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The natural impact of banana inflorescences (*Musa acuminata*) on human nutrition

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ABSTRACT

Banana inflorescences are popularly known as 'navels,' and they are used in Brazil as nutritional complements. However, the nutritional value of banana inflorescences (male flowers and bracts) has never been studied. Therefore, plant material of *Musa acuminata*, cultivar "ouro", was collected in Rio de Janeiro state, Brazil, and then submitted to chemical procedures to determine its nutritional composition. The experiment was arranged a completely randomized design and performed in triplicate. The sample composition analysis showed percentual average value for moisture, protein, fat and ash as 8.21, 14.50, 4.04 and 14.43, respectively. The dehydrated inflorescences were found to contain a significant nutritive complement based on their high content of potassium (5008.26 mg / 100 g) and fiber 49.83% (lignin, cellulose and hemicelluloses) revealing important functional and nutritional properties. In a parallel evaluation, the anatomical study revealed key elements for the recognition of *Musa acuminata* when reduced to fragments.

Key words: anatomical analysis, banana inflorescences, "banana-ouro", *Musa acuminata*, Musaceae, nutritional value.

INTRODUCTION

The Musaceae family, represented by the production of bananas (*Musa spp*), provides one of the most consumed fruits worldwide with enormous economic value and socioeconomic importance (Bernardi et al. 2004, Moreira et al. 2010). Essentially, the nutritional value of bananas is highlighted by the high intake of sugars, fiber, vitamins, and minerals and the very low intake of fat (Forster et al. 2002). Several species of *Musa* and *Ensete* are also used as ornamental plants and widely traded in international markets. This family has paleotropical distribution, and is formed by the genera Ensete, *Musa* and *Musella* (Häkkinen 2009, De Langhe et al. 2009) with around 80 species.

Musa is the largest genus of the Musaceae and includes both wild species and cultivated seed-sterile

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bananas and plantains. It has been estimated that *Musa* comprises about 70 species and over 500 cultivars, and new species continue to be discovered (Häkkinen and Hong 2007). However, many specific and infraspecific taxa are still confused and doubtful (Häkkinen and Väre 2008). The genus is native throughout the Indo-Malaysian region, in tropical and subtropical areas from Sri Lanka and eastern India, across south China and Southeast Asia to the southwest Pacific and northern Australia, but it is widely cultivated in all tropical regions of the world (Kennedy 2009). A number of distinct groups of edible bananas have been developed from species of *Musa* (Kennedy 2008), and over the years, considerable attention has been given to the genetics and biogeography of the process by which bananas with seedless fruits are domesticated (Perrier et al. 2009).

Inflorescences are discarded in abundance in banana culture fields, when the banana bunches are harvested, without any use. Yet, the inflorescences of *Musa acuminata* Colla ("banana-ouro", "gold banana"), also popularly known as "umbigos" ("navels"), are considered to be nutritional complements, mainly in the Brazilian rural areas. That part of the banana plant, including flowering stalks, is used to make pie filling and salads, or it is cooked in order to increase the yield of meat-based meals. Also, dehydrated inflorescences are a great nutritive complement based on their high content of potassium and fiber. In view of their high nutritional value, inflorescences can be used in the diet in the form of dehydrated flour and thus easily incorporated into food (Fingolo et al. 2011). From the viewpoint of health, this botanical part has high levels of minerals and fiber (Coelho et al. 2001).

The nutritional value of banana inflorescences (male flowers and bracts) has never been studied; thus, such investigation is timely, particularly since they are often discarded and used as organic soil fertilizer. Therefore, this work aims to contribute to the knowledge of *Musa acuminata* inflorescences by evaluating their anatomy and nutritive composition.

MATERIALS AND METHODS

Sample Preparation

The inflorescences (male flowers and bracts) of *Musa acuminata* were collected in Magé, Rio de Janeiro state, Brazil, in May, 2008. A voucher sample has been deposited, under the number RB 402574A, in the Jardim Botanico (Botanical Garden) of Rio de Janeiro Herbarium (RB). The inflorescences were manually cut into small pieces and dried at 40°C in an oven with controlled temperature and air circulation (MA 037, Marconi). This work was carried out at the Laboratory of Food Technology of the Department of Graduate Studies in Pharmaceutical Sciences, Center for Health Sciences of the Universidade Federal do Rio de Janeiro, RJ, Brazil. Fresh and dehydrated inflorescences were submitted to chemical analysis to determine moisture content and nutritional composition as crude protein, total fat, fixed mineral residue or ash, minerals (macro and microelements) and fiber. The analyses were performed in triplicate, except for the minerals with 6 determinations.

