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Review

Banana (*Musa* spp) from peel to pulp: Ethnopharmacology, source of bioactive compounds and its relevance for human health

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ABSTRACT

Ethnopharmacological relevance: Banana is a fruit with nutritional properties and also with acclaimed therapeutic uses, cultivated widely throughout the tropics as source of food and income for people. Banana peel is known by its local and traditional use to promote wound healing mainly from burns and to help overcome or prevent a substantial number of illnesses, as depression.
Aim of the study: This review critically assessed the phytochemical properties and biological activities of *Musa* spp fruit pulp and peel.
Materials and methods: A survey on the literature on banana (*Musa* spp, Musaceae) covering its botanical classification and nomenclature, as well as the local and traditional use of its pulp and peel was performed. Besides, the current state of art on banana fruit pulp and peel as interesting complex matrices sources of high-value compounds from secondary metabolism was also approached.
Results: Dessert bananas and plantains are systematic classified into four sections, *Eumusa, Rhodochlamys, Australimusa*, and *Callimusa,* according to the number of chromosomes. The fruits differ only in their ploidy arrangement and a single scientific name can be given to all the edible bananas, i.e., *Musa* spp. The chemical composition of banana's peel and pulp comprise mostly carotenoids, phenolic compounds, and biogenic amines. The biological potential of those biomasses is directly related to their chemical composition, particularly as pro-vitamin A supplementation, as potential antioxidants attributed to their phenolic constituents, as well as in the treatment of Parkinson's disease considering their contents in L-dopa and dopamine.
Conclusion: Banana's pulp and peel can be used as natural sources of antioxidants and pro-vitamin A due to their contents in carotenoids, phenolics, and amine compounds, for instance. For the development of a phytomedicine or even an allopathic medicine, e.g., banana fruit pulp and peel could be of interest as raw materials riches in beneficial bioactive compounds.

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1. *Musa* spp—Introduction

Musa spp, comprising dessert bananas and plantains, are among the world's leading fruit crops as source of energy in the diet of people living in humid tropical regions. Banana is a term including a number of hybrids in the genus *Musa*, dessert bananas and plantains, Musaceae (Robinson, 1996; Stover and Simmonds, 1987). And in Arabic *banan* means finger (SEBRAE, 2008).

Dessert bananas have firm pulp when the fruit is not ripe and soft pulp during its maturation (Kajuna et al., 1997). It is known that dessert banana pulp and peel contains some secondary metabolites in their composition, e.g. catecholamines (Kanazawa and Sakakibara, 2000), phenolics (Verde-Mendez et al., 2003), and carotenoid compounds (Van den Berg et al., 2000), as well as pyridoxine (vitamin B6—Leklem, 1999). Many of banana's volatile compounds such as esters (Pérez et al., 1997) and alcohols (Nogueira et al., 2003) play an important role in the aromatic properties of dessert bananas.

Plantains are generally the larger, more angular starchy fruits of hybrid triploid cultivars in the banana family intended for cooking (Robinson, 1996). They are rich in carbohydrates as the dessert banana, firmer and less valued as a fresh product even when mature, as they still contain starch at this stage (Valmayor et al., 2000). Plantains are consumed necessarily cooked and used as raw material for production of flour, crisps, beer, and wine (Akubor, 2003; Lemaire et al., 1997). As in dessert bananas, the pulp and peel of diverse plantain cultivars (Red Yade, Mbeta 1, Big Ebanga, Moto Ebanga, Batard, Essang, Mbouroukou no 1, and Mbouroukou no 3) also have phenolic compounds (Tsamo et al., 2015). Except in India and Southeast Asia, where while dessert bananas are consumed in large quantities, the use of cooked bananas and plantains is not so widespread (FAO, 2014). In Africa, especially Ghana and Uganda, they are important staple food crops (Dei-Tutu, 1975; Goode, 1974). The methods used to cook bananas and plantains do not generally entail elaborate processes, being prepared by boiling or steaming, baking or roasting and frying. However, in some areas, particularly West Africa, the fruit is also pounded. Roasted or baked bananas and plantains are also prepared in both East and West Africa by placing peeled or unpeeled fruit either on the ashes of a fire or in an oven (Walker, 1931; Dalziel, 1937; Boscom, 1951; Whitby, 1972; Goode, 1974; Tezenas du Montcel, 1979).

The genus *Musa* comprises all edible cultivars and was further divided into four sections, *Eumusa, Rhodochlamys, Australimusa*, and *Callimusa* according to the number of chromosomes (Table 1). Thus, the genome with eleven chromosomes ($2n=22$) is characteristic of *Eumusa* and *Rhodoclamys*, while ten chromosomes ($2n=20$) is found in *Callimusa* and also from *Australimusa. Eumusa* is the largest and the most geographically widespread section to which most cultivars derived from *Musa acuminata* Colla and *Musa balbisiana* Colla species belong (Stover and Simmonds, 1987). In its turn, the section *Australimusa* contains *Musa textilis* Née that also produces parthenorparic edible bananas such as the bananas collectively known as Fe'i cultivars found in the Pacific islands. The Fe'i bananas are characterized by their erect bunches, pink–red to purple sap and deep yellow or orange colored fruit pulps. However, the *Australimusa* distribution and variability are lesser than the *Eumusa*. The other two sections of *Musa*, *Rhodochlamus* and *Callimusa* are only appreciated for their ornamental properties, because parthenocarpy is absent and they do not produce edible fruit. In addition, there is one specie for which the relevant section has yet to be determined, i.e. *Musa ingens* N.W.Simmonds ($2n=14$) (Horry et al., 1997).

Carl Von Linné (1707–1778), the father of modern taxonomy, classified the banana species as *Musa x paradisiaca* L. and *Musa x sapientum* L. However, in 1955, the studies from the botanists Simond and Shepherd resulted in the development of a classification system to edible banana cultivars. Simond and Shepherd concluded that there were two wild species of banana (section *Eumusa*): *Musa acuminata* Colla and *Musa balbisiana* Colla.

In the taxonomic separation of *M. x sapientum* L. from *M. x paradisiaca* L., genotypic descriptions were used to delimit the constituent taxa in the *Musa* germplasm (Shepherd, 1990; Simmonds and Weatherup, 1990; Swennen, 1990; Swennen et al., 1995; Vuylsteke et al., 1991), due to the unavailability of more conservative data for characterization. Reports on taxonomic research on *Musa* (Shepherd, 1990; Simmonds and Weatherup, 1990; Swennen, 1990; Swennen et al., 1995) avoided the use of the names *Musa x paradisiaca* L. for plantain and *M. x sapientum* L. for banana. The morphological attributes in the characterization of the *Musa* genus and its molecular cytogenetic characterization had been also employed to distinguish between the two widely cultivated triploid *Musa x sapientum* L. and *M. x paradisiaca* L. (Osuji et al., 1997). The pattern of occurrence and distribution of the different types of stomata discriminate the diploid species *Musa acuminata* Colla and *Musa balbisian* Colla from their triploid cultivars (Osuji, 1995). Therefore, the occurrence of papillae on the abaxial bract surface of *M. x sapientum* L. and their absence in *M. x paradisiaca* L., as well as the occurrence of calcium oxalate crystals in the adaxial epidermis of *Musa acuminata* Colla and the absence in *M. x paradisiaca* L. can be used as taxonomic informations to distinguish the triploids (Osuji, 2006).

Actually, bananas differ only in their ploidy arrangement and currently most banana taxonomists seem to agree that a single scientific name can be given to all the edible bananas, i.e., *Musa* spp (El-Khishin et al., 2009). The hybrids arose from the two diploid species *Musa acuminata* Colla and *Musa balbisiana* Colla are native to Southeast Asia. There are diploid, triploid, and tetraploid hybrids composing subspecies of *Musa acuminata* Colla, and between *Musa acuminata* Colla and *Musa balbisiana* Colla (Robinson, 1996; Stover and Simmonds, 1987). Conventionally, the haploid contributions of the respective species to the cultivars are noted with the letters A and B. Therefore, the cultivars can present genomic combinations depending on the basic number of chromosomes, e.g., AA, AB, AAA, AAB, ABB, AAAA, AAAB, AABB, and ABBB (El-Khishin et al., 2009). Some important cultivars according to their genomic group and subgroup are shown in Table 2. The fruits from subspecies AA and AAA are sweeter and include almost all the cultivars of current market importance. Cooking bananas or plantains are hybrid triploid cultivar AAB, ABB, or BBB that have high starch content (Zhang et al., 2005). In addition, some cultivars have genome from other wild species, e.g., *Musa schizocarpa* N.W.Simmonds (S genome) from *Eumusa and Musa textilis* Née (T genome) from *Australimusa*. Researches with cultivars from New Guinea confirmed by genomic in situ hybridization the combination of other genomes, including AS, AAS, ABBS,

AAT and ABBT, with other species also contributing such as *Musa angustigermma* N.W.Simmonds (T genome) subgenus *Australimusa* and *Musa schizocarpa* N.W.Simmonds (S genome) subgenus *Rhodochlamys* (D'Hont et al., 2000).

