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Full Length Research Paper

Investigation of dietary fiber, protein, vitamin E and other nutritional compounds of banana flower of two cultivars grown in China

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The nutritional composition of banana flowers of two cultivars [cvs. Baxijiao (AAA) and Paradisical (AAB)] grown in Hainan of China has been studied. Flower samples were collected and extracted according to methods of Association of Official Analytical Chemists (AOAC). Results showed that banana flowers contained abundant dietary fiber (4.96-5.74 g/100g) and proteins (1.62-2.07 g/100 g). The major amino acids are glycine, leucine, alanine, and aspartic acid. Lysine had a lowest chemical score of 64% among the essential amino acids. In both species, flowers contained a higher composition of unsaturated fatty acids (65-66%), mainly the linoleic acid, while saturated fatty acids (mainly palmitic acid) is low. The contents of vitamin E, total saponin and flavonoids were 0.87-1.07, 0.12 and 5.27–5.90 mg/100 g, respectively. This study provides a fundamental nutritional data of banana flowers which can be essential in food science.

Key words: Banana flower, protein, dietary fiber, vitamin E.

INTRODUCTION

The banana (*Musa accminata* Colla) is a typical climacteric fruit and mainly grows in tropical and subtropical regions. In China, Bananas are well growing in south region including Hainan, Guangdong, Guangxi, Fujian, Yunnan and Taiwan provinces. The planting area of banana in China is nearly 311,100 hectares with an annual production of more than 804 million tons in 2008 (FAO, 2008) which has a huge economical value. In commercial situation after collecting the single bunch of bananas, lots of banana flowers are produced which has only been used as organic material and fertilizer in plantations in China until today (Yang et al., 2003). While Banana flower has tremendous nutritional value and can be consumed as food additive in many Asian countries such as Sri Lanka, Indonesia and Thailand. In Sri Lanka, it is consumed as a curry as well as a boiled or deep fried salad with rice and wheat bread (Wickramarachchi and Ranamukhaarachchi, 2005). Besides being consumed fresh, banana flower can also be made into various products such as dehydrated vegetable, pickle and canned food (Wickramarachchi et al., 2005; Yunchalad et al., 1995).

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Biologically active compounds, such as dopamine, noradrenaline, serotonin, isochronal-4-one derivative and anti-hyperglycaemic factors have been found in banana (Pari and Umamaheswari, 2000; Qian et al., 2007; Waalkes et al., 1958). Fruits, leaves, root and stalks from banana plants have been used to treat fevers, burns, diarrhea, inflammation, pains and snakebite in folkloric medicine (Coe and Anderson, 1999). While limited works have been done on banana flowers, Oliveira et al., (2006) found that fatty acids and sterols are the major families of the lipophilic components in the floral stalk of "Dwarf Cavendish" banana. The chloroform, water and ethanol extract of *Musa sapientum* flowers were found to exhibit hypoglycaemic activity in alloxan diabetic rat (Dhanabal et al., 2005; Grover et al., 2002; Pari and Umamaheswari 2000). Studies on the contents of vitamin C, tannin, myoinositol phosphates and alpha tocopherol in *M. sapientium* flower have been reported (Alarcon-Aguilaraa et al., 1998; Somsub et al., 2008). Ngamsaeng et al., (2006) investigated concentrations of crude saponin in *M. sapientium* flower and their relationship with the fermentation end-products by using the in vitro gas technique. However, there are no published studies on the nutritional composition of this material.

Recently, more attention has been focused on the utilization of agricultural by-products. Over 1,442,134 tons of bananas have been produced in Hainan annually (data provided by Ministry of Agriculture of the People's Republic of China). The amount of banana flowers, which comprises 2% or more by the weight of the banana fruits, is quite large. We suspect that banana flower has a huge nutritional value and healthy benefits. Therefore, the objective of present study was to investigate the basic nutritional composition of banana flowers of two cultivars grown in Hainan in order to provide the primary information in using of banana flowers in food industry.

