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Fruit Morphology and Nutritional Composition of Different Genome Groups of Six Bananas Cultivars from Bali Island

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Abstract

Bali is home to at least 43 banana cultivars, each serving a wide range of purposes. To support its future development, there is a need to obtain essential information on the morphological and nutritional characteristics of these bananas for domestic needs and the tourism market. Therefore, this study aimed to analyze the fruit morphology and nutritional composition of six local Balinese banana cultivars mainly consumed on Bali Island, namely Pisang Mas (AA), Buluh (AAA), Lumut (AAA), Susu (AAB), Raja (ABB) and Kepok (ABB) genomes. The observation of fruit morphology followed the guidelines of the International Plant Genetic Resources Institute method for bananas. The nutritional composition was analyzed using standard methods by measuring the proximate composition, vitamin C and concentrations of minerals K, Ca, Fe and P. Based on the morphological relationship coefficient values, it was discovered that all banana cultivars were closely related. Dessert bananas of Pisang Mas, Buluh, Lumut and Susu shared a close relationship with their ancestor *Musa acuminata*, which contributed to the 'A' genome. Meanwhile, Pisang Raja, which could be employed as a dessert or cooking banana, and Pisang Kepok as a cooking banana, exhibited a closer relationship. Various cultivars showed different nutritional compositions in their fruits. In every 100 g of edible portion, the nutrient values of the six bananas contained high carbohydrates and total energy, abundant vitamin C and K, moderate total fibers and protein, as well as low fat and Fe. Based on the nutritional composition, six Bali banana cultivars were found suitable as valuable ingredients in alleviating food insecurity or as dietary components.

Keywords: Bali; cooking banana; dessert banana; morphology; nutrient content

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INTRODUCTION

Bananas are the most popular dessert fruit globally and an essential food ingredient after rice, wheat and corn. In Bali Island, bananas are locally called as *biu*, playing an important role due to the significant uses of every part, including fruits, leaves, roots, stems, midrib, heart and others. For example, these plants can be used for dessert, cooking bananas, processed products, as well as in cultural and religious ceremonies, decorations/ornaments and medicinal ingredients (Rai et al., 2018).

Edible bananas are putatively derived from crossing wild-seeded species, namely *Musa acuminata* (AA genome) and *Musa balbisiana* (BB genome), resulting in cultivars being diploid (AA, AB, BB), triploid (AAA, AAB, ABB) or tetraploid (AAAA, ABBB) (Hapsari et al., 2017). Morphological assessments have determined that edible bananas comprise 22, 33 or 44 chromosomes with a base number of n = 11.

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This evaluation helps to determine the relative contribution of the two wild-seed parental species to their offspring. Therefore, the ploidy levels of crossed bananas include triploid, tetraploid and diploid, with seven genome configurations (Čížková et al., 2013).

The bananas commonly cultivated are AA, AAA, AAB and ABB genomic (Wahyuningtyas et al., 2009). The morphological characterization in different genomic groups is essential, as it directly relates to fruit characteristics and consumer preferences. For example, several bananas with AA genes have small fruits and straight longitudinal versus round transversal fruit shapes, such as Pisang Berlin and Mas (Hapsari and Lestari, 2016). Due to their curved fruit shape and easy fruit peel removal, AAA bananas, such as Ambon Kuning and Ambon Hijau, are popular in Indonesia. The AAB genomes such as Pisang Susu are characterized by medium to large fruit size, slightly rough texture and sweet taste (Fitriyah et al., 2017). Meanwhile, the ABB genomes are straight fruit-shaped, thick and waxy peel (Wahyudi et al., 2020), such as Kepok and Raja (Hapsari, 2011). Bananas with AA or AAA genes are favored for dessert, while those with AAB or ABB genomes, used for cooking need to be processed before consumption (Wahyuningtyas et al., 2009; Wahyudi et al., 2020).

Apart from fruit morphology, different genomic groups of bananas have unique nutritional compositions (Hapsari and Lestari, 2016; Dotto et al., 2019). Generally, people select bananas due to their accessibility, affordability and health benefits, even though the majority do not know the nutritional content or composition value (Rai et al., 2018). In developing the banana agroindustry, an analysis of nutritional composition is needed. The results can be used as important information for selecting the types suitable for dessert, processed products, health-related or other uses. Processed food products are not only in various snacks such as fried bananas, chips, sticks, snacks and others but have expanded to the processing industry to support food security. Consequently, the development of the banana agroindustry yields enhanced profitability and prosperity for farmers. When fresh consumption is not visible or the production is abundant, bananas can be used as flour for bread raw materials (Al-Sahlany and Al-musafer, 2020), additional ingredients for making ice cream (Yangilar, 2015), butter mixtures and cosmetics (Kumar Rana et al., 2018). The analysis of the nutritional composition is also important in relation to selecting specific types for dietary needs and body health due to the high energy content and low fat. Moreover, certain types of bananas enriched with protein, antioxidants, vitamins, minerals and other nutrients were favored by consumers for health and fitness purposes.