Whereas most of the cultivars come from the genomes of *Musa acuminata* Colla and *Musa balbisiana* Colla, it became almost impossible to point which is the banana species. To solve this problem it was developed a system called genomic cluster that uses the term species of *Musa* spp followed by the genomic group characterized by the letters A and B, respectively, from *Musa acuminata* Colla and *Musa balbisiana* Colla. If there is an interesting mutation that would constitute one or more new cultivars with a similar set of genotypes, it is called subgroup (Simmonds and Shepherd, 1955).

Ancestral bananas are fertile diploids while the main groups of bananas grown today are clones of plants, mostly triploids reproduced entirely vegetatively. For producers and consumers, this feature presents two advantages as triploid gives the plant vigor and makes it easier to grow than diploids. Second, the clonal propagation of 3*n* genotypes assures them genetic uniformity which facilitates management, both in the field and throughout the consumer market. However, triploid ensures sterility of the fruit enabling it to be eaten without risks of finding seeds. On the other hand, the nature of these plants also presents obstacles to their cultivation and improvement. First, the genetic uniformity of these plants facilitates the spread of diseases on banana plants. For example, the Cavendish varieties throughout the world are all susceptible to leaf spot diseases. Plantains are also susceptible to black leaf streak disease, whether in Africa, South America, or Asia. Furthermore, the sterility of the clones currently grown is a considerable hindrance to their genetic improvement (Jenny et al., 2003).

Generally, banana production is based on triploid cultivars. However, the diploid genomic becomes important because it is a source of resistance and tolerance alleles to biotic and abiotic stress (Jenny et al., 2003). The banana breeding programs worldwide have generated successful tetraploid hybrids from crosses between triploid cultivars and wild or improved diploids, which have agronomic traits of interest including small size, resistance to pests, and physicochemical quality of fruits (Silva et al., 2002).

2. Traditional use of pulp and peel

Plantains as well as dessert bananas and the other parts of the *Musa* spp plant, which include roots, pseudostems, stems, leaves, and flowers have long been used in local and traditional medicine in America, Asia, Oceania, India and Africa (Tsamo et al., 2015).

In the Brazilian local and traditional medicine banana peel has a history of utility to promote wound healing mainly by burns when used topically (Balbach, 1945). Peels of ripe bananas can be used to make a poultice for wounds, which is wrapped around an injury to reduce pain or swelling. As the inside of the peel has antiseptic properties, it can be wrapped directly around wounds or cuts in an emergency (INIBAP, 2002). Silva (2005) described some medicinal plants from Goiás, Brazil, and among them *Musa* spp. The banana tree has an important local and traditional value to treat anemic people. Bananas are a healthy food for children around six months, because it does not produce cramps or

Table 1
Systematic of the Musaceae family.

Family	Genus	Sections	Species	Subspecies
Musaceae	*Musa*	*Callimusa* (2*n*=20)	*Musa beccarii* N.W. Simmonds	
			Musa borneensis Becc.	
			Musa coccinea Andrews	
			Musa gracilis Holttum	
		Australimusa (2*n*=20)	*Musa textilis* Née	
			Musa angustigemma N.W. Simmonds	
			Musa bukensis Argent	
			Musa jackeyl W. Hill	
			Musa lolodensis Cheesman	
			Musa maclayl F.Muell.ex. Mikl.-Maclay	
			Musa peekelii Lauterb.	
			Musa lasiocarpa Franch.	
			Musa boman Argent	
			Musa troglodytarum L.	
		Eumusa (2n=22)	*Musa acuminata* Colla or *Musa cavendishii* Lamb.	*burmanica* N.W. Simmonds
				malaccensis (Ridl.) N.W. Simmonds
				truncata (Ridl.) Kiew
				microcarpa (Becc.) N.W. Simmonds
				errans (Blanco) R.V. Valmayor
			Musa balbisiana Colla	
			Musa basjoo Siebold & Zucc. Ex linuma	
			Musa cheesmani N.W. Simmonds	
			Musa flaviflora N.W. Simmonds	
			Musa halabanensis Meijer	
			Musa itinerans Cheesman	
			Musa nagensium Prain	
			Musa. x paradisiaca L.	
			Musa. x sapientum L.	
			Musa schizocarpa N.W. Simmonds	
			Musa sikkimensis Kurz	
			Musa sumatrana Becc.	
		Rhodoclamys (2*n*=22)	*Musa laterita* Cheesman	
			Musa ornata Roxb.	
			Musa sanguinea Hook. f.	
			Musa velutina H. Wendl. & Drude	

Table 2
Worldwide distribution of some banana cultivars according to their genomic group and subgroup.

Genomic group*	Subgroup	Cultivar	Fruit usage	Geographic distribution
AA	Sucrier	Frayssinette	Dessert banana	All continents
		Figue sucrée	Dessert banana	All continents
		Ouro	Dessert banana	Brazil
	Matti, Kadali, Sannachenkadali, Chingan, Calcutta 4, Sikuzani			India
	Pisang Lilin			Indonesia, Malaysia
	Pisang Berangan			Indonesia, Malaysia
	Lakatan			Indonesia, Malaysia
AAA	Gros Michel	Gros Michel	Dessert banana	All continents
	Cavendish	Lacatan, Poyo, Grand Naine, Williams, Petite Naine, Nanica	Dessert banana	All continents
	Figue rose	Figue rose	Dessert banana	All continents
	Lujugira	Intuntu	Cooking	East African highland
		Mujuba	Cooking	East African highland
		Caipira	Dessert banana	Brazil
		Yangambi-5	Dessert banana	Central and West Africa
	Giant cavendish	Grand Nain, Valery	Dessert banana	Egypt
	Dwarf cavendish			Egypt, India
	Red banana, Robusta, Green red, Monsmarie			India
AAAA	Champa Nasik	Champa Nasik	Dessert banana	East African highland
AAAB	Goldfinger	Goldfinger	Dessert banana	America, Australia
AB	Adukkan, Poomkali, Njalipoovan, Valiyakunnan, Adakkakunnan, Pedalimoongil, Velipputtubale			India
	Ney Poovan	Safet Velchi	Dessert banana	India, East Africa
		Sukari	Dessert banana	India, East Africa
AAB	Figue Pomme	Maca, Silk	Dessert banana	All continents
	Pome	Prata, Branca, Pacovan	Dessert banana	Brazil, India, Egypt
	Mysore, Poovan, Perumpadali, Dudhsagar, Palayankodan, Krishnavazhai, Charapadati, Nendran, Quintal nendran, Pedathi, Velipadathi			India
	Plantain	French, Horn	Cooking	Africa Caribbean
		Corne	Cooking	Africa Caribbean
		Batard, Mbouroukou-1, Mbouroukou-3	Cooking	Belgium
	Terra	Terra, Pacovan, D'Angola	Dessert banana	Brazil
ABB	Figo	Figo Vermelho or Figo Cinza	Dessert banana	Brazil
	Bluggoe	Bluggoe	Cooking	Philippines, America
	Poteau			Philippines, America
	Pisang Awak	Fougamou	Dessert banana	Philippines, America
	Kosthalontha, Karpooravalli, Boothibale, Konchikela, Peyan			India
	Matooke	Butobe	Cooking	East African Highland
AABB		Ouro da Mata	Dessert banana	Brazil
ABBB		Klue Terapod	Cooking	Philippines, America
BB	Elavazhai			India
BBB	Saba	Saba	Cooking	Indonesia, Malaysia

Note: *Source*: Bakry et al. (1997), Davey, et al. (2007), Nakasone and Paull (1999), Resmi et al. (2011), Rieger (2006), SEBRAE (2008).

* Represents combinations of the *Musa balbisiana* Colla and *Musa acuminata* Colla genomes. Cooking means plantain varieties

diarrhea. The juice from the pseudostem is sweetened and oral administrated in diarrhea. By topical administration, this juice is employed to wash ulcers and to treat aphtas in children. Infusion of the flowers of the banana plant in water followed by an overnight rest are used to treat health problems in the eyes. Syrup of banana flowers is used to heal pulmonary problems. Green banana is used by topical application in wound healing and cancer. Neiva et al. (2014) studied the traditional knowledge from plants used for the treatment of giardiasis in Brazil. Banana leaf and fruit were cited by the interviewees in health facilities from a municipal public primary healthcare and private institution specializing in digestive system diseases, in São Luís, Maranhão, Brazil.