MATERIALS AND METHODS

Sample preparation

Musa spp. 'Baxijiao' and 'Paradisiaca', the most popular and accessible in Hainan were chosen in this study. The banana flowers used were grown in the experimental field of Haikou experimental station (The Chinese Academy of Tropical Agriculture Sciences, Danzhou City and Hainan Province, China) from January to December in 2008. The plants were managed as the commercial practices with standard fertilization and culture management. Mature banana plants from four plots, approximately 30 square meters per plot, were collected, and then the flowers were manually separated from the plant. After separation, the samples were taken, thoroughly washed in running water, and then, freezing dried. For most of the analyses, dried samples were used while for analysis of vitamin E and fatty acids, fresh samples were used. After calculating the yields, the flowers were separately homogenized and packed in black polyethylene bags and stored at -20°C prior to further nutrient composition analysis.

Proximate composition analyses

Samples of banana flower were analyzed for proximate composition (moisture, protein, fat, ash and total dietary fiber) following the standard methods published by Association of Official Analytical Chemists (AOAC, 1995). Moisture content was estimated by gravimetric measurement of weight loss after drying the sample in an oven at 105°C until constant weight was obtained. Protein was determined by Kjeldahl method (Kjeldahl, 1883), and thereafter a conversion factor of 6.25 was used to calculate the total nitrogen to crude protein. Crude fat was analyzed by the Soxhlet extraction method. The content of ash was measured by gravimetric measurement of the sample in the furnace at 550°C until the constant weight was achieved. Total dietary fiber (TDF) was determined according to the AOAC enzymatic gravimetric method (1995).

Amino acids

The sample was hydrolyzed with 6 M HCL at 110°C under nitrogen atmosphere for 24 h. For further analysis, the cooled and filtered hydrolyzed was dried in vacuum desiccators at 45°C and then dissolved in citrate buffer (pH 2.2). After a pre-hydrolysis oxidation with performic acids, samples were hydrolyzed with HCL and analyzed 16 f amino acids directly. After this, sulphur-containing amino acids including cystine and methionine were determined. The each concentration amino acid were measured by using an automated amino acid analyzer (Hitachi L-8900, Japan), quantification and identification of amino acids were achieved by comparing the retention times of the peaks with those standards, according to standard program of AOAC (1995).

The contents of different amino acids recovered are presented as mg per g protein and are compared with the FAO/WHO/ UNU (1985) reference pattern. Each essential amino acid was expressed as a percentage of the corresponding amino acid in the reference protein sample. Essential amino acids score was calculated with reference to the FAO/WHO reference amino acid pattern (FAO/WHO, 1985).

Amino acid score = [Test amino acid / Reference amino acid] x 100

Mineral analysis

The samples were digested in $HNO_3/HClO_4$ for mineral determination. The mineral content (calcium, potassium, magnesium, iron, copper, lead, arsenic, mercury and sulphur) of each sample was determined by using a Varian Spectra atomic absorption spectrophotometer (model 220, Varian, US), and phosphorus was measured by spectrophotometric methods of AOAC (1995), the instrument was calibrated with known standards and samples analyzed at corresponding wavelengths.

Fatty acid contents

Fatty acids were transformed to their methyl esters (FAME) and were determined by using a gas chromatograph (GC) based on AOAC official method (AOAC, 1995). 2µl of the FAME sample were injected and GC separation was carried out on a capillary column:

Table 1. Proximate composition (g/100 g) of banana flowers of two cultivars (cvs Baxijiao and Paradisiaca).

Components	Baxijiao	Paradisiaca
Moisture	90.58±0.01a[A]	89.42±0.07b
Protein	2.07±0.01a	1.62±0.07b
Fat	0.4±0.00a	0.6±0.00b
Ash	1.19±0.05a	1.24±0.03a
TDF [B]	4.96±0.13a	5.74±0.36b
Carbohydrate [C]	91.39±0.18a	90.80±0.34a

[A] Data are mean values of three determinations ± S.D. Means in rows with different letters (a-b)are significantly different ($p<0.05$), based on ANOVA.
[B] TDF=total dietary fiber
[C] Carbohydrates levels of dry weight were calculated by the formulation: (carbohydrates= 100-protein-fat-ash-TDF).