Bananas contain vitamins (A, C, B1, B2 and B6), antioxidants, minerals (Fe, K, Se, Zn, Ca, P and Mg), as well as carbohydrates. According to Oyeyinka and Afolayan (2019) and Chandra et al. (2020), edible bananas contain approximately 90 calories, 70 g of water, 27 g of carbohydrates, 0.3 g of fat, 1.2 g of protein, 0.5 g of fiber, 385 to 500 mg of K, 30 to 35 mg of Mg, 22 to 30 mg of P, 3 to 8 mg of Ca, 0.42 to 0.60 mg of Fe, 10 to 20 mg of vitamin C, 0.18 mg of Zn and 0.51 mg of rib. This nutrient profile makes bananas essential for fighting malnutrition (Kookal and Thimmaiah, 2018) and meeting the dietary requirements of people across ages and regions (Dotto et al., 2019).

Rai et al. (2018) discovered 43 local banana cultivars across all regencies and cities in Bali. The six most consumed cultivars are Pisang Mas, Buluh, Lumut, Susu, Raja and Kepok. As a major tourist destination in Indonesia, the high demand and multifunctionality of bananas in Bali provide substantial opportunities for cultivation that cater to both domestic needs and the tourism market. However, the rapid development of the tourism industry has caused various crucial problems to the ecosystems, such as a drastic reduction in agricultural land due to the high conversion rate and the extinction of native local genetic resources, including the Bali banana cultivars. Consumers demand information on the uniqueness of the fruit morphology and the nutritional content of these bananas is not yet available.

This study aimed to analyze the fruit morphological characteristics and the nutritional composition of different genome groups of six banana cultivars from Bali Island, namely Pisang Mas (AA), Ambon Kuning/Buluh (AAA), Ambon Hijau/Lumut (AAA), Susu (AAB), Raja (ABB) and Kepok (ABB). The analysis was carried out to provide a foundational dataset for future development and consumer awareness, thereby contributing to the preservation of genetic resources in supporting the sustainability of the Bali banana cultivars. According to Kookal and Thimmaiah (2018), the variations in the nutritional composition of bananas offer the potential for developing value-added products. Dotto et al. (2019) stated that bananas in food-insecure areas can substitute staple foods through innovative recipes. Therefore, the results of this study were expected to be applied in developing countries to fight or alleviate malnutrition and address hidden hunger. Fostering increased banana consumption within a community can also increase cultivation, thereby supporting sustainable agricultural systems by developing banana-based farming systems (Ronner et al., 2023) and preventing the extinction of genetic resources (Kallow et al., 2022).

MATERIALS AND METHOD

Materials

In this study, six local Balinese banana cultivars were selected to represent four different genomic groups, as shown in Table 1. The samples were taken from the Bali Local Banana Germplasm Plantation in Celuk Village, Gianyar Regency, Bali, Indonesia, as indicated in Figure 1. The process involved acquiring fruits from the 2nd and 3rd hands of the upper bunch by purposive sampling method. This technique entailed determining the sample based on special considerations to ensure genotypic suitability and uniform fruit harvest at the fully ripe stage. After labeling the fruit samples, the bunch was covered for protection against pests and diseases. Subsequently, the fruits were harvested when the 2nd and 3rd hands of fruits on the bunch were fully ripe.

Fruit morphological characterization

The morphological fruit characterization observed in this study was according to the International Plant Genetic Resources Institute method (IPGRI, 1996). The characteristics observed included the position of the fruit bunch, the number of fruits per bunch, the number of hands per bunch, the weight of the hands and individual fruits, the length of the fruit, the length and width of the fruit pedicel, the longitudinal shape, the transversal section, the fruit apex, the remnants of flower relics at the fruit apex, as well as the color of the immature and mature fruit peel.

