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Research Article

A study on the morphological, physicochemical, nutritional and functional properties of commercially grown banana cultivars in the Southern Province of Sri Lanka

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Abstract - Banana (*Musa* spp.) is a commercially grown fruit crop in Sri Lanka, with 29 different cultivars grown in the country. This study aimed to compare the morphological, physical, chemical, nutritional, and functional properties of eight different banana cultivars (*Seeni, Ambul, Kolikuttu, Puwalu, Rath kesel, Anamalu*, Cavendish, and *Ambon*) commonly grown in the Southern Province of Sri Lanka. All the selected banana cultivars were found to exhibit significant differences in morphology. The cultivar *Rath kesel* cultivar exhibited the highest total soluble solids (18.4 ± 1.13), while the *Ambul* cultivar recorded the highest sugar content (36.4 ± 1.69 g/100 g). Considering the functional properties, the cultivar *Kolikuttu* recorded the highest phenolic content (55.13 ± 0.6 mg/100 g) and total antioxidant content (948.00 ± 4.24%). The highest flavonoid content was recorded in the cultivar *Ambon* (2.52 ± 0.34). The study indicates that the tested banana cultivars are a rich source of nutrients, and the other properties are different from each other.

Keywords: Antioxidant content, banana, chemical property, functional property, nutrient content.

1. Introduction

Banana is an edible fruit grown in tropical and subtropical regions of the world close to the equator, with characteristic seasonal variation in rainfall and temperature (Pua, 2017). The banana "tree" is technically not a tree, but it is a plant that grows several meters tall. It belongs to the genus Musa of the family Musaceae. In Sri Lanka, bananas are consumed as a fruit which is rich in nutrients and is easily available in markets throughout the year.

Bananas are the most produced and traded fruit in fresh form in the world. More than 130 countries worldwide cultivate bananas. After citrus, bananas are the second most produced fruit, accounting for over 16% of all fruits grown worldwide (Mohapatra et al., 2010). Over 1000 distinct banana species, which are broken down into 50 categories, are grown worldwide. Among other banana species, the cultivar "Cavendish" has been the center of the global banana trade (Perera et al., 1999).

In Sri Lanka, 29 different types of banana cultivars can be discovered. Among them, the widely grown banana cultivars are *Ambul*, *Seeni*, *Kolikuttu*, and *Ambun*. The most significant edible banana cultivars in Sri Lanka are triploids and fall into the AAA, AAB, and ABB groupings. Depending on their ploidy level, hybrid bananas are designated as AB, AAB, or ABB, while currently grown bananas with a purely A genomic makeup are designated as AA or AAA. Diploids with an AA constitution is mostly raised for their fruit and are parthenocarpy with varying levels of sterility.

There are seven traditional cultivars, such as *Rathambala*, *Nadee*, *Pulaathisi*, *Mondan*, *Atamaru*, *Suwandal*, and *Meti Kithala*, while the remaining 11 are commercial cultivars namely, *Seeni kesel*, *Ambun*, *Embul*, *Anamalu*, *Bin kesel*, *Kandula*, *Kolikuttu*, *Prasad*, Ash plantains, *Puwalu*, and *Nathran* (Athukorala et al., 2020).

Bananas are a healthy fruit that reduces the risk for some forms of cancer, heart disease, stroke, and other chronic ailments due to the presence of antioxidants and biologically active ingredients (Rajput et al., 2017) and occupy a significant place in the food guide pyramid. According to Rabbani et al. (2010), green bananas have antidiarrheal properties and are traditionally used to treat dyspepsia. Dessert bananas are known to shield the gastrointestinal mucosa from harm caused by aspirin (Best et al., 1984). All cultivars of banana are good treatments for constipation, where a larger percentage of bound phytochemicals that reach the colon may be the cause of the banana's therapeutic impact in the treatment of constipation. It helps to decrease the danger of high blood pressure and important for optimal heart and blood pressure function. Bananas may also reduce the incidence of stroke. It is one of the finest solid meals to introduce to newborns. The cholesterol-lowering properties of banana pulp is due to its dietary fiber content and banana provides an immediate, lasting, and significant energy boost.

When the fruit is young, banana pulp is solid; but, as it ripens, it becomes softer. Fresh banana fruit contains 75% water and 100 g of fruit gives 90 kcal. It has around 20 g of total carbohydrates per 100 g of fresh pulp, of which fiber is beneficial for controlling intestinal transit. In comparison to other fruits, bananas are generally a good source of K, Mg, Cu, and Mn in the diet, although they are relatively low in vitamin C and vitamin A. It is known that bananas are relatively high in pyridoxine (vitamin B6). Banana pulp contains free phenolic compounds, mainly gallic acid and catechin.

