AGRIVITA Journal of Agricultural Science. 2016. 38(3): 303-311

FRUIT CHARACTERISTIC AND NUTRIENT VALUES OF FOUR INDONESIAN BANANA CULTIVARS (*Musa* spp.) AT DIFFERENT GENOMIC GROUPS

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Received: October 22, 2015 /Accepted: May 9, 2016

ABSTRACT

Aims of this research were to describe the morphology and analyze nutrient values of mature fruits at three different genomic groups of Indonesian banana cultivars including Pisang Berlin (AA), Ambon Hijau (AAA), Raja Bandung (ABB) and Kepok (ABB). Fruit characterization results show that each banana cultivar had specific characteristics related to their genomic group. Pisang Berlin has bright yellow peel and pulp, sugary taste. Pisang Ambon Hijau has fine curved fruit shape, sweet taste and aromatic. Pisang Raja Bandung has medium thickness and yellow peel, firm flesh, sweet and slightly acidic taste. Pisang Kepok has thick coarse and yellow peel with dark brown blotches, mild sweet taste. Fruit characters of Pisang Berlin and Ambon Hijau are close related to their ancestral parents' *Musa acuminata* wild species, whereas Pisang Kepok and Pisang Raja Bandung as hybrid cultivars have intermediate characters between *Musa acuminata* and *Musa balbisiana* wild species. Nutrient analysis revealed that mature banana pulp contain of high carbo-hydrates (16.72-35.24 g $100g^{-1}$), total sugar (12.12-20.82 g $100g^{-1}$), vitamin C (16.45-30.27 g $100g^{-1}$) and potassium (275-375 g $100g^{-1}$); moderate protein (1.48-1.78 g $100g^{-1}$) and low fat (0.03-0.08 g $100g^{-1}$). About 100 g edible portion of banana fruit produce 73.43 to 148.80 calories.

Keywords: banana cultivar; fruit; genomic; morphology; nutrient values

INTRODUCTION

Edible bananas are important horticultural commodities that widely consumed by people around the world. Banana plants are very adaptive to environment especially during drought condition so that valuable for food security program particularly in the rural community of developing countries (Suhartanto, Sobir, Harti, & Nasution, 2009). At International trade, bananas were at fourth rank in gross value production of important global food crop (Arias, Dankers, Liu, & Pilkauskas, 2003). Bananas can be consumed both fresh as dessert and cooked (Burkill, Birtwistle, Foxworthy, Scrivenor, & Watson, 1966; Heyne, 1987; Onwuka, Onyemachi, & David-Chukwu, 2015). Beside the main fruit as food source, the other plant parts from roots until leaves are utilized for various purposes. In addition, bananas also play roles in cultural traditions in many South-East Asian countries (Espino, Jamaludin, Silayoi, & Nasution, 1992; Valmayor & Wagih, 1996).

The majority of edible bananas had their origins from two wild seeded banana species *i.e. Musa acuminata* Colla (contribute 'A' genome) and *Musa balbisiana* Colla (contribute 'B' genome). Wild seeded bananas are not much economically utilized but it linked to its role as a source of germplasm to improve banana quality in the future (Nasution & Yamada, 2001). A scoring method subjected to morphological character is used to identify and indicate the relative contributions of two wild species to the constitution of any given cultivars. Edible bananas have 22, 33 or 44 chromosomes with the basic number is n=11, so that ploidy levels of banana cultivars are diploid, triploid and tetraploid respectively with 7 genome configurations including *M. acuminata* cultivars consists of AA, AAA and AAAA and the hybrid forms (*M. acuminata x M. balbisiana*) consists of AB, AAB, ABB and ABBB (Frison & Sharrock, 1998; Simmonds, 1959). Furthermore, various techniques of molecular analysis to identify the genomic group of bananas has already been employed (Jesus et al., 2013).