Fruit nutrient composition analysis

The nutritional composition of fruit was determined at the Nutrition and Analytical Laboratories of the Faculty of Animal Husbandry, Universitas Udayana. The methodology proposed by Dotto et al. (2019) was used to analyze the nutritional composition of banana fruit. Depending on the cultivar of bananas, 16 fingers that were randomly selected from the second and third hands of each bunch were washed with water until clean. The pulp was cut into small pieces with a thickness of ±2 mm and baked at 70 °C for 12 hours. Furthermore, the sample was ground into flour and filtered through a 1 mm diameter sieve. Pulp flour was packed in airtight packaging and stored in the freezer at -20 °C. The nutritional composition was carried out simultaneously after all samples were ready to be analyzed. Variables observed included proximate composition (water content, ash, protein, fat, carbohydrates, total fibers and total energy), vitamin C and mineral concentrations of K, Ca, Fe and P. The process was carried out in three replicates and tested on each replicate to increase the accuracy of the measurement results.

The association of official analytical of chemists (AOAC) method was employed for proximate analysis (AOAC and Latimer, 2012) and the water content was examined using the gravimetric oven technique at a temperature of 105 °C. Meanwhile, ash was analyzed using a gravimetric oven furnish method at 600 °C. The Kjeldahl method measured protein, while the soxhlet was used to determine fat using destruction, distillation and titration. Carbohydrate content was calculated by reducing 100 g of banana pulp with total protein + moisture content + fat + ash. In contrast, total energy was measured per sample and calculated by summarizing the protein, fat and carbohydrate values multiplied by their equivalent calorie

Table 1. Banana cultivars as the material studied

Cultivar name	Synonym	Genomic group	Consumption type
Pisang Mas	Pisang Mas Sasih, Muli	AA	Dessert
Pisang Buluh	Pisang Ambon kuning	AAA	Dessert
Pisang Lumut	Pisang Ambon hijau, Ambon lumut	AAA	Dessert
Pisang Susu	Pisang Susu Madu	AAB	Dessert
Pisang Raja	Pisang Raja Bali	ABB	Cooking and dessert
Pisang Kepok	Pisang Saba	ABB	Cooking

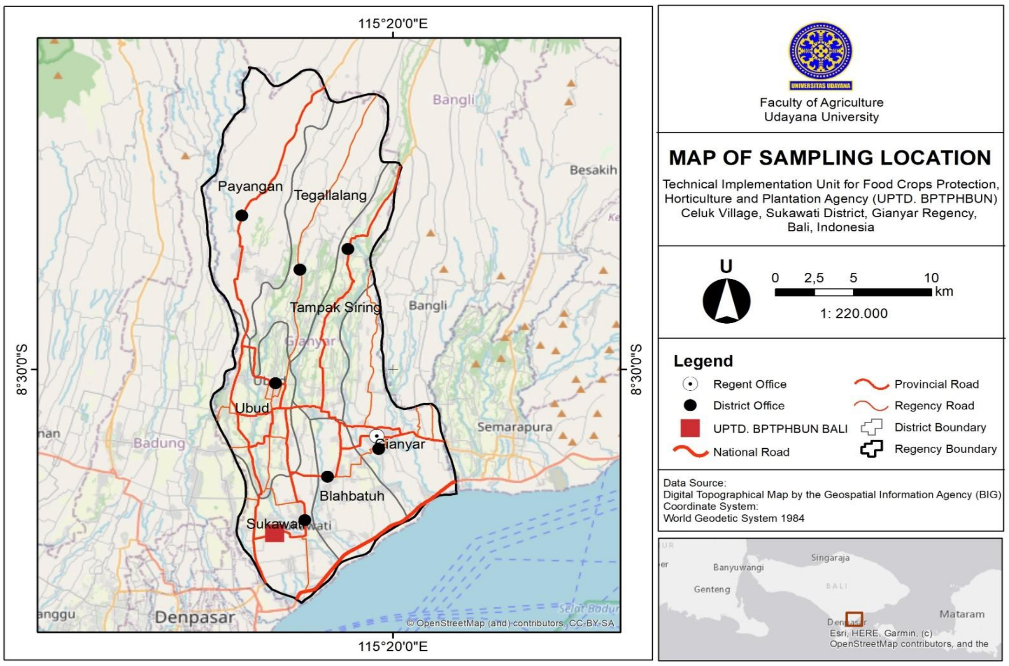


Figure 1. Map of sampling location

values. Carbohydrates in 1 g amount produced 4 calories, while protein and fat in each 1 g yielded 4 and 9 calories, respectively. Vitamin C, known as ascorbic acid content, was determined by iodine titrate ions. Subsequently, the Ca, K, P and Fe mineral concentrations were determined by the atomic absorption spectrophotometry (AAS) method.

