



## Fruit Morphological Characteristics and $\beta$ -carotene Content of Three Indonesian Dessert and Cooking Banana Cultivars

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### Abstract

Approximately, 325 cultivars of bananas were found in Indonesia. They have variation in shape, taste, color of fruit pulp, essential vitamins and mineral. The  $\beta$ -carotene is one of essential nutrient in banana with various concentration in every cultivar. The aims of this research were to describe the morphological characteristics and to analyze  $\beta$ -carotene content of mature fruits of three different genomic groups of Indonesian dessert and cooking banana cultivars namely Berlin (AA/dessert), Barangan (AAA/dessert), and Kepok (ABB/cooking). Morphological characterizations of fruits were conducted according to Descriptor for Banana from International Plant Genetic Resources Institute. The  $\beta$ -carotene content of mature banana pulp was analyzed using High-performance liquid chromatography (HPLC) method with three replications. Banana fruit characters were analyzed based on 15 descriptors. The bananas were then subjected to clustering analysis. The result showed that  $\beta$ -carotene content were  $27 \mu\text{g } 100\text{g}^{-1}$ ,  $5 \mu\text{g } 100\text{g}^{-1}$ , and  $3 \mu\text{g } 100\text{g}^{-1}$  fresh weight respectively. Berlin showed the highest value of  $\beta$ -carotene. Cluster analyses formed two groups. The first group consists of Berlin and Barangan while the second one consists of Kepok. This study can be used as a reference for people to consume bananas with high content of  $\beta$ -carotene in meeting the needs of vitamin A and as a consideration for the plant breeding especially for  $\beta$ -carotene improvement purpose.

### How to Cite

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## INTRODUCTION

The majority of edible bananas had origins from *Musa acuminata* Colla which contributes A genom (D'Hont et al., 2012) and *Musa balbisiana* Colla which contributes B genom (Davey et al., 2013). The genome formula for the hybrid of *M. acuminata* x *M. balbisiana* consists of AA, AB, AAA, AAB, ABB, AAAA, AAAB, AABB, and ABBB (El-Khishin et al., 2009).

The genetic differences in bananas showed morphological variation in their fruits. The characteristics of fruits from AA genomic group are bright yellow peel and pulp, with predominant sugary taste, while the fruits from AAA group are fine curved shape, sweet taste with aromatic flavor and the fruit of ABB group are thick coarse and yellow peel with dark brown blotches, they have mild sweet taste and must be cooked before eaten (Hapsari & Lestari, 2016). Characterization of morphological characteristics of mature fruit from different genomic group is important to the fruit identity and consumer's preferences.

Vitamin A deficiency is pronounced in developing countries and mainly affects children, woman in reproductive age and pregnant woman (Ekesa et al., 2012). Carotenoids are one of the most important classes of plant pigments and play a crucial role in the quality parameters of fruit and vegetables (Van Den Berg et al., 2000). Carotenoids in fruit and vegetables are generally rich in  $\beta$ -carotene and  $\alpha$ -carotene (Saini, Nile, & Park, 2015).  $\beta$ -carotene is known as a vitamin A precursor because  $\beta$ -carotene which enters human body will be absorbed and converted into vitamin A (Kidmose, Christensen, Agili, & Thilsted, 2007) boiled peeled and roasted peeled roots of six orange- and yellow-fleshed sweet potato varieties from Kenya to evaluate their vitamin A potential before and after household preparation. The boiling and roasting procedures were similar to traditional methods used in Kenya. Dried products, chips and flour, of the variety Zapallo were also analysed. The varieties differed in dry matter and  $\beta$ -carotene content (1240-10,800  $\mu\text{g}/100\text{ g}$  fresh weight (FW). Mature banana fruit contains of vitamin A, C, B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub> (A, Izundu, Helen, & Ngozi, 2016), and  $\beta$ -carotene (Fungo & Pillay, 2013).

The  $\beta$ -carotene content in bananas varies for each cultivar (Newilah et al., 2009) the carotenoid contents of 19 *Musa* cultivars and hybrids from the CARBAP (Douala, Cameroon. Carotenoids content and types in plant are influenced by several factors e.g. pre and post-harvesting factors, genotype, ripening time, cultivation method

and climatic conditions, as well as processing (Saini et al., 2015).