Anatomical and Histochemical Analysis

Samples of bracts and flowers were analyzed, either fresh or in ethanol 70% (Jensen 1962). Anatomical and histochemical studies were performed for fixed samples in buffered neutral formalin (Clark 1981). Samples were stained with Astra blue (C.I. not displayed) and safranin (C.I. 50240) (Bukatsch 1972). Slide assembly was performed by applying synthetic resin (Entellan) after ethanol dehydration of the histological sections.

Proximate Analysis

Moisture, protein, fat and ash contents from inflorescences were analyzed according to the methods of the Instituto Adolfo Lutz (IAL 2005), Brazil. Carbohydrate content and total energy value (TEV) were determined according to Brazilian legislative authority RDC 360 (BRASIL 2003).

Mineral Analysis

The concentration of minerals, including Na, Mg, P, K, Ca, Mn, Fe, Cu and Zn, was determined after the fixed mineral residue was obtained by inductively coupled argon plasma optical emission spectrometry (ICP-OES-Spectroflame Model P; 1200W power) (AOAC 2000) at the Mineral Laboratory, Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA, Pedra de Guaratiba, Rio de Janeiro, RJ, Brazil.

Fiber Analysis

Crude fiber (CF), acid detergent and neutral fiber (ADF and NDF) were evaluated after extraction with neutral detergent solution hydrolysis, according to the procedures described by Van Soest (1963a) and Mendez et al. (1985), respectively, using a six- plate setup for Dosi-fiber extraction (Tecnal). Lignin and cellulose contents were also determined (Van Soest 1963b).

Statistical Analysis

Data were analyzed according to a completely randomized design, representing the mean values of triplicate analysis or more, depending on the availability of the data. A replication consisted of a composite inflorescence sample from the same plant. Data were subjected to analysis of variance using the general linear models procedure of SAS (1999).

RESULTS AND DISCUSSION

Anatomical and Histochemical Analysis

The parthenocarpic fruit of *Musa acuminata* was developed from large and indefinite inflorescences. A set of bracts, burgundy on the outside and pale pink on the inside, were observed at the apex of the inflorescences. Trimerous tubular flowers, usually with sterile anthers that do not develop for the formation of fruits, were located in the axil of bracts (Fig. 1A). In cross-section, the middle region of the bract (Fig. 1B-D) revealed elliptical cells in the uniseriate epidermis of abaxial face with periclinal walls of thicker and conspicuous cuticle. The epidermal detachment of this region (Fig. 1E) revealed that the epidermis is formed by common polygonal cells with thick anticlinal walls and stomata. The epidermis in adaxial face (Fig. 1D, F) is uniseriate with rectangular to pentagonal ordinary cells having spherical to pyriform projections in external periclinal wall, which give papillose appearance to that face. Stomata with thickened walls were observed between the common cells. The mesophyll (Fig. 1B, 2A) consists of numerous layers of parenchymal tissue, with smaller cells near the epidermal layers and larger cells in the middle region interrupted by the formation of aeration chambers with branched parenchyma cells and prominent intercellular spaces.

Several idioblasts containing starch grains or raphides of calcium oxalate were observed among the parenchyma cells (Fig. 2B).

Collateral vascular bundles were observed throughout the mesophyll. Strands of sclerenchyma fibers were observed next to the adaxial epidermis. The cross section in the middle of the corolla tube (Fig. 3A) revealed uniseriate epidermis on both sides, consisting of circular to elliptical ordinary cells and mesophyll with a variable number of layers of parenchyma cells. Collateral vascular bundles were observed in the mesophyll (Fig. 3B). Stamens exhibited connectives with thickened epidermis and a variable number of layers of parenchyma cells with thin walls and variable shapes and sizes. Idioblasts containing raphides of calcium oxalate were observed among the parenchyma cells. The region of the pollen sacs (Fig. 3C) presented uniseriate epidermis with round cells, endothecium with thickening ring and collapsed inner layers. Spherical grains of pollen were occasionally visible.