Data analysis

The fruit morphology characters were analyzed using the unweighted pair group method average (UPGMA) software program to show similarities and differences concerning their genomic groups. The quantification of the data before morphological clustering analysis was defined as binary data. Meanwhile, the similarity index was measured in a range of values between 0 and 1 using the Bray and Curtis index. The nutritional composition was analyzed quantitatively by analysis of variance (F test) with SPSS software version 26. Before the analysis of variance, the homogeneity of the nutritional composition data was checked using the normality test. When the F test showed a significant difference, the least significant difference (LSD) test was performed to differentiate the average value among the local Balinese banana cultivars. The nutritional content of the fruit pulp was also analyzed descriptively by comparison with the daily needs, as stated in Indonesian Minister of Health Regulation Number 28 Year 2019, concerning the Recommended Nutritional Adequacy rate for the Indonesian Nation (Ministry of Health Republic of Indonesia, 2019).

RESULTS AND DISCUSSION

Fruit morphology

Table 2 showed the fruit morphological characteristics of each banana cultivar from Bali examined in this study. Compared to other cultivars, Pisang Mas exhibited the smallest fruit size with thin and cracked skin when ripe, as well as easy detachment from the fruit stalk, making peeling difficult. The pulp was bright yellow in color and had a sweet flavor, appealing to consumers. Pisang Buluh and Lumut were distinguished by their large fruit size, slightly curved fruit shape, smooth and unbroken skin, but easy peeling, facilitating their ideal and popular use as table fruit or dessert. Furthermore, several cultivars of Pisang Susu were identified in Bali depending on the color of the fruit peel after ripening, including yellow with gray spots, uniformly faded yellow, uniformly shiny yellow, brownish yellow and others. In this study, the sample used was Pisang Susu, the most widely cultivated cultivar with peel color after ripening indicated by yellow with gray spots. The assessed species had a specific characteristic of a round fruit shape, thin skin and easy break, similar to Pisang Mas. Although there was a similarity in fruit pedicel length of 2 cm or less, Pisang Susu was easy to peel. The pulp color was cream with a distinctive predominant taste of sweet

Table 2. Fruit morphological characteristics of six Bali banana cultivars

Character	Pisang Mas	Pisang Buluh	Pisang Lumut	Pisang Susu	Pisang Raja	Pisang Kepok
Fruit position	Curved upward (at a 45°angle upward)	Parallel to the stalk	Parallel to the stalk	Curved upward (at a 45°angle upward)	Curved upward (at a 45°angle upward)	Curved upward (at a 45°angle upward)
Number of hands per bunch	≤ 12	≤ 12	≤ 12	≤ 12	≤ 12	≤ 12
Number of fruits per bunch	126-200	≤ 125	≤ 125	≤ 125	126-200	126-200
Hand weight (g)	≤ 500	501-1000	501-1000	501-1000	501-1000	501-1000
Individual fruit weight (g)	≤ 75	76-200	76-200	76-200	76-200	76-200
Fruit length (cm)	≤ 15	16-20	16-20	≤ 15	≤ 15	≤ 15
Fruit pedicel length (mm)	10-20	10-20	≥ 21	10-20	≥ 21	≥ 21
Fruit pedicel width (mm)	5-10	> 10	> 10	> 10	> 10	> 10
Fruit shape (longitudinal)	Straight (or slightly curved)	Straight in the distal part	Sharp curve	Straight in the distal part	Straight in the distal part	Straight (or slightly curved)
Fruit section (transversal)	Rounded	Slightly ridged	Slightly ridged	Rounded	Pronounced ridges	Pronounced ridges
Fruit apex	Bottled-necked	Bottled-necked	Pointed	Bottled-necked	Bottled-necked	Blunt-tipped
Remains of flower relicts at the fruit apex	Persistent style	The base of the prominent style	Persistent style	Persistent style	The base of the prominent style	Without any floral relicts
Immature fruit peel color	Light green	Light green	Green	Light green	Silvery	Silvery
Mature fruit peel color	Yellow	Greenish to yellow	Greenish to yellow	Grey spots	Yellow	Yellow
Fruit peel thickness (mm)	Two or less	Two or less	Two or less	Two or less	Three or more	Three or more
Adherence to the fruit peel	Fruit does not peel easily	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily
Cracks in peel	Cracked	Without cracks	Without cracks	Cracked	Without cracks	Without cracks
Fruits fall from the hand	Deciduous	Deciduous	Deciduous	Deciduous	Persistent	Persistent
Pulp color before maturity	Cream	Ivory	Ivory	Ivory	Cream	Cream
Pulp color at maturity	Bright yellow	Ivory to yellow	Ivory to yellow	Cream	Cream to yellow	Cream to yellow
Pulp texture (mature fruit)	Soft	Soft	Soft	Soft	Firm	Firm
Predominant taste	Sugary	Sweet	Sweet	Sweet and slightly acidic	Sweet and slightly acidic	Mild, slightly tasty

