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Profiling of agronomic traits and folic acid in five dessert bananas (*Musa* spp.)

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Abstract

Many varieties of *Musa* spp. have been used as edible fruits around the world. Bananas belong to the genus *Musa,* whose fruits contain high calories and nutritional values. There is little data on agronomic traits and folic acid (FA) concentrations of different types of dessert bananas in Vietnam. This study aimed to determine such information in the fruits of five banana varieties, including Cau, Xiem, Gia Huong, Com, and Dole. Agronomic characteristics were considered, including fruit size and weight, peel colour and pulp firmness, while FA concentrations were quantified by high-performance liquid chromatography. The results showed significant differences among agronomic values and FA contents. Dole had the heaviest weight (175.48 g), followed by Xiem (123.71 g), Gia Huong (121.77 g), Com (103.12 g) and Cau (52.07 g). The size (length × width) of 5 cultivars has significant differences, including Dole (16.22 × 4.17 cm), Xiem (11.78 × 4.44 cm), Gia Huong (15.44 × 4.22 cm), Com (11.59 × 3.88 cm) and Cau (9.00 × 3.79 cm). For the colour results, most banana cultivars had yellow peels, except Gia Huong which remained green colour at ripening stages (b/a<0). The pulp firmness is expressed with the hardest value from Xiem (0.59 N), then Dole (0.36 N), Com (0.32 N), Cau and Gia Huong (0.29 N). The FA concentrations ranged 3-12 µg /100 g fresh weight. The cultivar Cau had the highest level of FA per 100 g fresh weight (12.04 µg), followed by Gia Huong (8.76 µg), Dole (6.00 µg), Xiem (4.62 µg), and Com (3.14 µg). The FA contents were positively correlated with the colour brightness L, performed by Pearson value, with r = 0.755 ($p<0.001$). On the other hand, an inverse correlation was found between FA concentration and the fruit weight (r = -0.542, $p<0.001$) and the pulp firmness (r = -0.337, $p<0.05$). In conclusion on 5 varieties of dessert bananas, measured values of agronomic traits and FA have been recorded, and Pearson analysis shows a positive relation between FA and colour brightness and a negative one between FA and fruit weight/firmness.

1. Introduction

Musa spp. is a monocot and widely cultivated in many geographic areas, including East Africa, the Caribbean, Southeast Asia, Mexico, America, and Australia (Tripathi *et al.*, 2007; Aurore *et al.*, 2009). Varieties of edible fruits of the *Musa* trees were classified into two main groups, including banana and plantain (Nelson *et al.*, 2006; Gibert *et al.*, 2009). These fruits are important crops around the globe, ranging from rice, wheat, and corn (Aurore *et al.*, 2009).

Among dessert bananas in Vietnam are Cau (AA), Gia Huong (AAA), Com (AAB), and Xiem (AABB). In addition to common types in local markets, Dole belongs to triploid (AAA) and an imported banana. Cau belongs to the diploid group (AA) according to international classification. In Asia, Cau is also called Pisang mas in Malaysia and Indonesia (Malaysian Food Composition Database, 1997), Amas in the Philippines (Esguerra *et al.*, 1992), and Kluai Khai in Thailand (Sangudom *et al.*, 2012).

According to a previous study on the origin of *Musa* cultivars (Ploetz *et al.*, 2007), the triploid hybrids (AAA) originated from *Musa acuminata*. The domesticated banana contains a triploidy (3n = 33 chromosomes), which includes some varieties of Cavendish subgroups. Later, hybrids involving *Musa balbisiana* created triploid AAB and tetraploid AABB cultivars (Sass *et al.*, 2016;

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Schoch *et al.*, 2020). In Vietnam, Com (AAB) and Xiem (AABB) are available (Le *et al.*, 1998; Nelson *et al.*, 2006; Ploetz *et al.*, 2007).

Banana fruits are nutrient-rich foods packed with carbohydrates and minerals (Ashokkumar *et al.*, 2018). One of the potential vitamins presented in banana fruits is folic acid (FA), $C_{19}H_{19}N_7O_6$ (Yon and Hyun, 2003; Delchier *et al.*, 2014; Ningsih and Megia, 2019). This vitamin is a water soluble-B complex involved in the synthesis of DNA, amino acids, and new blood cells (National Center for Biotechnology Information, 2023). Additionally, it plays an important role in the formation of the neural tube and the development of the nervous system in newborn babies.