PEG-20M (30 m×0.25 mm, I.D., 0.5µm film thickness, Supelco); Carrier gas is helium with a flow rate of 1.0 ml/min. The oven temperature was programmed for 250°C from an initial temperature of 180°C (0.5 min hold), rising to 215°C at 6°C/min, then cautiously rising to 230°C at 4°C/min, and held isothermal for 15 min as the standard injection temperature. Identification and quantification of fatty acid methyl esters were achieved by comparing the retention times of the peaks with those standards.

Vitamin E

The content of vitamin E was determined with High Performance Liquid Chromatography (HPLC, Shimadzu Co., Kyoto, Japan) as described by Ahn et al., (1995) .Total amount of vitamin E is the sum of α + γ + δ vitamin E.

Total flavonoid contentation

The determination of flavonoid was performed according to the colorimetric assay of Kim et al., (2003). Distilled water (4 ml) was added to 1 ml of diisopropyl fluorophosphates extract. Then, 5% sodium nitrite solution (0.3 ml) was added, followed by 10% aluminum chloride solution (0.3 ml). Test tubes were incubated at ambient temperature for 5 min, and then 2 ml of 1 M sodium hydroxide were added to the mixture. Immediately after, the volume of reaction mixture was filled up into 10 ml with distilled water. The mixture was thoroughly vortexed and the absorbance of the pink colour developed was determined at 510 nm. A calibration curve was prepared with catechin and the results were expressed as mg catechin equivalents (CEQ)/100 g sample.

Total saponin

The total saponin content was determined according to the spectrophotometric assay described by Baccou et al., (1977). 0.5 g ground banana flower samples were weighed into a screw-capped centrifuge tube, and added 10 ml of 80% aqueous methanol. The tubes were tightly capped and stirred overnight using a magnetic stirrer. The sample tubes were centrifuged at 3000 g for 10 min at room temperature and the supernatants were collected in 25 ml measuring flasks. The residues were washed thrice with 5 ml of 80% aqueous methanol, followed by centrifugation, and the supernatants were collected in volumetric flasks. The final volume was made to 25 ml with 80% aqueous methanol. Aliquot samples from the flasks were used for saponin determination. The results are expressed as diosgenin equivalents from a standard curve of different concentrations of diosgenin in 80% aqueous methanol.

Statistical analysis

Triplicate analyses were conducted for each sample. The experimental data were expressed as mean ± standard deviations of three separate determinations. One-way analysis of variance (ANOVA) was carried out on the experimental results using species as an independent variable. The significance of differences between means was compared by Tukey's multiple test at $p<0.05$. All calculations were performed using an ANOVA package from statistical analysis systems (SAS, version 8.0).

RESULTS AND DISCUSSION

Proximate composition analyses

The main nutritional compositions of Baxijiao and Paradisiaca flower samples are presented in Table 1. Although carbohydrate was not analyzed, total carbohydrate was calculated by %carbohydrates = 100 - (%protein + %fat + %ash) for purposes of comparison. Significant differences ($p < 0.05$) were found in the levels of moisture, protein, total dietary fiber (TDF) between Baxijiao and Paradisiaca flower samples.

The flower from two different cultivars contained 89.42 - 90.58 g/100 g moisture, which were similar to results of other banana species (91.8 - 92.2 g/100 g) from the Thailand (Somsub et al., 2008). All these flowers had high moisture levels, implying they have very short shelf life. The content of protein varied from 1.62 to 2.07 g/100 g. The higher protein content was found in the Baxijiao

Table 2. Amino acid profile of banana flowers of two cultivars (cvs Baxijiao and Paradisiaca).