and slightly acidic. The studied cultivars, namely Pisang Mas, Buluh, Lumut and Susu, were classified as dessert bananas or table fruit. However, Pisang Mas and Susu fruit sections were rounded transversally, while Buluh and Lumut were found to be slightly ridged.

The specific characteristics of Pisang Raja and Kepok included large individual fruit weight and the number of fruits per bunch, transversely fruit section pronounced ridges, fruit peel thickness of 3 cm or more, fruits fall from hand persistently, and mature pulp texture firm. There was a difference in fruit taste, where Pisang Raja exhibited sweet and acidic, which allowed for cooking and dessert usage. Meanwhile, Kepok was mild and slightly tasty, facilitating its use as cooking bananas only. This was consistent with the opinion of Hapsari and Lestari (2016), where Pisang Raja was reportedly consumed by the community as a dessert and cooking banana, while Kepok was only used as a cooking banana.

Fruit nutritional composition

All variables of nutritional composition analyzed showed significant differences between cultivars, except for total ash and protein which had no substantial effect. Table 3 showed the nutrient composition differences between fruit cultivars. The carbohydrate content of bananas was the most abundant among all nutrient variables ranging from 22.07 to 33.72 g 100 g^{-1}. Pisang Kepok, as a cooking banana, exhibited the highest carbohydrate (33.72 g 100 g^{-1}) and was significantly different from Pisang Mas, Buluh, Lumut and Susu. However, it was not significantly different from Pisang Raja as cooking and dessert banana compared to the water content. Pisang Kepok contained the highest carbohydrate (33.72%) but had the lowest water content (55.01%). Pisang Buluh has the lowest carbohydrate content (22.07 g 100 g^{-1}) and the highest water content (71.43%). Furthermore, the average water content for all bananas ranged from 55.01 to 71.43%, which aligned with the results of Thuy et al. (2021) for fully ripe bananas (71.84 to 74.06 g 100 g^{-1}). A similar pattern of carbohydrate banana values was obtained in a report by Dotto et al. (2019), which obtained a range from 21.59 to 29.96 g 100 g^{-1}. Hapsari and Lestari (2016) also stated that bananas contained high carbohydrates, ranging from 16.72 to 35.24 g 100 g^{-1}, and inversely proportional to the water content. According to Onwuka et al. (2015), 100 g of edible portion bananas provided approximately 17% of the recommended dietary allowance (RDA) for carbohydrates in children and adults (130 g day^{-1}). Consequently, the cultivars studied could be consumed to combat hidden hunger and food insecurity in banana-growing regions. Due to their high sugar and carbohydrates, ripe bananas have been prescribed or used as an acceptable alternative food for the diets of diabetic patients (Hermansen et al., 1992). Cooking bananas such as Pisang Kepok and Raja can be used as staple foods for areas with a long dry season because of their higher carbohydrate content.

Table 3 showed that the total ash and protein content of the banana cultivars studied were not significantly different, while the fat content exhibited distinct differences. Protein concentration ranged from 1.57 to 1.91 g 100 g^{-1}, with the highest concentration in Pisang Mas. The protein content of the bananas was the same

Table 3. Nutrient composition values of six Bali banana cultivars in 100 g edible portion