Musa (*M.*) *paradisiaca* L., commonly called Kaila in Pakistan, is traditionally used for the treatment of inflammation, rheumatism, gripe, diabetes, hypertension, cough, and bronchitis. Unripe bananas are astringent and their ashes are used to treat diarrhea (Morton, 1987). Plantain juice is used as an antidote for snake bite (Reid, 1961). In ethnoveterinary medicine, *Musa paradisiaca* L. is used to treat the hooves and injuries while its green fruit is used for the treatment of diarrhea (Lans et al., 2006). *Musa seminifera* Lour is native from Bangladesh and this plant is commonly known as Bichi kola, Aitta kola, or Doia kola, and distributed throughout the country. *Musa seminifera* Lour has been used in local and traditional medicine in Bangladesh in the treatment of diarrhea, dysentery, and excess menstruation (Partha and Hossain, 2007). In Thailand and India, banana is widely consumed as a food staple and has been traditionally used for gastrointestinal tract disorders as diarrhoea and gastritis (Bunyapraphatsara, 1996). Abe and Ohtani (2013) studied the local knowledge and uses of medicinal plants on Batan Island, the Philippines, and could provide new avenues for pharmacological investigations to improve healthcare for a range of ailments. The young leaves of *Musa paradisiaca* L., locally named viniveh (guyud variety), are used to treat fever and headache by forehead external application with oil. The ripe fruits of *Musa sapientum* L., locally named viniveh (tsina variety), are used to treat diarrhea through the intake of bananas three times a day. The juice from *Musa* spp, locally named viniveh, is used to treat abdominal pain (Abe and Ohtani, 2013). Iranian traditional medicine as a complementary and alternative medicine involves several non-pharmacological treatments, among which food therapy is the most notable. Data from an Arabic source indicate that *Musa* spp provides little nutriment and it is useful against heat in the chest, the lungs, and the bladder, and softens the stomach (Touwaide and Appetiti, 2013). Based on the resources of Iranian traditional medicine, bananas are prescribed for depressed patients (Tavakkoli-Kakhki et al., 2014).

According to Kumar et al. (2012), banana fruits from India are traditionally used to help overcome or prevent a substantial number of illnesses and health conditions as depression (related to the banana tryptophan content), anemia (high iron content which stimulates the production of hemoglobin), and blood pressure control (high potassium content and low in salt). Bananas can be source of vitamin B6. The vitamins B6 and B12, as well as the potassium and magnesium content help the body recover from the effects of nicotine withdrawal. Bananas can help people trying to give up smoking. The fruits are also used against constipation (high in fiber, including bananas in the diet can help restore normal bowel action), hangover (to build up depleted blood sugar levels), heartburn and ulcers (bananas have a natural antacid effect in the body), and against stress condition, because potassium content is a vital mineral (Bhutani and Atal, 1984; Kumar et al., 2012). Under the stress conditions, our metabolic rate rises, thereby reducing our potassium levels. These conditions can be rebalanced with the help of a high-potassium banana content. Taken a piece of banana peel and place it on the wart, with the yellow side out, can be a natural alternative to kill off a wart and to reduce swelling and irritation after a mosquito bite by rubbing the affected area with the inside of a banana skin (Kumar et al., 2012).

3. Banana fruit bioactive compounds

Fruit consumption has been increased due to a series of well-known nutritional and therapeutic effects on the human health, mostly resulting from their contents in phytochemicals with antioxidant properties, for instance. Recent studies indicate that frequent consumption of fruits might be related to the retardation of aging and prevention of certain illnesses including cancer and cardiovascular diseases (Wang et al., 1997; Bae et al., 2008; Kawasaki et al., 2008; Wright et al., 2008), which are related to cell oxidative stress caused by free radicals. Indeed, there is a large body of evidences that free radicals are responsible for the damage of lipids, proteins, and nucleic acids in cells, leading to several physiological and pathological abnormalities. According to Saura-Calixto and Goni (2006) and Wang et al. (1997), compounds from the plant secondary metabolism can be found in the fruits as carotenoids, phenolic acids, flavonoids, vitamin C and E contributing for the antioxidant activity, depicting a clear therapeutic potential. However, such phytochemical compounds that come from fruits are highly affected not only by genetic factors, but also by environmental ones in the geographic region of production, fruit maturity stage at harvest, farming practices, harvesting time, post-harvest handling and processing, and storage conditions (Rodriguez-Amaya, 2010). Because of its particularities, in special its low cost, banana is consumed all over the world and it can be considered an important fruit regarding its potential as functional and nutraceutical food.

3.1. Carotenoids

Carotenoids are a diverse group of yellow–orange pigments found in many biological systems, acting as accessory pigments in photosynthesis, for example. Several health-promoting effects of carotenoids such as immune-enhancement and reduction of the risk of developing degenerative diseases, cancer, cardiovascular diseases, cataract, and macular degeneration have been claimed (Krinsky and Johnson, 2005; Tapiero et al., 2004; Voutilainen et al., 2006). According to Erdman et al. (1993), alfa-carotene, beta-carotene, and beta-cryptoxanthin, but not lycopene, are known to have pro-vitamin A activity. This is associated with yellow, orange or red color they impart to many foods (Rodriguez-Amaya, 2001).

There are many reports in the literature about the existence of banana genotypes rich in those pigments. For example, Setiawan et al. (2001) determined the carotenoid content of 18 fruits, including banana (*Musa x paradisiaca* L.), commonly consumed in West Java, Indonesia. The authors observed a large sample-to-sample variation in β-cryptoxanthin, lycopene, and beta-carotene contents for the studied fruits as showed in Table 3.

Samples of fruit pulps of three plantain varieties (Batard, Mbourourkou-1, and Mbourourkou-3) and two dessert banana varieties (Cavendish and Yangambi-5) were assayed by Davey et al. (2006) for pro-vitamin A carotenoid content. *Trans*-alfa-carotene and *trans*-beta-carotene were found to occur as majoritarian compounds, with additional small amounts of the *cis*-beta-carotene (Table 3). Besides, the authors claim that these results were related to the banana cultivation sites and their genomic variability. Other significant carotenoid found was lutein, but in small amount. Lutein does not have pro-vitamin A activity, while having important antioxidant properties and human health benefits as inhibitor of the age-related macular degeneration.

Table 3
Concentration of pVACs (*t*-AC, *t*-BC, and *c*-BC) and RAE of some banana genotypes all over the world.