Anatomical data can be used to improve plant classification and identify some species. Many plants have been recognized on the basis of their distinctive

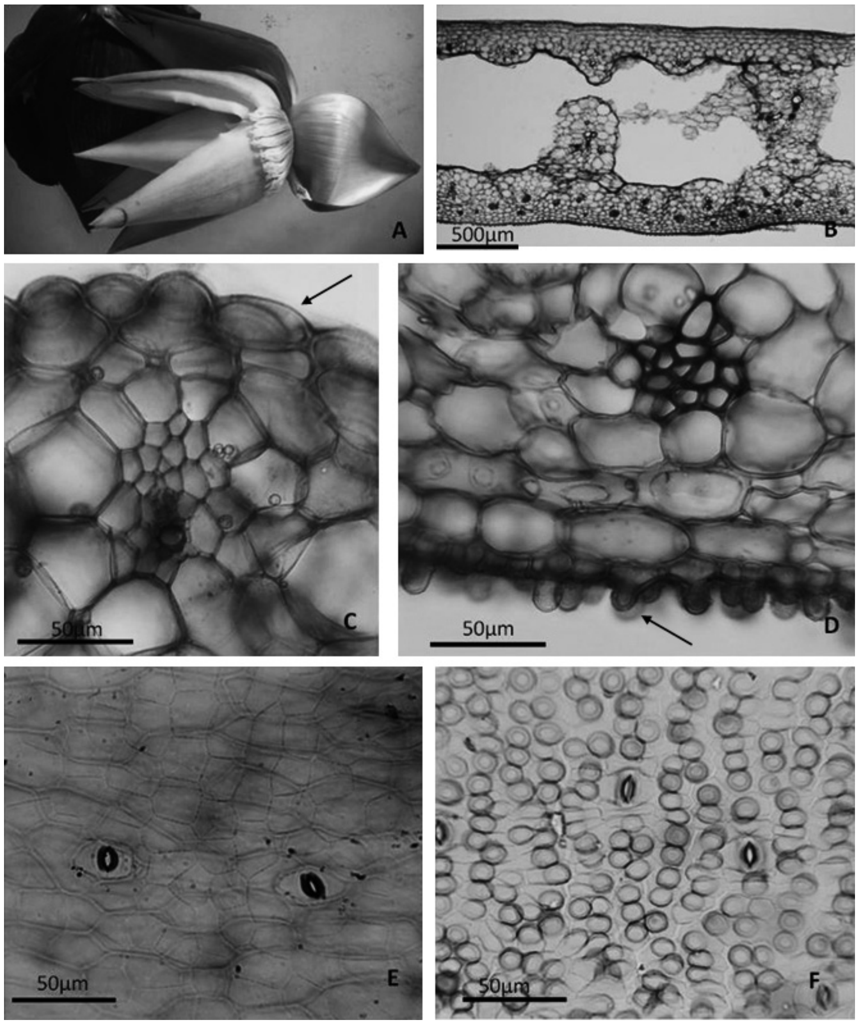

Fig. 1 - *Musa acuminata*. **A.** Appearance of the bracts and male flowers. **B.** Cross section of bract showing large aeration chambers. **C.** Detail of vascular bundle near the epidermis of the abaxial face (arrow) of the bract. **D.** Detail of sclerenchymatic fibers located near the epidermis of the adaxial face (arrow) of the bract. Note the appearance of the epidermis in this region. **E.** Front view of the epidermis in abaxial face of the bract, showing polygonal ordinary cells and paracytic stomata. **F.** Front view of the epidermis in adaxial face of bract showing the appearance of the projections of the ordinary cells and paracytic stomata.

anatomy. According to Dickson (2000), elements of the epidermis, such as trichomes and stomata, or inclusions in the parenchyma, have great relevance for the identification of plants. However, in the case of banana flowers ground as a powder, the constituents are difficult to detect by methods other than microscopy (Cutler et al. 2007). For this reason, we undertook the following analysis in order to characterize the bracts and floral parts of *Musa acuminata* with the objective of improving recognition of this plant.