Morphological characterization of mature fruits at different genomic groups are important to

Cite this as: Hapsari, L. & Lestari, D. A. (2016). Fruit characteristic and nutrient values of four Indonesian banana cultivars (*Musa* spp.) at different genomic groups. *AGRIVITA Journal of Agricultural Science*, *38*(3), 303-311. http://doi.org/10.17503/agrivita.v38i3.696
Accredited: **SK No. 81/DIKTI/Kep/2011**
Permalink/DOI: http://dx.doi.org/10.17503/agrivita.v38i3.696

be conducted as it is related to the fruit identity and consumer's preferences. The basic characteristic of banana of AA group are small size with attractive golden-yellow thin peel, light orange and soft pulp, predominant sweet taste (slightly sour) and aromatic fragrance. Bananas AAA group are more vigorous than the diploids and bear heavy, symmetrical bunches of large fruit and markedly curved with creamy white to yellow pulp, soft and fine textured, sweet taste with aromatic flavor. Fruit of AAB group bananas are characterized by its large fruit with thick coarse peel, orange; pulp creamy-orange, coarse texture and sweet tastes. Fruit of ABB group bananas are nearly straight, thick, coarse and waxy peel, and remains starchy when ripe so that must be cooked before eaten (Daniells, Jenny, Karamura, & Tomekpe, 2001; Espino, Jamaludin, Silayoi, & Nasution, 1992; Hapsari, 2013; Hapsari & Masrum, 2011; Simmonds, 1959; Vargas & Sandoval, 2005)

Composition and nutrient values of banana fruits are varies of each cultivar. Bananas are included as climacteric fruit. It is indicated by the increase of carbohydrates level in form of starch when the fruit turn mature (Anyasi, Jideani, & Mchau, 2013). According to some references not in particular cultivar name, in 100 g of edible portion mature banana produce approximately 90 calories; contains of 70 g water, 0.3 g fat, 27 g carbo-hydrate, 1.2 g protein and 0.5 g fiber. Essential minerals in high amount is present in bananas including magnesium (30-35 mg $100g^{-1}$), potassium (385-500 mg $100g^{-1}$), phosphorus (22-30 mg $100g^{-1}$), calcium (3-8 mg $100g^{-1}$), iron (0.42-0.6 mg $100g^{-1}$) and zinc (0.18 mg $100g^{-1}$).

It is vitamin rich contains of vitamin C (10-20 mg $100g^{-1}$), riboflavin 0.04-0.07 mg $100g^{-1}$), thiamine (0.04-0.08 mg $100g^{-1}$), panthotenin acid (0.26 mg $100g^{-1}$) and pyridoxine (0.51 mg $100g^{-1}$). It is low cholesterol and salt mineral (Anyasi, Jideani, & Mchau, 2013; Espino, Jamaludin, Silayoi, & Nasution, 1992; Heyne, 1987; Onwuka, Onyemachi, & David-Chukwu, 2015; Simmonds, 1959; Zomo, Ismail, Jahan, Kabir K., & Kabir M. H., 2014). The high nutrient values of bananas are important to fulfill the daily needs for people at any ages.

There are numerous of banana processing techniques *viz.* boiled or steamed, roasted or baked, fried also modern productions of chips, drying, pureeing and brewing. Unripe cooking bananas can be processed become flour. Flour of cooking banana is potential, which could be used or blended with wheat flour for baking, confectioneries and extruded foods (Anyasi, Jideani, & Mchau, 2013; Frison & Sharrocks, 1998; Onwuka, Onyemachi, & David-Chukwu, 2015). The roles of bananas are become more advocated and readily accepted as an important food source in supporting food security program.

Aims of this research were to describe the morphology and analyze nutrient values of mature fruits at three different genome groups of Indonesian banana cultivars including Pisang Berlin (AA), Ambon Hijau (AAA), Raja Bandung (ABB) and Kepok (ABB). The genomic group of those four bananas has already confirmed by molecular analysis using PCR-RFLP (Hapsari, Wahyudi, Azrianingsih, & Arumingtyas, 2015). Studies to characterize the fruit morphologies also reveal and compare the nutrient values of some Indonesian bananas at different genomic groups are needed to provide basic scientific information for society.

MATERIALS AND METHODS

Materials

Materials examined in this research were four Indonesian cultivars of banana which represent three genomic groups (Table 1) collection of Purwodadi Botanic Garden. The banana observed were the mid-hands of the bunch, which in fully mature stage already ripe but not over ripe.