Genotype	*t*-AC	*t*-BC	*c*-BC	RAE	Country	Reference
Aibwo/Suria #1	23.58 mg/gww	59.45 mg/gww	nd	2.95 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Aibwo/Suria #2	15.17 mg/gww	25.72 mg/gww	nd	2.77 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Bantol Red	70 nmol/gdw	130 nmol/gdw	11 nmol/gdw	7.63 μg/g	Philippines	Davey et al. (2009b)
Batard	35 pmol/gdw	36 pmol/gdw	5 pmol/gdw	2.51 ng/g	Belgium	Davey et al. (2006)
Batard	35 nmol/gdw	38 nmol/gdw	4 nmol/gdw	2.57 μg/g	Cameroon	Davey et al. (2007)
Baubaunio	2.49 mg/gww	3.32 mg/gww	nd	0.37 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Cavendish	8 pmol/gdw	6 pmol/gdw	1 pmol/gdw	0.47 ng/g	Humid tropical Africa	Davey et al. (2006)
Cavendish	8 nmol/gdw	5 nmol/gdw	1 nmol/gdw	0.42 μg/g	Cameroon	Davey et al. (2007)
Cavendish	nd	4.6 μg/gww	nd	0.38 μg/g	Belgium	Fungo and Pillay (2010)
Chek Porng Moan	50 nmol/gdw	65 nmol/gdw	9 nmol/gdw	4.23 μg/g	Camboja	Davey et al. (2009b)
Dimaemamosi	nd	24.17 μg/gww	nd	2.01 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Duningi	nd	7.43 μg/gww	nd	0.62 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Entukura	nd	4.90 μg/gww	nd	0.41 μg/g	Uganda	Fungo and Pillay (2010)
Enzirabahima	nd	3.19 μg/gww	nd	0.27 μg/g	Uganda	Fungo and Pillay (2010)
Fagufagu	15.24 mg/gww	34.28 mg/gww	nd	3.49 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Galeo	nd	12.55 μg/gww	nd	1.05 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Gatagata/Vudito #1	0.79 mg/gww	6.95 mg/gww	nd	0.61 μg/g	Makira, Solomon Islands	Englberger et al. (2010)
Gatagata/Vudito #2	0.42 mg/gww	4.47 mg/gww	nd	0.39 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
GCTV 215	nd	5.77 μg/gww	nd	0.48 μg/g	Belgium	Fungo and Pillay (2010)
Grand Naine	2 nmol/gdw	1 nmol/gdw	nd	0.09 μg/g	Cameroon	Davey et al. (2007)
Grand Naine	nd	4.47 μg/gww	nd	0.37 μg/g	Belgium	Fungo and Pillay (2010)
Gunih	nd	14.27 μg/gww	nd	1.19 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Henderneyargh	44 nmol/gdw	124 nmol/gdw	9 nmol/gdw	6.73 μg/g	Philippines	Davey et al. (2009b)
Huki Matawa	2.93 mg/gww	2.96 mg/gww	nd	0.37 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
IC2	nd	4.02 μg/gww	nd	0.33 μg/g	Belgium	Fungo and Pillay (2010)
Iholena Lele	78 nmol/gdw	107 nmol/gdw	6 nmol/gdw	6.67 μg/g	Hawaii	Davey et al. (2009b)
Kabucuragye	nd	1.41 μg/gww	nd	0.12 μg/g	Uganda	Fungo and Pillay (2010)
Katimor	74 nmol/gdw	84 nmol/gdw	7 nmol/gdw	5.57 μg/g	Philippines	Davey et al. (2009b)
Kibuzi	nd	4.28 μg/gww	nd	0.36 μg/g	Uganda	Fungo and Pillay (2010)
Kokopo	nd	11.42 μg/gww	nd	0.95 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Musa paradisiaca	nd	0.72–12.2 μg/gww	nd	0.06–1.02 μg/g	Indonesia	Setiawan et al. (2001)
Mbouroukou-1	31 pmol/gdw	34 pmol/gdw	6 pmol/gdw	23.48 ng/g	Belgium	Davey et al. (2006)
Mbouroukou-1	29 nmol/gdw	34 nmol/gdw	5 nmol/gdw	2.28 μg/g	Cameroon	Davey et al. (2007)
Mbouroukou-3	28 pmol/gdw	26 pmol/gdw	3 pmol/gdw	18.56 ng/g	Belgium	Davey et al. (2006))
Mbouroukou-3	26 nmol/gdw	25 nmol/gdw	3 nmol/gdw	1.77 μg/g	Cameroon	Davey et al. (2007)
Mbwazirume	nd	1.91 μg/ gww	nd	0.16 μg/g	Uganda	Fungo and Pillay (2010)
Mpologoma	nd	1.46 μg/ gww	nd	0.12 μg/g	Uganda	Fungo and Pillay (2010)
Musa spp (Uht ipali)	5.46 μg/gww	11.81 μg/gww	nd	1.21 μg/g	Pohnpei, Micronesian	Englberger et al. (2003a,b)
Musa spp (Usr wac)	6.77 μg/gww	20.82 μg/gww	nd	2.00 μg/g	Kosrae, Micronesian	Englberger et al. (2003a,b)
Musa troglodytarum (Uht en yap)	14.72 μg/gww	63.60 μg/gww	nd	5.91 μg/g	Pohnpei, Micronesian	Englberger et al. (2003a,b)
Musa troglodytarum (Uht karat)	2.96 μg/gww	9.18 μg/gww	nd	0.89 μg/g	Pohnpei, Micronesian	Englberger et al. (2003a,b)
Nakhaki	nd	4.62 μg/gww	nd	0.39 μg/g	Uganda	Fungo and Pillay (2010)
Nakitembe	nd	5.27 μg/gww	nd	0.44 μg/g	Uganda	Fungo and Pillay (2010)
Pagatau	nd	4.54 μg/gww	nd	0.38 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Pisang Mas	nd	11.39 μg/gww	nd	0.95 μg/g	Belgium	Fungo and Pillay (2010)
Pitu	nd	11.27 μg/gww	nd	0.94 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Pongani	nd	2.13 μg/gww	nd	0.18 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Porapora	nd	7.88 μg/gww	nd	0.66 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Pusit	99 nmol/gdw	101 nmol/gdw	9 nmol/gdw	6.93 μg/g	Philippines	Davey et al. (2009b)
Ropa	36.82 mg/gww	13.24 mg/gww	nd	2.64 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Saena	0.79 mg/gww	0.58 mg/gww	nd	0.08 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Tereza	nd	2.46 μg/gww	nd	0.21 μg/g	Uganda	Fungo and Pillay (2010)
Toraka Parao	2.50 mg/gww	5.26 mg/gww	nd	0.54 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Wambo	nd	19.04 μg/gww	nd	1.59 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Warowaro	< 0.02 mg/gww	1.66 mg/gww	nd	0.14 mg/g	Makira, Solomon Islands	Englberger et al. (2010)
Williams	nd	6.20 μg/gww	nd	0.52 μg/g	Belgium	Fungo and Pillay (2010)
Yalim	nd	16.27 μg/gww	nd	1.35 μg/g	Papua New Guinea	Fungo and Pillay (2010)
Yangambi-5	3 pmol/gdw	1 pmol/gdw	0 pmol/gdw	0.11 ng/g	West and Central Africa	Davey et al. (2006)
Yangambi-5	3 nmol/gdw	1 nmol/gdw	0 nmol/gdw	0.11 μg/g	Cameroon	Davey et al. (2007)
Wasolay	172 μg/gdw	74 μg/gdw	28 μg/gdw	14.51 μg/g	Papua New Guinea	Borges et al. (2014)
Jari Buaya	415 μg/gdw	525 μg/gdw	224 μg/gdw	70.37 μg/g	Malaysia	Borges et al. (2014)
Malbut	145 μg/gdw	102 μg/gdw	34 μg/gdw	15.96 μg/g	Papua New Guinea	Borges et al. (2014)
Jaran	127 μg/gdw	162 μg/gdw	nd	18.79 μg/g	Indonesia	Borges et al. (2014)
Saba	9 μg/gdw	61 μg/gdw	13 μg/gdw	6.00 μg/g	Costa Rica	Borges et al. (2014)
Caipira	2 μg/gdw	9 μg/gdw	nd	0.83 μg/g	Brazil	Borges et al. (2014)
Bucaneiro	17 μg/gdw	5 μg/gdw	nd	1.13 μg/g	Saint Lucia	Borges et al. (2014)
Nam	19 μg/gdw	22 μg/gdw	nd	2.62 μg/g	Thailand	Borges et al. (2014)
Thap Maeo	135 μg/gdw	147 μg/gdw	36 μg/gdw	19.38 μg/g	Brazil	Borges et al. (2014)

pVAC: pro-vitamin A carotenoid; *t*-AC: *trans*-alfa-carotene; *t*-BC: *trans*-beta-carotene; *c*-BC: *cis*-beta-carotene; RAE: retinol activity equivalents; nd=not determined; gww=g of wet weight; gdw=g of dry weight.

Davey et al. (2007) have shown in a within-fruit, within-hand, within-plant, and between-plants study that pro-vitamin A carotenoids contents varied significantly across all the sampled groups. In a further assay, Davey et al. (2009b) evaluated the pro-vitamin A carotenoid contents of 171 genotypes from *Musa*, e.g., bananas and plantains. The results indicated carotenoids varying within

genotypes to an average of ±20.5% per cultivar. In *Musa* pulp, over 90% of the total pro-vitamin A carotenoids are *trans*-alfa-carotene and *trans*-beta-carotene. The remaining 10% comprise *cis*-carotenoids, lutein, and other unidentified compounds. The Bantol Red (uncharacterized genome), Pusit (uncharacterized genome), Iholena Lele (AAB), Henderneyargh (AAB), Katimor (AAB), and Chek Porng Mean (uncharacterized genome) cultivars showed to contain the higher pro-vitamin A carotenoids, with values of 44 to 130 nmol/g dry weight (Table 3). The variations in pro-vitamin A carotenoids contents appear to be at least partly related to the differences in the developmental status of the fruit, as well as genotype-specific (Davey et al., 2009b).

Twenty six genotypes from Embrapa Mandioca e Fruticultura's banana germplasm active bank in Brazil were evaluated by Mattos et al. (2010). The triploids AAB and ABB genomic groups presented higher amounts of carotenoid content than the triploid AAA one, a trait associated to the B genome. Similar results were obtained by Englberger et al. (2003a) that analyzed the carotenoid content of 13 banana cultivars. *Musa troglodytarum* L. (local named Uht en yap), *Musa* spp (Usr wac), *Musa* spp (Uht ipali), and *Musa troglodytarum* L. (Uht karat) genotypes were found to have beta-carotene levels greater than 918 μg/100 g edible portion (Table 3). Although those banana genotypes are not documented by a cultivar name, they are thought to belong to the Cavendish subgroup, the primary banana cultivar marketed globally (INIBAP, 2002).

Banana genotypes from the International Institute of Tropical Agriculture germplasm collection in Uganda, Papua New Guinea, had the highest levels of beta-carotene with 24.17 μg/g edible pulp (Table 3). A positive correlation was detected between pulp color intensity and beta-carotene concentration. These findings concur with earlier observations reported for Micronesian and Brazilian bananas which showed that the content of beta-carotene is higher in yellow to orange bananas than in those with white or beige pulp. Indeed, carotenoid levels seem to increase with the intensity of fruit flesh coloration towards yellow and orange (Englberger et al., 2003a; Fungo and Pillay, 2010).