Proximate Composition (Fresh Inflorescences)

The results of proximate analysis of *M. acuminata* inflorescences are presented in Table I.

The average (%) contents of moisture, protein, fat and ash in *M. acuminata* inflorescences were 91.00, 1.79, 0.43 and 1.56, respectively. When comparing the inflorescence data with the nutritional value of traditional palm (*Euterpe edulis* Mart. - Arecaceae) and banana pseudostem palm

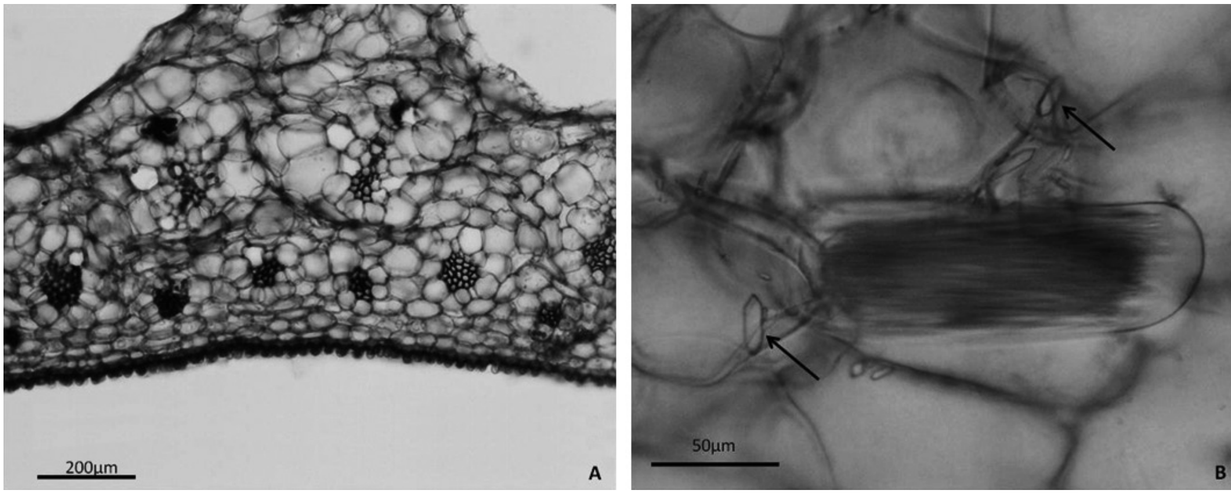

Fig. 2 - *Musa acuminata*. **A.** Detail of the cross section of bract showing the distribution of groups of sclerenchyma fibers parallel to the epidermis of the adaxial face. **B.** Detail of idioblasts displaying numerous raphides. Note starch grains in adjacent parenchyma cells (arrow).