Table 1. Banana materials examined in this study

No.	Cultivar name	Synonim	Genomic group	Consumption type
1.	Berlin	Muli, Maoli	AA	Dessert
2.	Ambon Hijau	Ambon Lumut, Buai	AAA	Dessert
3.	Raja Bandung	Bandung, Raja Siem, Siem, Awak	ABB	Cooking and dessert
4.	Kepok	Gajih, Ebung, Bung, Kepok Bung	ABB	Cooking

Fruit Characterization

Morphological characterizations were conducted according to Descriptor for Banana from IPGRI (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, adherence of the fruit peel, cracks in fruit peel, fruits fall from hand, pulp color, pulp texture and predominant taste.

Nutrient Analytical Testing

Nutrients analyses of mature banana pulp were conducted at Laboratory of Testing for Food Quality and Food Safety, Faculty of Agricultural Technology, University of Brawijaya. Parameter tested including proximate analyses (water, ashes, protein, fat and carbohydrates); total sugar; vitamin C; and potassium content. The nutrients testing were conducted in duplo reactions (twice repeated measurements on the same sample aims to improve the accuraccy of the experiments).

Water content was analyzed using gravimetric oven at 105ºC, while ashes content was analyzed using gravimetric furnish oven at 600ºC. Protein content was assigned by Kjedahl digestion, and fat content was analyzed with soxhlet method. The carbohydrates content was the difference between 100 g of banana pulp with the total amount of protein, fat, water and ashes. Total sugar content was estimated by anthrone method. The content of Vitamin C or ascorbic acids was determined by Iodine titrat ion and potassium (K) content was determined by Atomic Absorption Spectrofotometry (AAS) method.

Data Analyses

Fruit characters and nutrient values data obtained were compiled and analyzed comparative and descriptively in relation to its genomic group. Nutrient contents were also analyzed by comparing to nutrients daily need for Indonesian baby aged 1 to 3 years old and for male also female adults aged 19 to 29 years old as mentioned in a Ministerial Regulation number 75/2013 from Minister of Health, Republic of Indonesia. Total energy per sample was then calculated by summarizing of the carbohydrate, protein and fat values multiplied with its calories equivalent values. Carbohydrate in 1 gram amount produced 4 calories, protein in 1 gram amount produced 4 calories, while fat in 1 gram amount produced 9 calories.

Qualitative analysis of fruit characters are first numerical quantified using unweighted scoring method; subsequently it is subjected to clustering analysis using software of Paleontological Statistics (PAST) version 1.94b with paired group algorithm and Euclidean similarity measure whereas for nutrients data are directly imposed to analysis of clustering with measure Bray-Curtis similarity (Hammer, Harper, & Ryan, 2001).

RESULTS AND DISCUSSION

Fruit Characteristics

Fruit characterization results show that each banana cultivar had specific characteristics related to their genomic group as shown in Table 2 and Figure 1. Pisang Berlin (AA) has the smallest hand and individual fruits size of all cultivars. Its fruit peel is very thin, cracked and easy to fall from hand but it does not easy to peel. It has bright yellow color of peel and pulp also sugary taste so that very attractive to consumers (Table 1; Figure 1. 1A-1C). Pisang Ambon Hijau (AAA) is very popular due to its big fruit size, fine curved shape, soft and very aromatic pulp. It has greenish and thick peel, un-cracked, easy to fall from hand but it's easy to peel (Table 1; Figure 1. 2A-2C). Both Pisang Berlin and Ambon Hijau are favorite dessert bananas in Indonesia, especially in East Java.

Pisang Raja Bandung (ABB) examined here was different from common Pisang Raja/ Raja Bulu which has AAB genomic group. Morphological appearance of Pisang Raja Bandung (ABB) is similar to Pisang Awak. Pisang Awak is popular throughout South-East Asia, especially in Thailand, and is widely disseminated in other regions (Espino, Jamaludin, Silayoi, & Nasution, 1992). It has small to medium fingers with waxy greenish to yellow peel color. Tip of fruits has a small bottleneck, look like "apple" bananas (Wang, Kepler, & Hooks, 2009). The flesh is firm, ivory to yellow but some variants have white and pink pulp; and it may be seeded. It tasted sweet with slightly acidic; suitable as cooking bananas but

also good as dessert banana (Table 2, Figure 1. 3A-C). Meanwhile, Pisang Kepok has yellow peel color with dark brown blotches, thick and very coarse peel (Table 2, Figure 1. 4A-C). Morphological feature of Pisang Kepok is not much attractive; however it is the most favorable banana among cooking bananas in Indonesia. Its pulp is firm with mild sweet taste; and it also may be seeded.