There are many research articles on the physicochemical and functional properties of different banana cultivars in other countries like Indonesia, India, and Ethiopia (Dagnew et al., 2021). However, a detailed study on the comparison of morphological, physical, chemical, nutritional, and functional properties of banana cultivars grown in Sri Lanka is very limited. Perera et al. (1999) have explained about physicochemical characteristics such as peel thickness, firmness, peel to pulp ratio, pH, % titratable acidity and soluble solid content of *Ambon*, *Embul*, *Kolikuttu*, *Seeni kesel*, *Puwalu*, and *Anamalu*. Nadeeshani et al. (2019) have explained only about proximate and mineral composition of *Seeni*, *Ambul*, *Kolikuttu*, *Rathambala*, and *Puwalu*. Another article by Wasala et al. (2012) has done experiments on the physical and mechanical properties of three commercially grown banana cultivars in Sri Lanka. Thus, to the best of our knowledge, there is absence of information on the holistic and comparative studies on the morphological, physicochemical, nutritional, and functional properties of some commercially grown banana cultivars (*Musa* spp.) in Sri Lanka. *Kolikuttu*, *Ambon*, *Ambul*, *Seeni*, *Anamalu*, *Puwalu*, Cavendish, and *Rath kesel* are the most popular banana cultivars in Sri Lanka. Thus, in this research, morphological, physical, chemical, nutritional, and functional characteristics of *Ambon, Kolikuttu, Seeni, Ambul, Rath kesel, Anamalu, Puwalu,* and Cavendish were discussed and compared. The findings of this research will be beneficial for both banana farmers and food industry personnel engaged in product development using different banana varieties.

2. Materials and methods

2.1 Materials

In this study, eight different dessert-type banana cultivars namely *Seeni* (ABB), *Ambul* (AAB), *Ambon* (AAA), *Rath kesel* (AAA), *Anamalu* (AAA), *Puwalu* (ABB), Cavendish (AAA) and *Kolikuttu* (AAB) that represent three genomic groups were collected from household banana farms in Kamburupitiya, Sri Lanka. In order to determine the physical, chemical, nutritional, and functional properties of the banana fingers, the samples were taken from the two different mid-hands of the banana bunch with two different fingers randomly selected from each hand. All the samples were taken from naturally ripened banana fruits at the 6th stage of maturity.

2.2 Morphological characterization of the selected banana cultivars

The morphological characterization of the selected banana cultivars was done by observing the plant appearance, plant height, stem width, canopy size, length of the petiole, color, and shape of the flower, fruit color, and fruit shape, fruit size (weight, length, and girth) and the obtained results were tabulated.

2.3 Physical properties of selected banana cultivars

The firmness of the proximal, distal, and midpoints of the selected banana fingers was examined using a digital push-pull gauge (SH-500B made in China).

The color of the banana pulp was assessed following the method described by Wainwright and Hughes (1978) with some modifications using the colorimeter (BCM-200 made in China). The yellowness index and whiteness index were calculated as described by Falade and Oyeyinka (2015).

2.4 Nutritional properties of the selected banana cultivars

The moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate contents of the selected banana cultivars were measured as described in AOAC methods.

2.5 Determination of the chemical properties of the selected banana cultivars

2.5.1 Determination of pH

In order to determine the pH, bananas from each cultivar were blended separately and the pulps were taken. Ten grams of each sample of the pulp was homogenized with 40 mL of distilled water. The pH of the diluted pulp was measured using the pH meter (AD 132, Romania).

2.5.2 Determination of total soluble solids (TSS)

The total soluble solid content of each banana cultivar was determined as described by Ali et al. (2018). Ten grams of banana pulp was mixed with 40 mL of distilled water. The TSS values were determined using a digital refractometer (PAL-17S made in Germany). The measurements were taken at room temperature.

2.5.3 Determination of titratable acidity

The method given by Anyasi et al. (2015) was used to determine the titratable acidity of the banana samples using phenolphthalein as an indicator. The TA% was calculated and expressed as a percentage equivalent to malic acid.

2.5.4 Determination of sugar content

The total sugar content of each banana sample was determined using the phenol sulfuric method as described by Fernando et al. (2014) with some modifications. The sugar content was expressed as grams of sugar equivalent per 100 g of the sample by using the equation obtained from the linear regression of the glucose standard curve prepared with serially diluted sugar solution.

2.5.5 Determination of vitamin C

The vitamin C content of the banana pulp extract was measured according to the method reported by Baker and Flatman (2007) using 2, 6 Dichlorophenol method.

2.6 Methods used for determination of functional properties.

2.6.1 Preparation of sample

In order to extract the antioxidants available in bananas, one gram of each banana pulp was mixed with 10 mL of methanol. The sample was vortexed and centrifuged at 5000 rpm for 20 minutes, and the supernatant was taken as the sample. The same procedure was repeated three times and the pooled supernatant was used in further analysis.

2.6.2 Determination of flavonoid content

The total flavonoid content of the banana pulp extract was measured according to the method reported by Chandra et al. (2014) using the aluminum chloride colorimetric method with some modifications. One milliliter of stock solution (quercetin standard solution) or the sample was added into the 10 mL volumetric flask and mixed with four milliliters of distilled water. Then 0.3 mL of five percent $NaNO_2$ was added, and the mixture was kept for five minutes under normal room temperature conditions. Then 0.3 mL of 10% $AlCl_3$ was added to the mixture. At the sixth minute, two milliliters of sodium hydroxide were added to the above solution. The solution was volume up to 10 mL by adding distilled water. The mixture was vortex properly and kept for 15 minutes at room temperature for incubation at a dark place. The absorbance of the sample was taken by the spectrophotometer at 510 nm wave length. The total flavonoid content was expressed as milligrams of quercetin equivalent per one gram of the sample.