Borges et al. (2014) established the carotenoidic profile of accessions from the Embrapa Mandioca e Fruticultura germplasm from Brazil, aiming to select superior genotypes to be used in future crosses in the development of biofortified cultivars (rich in pro-vitamin A carotenoids). The study showed that the carotenoid content of *Musa* fruits mainly consists of beta-carotene and alfa-carotene, whereas the proportion of these compounds varied depending on the cultivars genotype. Results revealed the genotypes Jari Buaya, Thap Maeo, and Jaran as rich sources of pro-vitamin A, especially when compared to the main cultivars commercially available (e.g. Cavendish subgroup), Additionally, in the *Musa* germplasm assayed, a great variability for these compounds was found to occur, showing that the improvement of these characteristics can be obtained successfully in the banana genetic breeding program (Table 3).

Pro-vitamin A carotenoids differ in their vitamin A activities because of their distinct chemical structures. For this reason, the concept of retinol activity equivalent (RAE) has been adopted and it considers that 12 μg of *trans*-beta-carotene correspond to 1 μg of retinol (Yeum and Russel, 2002). The conversion factors for other possible isomers of *cis*-beta-carotene and *trans*-alfa-carotene are not known; therefore, for all these compounds (if present), a conversion factor of 24: 1, per μg of ingested carotenoid (Davey et al., 2009a) have been used. On the basis of these conversion factors, it is possible to calculate RAEs and thus the vitamin A nutritional value of banana genotypes as shown in Table 3.

An issue worth mentioning as one compares carotenoid contents among cultivars/genotypes refers to the analytical protocol used to extract, quantify, and identify those secondary metabolites. Indeed, a series of methods have been reported in literature, differing in any extension regarding one or more procedures and/or analytical techniques. For instance, an important but often ignored aspect of carotenoid analysis is the impact of the post-harvest processing and sample storage. Lyophilization continues to be widely considered the appropriate means of preserving biological sample. Davey et al. (2006) and (2009a) found no significant difference in the recoveries of total pro-vitamin A carotenoids from lyophilized and fresh banana samples and no further significant loss during storage of lyophilized tissue in the dark, at −20 °C. On the other hand, variable losses were detected to occur in frozen pulp tissues. However, sample lyophilization resulted in significant degradation of beta-carotene and especially lycopene, because it increases sample porosity with consequently exposure to oxygen during storage (Rodriguez-Amaya, 2010). This way, caution should be taken in comparative analysis of banana genotypes as sources of pro-vitamin A, since eventual conclusions might rely on erroneous approaches due to important methodological and analytical discrepancies.

3.1.1. Pro-vitamin A supplementation through banana fruit

Animals are unable to synthetize retinoids and need a dietary supply of these compounds in the form of vitamin A. The fat soluble vitamin A occurs in two major ways in Nature, mainly as retinyl esters from animal food sources or in the form of pro-vitamin A carotenoids from several plant species. The most abundant carotenoid is beta-carotene, a precursor of vitamin A also called pro-vitamin A, because its activity as vitamin A is only found after its conversion to retinol within the body (Chichili et al., 2005).

Because vitamin A is stored in the liver, some strategies are needed to ensure adequate vitamin A intakes for people, for example, supplements given daily or once every four to six months. An alternative to vitamin A is the fortification of commonly consumed foods to improve the diets of people helping to reduce the prevalence of vitamin A deficiency. The routine supplementation schedule to be followed was previously described in the WHO/UNICEF/IVACG/1997 Task Force publication "Vitamin A Supplements: A guide to their use in the treatment and prevention of vitamin A deficiency and xerophthalmia" (WHO—World Health Organization, 1998).

Not rare, native genotypes of bananas as previously demonstrated in this review contain meaningful amounts of pro-vitamin A carotenoids, which periodically administered to the diet might mitigate the vitamin deficiency and the famine in any extension. This is because by adopting the supplementation of vitamin A using external sources of food staples such as genetic bred or transgenic crops usually results in a strong dependency of the local communities and governments as to the furnishers of seeds, fertilizers, and pesticides, for instance. Furthermore, it is well known that the introduction of exogenous and genetic improved crop species in a given environment usually suffers from adaptation constraints that are time- and cost-relevant, mostly for marginal populations. Thus, the rational exploitation of native genotypes of bananas seems to sound a better choice to collaborate in avoiding vitamin A deficiency and xerophthalmia.

As example of the author's point of view above described, a study of the nutrient content of bananas was initiated by the Federated States of Micronesia due to the emergence of a serious problem of vitamin A deficiency among children and women. The previous work in Micronesia identified yellow/orange-fleshed carotenoid-rich banana cultivars, in particular Fe'i cultivars, with potential to alleviate vitamin A deficiency. Thirteen of the Micronesian banana cultivars analyzed contained enough pro-vitamin A carotenoids to meet at least half of the daily estimated vitamin A requirements for a non-pregnant and non-lactating woman. If a non-pregnant and non-lactating woman ate 500 g in a day of one

of the cooked *Musa troglodytarum* (uht en yap and uht karat bananas), or *Musa* spp (usr wac, uht ipali, usr wac es sie, usr kuria, usr macao, uht akatan bananas—Table 3) she would be able to obtain her total requirement of 500 mg of retinol equivalent (Englberger et al., 2003a). A similar comparison for a 2–5-year-old child shows that the child could obtain the total vitamin A requirement of 400 mg of retinol equivalent (FAO/WHO, 1988), by eating 250 g in a day of cooked *Musa troglodytarum* (uht en yap and uht karat bananas) and *Musa* spp (usr wac and uht ipali bananas—Table 3). However, studies on bioavailability of these foods have not yet been carried out and further investigation is needed to confirm the contribution of these foods to meeting vitamin A requirements (Englberger et al., 2003a).

There is a great diversity of Makira bananas in Solomon Islands as previous demonstrated by Englberger et al. (2010). Fe'i cultivars and three non-Fe'i cultivars were assessed for flesh color, fruit size, and other attributes and analyzed as to their pro-vitamin A carotenoids (alfa- and beta-carotene—Table 3) and total carotenoids. Prominent differences were observed in carotenoid contents which ranged from 5945 mg beta-carotene/100 g fresh weight in the yellow/orange fleshed Fe'i Aibwo/Suria genotype to 58 mg beta-carotene/100 g fresh weight in the white fleshed Saena one. Comparatively to cultivars with light-colored flesh, the yellow/orange-flesh cultivars generally showed to contain higher carotenoid concentrations. Total carotenoids varied from 137 to 9400 mg/100 g fresh weight among the studied genotypes, revealing a huge chemical diversity regarding that trait associated to the genetic variability of the Salomon islands' banana. Seven out of ten cultivars presented high pro-vitamin A carotenoid concentrations, meeting the estimated daily vitamin A requirements for pre-school children and non-lactating, non-pregnant female adults, within normal consumption patterns.

The nutrient-rich cultivars, including Fe'I genotypes, should be promoted for their potential to contribute to vitamin A intake and overall health. According to the number of banana fingers to meet the recommended safe intake for non-pregnant female adult some cultivars are thought to be of interest as, for instance: Aibwo/Suria: 0.6, Fagufagu: 1.5, Gatagata/Vudito: 2.3, Ropa: 2.7, Huki Matawa: 3.9, Toraka Parao: 4.4, and Baubaunio: 6.6. Similarly, for pre-school children and non-lactating women the number of banana fingers recommended is as follows: Aibwo/Suria: 0.4; Fagufagu: 1.2; Gatagata/Vudito: 1.8; Ropa: 2.1; Huki Matawa: 3.1; Toraka Parao: 3.5 and Baubaunio: 5.3 fingers/cultivar/daily intake, respectively, within normal consumption patterns (WHO, 2004).

3.2. Phenolic compounds and flavonoids

Phytochemicals, especially phenolics in fruits and vegetables, are the major bioactive compounds known for health benefits (Cook and Sammon, 1996). Bananas commonly consumed in Recife, eastern Brazil, have considerable amounts of some bioactive phytochemicals as observed in the fruit pulp of the cultivars "Pacovan" (*Musa acuminata* Colla) and "Comprida" (*Musa x paradisiaca* L.). The average values for the total phenolic compounds were 44.46 ± 5.46 and 52.02 ± 4.22 mg of catechin equivalent/100 g of fresh weight, respectively (Mèlo et al., 2006). According to Bravo (1998), the presence of polyphenols in fruits and vegetables is greatly influenced by genetic factors, environmental conditions, and degree of ripeness, for instance.