Table 2. Fruit morphological characteristics of four banana cultivars

Character	Berlin (AA)	Ambon Hijau (AAA)	Raja Bandung ABB)	Kepok (ABB)
Hand weight (g)	≤ 500	501–1,000	501–1,000	501–1,000
Individual fruit weight (g)	≤ 75	76–200	76–200	76–200
Fruit length (cm)	≤ 15	16–20	≤ 15	≤ 15
Shape of fruit (longitudinal)	Straight in the distal part	Sharp curve	Straight in the distal part	Straight (slightly curve)
Fruit section (transversal)	Rounded	Ridged (slightly)	Rounded	Pronounced ridges
Apex of fruit	Bottled-necked	Pointed	Bottled-necked	Pointed
Remain of flower residual	Base of the style prominent	Style persistent	Base of the style prominent	Without any floral relicts
Pedicel length (mm)	≤ 10	≤ 10	11–20	11–20
Pedicel width (mm)	5–10	>10	5–10	5–10
Peel color	Bright yellow	Greenish to yellow	Yellow	Yellow
Wax on peel	Absent	Absent	Present	Present
Peel thickness (mm)	Two or less	Three or more	Two or less	Three or more
Adherence of the peel	Fruit does not peel easily	Fruit peels easily	Fruit peels easily	Fruit peels easily
Cracks in peel	Cracked	Cracked	Without cracks	Without cracks
Fruits fall from hand	Deciduous	Deciduous	Persistent	Persistent
Pulp color	Yellow-orange	Ivory to yellow	Cream to yellow	Cream to yellow
Pulp texture	Soft	Soft	Firm	Firm
Predominant taste	Sugary	Sweet	Sweet and slightly acidic	Mild, slightly tasty

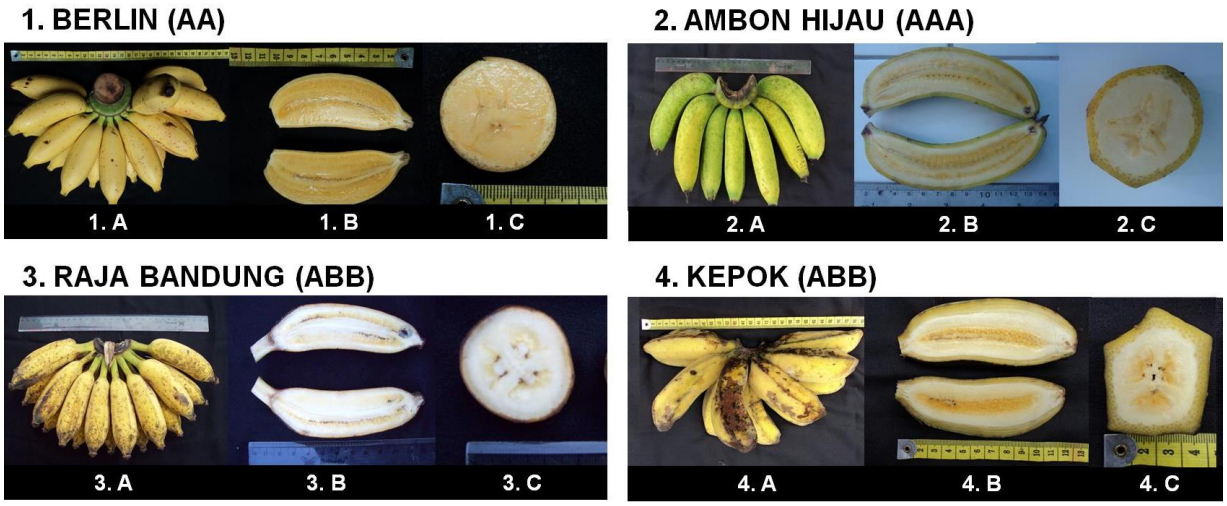

Figure 1. Mature fruit morphological characteristics of four banana cultivars: (A) a hand of fruits, (B) fruit longitudinal section and (C) fruit cross section