FA components in dessert bananas have been reported around the globe; they have not been published in Vietnam. This study aimed at conducting an independent and a regression analysis of the agronomical traits and FA components of 5 different varieties of dessert bananas.

2. Materials and methods

2.1 Sampling

Five varieties of bananas, including Xiem, Cau, Gia Huong, Dole, and Com, were purchased from the local market in Can Tho city, Vietnam. Representatives of 5 banana varieties are performed in Figure 1. The samples were kept at room temperature until the fruits reached ripening stage 6, according to previous studies (Madan *et al.*, 2014; Veroustraete, 2016).

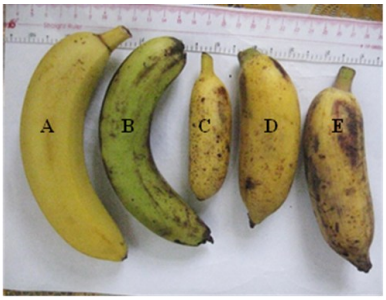

Figure 1. Experimental samples of 5 banana varieties: A) Dole, B) Gia Huong, C) Cau, D) Com and E) Xiem.

2.2 Size determination of banana fruits

The physical properties of banana fruits, including size and mass, were determined as per a previous study (Soltani *et al.*, 2011a). The length and width of each sample were determined by a flexible ruler with a precision of 1 mm. A digital balance with an accuracy of 0.01 g was used to measure the mass of each fruit whose weight of total fruits and the peels were recorded.

2.3 Texture analysis of banana fruit

The fruit pulps were analyzed by a penetration test using TMS-Pro (Food Technology Cooperation, America). The banana samples were cut into 15-mm-thick pieces, and a penetration depth of 10 mm was conducted with a slow speed of 1 mm per minute. The peak force was recorded after the measurement reached the target distance. Firmness values of the fruit pulps were calibrated by a 100 N load cell and expressed as Newton (N).

2.4 Colour determination of the fruit peels

The external colours of the fruit peels were nondestructively identified using ColorLite sph870 (Germany). The reading probe contacted completely with the surface of the fruit skin, and the colour values were expressed as L, a, and b values. Colour values were recorded as an average of 3 random points per fruit and calibrated using a white BAM standard.

2.5 Chromatographic analysis of folic acid

High-performance liquid chromatography (HPLC) was used for FA quantification. HPLC-graded chemicals were used, such as acetonitrile (#A9984, Fisher), FA powder (# F0608, Duchefa Biochemie, The Netherlands), and acetic acid (64-19-7, Merck).

The quantification of FA was conducted using a modified method from a previous study (Ningsih and Megia, 2019). Particularly, the mobile phase is chemically composed of acetic acid (solvent A) and acetonitrile (solvent B). The flow rate was at 1 mL/min, the processed temperature in the column was kept stable at 40°C, and the injection volume was 10 µL. The gradient elution was performed throughout the process (solvent A: solvent B at the ratio 2: 98). Chromatograms were detected using a UV detector at 283 nm. The HPLC procedure was analyzed using an UFLC-HPLC system (Shimadzu. Kyoto, Japan) comprising a degassing unit (DGU-20A5R), LC-20AD pumps, SIL-20AHT autosamplers, SPD-20A UV-VIS detector, and CTO10AS VP column oven. Reverse-phase separations were carried out using a Shimadzu C18 column (250 × 4.6 mm).

2.6 Statistical analysis

Data were expressed as mean ± standard deviation (SD), n = 9. SPSS 20.0 software was used to analyze by one-way analysis of variance (ANOVA). Comparisons of means were carried out using Fisher LSD analysis. Correlations between FA and agronomic values were identified by Pearson analysis. All values were considered to be significantly different when $p<0.05$.

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3. Results and discussion

3.1 Size of banana fruits

There were significant differences in banana length and width (Table 1). Dole and Gia Huong typically have a curved shape with the longest length, 16.24 cm and 15.44 cm. Conversely, 3 cultivars, including Cau, Xiem, and Com, have short, and straight shapes with the following length: 9.00, 11.78, and 11.59 cm. The width of the samples ranged from 3.79 to 4.44 cm ($p<0.01$).