Amino acid	Baxijiao (g/100 g)	Content (mg/g protein)	Paradisiaca (g/100 g)	Content (mg/g protein)	Whole hen's egg
Essential					
Threonine	0.06±0.00a	31.2	0.05±0.01b	31.2	51.2
Valine	0.05±0.00a	25.8	0.06±0.01a	34.8	68.5
Methionine	0.04±0.00a	17.9	0.03±0.00b	16.3	34.6
Isoleucine	0.04±0.01a	21.0	0.04±0.01a	26.5	62.9
Leucine	0.10±0.01a	50.4	0.09±0.01a	56.5	88.2
Tryptophan	0.06±0.00a	11.1	0.02±0.01b	9.3	16.2
Phenylalanine	0.05±0.01a	22.4	0.05±0.01a	29.5	56.3
Lysine	0.08±0.00a	37.3	0.06±0.01b	37.2	69.8
Total EAA	0.45±0.01a	217.1	0.39±0.05a	241.2	447.7
Non-essential					
Aspartic acid	0.15±0.01a	72.6	0.12±0.01b	75.2	---
Serine	0.08±0.00a	40.0	0.07±0.01b	43.0	---
Glutamic acid	0.30±0.00a	144.1	0.21±0.03b	132.1	127.4
Proline	0.09±0.01a	45.2	0.06±0.00b	34.7	41.6
Glycine	0.06±0.00a	28.4	0.05±0.01a	32.9	33.1
Alanine	0.10±0.00a	49.2	0.08±0.01b	51.8	59.2
Cystine	0.08+0.00a	37.1	0.06±0.01b	35.1	24.3
Tyrosine	0.04±0.00a	17.3	0.04±0.01a	22.3	41.6
Histidine	0.03±0.00a	15.3	0.03±0.00a	16.7	24.3
Arginine	0.08±0.01a	39.9	0.07±0.01a	42.3	61.0

Values are means ± standard deviations of triplicate determinations, Values in the same row followed by different letters are significantly different ($P < 0.05$), based on ANOVA.

flower which is significant different in comparison to Paradisiaca flower sample. Fattic concentration was generally low (0.4g/100 g Baxijiao and 0.6 g/100 g Paradisiaca) in both cultivars. The content of crude protein in two samples were higher than that in *M. sapientum* L. (1.34 g/100 g); however, the content of fat was lower than that in *M. sapientum* L (1.52 g/100 g) flower (Ngamsaeng et al., 2006). A significant difference in the fat and protein content is mainly due to different genetypes. It is also well known that banana flowers contain a significant amount of non-protein nitrogen, generally in the form of chitin in their cell walls. The total ash content of both species was very similar and closing to 1.25 g/100 g of dry weight basis. Not significant difference was found between Baxijiao and Paradisiaca samples (Table 1, $P>0.05$). Dietary fiber was found as the second abundant component, higher (4.96 - 5.74 g/100g) than those in fifteen different Chinese vegetables (1.1 - 4.6 g/100 g; Wills et al., 1984). A higher content of fibers in banana flowers indicates that the flowers can be consumed as dietary fiber supplements.

Amino acid composition

It is well known human-being and animal cannot synthesize all needed the amino acids, so some amino acids must be supplied through food consumption. Therefore foods and fodder rich in amino acids are desirable. The nutritional value of dietary proteins is evaluated by the quantity of essential amino acids (EAA). Table 2 showed the amino acid compositions of banana flower. Overall, 17 amino acids were determined in each sample. EAA accounted for 45% and 39% of total amino acid concentrations of Baxijiao and Paradisiaca flowers, respectively, which appro-ximated to the reference values of 40% recommended by FAO/WHO (1973). The content of total free amino acid contents are quite similar in both species and no major differences were observed in the before amino acid profiles, except for tryptophan, whose content was triple as high in Baxijiao flower as in Paradisiaca flower. Although significant ($p < 0.05$) differences existed between Baxijiao and Paradisiaca flower basis in threonine, methionine, tryptophan and

Table 3. Amino acid score of banana flowers of two cultivars (cvs Baxijiao and Paradisiaca).