Fruit Nutrient Values

Fruits of various cultivars differ in their nutrient values. The nutrient values of four Indonesian banana cultivars in 100 g of edible portion were shown in Table 3. Bananas contain of high carbohydrates (16.72 – 35.24 g $100g^{-1}$). Pisang Kepok as cooking bananas has the higher carbohydrates (35.24 g $100g^{-1}$) while Pisang Berlin as dessert bananas has the lowest carbohydrates (16.72 g $100g^{-1}$). It was in the contrary to the water content. Pisang Berlin has the higher water content (80.94%) whereas Pisang Kepok has the lowest water content (62.01%). At ripening stage, carbohydrates in cooking bananas are mostly in the form of starch than sugar whereas in dessert banana, mostly exist in the form of sugars. Thus, for cooking bananas, it must be cooked to make the starch available for the digestive organs.

Due to its high carbohydrates, cooking bananas become staple food in Western and Central Africa and in some archipelago countries in the Pacific also in certain areas on South-East Asia such as the Philippines, eastern Indonesia and Papua New Guinea which have long dry season (Valmayor & Wagih, 1996). Unripe cooking bananas are higher in carbohydrates level than ripe bananas in form of banana flour ranged between 78.85 to 79.88 g $100g^{-1}$ in African bananas *i.e.* Cardaba and Bluggoe cultivars. Thus, for starch production the unripe mature fruits after harvest should be processed immediately to prevent the decrease of starch content (Anyasi, Jideani, & Mchau, 2013; Onwuka, Onyemachi, & David-Chukwu, 2015).

Total sugar is a mixture of reducing sugar (glucose, mannose, fructose, lactose, maltose, etc.) and non-reducing sugar (sucrose) in which the result of starch hydrolysis (Zomo, Ismail, Jahan, Kabir K., & Kabir M. H., 2014). Pisang Raja Bandung and Pisang Kepok as cooking bananas (ABB) had higher total sugar than dessert bananas (AA and AAA). It was presumable due to their high starch content as cooking bananas. Furthermore, Pisang Raja Bandung (ABB) was slightly higher than Pisang Kepok (ABB) about 20.82 g $100g^{-1}$ and 17.03 g $100g^{-1}$ respectively (Table 3), that is why the taste of Pisang Raja Bandung (ABB) is sweeter and can be eaten both fresh or cooked. Meanwhile in term of dessert bananas, Pisang Ambon Hijau (AAA) contained higher total sugar than Pisang Berlin (AA). The total sugar of banana fruits is relatively equal to mango (17.3-20.75 g $100g^{-1}$) and jackfruit (13.80-17.89 g $100g^{-1}$) (Goswami, Hossain, Kader, & Islam, 2011; Ubwa, Ishu, Offem, Tyohemba, & Igbum, 2014).

Ripe banana is often restricted (the portion is limited) prescribed for diet of diabetic patients due to the high content of carbohydrates and sugars. Yet, under-ripe bananas (steamed /boiled) contain low glycaemic carbohydrates may become acceptable alternative meal for diabetic patients particularly the Type 2 Diabetes (Hermansen, Rasmussen, Gregersen, & Larsen, 1992).

Table 3. Nutrient values of four Indonesia banana cultivars in 100 gram edible portion

Parameter	Berlin (AA)	Ambon Hijau (AAA)	Raja Bandung (ABB)	Kepok (ABB)	Average	Nutrient values daily need*		
						Baby 1 – 3 y.o.	Male 19 – 29 y.o.	Female 19 – 29 y.o.
Water (%)	80.94	72.94	66.49	62.01	70.6	-	-	-
Ash (g)	0.79	0.78	0.82	0.89	0.82	-	-	-
Carbohydrates (g)	16.72	24.33	31.13	35.24	26.86	155	375	309
Protein (g)	1.48	1,92	1.51	1.78	1.67	26	62	56
Fat (g)	0.07	0.03	0.05	0.08	0.06	44	91	75
Total Sugar (g)	12.12	15.91	20.82	17.03	16.47	-	-	-
Vitamin C (mg)	25.54	19.10	16.45	30.27	22.84	40	90	75
Potassium (mg)	375	275	350	365	341.25	3,000	4,700	4,700
Energy (cal)	73.43	105.27	131.01	148.8	114.63	1,125	2,725	2,250

