arginine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 0.16± 0.04[b] | 1.08 ± 0.01[d] | 0.29± 0.02[e] | 0.43± 0.61[d] | 3.12 ± 0.31[e] | 0.20± 0.03[c] | 0.37 ± 0.55[d] | 0.45 ± 0.06[e] | 0.03 ± 0.41[b] | 0.42± 0.07[d] | 0.047 ± 0.01[c] | 0.30± 0.51[d] | 0.58 ± 0.99[b] | 0.14 ± 0.03[c] | 0.36± 0.05[b] | 0.31 ± 0.05[d] | 0.35± 0.08[a] | 0.45 ± 0.90[e] |
| II | 0. 17± 0.22[b] | 1.02 ± 0.09[c] | 0.26± 0.04[c] | 0.38± 0.70[c] | 3.01 ± 0.06[d] | 0.17± 0.03[b] | 0.33 ± 0.62[c] | 0.41 ± 0.05[c] | 0.04 ± 0.11[c] | 0.38± 0.07[c] | 0.048 ± 0.02[c] | 0.27± 0.55[b] | 0.62 ± 0.67[c] | 0.13 ± 0.02[b] | 0.41± 0.03[c] | 0.24 ± 0.05[c] | 0.47± 0.04[c] | 0.40 ± 0.75[d] |
| III | 0.19± 0.02[c] | 0.73 ± 0.012[b] | 0.28± 0.04[d] | 0.46± 0.43[e] | 1.95 ± 0.33[c] | 0.12± 0.04[a] | 0.31 ± 0.46[b] | 0.44 ± 0.06[d] | 0.02 ± 0.15[a] | 0.43± 0.04[e] | 0.035 ± 0.03[b] | 0.29± 0.95[c] | 0.69 ± 0.58[e] | 0.13 ± 0.02[b] | 0.42± 0.04[d] | 0.19 ± 0.03[b] | 0.56± 0.05[d] | 0.35 ± 0.55[b] |
| IV | 0.31± 0.65[d] | 0.05 ± 0.02[a] | 0.23± 0.02[b] | 0.27± 0.25[b] | 1.22 ± 0.95[b] | 0.13± 0.45[a] | 0.30 ± 0.41[a] | 0.32 ± 0.06[b] | 0.03 ± 0.62[b] | 0.34± 0.06[b] | 0.021 ± 0.01[a] | 0.23± 0.49[a] | 0.65 ± 0.86[d] | 0.09 ± 0.02[a] | 0.43± 0.05[e] | 0.12 ± 0.02[a] | 0.63± 0.05[e] | 0.38 ± 0.68[c] |
| V | 0.10± 0.28[a] | N.D | 0.15± 0.01[a] | 0.20± 0.24[a] | 0.75 ± 0.03[a] | N.D | N.D | 0.19 ± 0.11[a] | N.D | 0.16± 0.02[a] | 0.017 ± 0.01[a] | N.D | 0.44 ± 0.52[a] | N.D | 0.32± 0.06a | N.D | 0.41± 0.08[b] | 0.27 ± 0.75[a] |

[a]Means in columns followed by the same letters are not significantly different at p<0.05; values represent mean± SD, n=4.

## 3.9. Colour Measurement

The degree of lightness and yellowness increased with maturity but the degree of redness followed a decreasing trend (Table 9). The increase in degree of lightness with maturity might be attributed to reduction in browning potential with growth. Change in colour of the culinary banana is the major physical and chemical changes with the approach of maturation. This could be attributed to degradation of chlorophyll coupled with synthesis of other plant pigments usually carotenoids and anthocyanin. Therefore an increase in yellowness in fully matured culinary banana is associated with increase in total carotenoid content. Several studies have revealed that change in fruit colour is an important indicator to identify stage of crop maturity physically (Soltani *et al.*, 2011).

**Table 9. Effect of different stages of development on colour measurement of *Musa* ABB**

| Stage | L | a | b |
|---|---|---|---|
| I | 47.04±1.24a [a] | 2.87±0.04[e] | 6.49±0.05[a] |
| II | 60.62±1.12[b] | 2.19±0.03[d] | 7.79±0.12[b] |
| III | 70.31±1.35[d] | 2.04±0.03[c] | 8.29±0.08[c] |
| IV | 69.06±2.28[c] | 1.52±0.02[b] | 9.26±0.52[e] |
| V | 72.76±1.97[e] | 1.37±0.07[a] | 8.77±0.75[d] |

[a]Means in columns followed by the same letters are not significantly different at p<0.05; values represent mean± SD, n=4.

## 3.10. Optimum Stage of Harvesting

Pulp to peel ratio coupled with total soluble sugars are the most important parameters for harvesting. It increases with more maturity/ripeness and indicates differential changes in moisture content of peel and pulp (Adao and

Gloria, 2005). With increase in pulp to peel ratio or in other words the more is the maturity the more will be the total soluble sugars which is unsuitable for culinary purpose. In the present study, 50 DAE (stage III) is considered to be the optimum stage of harvesting (Table 10) because from this stage onwards there was more breakdown of starch and in turn more total soluble sugars were obtained and thereafter sharp increase in total soluble sugars at stage IV and V compared to the earlier stages. Therefore from culinary standpoint, 50 DAE (stage III) is the optimum stage for harvesting of *Musa* ABB.

**Table 10. Pulp to peel ratio vis-a-vis total soluble sugars**

| Stage | Pulp to peel ratio (g/100g) | Total soluble sugars (g/100g) |
|---|---|---|
| I | 1.23±0.75[a] | 0.64±0.03[a] |
| II | 1.69±0.94[b] | 0.72±0.05[b] |
| III | 2.01±0.95[c] | 1.35±0.03[c] |
| IV | 2.11±0.88[c] | 2.01±0.06[d] |
| V | 2.15±0.92[c] | 4.65±0.97[e] |

[a]Means in columns followed by the same letters are not significantly different at $p<0.05$; values represent mean±SD, n=4.

# 4. Conclusions

The present study reveals that the nutritional compositions are affected by various growth stages of culinary banana *Musa* ABB. Pulp to peel ratio and total soluble sugars suggest that 50 DAE is the optimum stage of harvesting. The culinary banana *Musa* ABB has potential applications of developing numbers of value added products. For instance, the antioxidant activity makes itan excellent ingredient for developing products like cookies, biscuits, bread etc. Furthermore, increased accumulation of starch renders mature tissue a potential source for commercial starch extraction and also presence of considerable amount of amylose allows for developing products which can be subjected to high temperature.

# Acknowledgements

Financial support received from Ministry of Defence, GoI, New Delhi is duly acknowledged. The authors are also grateful to Dr. T. Longvah and Dr. R. Ananthan of Food Chemistry Division, National Institute of Nutrition, Hyderabad, A.P., India for their help.

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