Many of the natural antioxidants exhibit a wide range of biological effects including antibacterial, antiviral, anti-inflammatory, antiallergenic, antithrombotic, and vasodilatory actions (Cook and Sammon, 1996). Banana pulp contains various antioxidants, e.g., vitamins, carotenoids, and phenolic compounds such as catechin, epicatechin, lignin and tannins, and anthocyanins (SEBRAE, 2008; Someya et al., 2002). For this reason, the banana cultivars from Malaysia (southeast Asia) were chosen for analysis by Sulaiman et al. (2011), due to their high consumption by local people and common availability in local markets. Aqueous extract from Awak pulp showed the highest total phenolic content (0.36 ± 0.01 mg of gallic acid equivalent/g fresh weight).

Borges et al. (2014) analyzed the phenolic compounds and total flavonoids content of 29 banana accessions belonging to the Embrapa Mandioca e Fruticultura germplasm in Brazil. UV–visible spectrophotometry was initially used and revealed an interesting discrepancy of contents of these secondary metabolites among the banana accessions. The average content of phenolic compounds for all the samples was 24.23 mg of gallic acid equivalent/100 g dry pulp. By analyzing all the accessions, the total flavonoids average content was 2.41 mg of quercetin equivalent/100 g of dry pulp. The catechins epicatechin and gallocatechin were detected, by reverse-phase high performance liquid chromatography, to be the most abundant compounds in the pulp of the studied biomass, highlighting Nam (114.44 μg/100 g of dry pulp) and Highgate (359.96 μg/100 g of dry pulp) cultivars, respectively. In addition, triploid genotypes showed the major contents of phenolic compounds (Highgate cultivar), as well as total flavonoids (Wasolay cultivar), an important finding for future crosses in order to develop biofortified cultivars (Borges et al., 2014).

In the group of polyphenolic compounds, flavonoids have been extensively studied and include catechins, proanthocyanins, anthocyanidins, flavones, flavonols, and their glycosides. Studies on the structure-activity relationship have afforded consistent evidence revealing the specific role of structural components and requirements for scavenger radicals, chelating action, and oxidizing activity of flavonoid compounds. In fact, the in vitro antioxidant activity of flavonoids and their metabolites depends on the arrangement of functional groups in the nuclear structure (Heim et al., 2002). Most of the beneficial effects of flavonoids on human health are attributed to their antioxidant and chelating properties (Heim et al., 2002) and also to antimutagenic and antitumoral effects (Middleton and Harborner, 1986; Rice-Evans et al., 1996). Flavonoids inhibit a variety of enzyme systems. Among them, there are several oxygenases such as prostaglandin synthase, the key enzyme in eicosanoids biosynthesis. Further, flavonoids also act by inhibiting the hyaluronidase activity helping to maintain proteoglycans of connective tissue and preventing the spread of bacterial or tumor metastases (Havsteen, 2002). By hindering the oxidation reactions, in which flavonoids are preferentially oxidized, they preserve the body's natural antioxidants such as ascorbic acid (Korkina, Afanas'ev (1997)).

Lewis et al. (1999) identified the flavonoid leucocyanidin as the major product in aqueous extract of unripe plantain pulp (*Musa x sapientum* L.), that also showed significant anti-ulcerogenic activity. In general, this suggests that flavonoids, leucocyanidin analogues in particular, may have considerable therapeutic potential in the treatment of gastric diseases.

The consumption of tropical fruits has been associated with many medicinal properties. Alothman et al. (2009) studied a local cultivar of banana known as Pisang mas, in Malaysia. The authors determined the polyphenolic contents in aqueous extract (27.0 ± 1.96 mg gallic acid equivalents/100 g fresh weight) and also in acetone 90% (v/v), resulting in higher phenolic amounts, e.g., 72.2 ± 2.03 96 mg gallic acid equivalents/100 g fresh weight. Similarly, the flavonoid content was also determined in the aqueous extract (13.7 ± 1.55 mg catechin equivalents /100 g fresh weight) and in that organosolvent extract, and a superior amount was detected in the later, i.e., 23.7 ± 0.75 mg catechin equivalents /100 g fresh weight. The antioxidant activities of the banana fruit extracts varied considerably. The aqueous extract exhibited a FRAP of 0.59 ± 0.15 μmol Fe(II)/g fresh weight and a $36.8\% \pm 2.93\%$ DPPH inhibition as the acetone extract showed a FRAP of 5.26 ± 0.35 μmol

Fe(II)/g fresh weight and 68.0% ± 0.51% DPPH inhibition. The anti-ulcerogenic activity from unripe plantain pulp could be explained by the higher antioxidant activity of the organosolvent extracts, directly correlated to their superior amounts of phenolic compounds and the flavonoid leucocyanidin.

3.3. Amine compounds

Catecholamines, e.g. dopamine, norepinephrine (noradrenaline), and epinephrine (adrenaline), are a group of biogenic amines (Steiner et al., 1996). Probably, the best well known example of action of those biogenic amines in mammals as neurotransmitters is their hormonal regulation on the glycogen metabolism (Kimura, 1968). In its turn, in plants a wider number of biosynthetic pathways can be performed favoring the obtainment of more catecholamine types (Smith, 1980), i.e., chemodiversity.

Though typically found in mammals, catecholamines have been also reported to occur in many plants in considerable amounts as showed by Ponchet et al. (1982) in the pulp of bananas (*Musa acuminata* Colla and *Musa. s sapientum* L., var. Baracoa) and plantain, for example. Anderson et al. (1958) showed that the ingestion of bananas produces an increased urinary excretion of the serotonin (5-hydroxytryptamine) metabolite 5-hydroxyindoleacetic acid. Based on the observation reported by those authors, Waalkes et al. (1958) determined by fluorometry and for the first time the catecholamines composition of acetone acidified extracts of banana pulp (serotonin: 28 μg/g; norepinephrine: 1.9 μg/g, and dopamine: 7.9 μg/g). The presence of 3,4-dihydroxyphenylalanine (L-dopa) was also found in the fruits. Those potent physiologic agents present in a food as widely distributed as the banana is clinically interesting.

By analyzing banana pulp antioxidants, Kanazawa and Sakakibara (2000) identified in *Musa cavendishii* Lamb. dopamine as a strong water-soluble metabolite. The amounts of that biogenic amine were determined in pulp at the various ripening stages defined by color scores as follows: all green (1), light green (2), half-green (3), half-yellow (4), green chip (5), full yellow (6), star (7), and duffel (8) (Loeseck, 1950). According to the ripening stages, the dopamine levels in ripened banana pulp ready to eat were 7.0 ± 2.0 mg/100 g of 1–3 stages, 9.1 ± 3.1 mg/100 g of 4–6 stages, 7.3 ± 2.4 mg/100 g of 6–7 stages, and 3.4 ± 2.2 mg/100 g of 7–8 stages (Kanazawa and Sakakibara, 2000).

4. Banana peel as an interesting complex matrix of high-value compounds

Generally, peels from consumed bananas are used in the animal feeding, as organic fertilizer or they are simply discarded (Charrier et al., 2004). Disposal of these peels (pomace) may cause environmental problems. In Costa Rica, for instance, it is common to practice the disposal of banana excess and waste in the rivers. However, the high carbohydrate content of that biomass increases the oxygen biochemical demand in rivers and reduces the populations of aquatic animals causing an imbalance in the ecosystem (Zhang et al., 2005).

Currently, there are few reports in literature describing the usage of this pomace, e.g., production of ethanol (Tewari et al., 1986), methane (Bardiya and Somayaji, 1996; Gunaseelan, 2004), feed for livestock (Onwuka et al., 1997), or as adsorbents for water purification (Annadurai et al., 2004). Depending on the technology employed, the pomace can be converted into commercial products either as raw material for secondary processes such as ingredients of new products with therapeutic activity. These natural products can also be used directly as functional compounds in human nutrition and prevention and health care. Indeed, among the numerous sources of bioactive compounds, banana peel could be considered one of the complex plant matrix rich in high-value compounds (Laufenberg et al., 2003). Banana peel is rich in phytochemical compounds, mainly antioxidants. Ripe banana peel contains the anthocyanins delphinidin and cyaniding (Seymour, 1993), and catecholamines (Kanazawa and Sakakibara, 2000).

4.1. Carotenoids

Carotenoids are also natural antioxidants and they contribute to the stability of foods. Such pigments are not evenly distributed in the food itself as various investigators have found that carotenoids are usually more concentrated in the peel than in the pulp of fruits and vegetables (Rodriguez-Amaya, 2001).

Three plantain varieties (Batard, Mbourourkou-1, and Mbourourkou-3) and two dessert banana varieties (Cavendish and Yangambi-5) were investigated by Davey et al. (2006) for pro-vitamin A carotenoid content. Banana peel has substantially higher carotenoid values in some varieties than the underlying fruit pulp and that the pro-vitamin A carotenoids present consist primarily of *trans*-beta-carotene. Banana peel (*Musa* spp, cv. Prata Anã) might be considered a source of carotenes as *trans*-beta-carotene (174.87 ± 7.86 μg/g dry weight), *trans*-alfa-carotene (164.87 ± 10.51 μg/g dry weight), and *cis*-beta-carotene (92.21 ± 5.37 μg/g dry weight), which are the major carotenoids from this raw material. That biomass is also source of lutein (39.70 ± 9.06 μg/g dry weight), zeaxanthin (7.21 ± 1.07 μg/g dry weight) and beta-cryptoxantin (1.21 ± 0.37 μg/g dry weight) in minor concentrations. Banana peel is a kind of important raw material that might be more exploited regarding its carotenoidic concentration as well as in the pulp.