Remarks: * Nutrient values daily need in accordance with Ministerial Regulation, Minister of Health, Republic of Indonesia number 75/2013

The protein values of bananas were in moderate level, it varied from 1.48 g $100g^{-1}$ to 1.78 g $100g^{-1}$ with the highest amount in Pisang Ambon. Protein value of banana pulp is higher than jackfruit which only 0.57 g $100g^{-1}$ to 0.97 g $100g^{-1}$ but relatively equal to mango (1.30-1.65 g $100g^{-1}$) (Goswami, Hossain, Kader, & Islam, 2011; Ubwa, Ishu, Offem, Tyohemba, & Igbum, 2014). The fat values of bananas were very low, only about 0.03 g to 0.08 g. The total energy calculation varies from 73.43 calories to 148.8 calories. Banana is recommended for diet food, it provides source of high energy, moderate protein but very low fat.

Banana contains high of vitamin C varies from 16.45 mg $100g^{-1}$ to 25.54 mg $100g^{-1}$. It is much higher than mango (6.04-11.23 mg $100g^{-1}$) and jackfruit (4.57-8.18 mg $100g^{-1}$) (Goswami, Hossain, Kader, & Islam, 2011; Ubwa, Ishu, Offem, Tyohemba, & Igbum, 2014). Nutrient values of 100 g edible portion of banana is adequate to fulfill the carbohydrates and vitamin C daily values for babies aged one to three years old whereas for adults need more quantities. About 300 g of bananas are needed to fulfill vitamin C for female adults per day whereas male adults need 400 g. Vitamin C is a water-soluble vitamin in which necessary for normal growth and development of tissues. It is an antioxidant which helps the iron absorption, to maintain tissue protein collagen connectivity, and to protect bodies against the infection (Walingo, 2005).

Banana is one of fruits with high level of potassium. Potassium content in bananas were varies between 275 mg to 375 mg. Pisang Berlin has the highest potassium level. It is a very important mineral to balance fluid of our body. It helps the cells properly functions by keeping the water balance and internal pressure. However, for those who have problems of kidney (usually the elderly) may need to limit the potassium intake (Kumar, Bhowmik, Duraivel, & Umadevi, 2012).

Nutrient values are the interaction results between genetic and environment factors. Concentration and bioavailability of essential and potential minerals, organic nutrients in the soil and plant health will affect the crop quality and nutrient values. In order to increase the yield quality including its nutrients values, fertilization (manure and/or artificial fertilizer) are needed. Numerous studies have shown that high N supply may negatively affect the yields quality such as nitrate, starch, sucrose, oil and vitamin C whereas high N supply may increase protein and some vitamins such as carotene and thiamin (Weisler, Behrens, & Horst, 2001).

Clustering Analysis Results

Phenotypic variation of fruit character is qualitative trait that very much affected by genetic factor inherited from the parental (Allard, 1960; Arif, Sujiprihati, & Syukur, 2011). The fruit characters of Pisang Berlin (AA) and Ambon Hijau (AAA) were close related to their ancestral parents' wild seeded *M. acuminata* species. There are some other banana cultivars in which included as AA genomic group e.g. Pisang Emas, Jaran, Rayap, Rejang, Trimulin etc. (Hapsari & Masrum, 2011), whereas the AAA genomic group e.g. Pisang Ambon Hong, Byok, Kayu, Kreas, Nona, Santen, Williams, etc. (Hapsari, 2013).

Pisang Raja Bandung (ABB) and Kepok (ABB) as hybrid cultivars have intermediate characters between two ancestral parents' wild seeded species *M. acuminata* and *M. balbisiana*; but much close related to *M. balbisiana* than *Musa acuminata* since it contained two 'B' genomes. Other banana cultivars in which included as ABB genomic group e.g. Pisang Saba Awu, Saba Landa, Kates, Klutuk Sukun, Baflo, Tlekung, Usuk, Susu Gabug, Lempeleng, etc. (Hapsari, Lestari & Masrum, 2015).