Amino acid	Content (mg/g protein)		Reference	Score (%)	
	Baxijiao	Paradisiaca		Baxijiao	Paradisiaca
Threonine	31.2	31.2	34	92	92
Tryptophan	11.1	16.2	11	101	147
Cystine + methionine	55.0	57.4	25	220	230
Valine	25.8	34.8	35	74	99
Phenylalanine + tyrosine	39.7	51.8	63	63	82
Isoleucine	21.0	26.5	28	75	95
Leucine	50.4	56.5	66	76	86
Lysine	37.3	37.2	58	64	64
Total	271.5	311.6	320	85	97

Reference: Reference amino acid pattern of preschool children (2–5 years) (FAO/WHO/UNU, 1985).

lysine contents, no significant ($p > 0.05$) were noted in the total contents of the EAA examined.

In addition, the percentage of savoury amino acids (asparagines and glutamic acid) and sweet amino acids (glycine and alanine) to total amino acids were as high as 30.7, 28.5 and 11.0, 11.6%, respectively. Mostly, the non-essential amino acids were obtained in fairly high amounts. Some, such as glutamic acid and cystine, were presented in amounts exceeding the FAO/WHO (1973) reference protein requirements.

The nutritional value was evaluated by comparing the ratio of essential amino acids in banana flower with the respective amino acids based on hen's eggs. Table 3 showed the essential amino acid pattern of two samples as compared with that of hen's eggs reported by FAO/WHO (1973). The EAAs profile of the protein of banana flower (271.5 and 311.6 mg/g protein) was lower than those the FAO/WHO pattern (320 mg/g protein), whereas the contents of tryptophan and cystine + methionine were higher than the reference values recommended by FAO/ WHO. The results of amino acid score indicated that Paradisiaca flower had a higher amino acid score, resulting a better nutritional protein quality than Baxijiao flower. The lysine of two samples has a low chemical score value (64%) and thus it seemed to be the limiting essential amino acid in banana flower.

Mineral contents

The mineral contents of banana flowers were listed in Table 4. The concentrations of magnesium, calcium, potassium, phosphorus, iron and sulphur of Baxijiao samples were significantly different ($p < 0.05$) from that of Paradisiaca flower; however, no significant differences ($p > 0.05$) were observed in the case of copper, mercury, arsenic and plumbum contents. As expected, all the major elements evaluated in this study were found in both samples, with potassium being the highest, especially in the Paradisiaca flower. The flowers contained four of these major elements, phosphorus was the most abundant mineral in banana flower, followed by calcium, magnesium and sulphur. The results were similar to the reported values by Ngamsaeng et al. (2006). Regarding the micro nutritions, the flower had high concentration of iron. These results revealed that a wide variation was observed in the quantitative composition of mineral in flowers from different banana cultivars. This could be due to their growing environmental conditions and genetic variations of each cultivar. The guidance of mineral nutritional intake for 4-6 years old children (China Nutrition Institute, 2001) indicated that banana flower is a good mineral source of magnesium, iron, copper and potassium.

Fatty acid composition

Precursor flavour compound could be the unsaturated fatty acids. As shown in Table 5, five fatty acids were identified in banana flower (palmitic acid, stearic acid, oleic acid, linoleic acid and α-linolenic acids). Baxijiao contained significantly ($p < 0.05$) higher proportion of fatty acid than Paradisiaca. There were no uncommon fatty acids. Mono-unsaturated and poly-unsaturated fatty acids contributed 19 and 47%, respectively. Unsaturated acids of both cultivars accounted for more than 60% of the total fatty acids, mainly the oleic, linoleic and α-linolenic acids, which are benefit to lower the risk of cardiovascular diseases (Ezeagu et al., 1998). The results also showed palmitic acid (16:0) was the main saturated fatty acid at 34%.

Table 4. Mineral content (mg/100 g) of banana flowers of two cultivars (cvs Baxijiao and Paradisiaca).