Indonesia is the center of banana diversity (Daniells, Karamura, Jenny, & Tomekpe, 2001). Indonesia has approximately 325 banana cultivars (Valmayor et al., 2002). The diversity of banana cultivar in Indonesia is the potential to provide food to meet the needs of vitamin A for Indonesian population.

The studies about  $\beta$ -carotene content in Indonesian banana cultivar are rare. Setiawan et al. (2001) reported that Ambon banana has 97  $\mu\text{g}$  100g<sup>-1</sup> of  $\beta$ -carotene. Another study showed 6650  $\mu\text{g}$  100g<sup>-1</sup> of carotenoid found in *Musa troglodytarum* (Samson, 2012). The Raja banana has 0.222 mg 100 g<sup>-1</sup> and Kepok banana has 0.261 mg 100 g<sup>-1</sup> of  $\beta$ -carotene (Zarnila et al., 2018). However, there are no information about  $\beta$ -carotene content in popular dessert banana cultivars e.g Berlin and Barangan.

The aims of this study were to describe the morphological character and to analyze  $\beta$ -carotene content of mature banana fruits from three different genomic groups of Indonesian dessert and cooking banana cultivars namely Berlin (AA/dessert), Barangan (AAA/dessert), and Kepok (ABB/cooking). The genomic group of Berlin and Kepok has already confirmed by molecular analysis using PCR-RFLP (Hapsari, Wahyudi, Azrianingsih, & Arumingtyas, 2015). While the genomic group of Barangan has already confirmed by molecular analysis using PCR-SSR and cytological characterization (Christelová et al., 2017) their production represents an important contribution to the economies of many countries in Asia, Africa, Latin-America and Pacific Islands. Most importantly, bananas are a staple food for millions of people living in the tropics. Unfortunately, sustainable banana production is endangered by various diseases and pests, and the breeding for resistant cultivars relies on a far too small base of genetic variation. Greater diversity needs to be incorporated in breeding, especially of wild species. Such work requires a large and thoroughly characterized germplasm collection, which also is a safe depository of genetic diversity. The largest ex situ *Musa* germplasm collection is kept at the International Transit Centre (ITC). The  $\beta$ -carotene content information in bananas can be used as a reference for people to consume banana with higher content of  $\beta$ -carotene in meeting the need of vitamin A. In the future, information about  $\beta$ -carotene content in Indonesian banana cultivars will support the banana breeding program.

## METHODS

### Plant Material

Three Indonesian cultivars of banana used in this study which represent three genomic groups (Table 1) were collected in Pontianak, West Kalimantan in August 2018.

### Fruit Characterization

Morphological characterizations were conducted following Descriptors for Banana (*Musa* spp.) (International Plant Genetic Resources Institute, 1996). Characters recorded including hand weight, fruits number per hand (the bunch observed was on the mid-hand), weight of fruit, length of fruit (measured as the internal curvature of the fruit without pedicel), shape of fruit at longitudinal arc, fruit transverse section, apex of fruit and residual of flower relicts at fruit apex (observed at the distal end of the fruit), pedicel length, pedicel width, peel color, peel thickness, pulp color, pulp texture, and predominant taste.

### $\beta$ -Carotene Analytical Testing

$\beta$ -carotene analyses of mature banana pulp were conducted at PT Saraswanti Indo Genetech Bogor in August 2018. The content of  $\beta$ -carotene was determined by High-performance liquid chromatography (HPLC) method.

### Data Analyses

Fruit character data obtained were compiled and analyzed comparatively and descriptively in relation to its genomic group. Qualitative analysis of fruit characters were used NTSYSpc version 2.11a. Coefficient of similarity was analyzed by SIMQUAL (Coefficient of similarity for Qualitative Data) using the simple matching (SM). Clustering analysis was analyzed using SAHN (Sequential Agglomerative Hierarchical and Nested clustering) by the methods of unweighted pair group method with arithmetic mean (UPGMA). The dendrogram was created using tree display (TREE).