Table 1. The fruit sizes.

Samples	Length (cm)	Width (cm)
Xiem	11.78±1.54^{a}	4.44±0.39^{a}
Cau	9.00±0.66^{b}	3.79±0.22^{b}
Gia Huong	15.44±0.53^{c}	4.22±0.36^{ab}
Com	11.59±0.63^{a}	3.88±0.11^{b}
Dole	16.24 ±1.19^{c}	4.17±0.17^{abc}
p	<0.001	<0.01

Values are presented as mean±SD (n = 9). Values with different superscripts within the same column are statistically significantly different $p<0.05$.

This research showed that Dole and Gia Huong have a long shape that is similar to Cavendish AAA in Malaysia (18.00 × 6.00 cm) (Alkarkhi *et al.*, 2011) and *M. paradisiaca* in Vietnam (17.47 × 4.34 cm) (Bui *et al.*, 2021). Results additionally showed that Cau has the smallest size (9.00 × 3.79 cm) compared to the remaining varieties. Due to their small size, Cau was also called "Cau man" in a previous study (Tran and Vo, 2017). Other types of bananas, including Xiem and Com, had round and straight shapes determined in previous documents (Le *et al.*, 2013; Puangsuwan *et al.*, 2021). In conclusion, our samples in this research are representative of dessert bananas described in the plant classification system (Nelson *et al.*, 2006).

3.2 Weigh of banana fruits, peels and pulps

In Table 2, the total weight of Dole, Com and Gia Huong reached 175.48 g, 103.12 g and 121.77 g, with subsequent ratio of peel/pulp weight at 33.15: 66.85%, 32.29:67.71% and 38.38:61.62%. On the contrary, Xiem (123.71g), Cau (52.05 g) had peel/pulp ratio at 21.47: 78.53%, and 26.58:73.42%.

The result in Table 2 indicates the weight of the total fruit, peel/pulp ratio, for each banana sample. Dole, Com, and Gia Huong had rather thick peels whose weight percentages were around half that of the pulp. Xiem and Cau had thinner peels whose weights were subsequently 3.66 and 2.86 times lesser than that of the pulp. In comparison with the previous study, the total weight of Dole (175.48 g) was as similar to that of *M. paradisiaca* L. in the North of Vietnam (185.21 g) (Bui *et al.*, 2021). In relation to *Musa* classification (Malaysian Food Composition Database, 1997; Le *et al.*, 1998; Ploetz *et al.*, 2007), Cau (AA) and Xiem (AABB) had thin peels and thick pulp (1: 5) while Gia Huong and Dole (AAA), and Com (AAB) had thick peels and thinner pulp. The weight of banana fruits, their peels and pulps were therefore typical for each variety.

Table 2. Weight of banana fruits, peels and pulps.

Samples	Total weight	Peel weight	Pulp weight
Xiem	123.71±2.80^{a}	21.47±1.32^{a}	78.53±1.32^{a}
Cau	52.07±9.90^{b}	26.58±2.33^{b}	73.42± 2.33^{b}
Gia Huong	121.77±6.03^{a}	38.38±1.92^{c}	61.62±1.92^{c}
Com	103.12±4.02^{c}	32.29±2.97^{d}	67.71±2.97^{d}
Dole	175.48±13.23^{d}	33.15±3.19^{d}	66.85±3.18^{d}
p	<0.001	<0.001	<0.001

Values are presented as mean±SD (n = 9). Values with different superscripts within the same column are statistically significantly different $p<0.05$.

3.3 Colour of the fruit peels

The colour of banana fruit peels in this research was determined by ColorLite sph870 equipment. Many studies have used peel colour to evaluate the fruit quality in tomatoes, papaya, and mango, whose colours become mostly beautiful during the edible period (Khandaker *et al.*, 2018). At certain stages of ripening, banana fruits achieve the highest sensory score of sweetness, flavours, tastes, and nutrient-dense values such as flavonoids, and anthocyanins (Khandaker *et al.*, 2018).