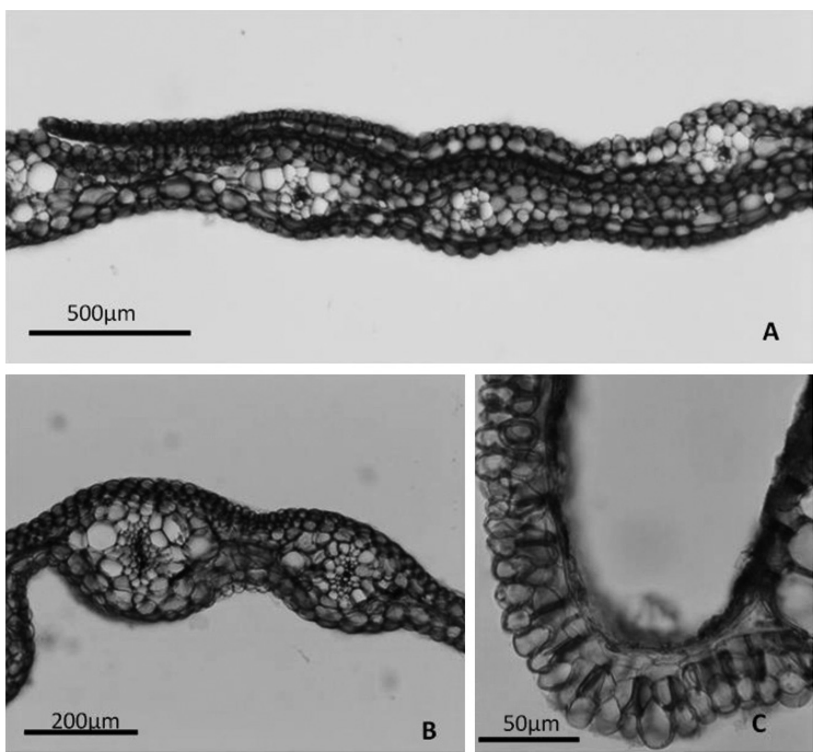

Fig. 3 - *Musa acuminata*. **A.** Transverse section of corolla tube. **B.** Detail of the tepal showing parallel collateral vascular bundles. **C.** Detail of cross section of anther showing the thickening of endothecium cells.

(Table II), the nutritional composition was found to be similar. However, total carbohydrate content (5.19 g / 100 g) in this study was above the average found in other studies (Table II), essentially because our analysis of *M. acuminata* fresh inflorescences included dietary fiber, whereas the other studies

TABLE I
Proximate composition of products of *M. acuminata* inflorescences (g / 100 g of fresh product).

Chemical analysis %	Content[a]
Moisture	91.0 ± 0.54 AV 0.59
Protein	1.79 ± 0.23 AV 12.9
Fat	0.43 ± 0.10 AV 23.3
Ash	1.56 ± 0.04 AV 2.56
TEV (kcal/g)	31.8 ± 1.57 AV 4.94

[a] Means of three determinations ±SD. AV means analysis of variance.

did not. The total energy value (TEV) in this study (Table I) is approximately twice as high as found in the traditional palm (Coelho et al. 2001) (Table II).

Proximate Composition (Dehydrated Sample)

The results of proximate analysis of *M. acuminata* dehydrated inflorescences are presented in Table III. The inflorescences presented a high percentage of total carbohydrate (58.82%), including fiber. The average (%) contents of moisture, protein, fat and ash were 8.21, 14.50, 4.04 and 14.43, respectively.

Fiber Analysis

The fiber profile of *M. acuminata* is shown in Table III. The inflorescences reveal a high percentage of insoluble fibers at 49.83% (lignin, cellulose and hemicelluloses), showing important functional properties, since the daily adult consumption should be 25 g of fiber a day, according to Brazilian legislative authority RDC 360 (BRASIL 2003).

Mineral Content

The mineral concentration of dehydrated *M. acuminata* is presented in Table IV. The inflorescences were very rich in potassium (5,008.26 mg / 100 g), the most abundant macroelement in banana inflorescences, followed by calcium (377.63 mg / 100 g) and phosphorus (365.86 mg / 100 g). The other elements, in descending order, included magnesium, sodium, manganese, zinc, iron, and copper.

CONCLUSION

The analysis of *M. acuminata* inflorescences revealed their considerable nutritional value and low caloric content. Also, dehydrated inflorescences were found to contain a significant nutritive complement based on their high content of potassium and fiber. In view

TABLE II
Average values of proximate composition of banana pseudostem palm (*Musa acuminata*) products and traditional palm (*Euterpe edulis*) (g / 100 g of fresh product).

Chemical analysis %	Banana pseudostem (*Musa acuminata*) content[a]	Banana pseudostem (*Musa acuminata*) content[b]	Traditional palm (*Euterpe edulis*) content[c]	Traditional palm (*Euterpe edulis*) content[d]
Moisture	92.6	94.5	93.7	91.7
Protein	1.89	1.10	1.62	2.27
Carbohydrates (by difference)	2.16	1.63	1.67	3.07
Carbohydrate (glycid)	1.73	n.a.	n.a.	n.a.
Fat	0.85	1.92	0.53	0.64
Ash	1.17	0.90	0.76	n.a.
Fiber	1.32	1.17	1.65	0.90
TEV (kcal/g)	n.a.	n.a.	n.a.	16.3

[a] Gomez (1967). [b,c,d] Coelho et al. (2001). [n.a.] Not analyzed.

TABLE III
Proximate composition and fiber analysis of *M. acuminata* inflorescences (g / 100 g dehydrated basis).