Parameters	Pisang Mas	Pisang Buluh	Pisang Lumut	Pisang Susu	Pisang Raja	Pisang Kepok	LSD 5%
Water content (%)	65.25^{ab}	71.43^{a}	71.71^{a}	67.81^{a}	57.54^{b}	55.01^{b}	7.99
Carbohydrate (g)	24.42^{b}	22.07^{b}	22.95^{b}	24.89^{b}	26.08^{ab}	33.72^{a}	7.77
Total ash (g)	1.00^{a}	1.09^{a}	1.10^{a}	1.22^{a}	1.21^{a}	1.14^{a}	0.32
Protein (g)	1.91^{a}	1.57^{a}	1.61	1.81^{a}	1.86^{a}	1.79^{a}	0.44
Fat (g)	2.60^{b}	1.30^{c}	1.69^{bc}	1.78^{bc}	3.60^{a}	2.34^{b}	0.94
Total energy (cal)	73.71^{bc}	74.74^{ab}	74.82^{ab}	73.44^{bc}	76.59^{a}	71.61^{c}	2.32
Total fibres (g)	2.06^{cd}	1.65^{d}	1.82^{d}	2.50^{bc}	2.06^{cd}	3.64^{a}	0.78
K (mg)	390.60^{b}	329.31^{b}	390.46^{b}	346.43^{b}	541.53^{a}	359.10^{b}	136.75
Ca (mg)	6.72^{ab}	4.67^{b}	5.04^{ab}	6.51^{ab}	6.45^{ab}	7.03^{a}	2.05
Fe (mg)	0.56^{ab}	0.69^{ab}	0.18^{b}	1.39^{a}	0.67^{ab}	1.28^{a}	1.08
Vitamin C (mg)	11.34	12.23	25.87	28.13	37.09	37.68	-)

Note: value-based on dry weight except for water content; the numbers followed by the same letter in the same column show a significant difference in the 5% level LSD test; -) data was not statistically analyzed as Pisang Berlin, Lumut, Raja and Kepok cultivars (1.48 to 1.78 g 100 g^{-1}), as reported by Hapsari and Lestari (2016). This concentration was relatively higher compared to Dotto et al. (2019), which obtained 0.61 to 1.75 g 100 g^{-1}. The protein content of banana pulp was higher than jackfruit, which was only 0.57 to 0.97 g 100 g^{-1} but relatively equal to mango at 1.30 to 1.65 g 100 g^{-1} (Ubwa et al., 2014). Generally, protein is needed for the human body to supply an adequate amount of required amino acids (Courtney-Martin et al., 2016; Nunes et al., 2022). In this study, the total ash varied from 1.00 to 1.22 g 100 g^{-1} and was relatively similar to 1.09 g 100 g^{-1} obtained by Ohizua et al. (2017). This value was lower than the total ash obtained by Pragati et al. (2014) and Vazquezshy et al. (2012), ranging from 2.89 to 2.93 g 100 g^{-1} and 3.52 to 3.75 g 100 g^{-1}. The fat content differed significantly among cultivars, with the highest amount in Pisang Raja and the lowest in Buluh. The value of fat content from 1.30 to 3.60 g 100 g^{-1} was lower compared to 2.34 g 100 g^{-1} and 1.03 to 1.44 g 100 g^{-1} obtained by Pragati et al. (2014) and Ohizua et al. (2017). Although the amount of fat was low, the variation among cultivars was statistically significant. In this study, 100 g of bananas supply 5% of the RDA for adult fat (44 to 77 g day^{-1}) (Onwuka et al., 2015).

According to Table 3, the banana cultivars varied significantly in terms of total energy and total fiber. The total energy calculation ranged from 71.61 to 76.95 calories, with Pisang Raja and Kepok having the highest and lowest amounts, respectively. Meanwhile, the total fiber ranged from 1.65 to 3.64 g 100 g^{-1}, with Pisang Kepok and Buluh having the highest and lowest values, respectively. These were consistent with previous banana dietary fiber content results, ranging from 2.34 to 2.74 g 100 g^{-1} and 2.75 to 2.96 g 100 g^{-1}, as obtained by Ohizua et al. (2017) and Anggraeni and Saputra (2018). This indicated that bananas served as an excellent source of high fiber and energy as well as moderate protein, with extremely low fat content (Afzal et al., 2022). According to the regulation of the Indonesian Minister of Health Number 28 year 2019, the daily energy needs are 1,125 kcal for infants aged 1 to 3 years old; 2,250 kcal for women and 2,275 kcal for men. This indicated that only about 1.469 g edible portion of Pisang Raja was required to meet daily energy for babies, 2.938 g and 2.970 g for female and male adults, respectively. Banana-based foods and other low-fat diets help weight loss and reduce severe medical risk conditions such as heart disease and diabetes. According to Ioniță-Mîndrican et al. (2022), dietary fiber functions a central role in human nutrition, as it reduces cholesterol and increases the removal of blood sugar, bowel health and impending mutagens. A 100 g serving of the banana studied contributed approximately 12% of the suggested daily intake of dietary fibers. The consumption of food products with low fat and high fiber content has been identified as one of the most current trends in nutrition and health (Tapsell et al., 2016). Pisang Kepok is a low-energy, high-fiber food that provides health benefits. In this study, the protein content of cultivars was lower compared to soybeans and beans, which ranged from 23 to 34% (Comai et al., 2011). Consequently, consumers who depend on bananas as their primary source of protein should supplement this deficiency by consuming protein-rich foods.