Table 3 shows a significant difference among colour values including brightness (L), colour green to red (a), and colour blue to yellow (b/a = 6.49 -7.00). Most of the fruits obtained yellow colour at the experimental times, except Gia Huong, which remained green peel colours, performed by b/a = -17.00, $p<0.001$. Additionally, Cau achieved the most beautiful shining colour (L = 65.91), which is significantly different from the remaining samples. Previous studies have indicated the contribution of polyphenol content in fruit peels and pulps (Snoeck *et al.*, 2011). The brightness of Gia Huong is involved by multiple components such as chlorophyll, carotenoids, and antioxidative properties in the skin (Pham *et al.*, 2021).

The results on the fruit peel colours were associated with previous data showing that most dessert bananas gain typical yellowness at ripening times (Nelson *et al.*, 2006; Tripathi *et al.*, 2007). The CIELAB results were correlated with the RGB colour model for dessert bananas (Soltani *et al.*, 2011b). The green colour of Gia Huong at the ripening stages was previously described (Pham *et al.*, 2021).

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Table 3. Colour of the banana peels.

Varieties	Colour			
	L	a	b	b/a
Xiem	53.59±5.86^{bcd}	4.52±1.53^{acd}	25.70±7.46^{a}	6.49±2.89^{b}
Cau	65.91±6.52^{a}	5.18±1.73^{a}	32.93±4.86^{b}	6,98±2.09^{b}
Gia Huong	56.81±3.42^{b}	-2.78±1.93^{b}	28.37±3.13^{a}	-17.00±45.23^{a}
Com	51.18±6.77^{bcd}	4.74±0.94^{acd}	31.96±4.25^{b}	7.00±1.53^{b}
Dole	50.08±7.70^{c}	3.83±1.34^{c}	25.42±3.87^{a}	6.90±2.66^{b}
p	<0.001	<0.001	<0.001	<0.001

Values are presented as mean±SD (n = 9). Values with different superscripts within the same column are statistically significantly different $p<0.05$.

3.4 Firmness of the fruit pulps

Firmness is one of the important indicators of fruit quality, including bananas (Khandaker *et al.*, 2018). This research determined the fruit firmness using a physical analyser, TMS-Pro (America). Samples in this study were at ripening stage 6, which is edible and obtains typical colour at the experimental time. The data in Figure 2 shows that Xiem had the hardest pulp, with the highest value at 0.59 (N) compared with the remaining banana ($p<0.001$). Cau and Gia Huong had similar pulp firmness at 0.29 N, which is twice and 1.24 times lower than that of Xiem ($p<0.001$) and Dole ($p<0.05$). The pulp firmness of Com was not significantly different compared with Cau and Gia Huong.

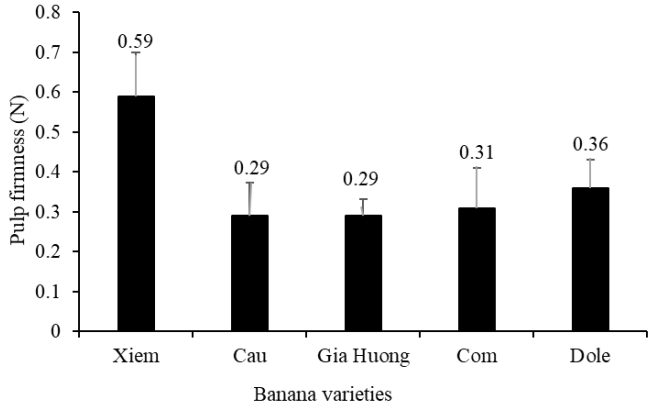

Figure 2. Fruit firmness of 5 banana varieties.

Previously, ripening bananas at the consumption time achieved sensory scores of 6/10 for the firmness, 8/10 for the colour, 9/10 for the flavour and sweetness (Khandaker *et al.*, 2018). The physical firmness of banana fruits in this study has been associated with the results from previous studies (Khandaker *et al.*, 2018).

3.5 Folic acid quantification of banana fruits

The concentration of FA in the experimental samples was quantified using UFLC-HPLC system (Shimadzu). Chromatograms of FA were detected at a wavelength of 283 nm. The retention time (RT) ranged between 2.7-3 mins (Figure 3).