2.6.3 Determination of total phenol content (Folin- Ciocalteu method)

The total phenolic content of banana pulp extract was measured according to the method reported by Chandra et al. (2014) using folin-ciocalteu reagent with some modification.

Preparation of standard curve

Two milliliters of 10% folin-ciocalteu reagent were mixed with two milliliters of the standard solution (Gallic acid) and mixed well. Then the mixture was kept for two minutes and two milliliters of (7.5% w/v) sodium carbonate solution was added. The solution was volume up to 10 mL and mixed well using the vortex. The resultant solution was kept in a dark place for 120 minutes and the absorbance was taken at 760 nm. The gallic acid standard curve was prepared using four different concentrations of gallic acid (7.812, 15.625, 31.25, and 62.50 g/mL). the same procedure was followed for the samples using 400 μL of the sample. The obtained results were expressed as mg of Gallic acid equivalents per 100 g of the sample (mg GAE/ 100 g).

2.6.3 Determination of total antioxidant activity by DPPH assay method

The total antioxidant content of banana pulp extract was measured according to the method reported by Cuvelier and Berset (1995) with some modifications, and the results were expressed as the Trolox equivalent (TE) in grams per one gram of the sample.

Preparation of the standard curve

To create a control sample, four milliliters of DPPH solution and 0.4 mL of methanol were combined. A UV-Vis Spectrophotometer was used to measure the absorbance at 517 nm. Initially, 0.4 mL of the stock solution was added to four milliliters of 0.1 mM DPPH methanolic solution, and the mixture was vortexed well. Samples were left in the dark for 30 minutes, and a spectrophotometer was used to measure their absorbance at 517 nm. The same procedure was followed using 400 μL of the sample. The result was calculated as the TE in milligrams per gram using an equation created by linearly regressing. The Trolox standard curve was made from a Trolox solution that had been serially diluted (2000, 1750, 1500, 1250, 1000 M).

3. Result and discussion

3.1 Morphological characterization of the selected banana cultivars

The morphological characters of the eight different banana cultivars were examined and the obtained results are summarized in Table 1. The selected cultivars varied in stem diameter, pseudo stem color, canopy size, and petiole length. The true stem is formed when the plant begins to form reproductive organs. Peel color and peel thickness are also significant morphological characteristics used to differentiate the selected cultivars.

Table 1. Morphological characterization of the selected banana cultivars

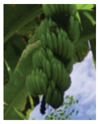
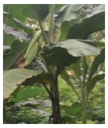
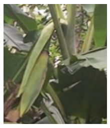
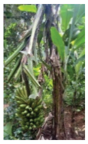
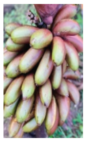
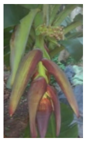
Banana cultivar	Plant appearances	Plant height (feet)	Stem width (feet)	Canopy sizes	Length of the petiole	Flower			
Seeni kesel	Plants are pale green or light green. Leaves are comparatively round and short.	6.5	1.45	8	1.15	Dark red in color			
Ambon	Petioles are red in color. plant height and width comparatively higher than Anamalu	8.1	1.04	8	2				

Table 1. Morphological characterization of the selected banana cultivars (cont.)

Banana cultivar	Plant appearances	Plant height (feet)	Stem width (feet)	Canopy sizes	Length of the petiole	Flower	
Anamalu	Stems are light dark, long, and less width stem Leaf petiole dark in color Leaves are long and narrow	9.1	1.2	7	1.2	long and narrow	  
Ambul	Stem is comparatively dark. Long and narrow leaves.	9	1.2	6	1.2		  
Cavendish	Medium-sized plants, have long leaves with light green colour appearances.	6	1.6	7	1.1		  
Kolikuttu	Plants are pale green in color. Leaves are moderately narrow and long. Dark green in color	7/8	1.1	7	1.2	Dark purple in color	  
Puwalu	Plants are green in color. Leaves are moderately wide and long. Green in color	9/10	1.1	8.5	1.5	Dark purple in color	 
Rath kesel	Fruits are initially reddish-brown to greenish in color. Their skin is smooth, and the fruits are comparatively larger than those of *Seeni* and *Ambul*.	9.5	1.25	8	1.4	Purplish brown color	  