## RESULTS AND DISCUSSION

### Fruit Characteristics

Fruit characterization result showed that

each genomic group had specific characteristics (Table 2 and Figure 1). Berlin (AA) has bright yellow peel, sugary taste, persistent style, smallest hand and individual fruit size than other cultivars in this study (Table 2; Figure 1). Bright yellow peel and sugary taste of pulp are very attractive to consumers and cause this cultivar becomes favorite dessert banana in Indonesia, especially in East Java (Hapsari & Lestari, 2016) and West Kalimantan. Flower relict is distinguishing character between Berlin in Pontianak and Berlin in Purwodadi Botanic Garden. Berlin from Pontianak has persistent style (Table 2; Figure 1) while Berlin from Purwodadi Botanic Garden has base of the style prominent at the fruit apex (Hapsari & Lestari, 2016).

Barangan has the longest fruit compared to Berlin and Kepok, it also has thin yellow peel with red blotches, curved shape and sweet taste (Table 2 and Figure 1). Barangan from Deli Serdang districts has straight shape and yellow peel color (Ambarita, Bayu, & Setiado, 2015). Barangan is favorite dessert banana in West Kalimantan.

Kepok has the thickest peel and very coarse compared to Berlin and Barangan, it also has yellow peel color with black blotches, and mild sweet taste (Table 2 and Figure 1). The thickest peel with yellow color of pulp and pronounced ridges of transversal fruit section are the characteristics of Kepok in this study which is similar with Kepok banana from Yogyakarta (Wahyuningtyas, Retnoningsih, & Rahayu, 2009). The blotches color in peel is distinguishing character between Kepok in Pontianak and Purwodadi Botanic Garden. Kepok in Pontianak has black blotches (Figure 1G) while Kepok in Purwodadi Botanic Garden has brown blotches (Hapsari & Lestari, 2016). Kepok (ABB) cultivar used in this study is different with Awak (ABB) banana in apex fruit shape in which Kepok has pointed shape (Table 2) while Awak has lengthily pointed shape (Sunandar & Kahar, 2017). Kepok is the most favorable banana among cooking bananas in Indonesia. As a cooking banana, Kepok has 35.24 g 100g<sup>-1</sup> of carbohydrates content (Hapsari & Lestari, 2016). The higher carbohydrates content in cooking bananas is because carbohydrate is mostly in the form of starch than sugar at ripen-

**Table 1.** Banana fruit used in this study

Cultivar name	Other name	Genomic group	Consumption type
Berlin	Muli, Maoli	AA	Dessert
Kepok	Gajih, ebung, bung, Kepok Bung	ABB	Cooking
Barangan	Berangan, Lakatan	AAA	Dessert

**Table 2.** Fruit morphological characteristics of three banana cultivars

Character	Berlin (AA)	Barangan (AAA)	Kepok (ABB)
Hand weight (g)	501 – 1000	501- 1000	1501 – 2000
Individual fruit weight (g)	≤ 75	≤ 75	76 – 200
Fruit length (cm)	≤ 15	≤ 15	≤ 15
Pedicle length (mm)	11 – 20	11 – 20	21 – 30
Pedicle width (mm)	11 – 15	16 – 20	11 – 15
Peel thickness (mm)	Two or less	Two or less	Three or more
Apex of fruit	Bottled-necked	Blunt-tipped	Pointed
Shape of fruit (longitudinal)	Straight in the distal part	Sharp curve	Straight
Fruit section (transversal)	Rounded	Ridged (slightly)	Pronounced ridges
Remains of flower relicts	Persistent style	Base of the style prominent at the fruit apex	Without any floral relicts
Fruits fall from hand	Deciduous	Deciduous	Persistent
Peel color	Bright Yellow	Yellow	Yellow
Pulp texture	Soft	Soft	Firm
Predominant taste	Sugary	Sweet	Mild, slightly tasty
Pulp color	Yellow-orange	Cream to Yellow	Cream to Yellow

ing stage (Hapsari & Lestari, 2016).