4.2. Phenolic compounds

The potential of plant biomasses as source of bioactive compounds also refers to the by-products and/or residues of a given production system. For instance, fruit residues (i.e., pomace) are inexpensive, easily available, and contain bioactive molecules. Consequently, over the past years research focus has shifted to such residues as a possible source of antioxidants compounds. Shui and Leong (2006) reported that antioxidant compounds as (−)-epicatechin and proanthocyanidins, which existed as dimers through pentamers in star fruit (*Averrhoa carambola* L.) residues, delay oxidative rancidity of soya bean oil to a greater extent than butylated hydroxytoluene (BHT). Babbar et al. (2011) investigated the antioxidant potential in terms of ABTS and DPPH scavenging abilities, ferric reducing antioxidant power, and phenolic contents of residue extracts of four important fruits grown in Ludhiana, India, between them the banana peel. The antioxidant activities in terms of ABTS determined for banana peel were found to be 5.67 ± 0.32 mg trolox equivalent/g dry weight, respectively. The methanolic extracts considerably differed in the antioxidant activity as measured by the DPPH method, e.g., banana peel: 83 ± 0.70%. Such findings reveal an important trait of banana peel as source of compounds able in scavenging free radicals as antioxidant mechanism of action, comparatively to other plant residual biomasses. By relating antioxidant activity to phenolic contents in biomass samples one could expect a direct relationship for those variables, as it seems not to be the case for the banana peel as demonstrated by Babbar et al. (2011) and other studies (Demiray et al., 2009; Sulaiman et al., 2011). Indeed, for example, carotenoids as beta-carotene and vitamins are not phenolic compounds, but they might also contribute in enhancing antioxidant activity in banana peel extracts. On the other hand, one can assume that even low amounts of phenolic compounds in plant extracts can afford prominent antioxidant activities depending on the types of those secondary metabolites, typically indicating that the qualitative profile of the phenolic extract is

meaningful. Whether that is the case for the banana peel samples it remains to be elucidated. Besides, banana peels might be an important source of antioxidant compounds considering a growing interest of the food and pharmaceutical industries on medicinal plant biomasses for development of new therapeutic and prophylactic products. In order to pursue a further technological usage of that residual biomass, in vivo studies in both pre-clinical and clinical levels on the toxicology, bioavailability, distribution, metabolization, and excretion of phenolic compounds from banana peels extracts are needed to subsidize an eventual industrial application.

Oxygen free radical processes are involved in both physiological and pathological conditions, which skin tissue repair caused mainly by trauma and burns (Croft, 1998; Sies, 1985). The role of antioxidants in the removal of inflammation products is already known and these compounds are also beneficial in wound healing for other reasons. Antioxidants work against the excess of proteases and reactive oxygen species (ROS), protecting protease inhibitors from oxidative damage. In addition, antioxidants can prevent destruction of fibroblasts and other cells caused by ROS over generation, and therefore may be important in the successful treatment of lesions (Houghton et al., 2005). The Brazilian local and traditional knowledge described by Balbach (1945) (Section 2) corroborated the role of antioxidants in banana peel.

Despite the predominance of substances from synthetic origin in the therapeutic arsenal, including antiinflammatory drugs, in recent years there has been a renewed interest in local and traditional therapeutic practices by many health professionals. Hence, herbs and other phytochemicals have been used as an alternative or complementary therapy. For example, many phytotherapeutics, including extracts of *Aloe vera*, passion fruit (*Passiflora edulis*), aroeira (*Schinus terebinthifolius*), and unripe banana (*Musa x sapientum* L.) have been tested and used in the treatment of skin lesions (Agarwal and Goel, 2008; Castelo et al., 2006; Garros et al., 2006).

The antioxidant compounds from commercial banana peel *Musa cavendishii* Lamb. were studied by Someya et al. (2002) and the antioxidant gallocatechin was identified. In fact, gallocatechin was more abundant in peel (158 mg/100 g dry weight.) than in pulp (29.6 mg/100 g dry weight.) in *Musa cavendishii* Lamb. genotypes as the antioxidant activity of the banana peel extract against lipid auto-oxidation was stronger than that of the banana pulp extract. This result was consistent with the gallocatechin analysis and its higher content may account for the better antioxidant effects. Thus, banana peels might be considered as a good source of natural antioxidants for foods, as well as among others possible applications.

The antioxidant activity of banana peel extracts (*Musa x paradisiaca* L.) was studied using an experimental model of rats subjected to a normal diet compared to rats with a diet rich in fatty acids. Animals treated orally with banana peel extract showed significantly decreased concentrations of peroxidation products (MDA), hydroperoxides, and conjugated dienes. At the same time, the enzymatic activities of catalase and superoxide dismutase increased significantly in treated animals, as well as the concentration of reduced glutathione (Vijayakumar et al., 2008).

According to Agarwal and Goel (2008), plantain banana (*Musa x sapientum* L.) has been shown peptic ulcer protective activity. With the premise that the drug promoting ulcer healing could have effect on wound healing activity in rats by oral doses (50, 100 and 200 mg/kg/day) of aqueous (MSW) and methanolic (MSE) extracts were investigated. Both MSW and MSE (100 mg/kg) showed optimal effect on wound contraction and epithelization in excision wound when administered for 21 days. Both MSW/MSE (100 mg/kg for 10 days) increased wound breaking strength and levels of hydroxyproline, hexuronic acid, hexosamine, superoxide dismutase, reduced glutathione in the granulation tissue and decreased percentage of wound area, scar area and lipid peroxidation comparatively to the control group. This indicate that plantain banana extracts favoured wound healing, a biological activity related to their antioxidant effect and to the property of modulate various wound healing biochemical parameters, promoting the process of early keratinisation and healing.

Unripe banana peel contains leucocyanidin, a flavonoid that induces cell proliferation by increased incorporation of thymidine into cellular DNA (Novak et al., 2003), accelerating the healing of skin wounds (Lewis et al., 1999). The pulp and peel of unripe banana have been used in the treatment of cracked nipples and peptic ulcers in humans (Novak et al., 2003). Studies with rats have shown the efficacy of unripe banana in the prevention and treatment of peptic ulcers. Interestingly, the active agent in unripe bananas is water soluble and becomes inactive in ripe bananas (Best et al., 1984).

Gallocatechin consists of the largest groups of naturally occurring phenols with antioxidant potential that is widely distributed in leaves, seeds, bark, and flowers of plants (Heim et al., 2002). *Musa* spp peel gallocatechin–rich extract (GE: 106.6 μg/mL) wound healing potential were studied. GE treatment was able to decrease the epithelization period, healing the lesions in 9 days, as well as to increase the hydroxyproline content over the treatment period, Histological analysis of the lesions confirmed the GE healing potential, showing fibroblast proliferation and induction of re-epithelialization process. On the one hand, ROS are necessary for effective defense against invading pathogens and cell signaling and even in the absence of infection, low levels of ROS are necessary for cell signaling, especially angiogenesis. Consequently, a closer relationship between production and detoxification of ROS is crucial for the normal repair process of an injury. The results of this study suggest that the extract of *Musa* spp banana peel was able to prevent oxidative damage to cellular structures in the lesion bed during the experimental period, which was more important in the early days of the healing process apparently because it allowed the control of ROS levels. The injury space conditioned to cellular proliferation culminated quickly and effectively in the end of that healing process (Pereira, 2010).

To assess the effects of unripe *Musa sapientum* peel on the healing of surgical wounds in rats, Atzingen et al. (2013) used a 4% *M. x sapientum* L. peel gel for the treatment of the lesions by excision model. The treatment of surgical wounds showed to be effective, resulting in an increased number of polymorphonuclear cells on day 7, reduced wound contraction, reduced vascular proliferation, and increased concentration of collagen fibers on day 21.

4.3. Amine compounds

The tradicional use of bananas in India, described by Kumar et al. (2012) and related to the banana tryptophan content, is about to prevent or help a substantial number of illnesses and health conditions as depression. This traditional Indian knowledge is directly related to the researches from Chemuturi and Donovan (2006), Hashizume et al. (1987), Kanazawa and Sakakibara (2000), Murata et al. (1988), and Wang et al. (2013), for instance. Considering that tryptophan is one of the precursor aminoacids for dopamine synthesis, directly affecting the content of this biogenic amine in banana peel, and the increasing interest on Parkinson's disease, the possibility of prevent or treat that neurodegenerative disease by using banana peel as biomass source of dopamine is thought to be relevant.