3.2 Physical properties of the selected banana cultivars

The physical properties of the banana fingers such as weight, length, and girth (Table 2), along with the color and the firmness of the flesh of the selected banana cultivars were tested and the obtained values were summarized (Table 3). When considering the weight of the banana, the highest value obtained by the cultivar *Anamalu* (130.82 ± 8.13 cm) followed by *Seeni*, *Ambul*, *Ambon*, Cavendish, *Puwalu*, *Rath kesel*, and *Kolikuttu*. The length of the banana fingers was measured as the left and right curves, and the results showed that the highest value for the left and right curves was obtained by the cultivar *Anamalu* (18.50 ± 0.14 cm and 22.76 ± 0.77 cm respectively) while the lowest was obtained by the cultivar *Seeni* (8.75 ± 0.35 cm). Moreover, as it is having the largest finger size out of the tested cultivars, the cultivar *Puwalu* showed the highest top girth (13.90 ± 00 cm), mid girth (15.50 ± 0.14 cm), and bottom girth (14.80 ± 0.14 cm) values. According to the results shown in Table 2, the girth of the banana fingers of each cultivar was found to be high in the middle while it was found to be low at both top and bottom points, and similar patterns were reported by Lanka (2012). Moreover, according to Anyasi et al. (2015), studying the width at a distal end, midpoint, and proximal end is important as these parameters are useful in making the morphological structure of the banana fruit. Furthermore, as reported by Dadzie and Orchard (1997), these morphological characters are useful in the characterization and differentiation of one banana cultivar from another. Further, studying fruit size is important when designing grading and sorting equipment in the banana processing industry. Moreover, studying fruit length has also become an important determinant in assessing the stage of maturity during harvesting (Dadzie & Orchard, 1997).

The color of the banana flesh of each cultivar was tested, and the obtained values were recorded as L*, a*, and b* values (Table 3). The highest L* value was received by the cultivar *Puwalu* while the lowest L* value was obtained by the cultivar *Ambul*. Moreover, compared to the other, when considering the ΔL* values, the cultivar *Ambul* was found to have the darkest pulp color while the cultivar *Puwalu* has the lightest pulp color.

Texture perception is an important attribute in evaluating the quality of fruits and vegetables and it is important in determining the acceptability of fresh fruits (Konopacka & Plocharski, 2004). Moreover, Harker et al. (1996) reported that other than the color and aroma, the firmness of a fruit is one of the most important quality attributes when selecting fruits. Thus, the firmness of each banana finger was measured at the top, mid, and bottom points (Table 3), and as per the results, the cultivar *Seeni* showed the highest firmness in their fruits. According to Kojima et al. (1996), firmness determines the availability of the polymers that are responsible for pulp texture, where a higher level of firmness indicates the presence of higher amounts of polymers in the pulp. Thus, as per the results, the cultivar *Seeni* could possess a comparatively higher level of polymers when compared to the other cultivars even though they are at the same stage of maturity. Moreover, Charles and Tung (1973) reported that the texture of the flesh could depend on the cultivar, growing practices, and ripening procedures.

Table 2. Weight, length, and girth of selected banana cultivars

Banana cultivar	Weight (g)	Length (cm)		Girth (cm)			Characteristic of the fruit
		Left curve	Right curve	Top	Mid	Bottom	
Ambon	111.07±11.69^{a}	16.3±0.14^{ab}	20.85±0.49^{ab}	12.5±0.70^{ab}	15±00^{a}	11.25±0.07^{cd} ^{a}	Heavy Fruits, well-rounded in shape. A higher number of banana tiers per bunch. A well-grown bunch has around 11 tiers. Harvest around 60 kg. Less curved than *Anamalu* The flesh is yellowish in color. 
Kolikuttu	39.25±4.23^{d}	10.4±0.14^{cd}	15.45±0.07^{cd}	10±00^{cd}	12.15±0.07^{c}	11±00^{d}	The individual bananas are around 15 cm long. Slightly curvy shape. Brownish spots on the skin. Thin skin when ripening. When ripening, spots appear on skin, and skin cracks in a vertical way. Creamy white flesh. 
Ambul	60.93±3.03^{bcd}	12.5±00^{b}	12.75±0.21^{cd}	10.95±0.07^{bc}	12.6±0.14^{c}	10.6±0.14^{d}	Slender, sharp end comparatively small fruits. Appear with a concave shape. The sweet and pungent smell when ripened. 

Table 2. Weight, length, and girth of selected banana cultivars (cont.)

Banana cultivar	Weight (g)	Length (cm)		Girth (cm)			Characteristic of the fruit
		Left curve	Right curve	Top	Mid	Bottom	
Seeni	62.65 ± 4.30^{bc}	8.75 ± 0.35^{cd}	10.5 ± 00^{d}	8.4 ± 0.28^{d}	10.1 ± 0.14^{d}	8.35 ± 0.21^{e}	Green appearances. Well, round, small fruits with sharp longitudinal ridges. Have sticky flesh. The ripening fruit color changes to buff yellow. 
Anamalu	130.82 ± 8.13^{a}	18.50 ± 0.14^{a}	22.76 ± 0.28^{a}	11.25 ± 0.21^{bc}	12.10 ± 42^{c}	11.65 ± 0.0^{cd}	Long, slender, and curved fruits. Dark spots when ripening. Relatively thick peel. 
Cavendish	65.75 ± 2.11^{bc}	13.85 ± 1.06^{a}	22.75 ± 0.77^{a}	11.65 ± 0.21^{bc}	13.30 ± 0.14^{bc}	12.60 ± 0.28^{bc}	Blunt-ended fruits with shiny peel. Soft edges in fruits. 