#### **β-carotene Value**

Fruits of various cultivars differ in their β-carotene values. The β-carotene values of three Indonesian banana cultivars are shown in Table 3. Bananas contain high β-carotene (3 – 27 μg 100g<sup>-1</sup>). Berlin as dessert bananas has the highest β-carotene (27 μg 100g<sup>-1</sup>) while Kepok as cooking bananas has lowest β-carotene (3 μg 100g<sup>-1</sup>) (Table 3). The β-carotene contents of Berlin is relatively equal to Cavendish (0.26 μg g<sup>-1</sup>) (Lokesh, Divya, Puthusseri, Manjunatha, & Neelwarne, 2014) we sought to focus research on local, affordable and well-accepted sources of provitamin A carotenoids. As dessert bananas are consumed fresh round the year and processed as products, this study investigated whether post-climacteric biochemical changes are linked to carotenoid degradation in four Indian varieties, one commercial (Cavendish, AAA. Kepok in this study has 3 μg 100g<sup>-1</sup> of β-carotene (Table 3) which is lower than Kepok from Sulawesi which contain β-carotene of 26.1 μg 100g<sup>-1</sup> (Zarnila et al., 2018). The difference of β-carotene is possibly related to geographical origin of the genotypes (Fungo & Pillay, 2013). The β-carotene content varies in each fruit e.g. Apricot (var. hargrand) with 170 μg g<sup>-1</sup> and peach with 9.3 μg g<sup>-1</sup> (Campbell & Padilla-Zakour, 2013) components with various health

benefits. Fruit peel has been found to possess high concentrations of these compounds yet is often removed prior to canning. We studied how phytochemical content and composition were affected by peeling in three peach and three apricot varieties. Peeling decreased carotenoid content while its effect on phenolic content and antioxidant capacity in both fruits was variety dependent. Significant diffusion of phenolics into syrup was found (>. 30%.

In *Musa*, β-carotene contents vary significantly according to their genomic groups and related to the ripening process of the pulps or their stage of post-harvest maturity (Newilah et al., 2009) the carotenoid contents of 19 *Musa* cultivars and hybrids from the CARBAP (Douala, Cameroon, geographical origin of the genotypes (Fungo & Pillay, 2013), and part of plant (Aquino et al., 2018). The accessions from PNG had the highest levels of β-carotene with values ranging from 204.9 μg 100g<sup>-1</sup> in the cultivar 'Pongani' to 2594.0 μg 100g<sup>-1</sup> in 'Dimaemamosi' (Fungo & Pillay, 2013). Uht en Yap banana from Micronesia has 4960 μg 100g<sup>-1</sup> β-carotene (Englberger, Darnton-hill, Coyne, Fitzgerald, & Marks, 2003). In other study, Modok Gier banana (AA) genotype is known to have 1605 μg 100g<sup>-1</sup> of total carotenoid content while Saney banana (AAB) genotype has 1924 μg 100g<sup>-1</sup> of carotenoid (Amorim et al., 2009). Similarly, studies conducted in Cameroon



**Figure 1.** Morphological characteristics of mature fruit of three banana cultivars. Berlin (A-C): (A) hand of fruits, (B) Longitudinal section (C) and fruits cross section; Barangan (D-F): (D) hand of fruits (E) Longitudinal section (F) and fruits cross section ; and Kepok (G-I): (G) hand of fruits (H) Longitudinal section (I) and fruits cross section (I).

showed that two triploid (AAB) genotypes, Btard and Mbouroukou n°1 has  $\beta$ -carotene content of 1988 and 1729  $\mu\text{g } 100\text{g}^{-1}$  respectively (Newilah et al., 2009) the carotenoid contents of 19 Musa cultivars and hybrids from the CARBAP (Douala, Cameroon. In Indonesia, Pisang Ambon has 97  $\mu\text{g } 100\text{g}^{-1}$   $\beta$ -carotene (Setiawan, Sulaeman, Giraud, & Driskell, 2001) banana, guava, jackfruit, kedondong, kemang, mango, mangosteen, orange, papaya, pineapple, rambutan, salak, sawo, starfruit, tangerine, red watermelon, and yellow watermelon. Nanjangud rasabale (AAB) and chandran (AAA) has  $\beta$ -carotene content of 0.66 and 8.38  $\mu\text{g } \text{g}^{-1}$  respectively (Lokesh et al., 2014) we sought to focus research on local, affordable and well-accepted sources of provitamin A carotenoids. As dessert bananas are consumed fresh round the year and processed as products, this study investigated whether post-climacteric biochemical changes are linked to carotenoid degradation in four Indian varieties, one commercial (Cavendish, AAA. The  $\beta$ -carotene content in pulp is higher than peel in Terrinha banana

(Aquino et al., 2018).