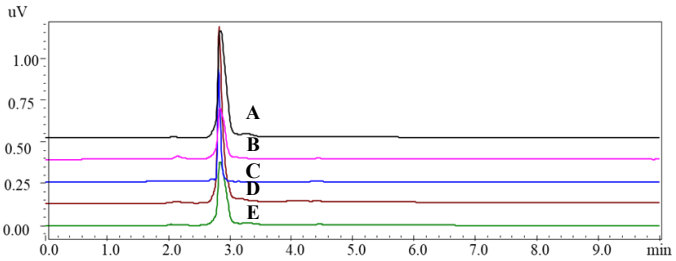

Figure 3. Chromatogram of the folic acid in 5 banana varieties: A) Dole, B) Gia Huong, C) Cau, D) Com and E) Xiem.

Table 4 shows that FA contents per 100 g fresh weight subsequently decreased: Cau (12.04 µg) > Gia Huong (8.76 µg) > Dole (6.00 µg) > Xiem (4.62 µg) > Com (3.14 µg). These FA levels tend to be lower than the results of dessert bananas in Indonesia (Ningsih and Megia, 2019) and Mexico (García-Salinas *et al.*, 2016). However, the results were rather similar to those found in Malaysia (5-7 µg/100 g), particularly wild bananas *Musa acuminata* and *Musa paradisiaca* (Chew *et al.*, 2012). A similar amount of 5-CH_3-H_4folate, which is an FA derivative, was found in dessert bananas (Delchier *et al.*, 2016). From these data, it was suggested that FA found in the samples in this study may be a form of 5-CH_3-H_4folate.

Table 4. Folic acid concentrations in banana pulps.

Samples	FA concentration (µg/100 g)
Xiem	4.62±0.58^{c}
Cau	12.04±1.69^{a}
Gia Huong	8.76±1.90^{b}
Com	3.14±1.58^{e}
Dole	6.00±0.58^{d}
p	< 0.001

Values are presented as mean±SD (n = 9). Values with different superscripts within the same column are statistically significantly different $p<0.05$.

3.6 Correlations between folic acid and agronomic characteristics

Table 5 shows the Pearson analysis between FA contents and agronomic characteristics. There was a

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positive correlation between the peel brightness L and FA, with r = 0.76, p<0.001. This indicates that the brighter the fruit peels, the higher the amount of FA. Conversely, there was a negative correlation between FA and fruit weight, with r = -0.54 (p<0.001), and fruit firmness, with r = -0.34 (p<0.05).

Table 5. Pearson correlation between FA and the agronomic traits

	Pearson	P-value (2-tailed)
Length	- 0.261	0.090
Width	- 0.087	0.581
Weight	- 0.542	< 0.001
Peel ratio	0.005	0.976
Pulp ratio	-0.005	0.976
L	0.755	< 0.001
b/a	-0.274	0.072
Firmness	-0.337	0.025

Values are presented as mean±SD (n = 9). Values with different superscripts within the same column are statistically significantly different $p<0.05$.

This study shows the relation between FA quantity and agronomic properties in the conducted samples. Previous studies have mentioned a close correlation between ripening stages and nutrient scales in fruits (Obiageli *et al.*, 2016). Particularly, colour is an indicator of the quality standard of edible food, showing chemical properties, sweetness and nutrients (Francis, 1995). Another research on pumpkin fruits demonstrated a negative correlation between colour brightness (L) and carotenoid content of the fruits (Seroczyńska *et al.*, 2006). In conclusion, the banana fruits in this study have a certain amount of FA and are associated with agronomic traits including peel colour brightness, pulp firmness and fruit weight.

4. Conclusion

This research has indicated some agronomic traits and FA concentrations in five varieties of dessert bananas in Vietnam, including Cau, Gia Huong, Xiem, Com, and Dole. Cau had the highest concentration of FA per 100 g fresh weight (12.04 µg), and Gia Huong (8.76 µg). The reduced amount was recorded for Dole (6.00 µg), Xiem (4.62 µg), and Com (3.14 µg). There were correlations between FA contents and the agronomic properties, including brightness of the fruit peels, fruit weight, and pulp firmness.

Conflict of interest

The authors declare no conflict of interest.

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