Table 2. Weight, length, and girth of selected banana cultivars (cont.)

Banana cultivar	Weight (g)	Length (cm)		Girth (cm)			Characteristic of the fruit
		Left curve	Right curve	Top	Mid	Bottom	
Puwalu	45.55±0.96^{cd}	11.35±0.28^{bc}	16.45±0.49^{bc}	13.90±00^{a}	15.50±0.14^{a}	14.80±0.14^{a}	Extremely sweet and aromatic. Curved in shape. Yellow skin-tinged brown when ripe. The flesh is straw yellow. Just like the *Kollikuttu* banana. The cross-section of the banana is triangular in shape. Height of banana bunch 3 ft. 
Rath kesel	73.35±1.70^{b}	11.00±0.28^{bc}	16.95±0.91^{bc}	12.40±0.98^{ab}	14.65±1.06^{ab}	13.60±0.98^{ab}	The fruit peel is quite thick and puffy. Ripe fruits are reddish brown-green, turning pink to red when ripe. The edges of the petioles are found to be pink, and red in color. 

Note: Means with different superscripts on the same column are statistically different ($P < 0.05$).

Table 3. Color and firmness of the flesh of selected banana cultivars

Banana cultivar	color			Firmness (kg cm^{-2})		
	L	a	b	Top	Mid	Bottom
Ambon	42.62±3.70^{c}	13.05±2.94^{ab}	13.58±3.31^{a}	0.75±0.07 ^{a}	0.5±0.14^{c}	0.45±0.07^{b}
Kolikuttu	41.04±2.49^{c}	13.02±0.25^{ab}	13.25±1.66^{a}	0.75±0.07 ^{a}	0.8±0.28^{c}	0.45±0.07^{b}
Ambul	39.25±1.23^{c}	13.88±2.62^{a}	11.99±4.64^{a}	0.40±00 ^{a}	0.55±0.21 ^{c}	0.45±0.21^{b}
Seeni	44.77±2.19^{bc}	13.50±2.24^{a}	9.58±2.12 ^{a}	1.1±0.42^{a}	2.2±0.70^{a}	2.25±0.07^{a}
Anamalu	75.45±14.07^{a}	7.58±1.49^{abc}	7.22±1.49^{a}	0.55±0.07^{a}	0.60±0.00^{c}	0.65±0.07^{b}
Cavendish	64.89±0.01^{ab}	5.32±0.78^{c}	13.28±0.15^{a}	0.50±0.00^{a}	0.65±0.07^{c}	0.50±0.00^{b}
Puwalu	75.68±5.11^{a}	5.88±0.51^{bc}	11.26±1.50^{a}	0.40±00^{a}	0.65±0.07^{c}	0.75±0.07^{b}
Rath kesel	73.31±3.74^{a}	11.26±1.57^{ab}	11.94±5.26^{a}	1.11±0.07^{a}	1.20±00^{b}	1.35±0.07^{ab}

Note: Means with different superscripts on the same column are statistically different ($P < 0.05$).

3.3 Chemical properties of the selected banana cultivars

The chemical properties such as pH, total soluble solids (TSS), titratable acidity, vitamin C content, and the total sugar content of the selected banana cultivars were measured, and the obtained results were summarized in Table 4.

The cultivars *Rath kesel* showed a significantly higher level of pH than that of *other* cultivars ($P < 0.05$). A study on noncommercial unripe banana cultivars by Anyasi et al. (2015) reported that the pH of the tested banana cultivars varied within the range of 5.36 ± 0.02 to 6.12 ± 0.03. However, according to Perera et al. (1999), the pH of ripened *Ambon, Embul, Kolikuttu, Senikehel, Puwalu,* and *Anamalu* were found to vary within the range of 3.73 to 4.80, and the results of the current study are also in accordance with that.

When considering the titratable acidity, the cultivars *Kolikuttu, Puwalu,* and *Seeni* showed the highest titratable acidity (0.40 ± 0.00) while the lowest was recorded by the cultivar Cavendish and *Rath kesel* (0.13 ± 0.00). According to Anyasi et al. (2015), the titratable acidity of noncommercial unripe bananas was found to vary from 1.61 ± 0.03 to 3.40 ± 0.08. Moreover, the findings of Perera et al. (1999) showed that the titratable acidity of ripen cultivars of *Ambon, Embul, Kolikuttu, Seeni Kehel, Puwalu,* and *Anamalu* varied in a range of 4.55 to 10.50. However, the titratable acidity values obtained in the current research were comparatively lower than the values reported in Perera et al. (1999) and Anyasi et al. (2015). This could be due to the changes in the cultivar the stage of maturity of the fruits used and the method used in the determination of the titratable acidity.