In the present work, the genomic group AA (Berlin) have higher content of  $\beta$ -carotene compared to those from ABB (Kepok) and AAA groups (Barangan) (Table 3). The variation in carotenoid content in banana is possible related to specific genotype (Davey et al., 2009).

**Table 3.** The  $\beta$ -carotene content of three Indonesian banana cultivars in 100 grams edible portion

Parameter	Berlin	Barangan	Kepok
$\beta$ -Carotene ( $\mu\text{g } 100\text{g}^{-1}$ )	27	5	3

#### Cluster Analysis of Fruit character

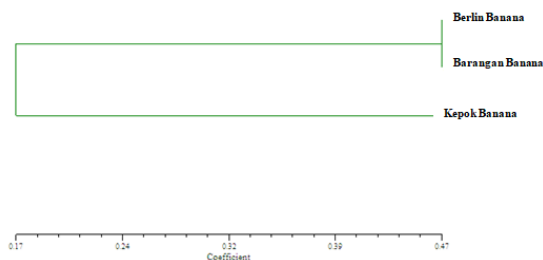
Morphological variation of fruit characteristic is affected by genetic factor from the parents. The fruit characters of Berlin (AA) and Barangan (AAA) are closely related to wild seeded *M. acuminata* as their ancestral parents. There are some other banana cultivars in which included as AA genomic group beside Berlin e.g. Pi-

sang Jari Buaya, Lilin (Daniells et al., 2001), Mas, Pinang, Masam (Valmayor et al., 2002), Dokare, Jambe, and Orlin (Hapsari et al., 2015) and the other AAA genomic group beside Barangan e.g Pisang Kayu, Santen, Raja Kenanga, Raja Molo (Hapsari et al., 2015), Ambon, Gros Michel, and Cavendish (Daniells et al., 2001).

Kepok (ABB) as hybrid cultivars have intermediate characters between two wild seeded species *M. acuminata* and *M. balbisiana*. The fruit character of Kepok was closely related to *M. balbisiana* than *M. acuminata* since it contained two 'B' genomes. Other banana cultivars that have ABB genomic group beside Kepok e.g. Awak (Daniells et al., 2001), Kates, Raja Prentel, and Sobo Awu (Hapsari et al., 2015).

Cluster analysis showed that fruit characters were clustered according to its genome constitution (Figure 2). Fruit character of three Indonesian banana cultivars were clustered into two groups. Berlin (AA) was clustered together with Barangan (AAA) as group 1 with coefficient of similarity by 47% while Kepok (ABB) was clustered as group 2 with coefficient of similarity by 17% (Figure 2). Similar studies conducted by Hapsari & Lestari (2016) showed that fruit characters were clustered according to its genome constitution e.g. Berlin (AA) was clustered together with Ambon Hijau (AAA) and Raja Bandung (ABB) was clustered together with Kepok (ABB).

One cultivar of Indonesian dessert banana from AA group (Berlin cultivar) has a good nutrition value as a source of  $\beta$ -carotene. Berlin banana cultivar has potential as a medium to address nutritional problem especially vitamin A deficiency. The high  $\beta$ -carotene in Berlin banana cultivar can be used as a reference for people to consume Berlin banana cultivar in meeting the need of vitamin A.



**Figure 2.** Dendrogram of cluster analysis based on morphological characteristics of mature banana fruit.

The analysis related to the other carotenoid forms and different maturity stage in banana is needed to provide more detail information about carotenoid content. Further study of

$\beta$ -carotene analysis to more samples of other Indonesian banana cultivars will support the banana breeding program to find cultivars that have higher  $\beta$ -carotene content.

## CONCLUSION

The  $\beta$ -carotene content of three Indonesian dessert and cooking banana cultivars is ranging from 3-27  $\mu\text{g } 100\text{g}^{-1}$ . Berlin banana cultivar from AA group cultivar shows the highest of  $\beta$ -carotene content. Fruit characters of Berlin (AA) banana cultivar and Barangan (AAA) banana cultivar are closely related to *M. acuminata* wild species, whereas Kepok (ABB) banana cultivar has intermediate characters between *M. balbisiana* and *M. acuminata* wild species.

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