Cluster analysis showed that its fruit characters clustered according to its genome constitution. It was clustered into two groups. Pisang Berlin (AA) was clustered together with Pisang Ambon Hijau (AAA) as group 1 with taxonomic distance 3.6 whereas Pisang Raja Bandung (ABB) was clustered together with Pisang Kepok (ABB) as group 2 with taxonomic distance 4.0. Both groups were separated with taxonomic distance about 4.5 (Figure 2A).

Cluster analysis based on nutrient values of four Indonesian banana cultivars showed different pattern compared to the morphological character result. All of them were clustered together and become sisters in the group which means their nutrient values were quite similar and in the same range according to Bray-Curtis similarity measure. However, Pisang Raja Bandung and Pisang Kepok both as cooking bananas (ABB) were having high similarity of nutrient values about 95.80% whereas Pisang Ambon Hijau was the most different in nutrient values to others with similarity 87.40% (Figure 2B).

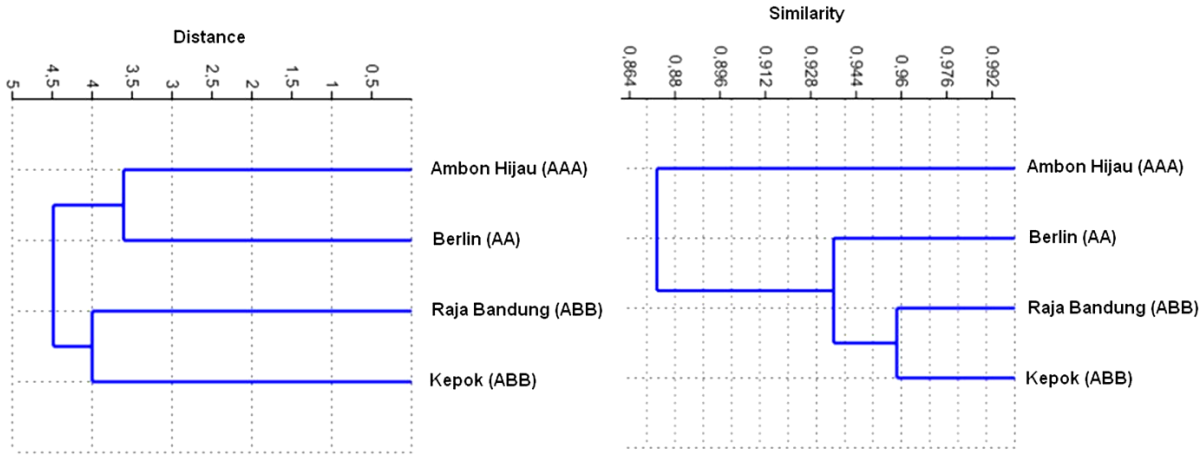

Figure 2. Dendogram clustering analysis based on (A) morphological characters of mature fruit and (B) nutrient values

CONCLUSION AND SUGGESTION

Fruit morphological characterization results show that each banana cultivar had specific characteristics related to their genomic group. Fruit characters of Pisang Berlin (AA) and Ambon Hijau (AAA) were close related to their ancestral parents' *M. acuminata* wild species, whereas Pisang Raja Bandung (ABB) and Pisang Kepok (ABB) have intermediate characters between *M. balbisiana* and *M. acuminata* wild species. Fruits of various cultivars differ in their nutrient values. The nutrient values of four Indonesian banana cultivars in 100 g of edible portion contained high carbohydrates, total sugar, potassium and vitamin C; moderate protein, low fat and high calories. Due to its high nutrient values, bananas are nutritious food recommended for people at all ages, especially for baby, also diet food for adults but consumption must be limited for diabetic and kidney problem patients.

The analysis of other essential vitamins and mineral were needed to provide more detail nutrient values information. Further study of nutrient analysis to more samples of other Indonesian banana cultivars followed by selection will support the banana breeding program in Indonesia.

ACKNOWLEDGEMENT

This research was funded by DIPA fund of Purwodadi Botanic Garden, Indonesian Institute of Sciences under thematic research entitled "Revitalization collection and diversity study of Musaceae in Purwodadi Botanic Garden". The authors were also acknowledged to Laboratory of Testing for Food Quality and Food Safety, Faculty of Agricultural Technology, University of Brawijaya for the nutrient testing services.

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