The vitamin C content of the tested banana cultivars was examined, and according to the results (Table 4), the highest vitamin C of 19.54 ± 3.08 content was obtained in the cultivars *Kolikuttu* and *Seeni*. Moreover, a significant difference was observed in the vitamin C content of the tested cultivars. According to Mohapatra et al. (2010), the vitamin C content of two different dessert banana cultivars belonging to AAA and AAB groups was reported as 4.5 ± 0.3 mg/100 g and 12.7 ± 0.7 mg/100 g, respectively.

TSS content and the sugar content of the tested banana cultivars were also examined. As per the results, the cultivar *Puwalu* showed the highest TSS content (19.20 ± 00 °Bx) while the cultivar *Kolikuttu* gave the lowest TSS content (13.2 ± 3.39 °Bx). Similarly, the cultivar *Kolikuttu* has the lowest sugar content of 11.7 ± 0.02 g/100 g. Moreover, the sugar content of the tested cultivars varied significantly and the cultivar *Ambul* gave a significantly higher level of sugar content (36.4±1.69 g/100 g). A study on the chemical and nutritional composition of selected banana cultivars in Kerala by Siji and Nandini, (2017) reported that the TSS content of the tested cultivars varied in a range of 17.83 °Bx to 23.9 °Bx, and the findings of the current study were also in accordance. Moreover, according to Perera et al. (1999), the TSS content of *Ambun*, *Ambul*, *Seeni*, and *Kolikuttu* was 19.67 °Bx, 20.96 °Bx, 25.58 °Bx, and 21.86 °Bx, respectively, and the variation in the findings could be due to the varietal difference and difference in the cultivation conditions.

Table 4. Chemical properties of selected banana cultivars

	pH	TSS	Titratable acidity	Vitamin C	Sugar content
Ambon	4.45±0.70^{d}	16.20±1.41^{a}	0.335±0.09^{ab}	15.16±3.00^{ab}	13.13±0.81^{de}
Kolikuttu	4.40±0.00^{d}	13.20±3.39^{a}	0.40±0.00^{a}	19.54±3.08^{a}	11.70±0.02^{e}
Ambul	4.80±0.00^{c}	16.50±0.84^{a}	0.268±0.00^{b}	15.96±3.06^{b}	36.40±1.69^{a}
Seeni	4.90±0.00^{c}	14.80±1.69^{a}	0.40±0.00^{a}	19.54±3.08^{a}	17.45±0.01^{d}
Anamalu	6.20±0.00^{a}	18.00±0.56^{a}	0.26±0.00^{bc}	13.03±0.00^{ab}	32.35±07^{ab}
Cavendish	4.70±0.14^{cd}	17.80±0.28^{a}	0.13±0.00^{c}	17.37±0.00^{a}	23.50±1.13^{c}
Puwalu	5.70±0.14^{b}	19.20±0.00^{a}	0.40±0.00^{a}	8.68±0.05^{b}	29.45±0.63^{b}
Rath kesel	6.50±0.00^{a}	18.40±1.13^{a}	0.13±0.00^{c}	8.68±0.00^{b}	33.05±3.04^{ab}

Note: Means with different superscripts on the same column are statistically different ($P < 0.05$).

3.4 Nutritional properties of selected banana cultivars

In order to determine the nutritional composition, the proximate composition of each banana cultivar was determined, and the obtained results are summarized in Table 5. As per the results, the cultivar *Ambon* showed the highest moisture content (77.4 ± 2.54 %), while the cultivar *Seeni* gave the lowest (68.55 ± 1.9 %). A study by Nadeeshani et al. (2019) reported that the moisture content of *Seeni kesel, Ambul, Kolikuttu, Rathambala,* and *Puwalu* varied in a range of 67.24 ± 2.19 % to 73.14 ± 0.56 % and the results of the current study are also in accordance with it. A study by Hasanah et al. (2017) reported that the moisture content of cultivars *Barangan, Masak hijau,* and *Singapura* varied in a range of 70.98% to 77.54%. Moreover, according to the results summarized in Table 2, the firmness of the cultivar *Seeni* showed the highest value, and this could be due to the reported significantly lower level of moisture in the cultivars cultivar *Seeni*.

As per the results, no significant difference in ash content was observed in the tested cultivars. The cultivar *Ambon* showed the highest ash content (2.01 ± 0.29 %), while the cultivar *Rath kesel* gave the lowest (0.60 ± 0.28%). A study by Nadeeshani et al. (2019) reported that the ash content of *Seeni, Ambul, Kolikuttu, Rathnamalu,* and *Puwalu* varied in a range from 1.18 ± 0.05 % to 3.89 ± 0.38%. Another study by Hasanah et al. (2017) reported that the ash content of cultivars *Barangan, Masak Hijau,* and *Singapura* varied in a range from 0.78% to 1.05%.