Components	Content[a]
Moisture	8.21 ± 0.17 AV 2.07
Protein	14.5 ± 0.40 AV 2.76
Fat	4.04 ± 0.07 AV 1.73
Ash	14.4 ± 0.64 AV 7.77
Lignin	14.8 ± 1.15 AV 7.77
Cellulose	14.4 ± 0.84 AV 5.84
Hemicellulose	20.6 ± 1.02 AV 4.94

[a]Means of three determinations ± SD. AV means analysis of variance.

TABLE IV
Mineral concentrations (mg / 100 g dehydrated basis) and adequate intakes of Brazilian adults (AI).

	Mineral	AI mg/day	Content[a] mg/100g
Macro			
	Magnesium*	260	250.1 (14.47) AV 5.78
	Phosphorus*	700	365.9 (18.7) AV 5.10
	Potassium***	4700	5008.3 (86.9) AV 1.74
	Calcium*	1000	377.6 (24.0) AV 6.35
	Sodium**	2400	39.7 (11.0) AV 27.8
Micro			
	Manganese*	2.3	8.77 (0.45) AV 5.13
	Iron*	14	3.69 (0.78) AV 21.1
	Copper*	0.9	1.37 (0.35) AV 25.6
	Zinc*	7	4.01 (0.67) AV 16.7

[a]Means of six determinations ±SD. AV means analysis of variance.
A.I.: Adequate intake of Brazil adults (*BRASIL 2005, **BRASIL 2003 and ***"National Policy and Resource Center on Nutrition and Aging" 2008). The data were from adults; no A.I. data from children were available.

of their high nutritional value, inflorescences can be used in diets in the form of dehydrated flour, easily incorporated into food. Even though inflorescences discarded at the time of harvest do not present any environmental problems, their nutritional value is lost. Based on the results of the present study, however, it was found that introducing banana inflorescences into the human diet could have significant nutritive impact. In addition, anatomical characterization of the bracts and floral parts of *Musa acuminata* revealed important elements for their recognition and taxonomy, including the pattern of epidermal cells of the bracts, crystals, aeration chambers, and other characteristics.

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RESUMO

Inflorescências de bananeira são popularmente conhecidas como "umbigos", e esses são usados no Brasil como complementos nutricionais. No entanto, o valor nutricional das inflorescências (flores masculinas e brácteas) de bananeira nunca foi estudado. Portanto, o material vegetal de *Musa acuminata* cultivar "ouro" foi coletado no Rio de Janeiro, Brasil e, em seguida, submetido aos procedimentos químicos para determinar a sua composição nutricional. As análises foram realizadas em triplicata. A análise da composição da amostra apresentou teor percentual médio de umidade, proteína, lipídeos e cinza de 8,21, 14,50, 4,04 e 14,43, respectivamente. As inflorescências secas mostraram significativo complemento nutritivo baseado no alto conteúdo de potássio (5.008,26 mg / 100 g) e de fibra 49,83% (lignina, celulose e hemiceluloses) revelando importantes propriedades funcional e nutritiva. Em uma avaliação paralela, o estudo anatômico mostrou elementos fundamentais para o reconhecimento de *Musa acuminata*, quando reduzida a fragmentos.

Palavras-chave: análise anatômica, inflorescência de bananeira, "banana-ouro", *Musa acuminata*, Musaceae, valor nutricional.

REFERENCES

AOAC. 2000. Official methods of analysis, 17th ed., Washington, DC: Association of Official Analytical Chemists.

Bernardi WF, Rodrigues BI, Cassiere-Neto P, Ando A, Tulmann-Neto A, Ceravolo LC and Montes SMNM. 2004. Micropropagação de baixo custo em bananeira cv. Maçã em meios com diferentes fontes de carbono e avaliação da performance em campo das mudas produzidas. Rev Bras Frutic 26: 503-506.

Brasil. 2003. Regulamento Técnico sobre Rotulagem Nutricional de Alimentos Embalados. Resolução RDC ANVISA/MS nº. 360, de 23 de dezembro de 2003. Brasília, DF: Diário Oficial da União.

Brasil. 2005. Regulamento técnico sobre a ingestão diária recomendada (IDR) de proteína, vitaminas e minerais. Resolução RDC ANVISA nº 269, de 22 de setembro de 2005. Brasília, DF: Diário Oficial da União.