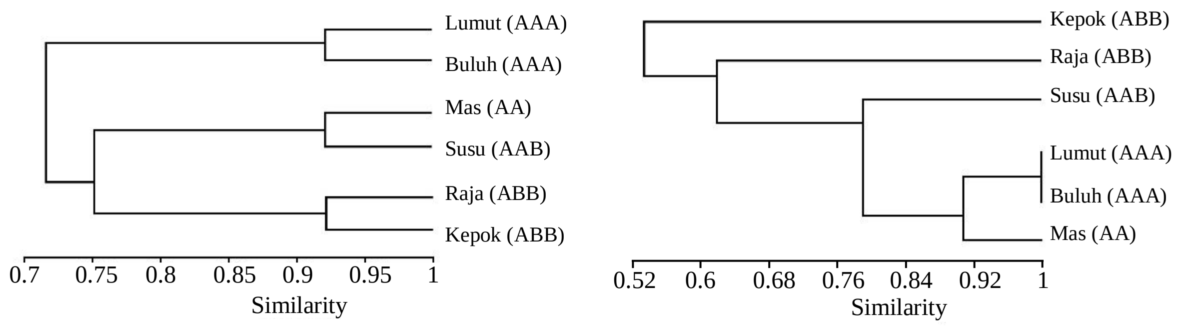
The vitamin C content in banana cultivars was varied, ranging from 11.34 to 37.68 mg 100 g^{-1}. As shown in Table 3, the highest value of vitamin C was in Pisang Kepok (37.68 mg) and the lowest in Pisang Mas (11.34 mg). The content of vitamin C in all banana cultivars was significantly higher compared to jackfruit (4.57 to 8.18 mg 100 g^{-1}) and mango (6.04 to 11.23 mg 100 g^{-1}) (Ubwa et al., 2014). According to the regulation of Indonesian Minister of Health Number 28 year 2019, the daily Vitamin C is 40 mg for 1 to 3 years old babies, 75 mg for female adults and 90 g for male adults. This indicated that a serving of Pisang Kepok, containing approximately 125 g of edible portion, is sufficient to meet the recommended daily intakes of vitamin C for babies, 300 g for women and 400 g for men. Vitamin C is a water-soluble nutrient necessary for the normal growth and development of human tissues. Furthermore, it functions as an antioxidant and cofactor that assists Fe absorption, protects bodies against infection and maintains tissue protein collagen connectivity (Carr and Maggini, 2017).

As illustrated in Table 3, different banana cultivars significantly affected K, Ca and Fe. The K nutrient was the most abundant element in all of the cultivars, ranging from 329.31 to 541.53 mg 100 g^{-1}, with the highest and lowest amount in Pisang Raja and Buluh, respectively. The most negligible element concentration in assessed banana cultivars was Fe, which varied between 275 to 375 mg 100 g^{-1}, with the highest and lowest values in Pisang Susu and Lumut, respectively. The Ca concentration also varied between 4.67 to 7.03 mg 100 g^{-1}, higher than Fe content but significantly lower compared to K. Díaz-Tocados et al. (2022) identified Ca as important in forming strong bones, cell metabolism, and heart function. Pisang Kepok exhibited the highest Ca content but only differed from Buluh. Dotto et al. (2019) found that bananas contained 410 mg 100 g^{-1} of K, 6.07 mg 100 g^{-1} of Ca and 0.56 mg 100 g^{-1} of Fe, which was similar to the results of this study. The high levels of K elements made the cultivars assessed beneficial to people with high blood pressure and cardiovascular compromises (Miller, 2012). The elevated K and Ca content in Pisang Raja indicated an elevated physiological ability to absorb minerals (Zhang et al., 2010). According to Kumar et al. (2012), K is an essential mineral to balance body fluid and enables the cells to properly function by maintaining the internal pressure and water balance. However, those who have kidney problems need to limit K intake, leading to the selection of Pisang Buluh. Thrombocyte hemoglobin transports oxygen from the lungs to the tissues, necessitating Fe as a component of numerous enzyme systems in the body. The Fe deficiencies are core public health concerns, specifically for child and maternal health (Black et al., 2013). Therefore, banana-based diets could add other types of food intake rich in Fe to ensure nutritional balance.