Element	Baxijiao	Paradisiaca	A.I (mg/day)
Magnesium	34.13 ± 0.00a	48.73 ±0.00b	3.5
Potassium	571.33 ± 0.00a	553.33 ± 0.01b	1500.0
Calcium	33.27 ± 0.00a	56.00 ± 0.00b	800.0
Phosphorus	53.27 ± 0.00a	73.33 ± 0.00b	500.0
Iron	43.44 ± 0.12a	56.40 ± 0.12b	12.0
Copper	13.60 ± 0.01a	13.00 ±0.05a	1.0
Sulphur	27.03 ± 0.00a	37.00 ± 0.00b	
Mercury	0.03 ± 0.00a	0.03 ± 0.00a	
Arsenic	0.20 ± 0.00a	0.18 ± 0.00a	
Plumbum	0.35 ± 0.01a	0.34 ± 0.00a	

Values are means ± standard deviations of triplicate determinations.
Values in the same row followed by different letters are significantly different ($P < 0.05$), based on ANOVA.
A.I.: Adequate intakes of Chinese children (4–6 years) (China Nutrition Institute, 2001).

Table 5. Fatty acids composition of banana flowers of two cultivars (cvs Baxijiao and Paradisiaca).

Fatty acid elements	Baxijiao	Paradisiaca
Palmitic acid (C16:0)	0.09±0.01a	0.06±0.01b
Stearic acid (C18:0)	0.02±0.00a	0.01±0.00b
Oleic acid (C18:1)	0.06±0.01a	0.03±0.01b
Linoleic acid (C18:2)	0.12±0.01a	0.08±0.01b
α-Linolenic acid (C18:3)	0.03±0.01a	0.02±0.01a

Values are means ± standard deviations of triplicate determinations.
Values in the same row followed by different letters are significantly different ($P < 0.05$), based on ANOVA.

Vitamin E, total saponins and flavonoids

The major physiological function of vitamin E is its antioxidant activity. Vitamin E protects the fatty acids by interfering with the free radical reactions that can result in cellular damage and is protective against approximately 80 diseases, such as cancer, cardiovascular diseases (Gey et al., 1992). The amount of vitamin E in Baxijiao flower was found to be significantly lower than Paradisiaca ($p < 0.05$) (Table 6).The value found in banana flowers in this study was higher than those reported in other tropical plants (Ching and Mohamed, 2001). The difference of vitamin E in banana flowers depends on the cultivars.

Saponins are a diverse group of compounds containing an aglycone moiety linked to one or more sugar or oliogosaccharide residues. Some of the major biological effects of saponin in animal include erythrocyte haemolysis; effects on growth, feed intake and nutrient absorption and effects on cholesterol and bile acid metabolism (Cheke, 1996). The saponin concentration of samples, which ranged from 0.11-0.12%, is lower than previous 1.3% obtained in banana leaf (Ngamsaeng et al., 2006). No significant difference was found between two cultivars (Table 6).

Flavonoids have gained considerable interest as they are confirmed to be very effective in reducing the risk of cardiovascular diseases by lowering the oxidation of LDL as well as preventing other degenerative diseases (Pierini et al., 2008). The current results have confirmed that higher flavonoids (5.27 to 5.90 mg/100 g) were present in banana flowers than in banana peel, in contrast to previous reports (Lima et al., 2008). It is suggested, therefore, that banana flowers are a good source of flavonoids.

Table 6. Chemical composition of banana flowers of two cultivars (cvs Baxijiao and Paradisiaca).

Component	Baxijiao	Paradisiaca
Vitamin E (mg/kg)	0.87±0.04a	1.07±0.06b
Total Saponin (g/100 g)	0.11±0.00a	0.12±0.01a
Total Flavonoids (mg/100 g)	5.90±0.75a	5.27±0.47a

Values are means ± standard deviations of triplicate determinations, Values in the same row followed by different letters are significantly different ($P < 0.05$), based on ANOVA.

Conclusion

This research has comprehensively investigated the nutritional composition of banana flowers of two cultivars, Baxijiao and Paradisiaca. The results indicate that banana flowers are good source of minerals, such as magnesium, iron and copper. It contains high quality protein because of its well balanced essential amino acid in addition to high dietary fiber and flavonoid concentrations. The utilization of banana flowers could provide additional benefits in reducing the banana waste, and increasing the use in food science. Further studies are needed to document the biological effect of banana flower in physiology and healthy benefits of human being. These may include the investigation of its effect of tannin, phytate, total phenolics flavonoid, alkaloid and sterol in human health as daily diet components.

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