Bukatsch F. 1972. Bemerkugen zur Doppelfärrbung Astrablau-Safranin. Mikrokosmos 61: 255.

Clark G. 1981. Staining procedures. Baltimore, London: Williams & Wilkins, 512 p.

Coelho RRP, Mata MERMC and Braga MED. 2001. Alterações dos componentes nutricionais do pseudocaule da bananeira quando processado visando sua transformação em palmito. Rev Bras Prod Agr 3: 21-30.

Cutler DF, Botha CEJ and Stevenson DW. 2007. Plant anatomy: an applied approach. Malden: Blackwell Publishing, 302 p.

De Langhe E, Vrydaghs L, Maret P, Perrier X and Denham T. 2009. Why bananas matter: an introduction to the history of banana domestication. Ethnobotany Res Appl 7: 165-177.

Dickson WC. 2000. Integrative plant anatomy. Florida: Academic Press, 533 p.

Fingolo CE, Moura MRL and Kaplan MAC. 2011. Farinha Nutritiva, Processo de Produção da Farinha Nutritiva e Seus Usos. *Brazilian Patent* PI0905055-8A2.

Forster MP, Rodríguez ER and Romero CD. 2002. Differential characteristics in the chemical composition of bananas from Tenerife (Canary Islands) and Ecuador. J Agr Food Chem 50: 7586-7592.

Gomez E. 1967. O talo da bananeira como alimento humano (Comunicação prévia). Rev Farm Bioquim Univ São Paulo 5: 259-268.

Häkkinen M. 2009. *Musa chunii* Häkkinen, a new species (Musaceae) from Yunnan, China and taxonomic identity of *Musa rubra*. J Syst Evol 47: 87-91.

Häkkinen M and Hong W. 2007. New species and variety of *Musa* (Musaceae) from Yunnan, China. Novon 17: 440-446.

Häkkinen M and Väre H. 2008. Typification and check-list of *Musa* names (Musaceae) with nomenclatural notes. Adansonia 30: 63-112.

IAL. 2005. Normas analíticas do Instituto Adolfo Lutz: Métodos químicos e físicos para análise de alimentos. v.1, 4a ed., São Paulo, SP: Instituto Adolfo Lutz, 1018 p.

Jensen WA. 1962. Botanical histochemistry. San Francisco, CA, USA: H. H. Freeman, 408 p.

Kennedy J. 2008. Pacific bananas: complex origins, multiple dispersal? Asian Perspectives 47: 75-94.

Kennedy J. 2009. Bananas and people in the homeland of genus Musa: not just pretty fruit. Ethnobotany Res Appl 7: 179-198.

Mendez MHM, Derivi SCN, Rodrigues MCR, Fernandes ML and Machado RLD. 1985. Método de fibra detergente neutro modificado para amostras ricas em amido. Ciênc Tecnol Aliment 5: 123-131.

Moreira A, Castro C and Fageria NK. 2010. Efficiency of boron application in an Oxisol cultivated with banana in the Central Amazon. An Acad Bras Cienc 82: 1137-1145.

National Policy and Resource Center on Nutrition and Aging. 2008. Table 1: Dietary Reference Intakes for Older Adults, FIU. Available at: <http://nutritionandaging.fiu.edu/DRI_and_DGs/DRI%20Table%203%20pages%209-13-2004.pdf>. Accessed 20 April 2011.

Perrier X, Bakry F, Carreel F, Jenny C, Horry JP, Lebot V and Hippolyte I. 2009. Combining biological approaches to shed light on the evolution of edible bananas. Ethnobotany Res Appl 7: 199-216.

SAS. 1999. SAS System for Windows, version 8. Cary, North Carolina: SAS Institute.

Van Soest PJ. 1963a. Use of Detergent in the Analysis of Fibrous Feed II, A Rapid Method for determination of Fiber and Lignin. J Ass Offic Agri Chem 46: 829-835.

Van Soest PJ. 1963b. Use of Detergent in the Analysis of Fibrous Feed I, Preparation of Fiber Residues of Low Nitrogen. J Ass Offic Agri Chem 46: 925-929.