Fruit morphology and nutrient clustering analysis

Cluster analysis based on the morphological characteristics of six local Balinese banana cultivars showed a pattern from the nutrient composition values in Figure 2. The phenotypic relationship coefficient values of 0.74 to 0.91 (74 to 91%) based on morphological characters listed in Table 2 indicated that the cultivars observed were closely related. According to Ghosh et al. (2014) and Szabo et al. (2021), the similarity distance was considered fair when the phenotypic relationship coefficient value was less than 60%. The results of the dendrogram analysis explained the percentage of similarity between plant cultivars and their fruit morphology distance. This included the differences or populations within a particular cultivar (Karyawati et al., 2022; Sayed et al., 2022). According to Rinaldi et al. (2014) and Karyawati et al. (2022), a smaller phenotypic distance suggested closer similarities between cultivars.

Morphologically, trait clustering analysis showed that six cultivars clustered into two groups, at a coefficient of 74% (Figure 2a). Group 1 consisted of two cultivars (Pisang Lumut and Buluh), while Group 2 comprised Pisang Mas, Susu, Raja and Kepok. Furthermore, Group 2, with a coefficient of 76% was also divided into two groups, consisting of two cultivars. Pisang Mas and Susu were clustered together as Group 1, while Raja and Kepok as Group 2. The phenotypic variation in fruit characteristics represents a qualitative trait significantly affected by genetic factors from the parents (Hapsari and Lestari, 2016). The data from this study showed that Pisang Lumut and Buluh, as cooking cultivars included in the AAA genomic group, shared similar properties on some morphological variables. These included a slightly ridged transversal fruit section, a mature fruit peel transitioning from greenish to yellow, pulp color at maturity ivory to yellow, and a predominant taste of fruit sweet. Hapsari and Lestari (2016) stated that Ambon Hijau (Pisang Lumut) exhibited intermediate characteristics between two ancestral parent's wild seeded species (*M. acuminata* and *M. balbisiana*) but was closely related to *M. acuminata* (dessert banana) than



a. b.

Figure 2. Dendrogram clustering analysis based on morphological characters of mature fruit (a) and nutrient composition values (b)

M. balbisiana (cooking banana). Pisang Mas as a dessert banana, is morphologically similar to Susu, which is a dessert and cooking banana. According to Hapsari and Lestari (2016), bananas with an AA genome were closely related to their traditional wild-seeded *M. acuminata* species. Pisang Raja and Kepok, which were included in the ABB genomic group, morphologically exhibited the same characteristics as the two ancestral wild seeded *M. balbisiana* species (Gusmiati et al., 2018). These results aligned with Hinge et al. (2022) and Maldonado dos Santos et al. (2022), where cultivars in one genome group showed similar morphological and physiological characteristics.

Based on the nutrient composition listed in Table 3, the six banana cultivars resulted in phenotypic relationship coefficient values ranging from 0.53 to 0.90 (53 to 90%), as shown in Figure 2b. The value of the assessed cultivars was less than 60%, indicating no close relationship between cultivars, according to Ghosh et al. (2014). Figure 2b also showed that at the coefficient of 53%, all cultivars clustered into two groups. Pisang Kepok as a cooking banana was grouped separately, indicating its distinct nutritional content compared to others. Meanwhile, Pisang Raja, Susu, Lumut, Buluh and Mas were clustered together and became a family in the group, highlighting the similarity in their nutrient values. Pisang Mas, Buluh and Lumut as dessert had similar nutrient values of 90%, while Pisang Susu exhibited 87.40%.

CONCLUSIONS

This study showed that the six bananas were closely related, as indicated by the phenotypic relationship coefficient. Pisang Mas, Buluh, Lumut and Susu were morphologically suitable as desserts, and the characteristics were closely related to their ancestral *M. acuminata* (contributed ‘A’ genome). Pisang Raja as a dessert or cooking banana and Pisang Kepok were morphologically closer to their parental *M. balbisiana* (contributed ‘B’ genome). Generally, fruits of diverse cultivars exhibit variations in their nutrient composition. The nutrient values of the six bananas in 100 g of edible portion contained high carbohydrates (22.07 to 33.72 g), 71.61 to 76.95 calories of total energy, 329.31 to 541.53 mg of K, and 11.34 to 37.68 mg of vitamin C, moderate protein (1.00 to 1.22 g) and 1.65 to 3.64 g of total fibers, low fat (1.30 to 3.60 g 100 g-1) and 275 to 375 mg of Fe. Based on these results, the six Bali banana cultivars are suitable for dietary food as a source of high energy and low fat. However, protein and Fe-rich foods should be consumed to compensate for the deficit in bananas and ensure nutritional balance.

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