There is a significant difference in the fat content within the tested eight cultivars. As the results, the cultivar *Ambul* showed the highest fat content (0.96 ± 0.05%), while the cultivar Cavendish gave the lowest (0.15 ± 0.05%). A study by Nadeeshani et al. (2019) reported that the fat content of *Seeni, Ambul, Kolikuttu, Rathnamalu,* and *Puwalu* varied in a range of 0.14 ± 00% to 0.2 ± 0.02%. Another study by Plantain and Afolayan (2019) reported that the fat content of *Musa Sinensis* L. and *Musa Paradisiaca* L. ranged between 0.15 ± 0.00% to 0.24 ± 0.00%. Hasanah et al. (2017) reported that the fat content of cultivars *Barangan, Masak Hijau, and Singapura* varied in a range of 0.33% to 0.34%. Moreover, the study by Sad et al. (2018) reported that the fat content of cultivars *Sagor, Champa, Shali,* and *Bichi* varied in a range between 0.98 ± 0.06% to 1.38 ± 0.08%.

The highest fiber content was shown in *Rath kesel* (4.00 ± 00 %), while the cultivar *Kolikuttu* showed the lowest (0.25 ± 0.07 %). A study by Hasanah et al. (2017) reported that the fiber content of cultivars *Barangan*, *Masak hijau*, and *Singapura* varied in a range from 1.28% to 1.51%. Khoozani et al. (2019) reported that the fiber content of flours produced from banana pulp from banana at 6th to 7th stage varied in a range between 17% to 18% (dry basis). There is a significant difference in the protein content within the tested eight cultivars. As a result, the cultivar Cavendish showed the highest protein content (1.45 ± 0.07%) while the cultivar *Kolikuttu* showed the lowest protein content (0.79 ± 0.07%). A study by Nadeeshani et al. (2019) reported that the protein content of *Seeni, Ambul, Kolikuttu, Rathnamalu,* and Puwalu varied in a range from 1.20 ± 0.02% to 1.40 ± 0.04%, and the results of the current study are also in accordance with that. Hasanah et al. (2017) reported that the protein content of cultivars *Barangan, Masak Hijau,* and *Singapura* varied in a range of 0.9% to 1.03%. Moreover, the protein content of cultivars *Sagor, Champa, Shali,* and *Bichi* was found to be varied in a range between 1.28 ± 0.02% to 1.82 ± 0.06% (Sad et al., 2018).

As per the results in Table 5, the cultivar *Seeni* showed the highest carbohydrate content (26.77 ± 2.51%) while the cultivar *Ambon* showed the lowest total carbohydrate content (18.65 ± 2.33%). Nadeeshani et al. (2019) reported that the total carbohydrate content of *Seeni, Ambul, Kolikuttu, Rathnamalu,* and *Puwalu* varied in a range from 13.46 ± 0.36% to 26.46 ± 0.36%, and the results of the current study are in accordance with that. A study by Hasanah et al. (2017) reported that the total carbohydrate content of cultivars *Barangan, Masak hijau,* and *Singapura* varied in a range of 20.26% to 26.68%. Sad et al. (2018) reported that the total carbohydrate content of cultivars *Sagor, Champa, Shali,* and *Bichi* varied in a range between 20.17 ± 0.76 % to 22.71 ± 0.04 %.

Table 5. Nutritional properties of selected banana cultivars

Banana cultivar	Moisture content	Ash	Crude fat	Fiber	Crude protein	Total carbohydrates
Ambon	77.40±2.54[a]	2.01±0.29[a]	0.37±0.11[ab]	0.60±0.00[e]	0.97±0.01[bc]	18.65±2.33[b]
Kolikuttu	76.01±0.86[a]	1.255±0.37[a]	0.41±0.26[ab]	0.25±0.07[e]	0.79±0.07[c]	20.74±2.34[ab]
Ambul	74.27±0.17[b]	1.02±0.14[a]	0.96±0.05[b]	2.33±0.46[c]	0.92±0.09[bc]	19.58±2.29[ab]
Seeni	68.55±1.90[ab]	0.93±0.24[a]	0.15±0.05[ab]	0.31±0.01[e]	0.84±0.06[c]	26.77±2.51[a]
Anamalu	73.16±0.70[ab]	1.80±0.28[a]	0.45±0.21[ab]	1.66±0.00[d]	0.91±0.14[bc]	22.02±0.60[ab]
Cavendish	72.83±2.12[ab]	0.80±0.56[a]	0.01±0.00[ab]	4.66±0.00[a]	1.45±0.07[a]	20.26±1.48[ab]
Puwalu	72.83±2.12[ab]	1.00±0.28[a]	0.15±0.21[ab]	3.00±0.00[b]	1.30±1.14[ab]	21.72±2.33[ab]
Rath kesel	69.83±0.70[ab]	0.60±0.28[a]	0.80±1.13[ab]	4.00±0.00[a]	1.14±0.21[abc]	23.62±1.33[ab]

Note: Means with different letter superscripts on the same column are statistically different ($P < 0.05$).

3.5 Functional properties of selected banana cultivars

In order to determine the functional properties, total phenolic content, flavonoid content, and total antioxidant content of each banana cultivar were determined, and the obtained results are summarized in Table 6. As per the results, the cultivar *Kolikuttu* showed the highest total phenolic content (55.13 ± 0.61 mg GA/100 g), while the cultivar *Seeni* gave the lowest (15.69 ± 0.44 mg GA/100 g). A study by Sad et al. (2018) reported that the total phenolic content of cultivars *Sagor, Champa, Shail,* and *Bichi* varied in a range from 0.3443 ± 1.4300 mg GA/100g to 1.1947 ± 4.7700 mg GA/100 g. Another article by Youryon and Supapvanich (2017) recorded the total phenolic content of mature green, ripe, and overripe banana fruits, and the total phenolic content of ripened banana fruits was recorded at around 50 mg GA/100 g (500 µg GA/g). Another study by Fatemeh et al. (2012) reported that the total phenolic content of ripened dream pulp and ripened Cavendish pulp flours ranged between 75.01 ± 0.82 mg GA/100 g dry matter to 230.21 ± 1.19 mg GA/100 g dry matter.

As per the results, the cultivar *Ambon* showed the highest flavonoid content (2.52±0.34 mg quercetin/g), while the cultivar Cavendish gave the lowest (0.22 ± 0.19 mg quercetin/g). A study by Gadhave et al. (2012) reported that the flavonoid content of cultivars green, yellow, *Rasthali,* and *Karpuravali* varied in a range from 3.06 ± 0.025mg QE/g to 4.78 ± 0.334 mg QE/g and the results of the current study are also in accordance with it. Research by Youryon and Supapvanich (2017) recorded the total flavonoid content of ripened banana fruit around 0.08 mg catechin/g (80 µg catechin/g). However, the results of the current study are a little lower than the results of the above studies, and it could be due to the changes in cultivar and cultivation conditions. Moreover, research by Fatemeh et al. (2012) reported that the flavonoid content of ripened dream pulp and ripened Cavendish pulp flours ranged between 0.3901 ± 1.17 mg catechin/g (39.01 ± 1.17 mg CEQ/100 g dry matter) to 1.964± 0.89 mg catechin/g (196.45 ± 0.89 mg CEQ/100 g dry matter).

The total antioxidant capacity of each cultivar was measured using the DPPH radical scavenging method, and as per the results, the cultivar *Kolikuttu* showed the highest antioxidant content (948.00 ± 4.24 mg TE/g), while the cultivar *Ambon* gave the lowest (558.00 ± 5.65 mg TE/g). A study by Sad et al. (2018) reported that the antioxidant content of cultivars *Sagor*, *Champas*, *Shail*, and *Bichi* varied in a range from 913.07 ± 0.04 mg TE/g (91.37 ± 0.44%) to 621.04 ± 3.23 mg TE/g (62.14 ± 3.23%) and the results of the current study are also in accordance with it. Another study by Fatemeh et al. (2012) reported that the total antioxidant amount of ripened dream pulp and ripened Cavendish pulp flours ranged between 265.05 ± 0.86 mg TE/g (26.55 ± 0.86%) to 293.08 ± 0.70 mg TE/g (29.38 ± 0.70%).

Table 6. Functional properties of selected banana cultivars

Banana cultivar	Total phenolic content (mg GA/100 g)	Flavonoid content (mg quercetin /g)	Antioxidant content (mg TE/g)
Ambon	45.31 ± 0.96^{b}	2.52 ± 0.34^{a}	558.00 ± 5.65^{d}
Kolikuttu	55.13 ± 0.61^{a}	1.64 ± 0.17^{abc}	948.00 ± 4.24^{a}
Ambul	16.77 ± 0.13^{c}	1.88 ± 0.94^{ab}	748.00 ± 1.41^{bc}
Seeni	15.69 ± 0.44^{c}	1.09 ± 0.06^{abc}	918.00 ± 2.82^{a}
Anamalu	26.00 ± 0.35^{d}	1.54 ± 0.12^{abc}	626.00 ± 5.65^{cd}
Cavendish	36.70 ± 0.14^{d}	0.22 ± 0.19^{c}	896.00 ± 4.24^{ab}
Puwalu	29.20 ± 0.007^{d}	1.48 ± 0.17^{abc}	916.00 ± 4.24^{a}
Rath kesel	24.20 ± 0.35^{d}	0.60 ± 0.12^{bc}	146.00 ± 2.82^{e}

Note: Means with different letter superscripts on the same column are statistically different ($P < 0.05$)

4. Conclusion

The results of the current study indicate that all the tested banana varieties are morphologically different from one another, making it possible to use these characteristics for accurate identification of different banana cultivars. Moreover, the results of nutritional analysis prove that bananas are an excellent source of fiber and carbohydrates. Moreover, bananas are rich in antioxidants and vitamin C, while the physical, chemical, nutritional, and functional properties of bananas vary across different varieties. Further, the findings of the current study will be helpful for banana farmers, breeders, and food industry personnel.

Artificial intelligent declaration

The authors do not utilize any AI tool in the preparation of this work. Subsequently, the author(s) conducted a thorough review and editing process, taking full responsibility for the content of the publication.

Human/Animal ethics declaration

Not applicable

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