Kanazawa and Sakakibara (2000) considered that bananas should contain antioxidants in peel to shield against peroxidizing factors. Tropical fruits have strong antioxidant activity, as well as

banana peel water-extract that suppressed the auto-oxidation of linoleic acid by 65-70% after 5-day incubation in an emulsion system by peroxide value determination and thiobarbituric acid reactivity. According to the ripening stages (Loeseck, 1950), the peel dopamine levels (1290 ± 420 mg/100 g of 1–3 stages, 430 ± 210 mg/100 g of 4–6 stages, 380 ± 160 mg/100 g of 6–7 stages, and 500 ± 270 mg/100 g of 7–8 stages) were higher than the ripened banana pulp (7.0 ± 2.0 mg/100 g of 1–3 stages, 9.1 ± 3.1 mg/100 g of 4–6 stages, 7.3 ± 2.4 mg/100 g of 6–7 stages, and 3.4 ± 2.2 mg/100 g of 7–8 stages (Kanazawa and Sakakibara, 2000). Levodopa was also determined in banana peel (*Musa* spp, cultivar Prata Anã) acidified extracts (full yellow: 150 ± 32 mg/100 g dry weight). Dopamine also shows higher antioxidant capacity in vitro (by DPPH assay) comparatively to other natural antioxidants as ascorbic acid, glutathione reduced, and several phenolic compounds, as gallocatechin gallate, for instance (Kanazawa and Sakakibara, 2000).

The biogenic amines are important in the metabolic pathways for plants pathogen resistance (Newman et al., 2001; Roepenack-Lahaye et al., 2003), they also affect plant growth and development by their interaction with phytohormones via auxin oxidation (Kuklin and Conger, 1995), influence plant flowering (Khurana et al., 1987), and sugar metabolism (Szopa et al., 2001). In fact, catecholamines in both methylated or non-methylated forms are required in small quantities (Kulma and Szopa, 2007) and have important regulatory functions (Kulma and Szopa, 2007), showing a rapid intracellular increased in plant leaves submitted to wounding (Bruhn and Lundstrom, 1976), water stress (Swiedrych et al., 2004), and ABA treatment (Swiedrych et al., 2004; Szopa et al., 2001). Besides the vegetal approaches, banana peel biomass might be considered as a raw material source of that biogenic amine for the development of a pharmaceutical formulation for the treatment of Parkinson's disease, especially the peels where the highest concentration of dopamine have been found in comparison to the pulp, as showed by Kanazawa and Sakakibara (2000).

4.3.1. Parkinson's disease

Since its initial description, by James Parkinson in 1817, Parkinson's disease (PD) has been characterized as a movement disorder, and its diagnosis is based on the presence of two or more cardinal motor signs: tremor at rest, decrease of voluntary movements, bradykinesia, rigidity, stooped posture, and postural instability (Barrio et al., 1997; Deumens et al., 2002). PD is the second neurodegenerative disorder related to age and the most common in humans, behind only Alzheimer's disease. The primary cause of PD is not fully understood. Indeed, epidemiological studies have highlighted that some environmental factors may be associated with an increased risk of developing PD, such as exposure to certain types of herbicides and pesticides (Fall et al., 1999; Vanacore et al., 2002). Recent findings suggest that it might be associated with oxidative stress triggered by one or more factors, such as brain aging, genetic predisposition, mitochondrial abnormalities, free radical production, and environmental toxins (Alexi et al., 2000; Olanow et al., 1998).

Since it was introduced on 1960, levodopa has been the most widely used and effective drug for the symptomatic therapy of PD (Olanow et al., 2006). According to Obeso et al. (2000), a constant firing rate of CNS dopamine neurons, stable striatal dopamine concentration, and the continuos activation of striatal dopamine receptors are essential for normal basal-ganglia function (Bédard et al., 1986; Grondin et al., 1996; Jenner, 2000). Engber et al. (1989), Juncos et al. (1989), Morissette et al. (1997), and Pavon et al. (2006) findings demonstrated that standard doses of levodopa are unable to restore basal-ganglia physiological activity to normal, because non-physiological discontinuous or pulsatile dopamine replacement induces disruption in the dopamine-denervated basal ganglia leading to the development of motor complications and dyskinesia characteristic from PD. Also disease severity can influence the risk that a drug will induce pulsatile stimulation and motor complications (Bédard et al., 1986; Pearce et al., 1998). The pulsatile stimulation of striatal dopamine receptors can induce molecular and neurophysiological changes in striatal neurons that are associated with dyskinesias. Stocchi et al. (2002) studied 40 patients with advanced PD with severe levodopa-related motor complications and they showed the benefit of continuous infusion of lisuride (levodopa formulation). In addition, studies in animal models in which dyskinesias associated with intermittent delivery of either levodopa or an agonist of dopamine can be avoided with continuous delivery of the drug (Bibbiani et al., 2005, Blanchet et al., 1995). A long-acting oral therapy that reflects the pharmacokinetics and clinical benefits of levodopa would be a better alternative treatment without the motor complications (Alexi et al., 2000; Olanow et al., 1998).

4.3.2. Bioavailability of amine compounds

In dogs, monkeys, and humans, more than 99% of the circulating dopamine is present in two isomeric forms, dopamine-3*O*-SO_4 and dopamine-4*O*-SO_4, which differ in metabolic stability and biological activity (Johnson et al., 1980). According to Hashizume et al. (1987), oral administrations of dopamine (50 mg/body) and 1-dihydroxyphenylalanine (L-dopa, 250 mg/body) increased the plasma levels of these dopamine sulfates almost 100-fold. Intravenous dopamine infusion (5 pg/kg/min during 30 min) markedly increased the plasma free dopamine concentration. The increase in total plasma dopamine sulfate (dopamine-3*O*-SO_4 and dopamine-4*O*-SO_4) after intravenous administration of dopamine was less than its oral administration. The activity of the enzyme phenol-sulfotransferase is found in the liver, kidneys, gut, brain, platelets, and in many other human tissues (Whittemore et al., 1985). Hashizume et al. (1987) finds indicate that *O*-sulfation of dopamine may be in the intestine, especially 3-*O*-sulfation, which is the main pathway for metabolism of L-dopa and orally administrated dopamine.

It has been known that catecholamines are metabolized by cathechol-*o*-methyl transferase (COMT), monoamine oxidase (MAO), and sulphotransferase (SFT). Murata et al. (1988) studied the bioavailability and pharmacokinetics of intravenous and oral dopamine in dogs. Intravenous administration of aqueous solution of 10 mg of dopamine, whose concentration decreased rapidly after administration, results in two main metabolites determined in the animals' plasma, dopamine-3*O*-SO_4 (2.7%) and 3,4-dihydroxyphenyl acetic acid (4.9%). Oral administration of an aqueous solution of 100 mg of ^{14}C dopamine in dogs showed a low bioavailability of the drug (approximately 3%). This reflects its extensive first-pass metabolism in the intestine and also in the liver during the absorption process, which resulted in urinary excretion of ^{14}C dopamine-3*O*-SO_4 predominantly.

Considering that one banana fruit weight approximately 100 g and the levels of dopamine in the banana pulp at 4–6 stages (9.1 ± 3.1 mg/100 g, *item* 3.3), the ingestion of the fruit is not enough to supply the treatment of PD's by facing first-pass metabolism. On the other hand, banana peel could be an alternative dopamine source (1290 ± 420 mg/100 g of 1–3 ripening stage), which is 142 times higher than the pulp content (Kanazawa and Sakakibara, 2000), an important issue for the development of pharmaceutical formulations.

To deal with first-pass metabolism, Murata et al. (1989) synthesized a dopamine prodrug *N*-(*N*-acetyl-L-methionyl)-*O*,*O*-bis(ethoxycarbonyl)dopamine. Protecting the catechol system and the amino group, with ethoxycarbonyl or *N*-acetyl-L-methionyl group, it is possible to decrease the first-pass metabolism of oral

dopamine and improve its bioavailability (approximately 30%) in dogs. Regarding the pharmacokinetic of dopamine and dopamine prodrug, Murata et al. (1990) studied their absorption and metabolism also in dogs. After oral administration, the absorption rate constant of dopamine was smaller than the formation rate constants of the metabolites dopamine-*O*-SO_4 and 3,4-dihydroxyphenyl acetic acid in the dog's plasma. In addition, when the prodrug *N*-(*N*-acetyl-L-methionyl)-*O*,*O*-bis(ethoxycarbonyl)dopamine was orally administrated, the formation rate constant of *N*-(*N*-acetyl-L-methionyl)dopamine was larger than the metabolic formation rate contants of dopamine-*O*-SO_4 or 3,4-dihydroxyphenyl acetic acid. In conclusion, dopamine prodrug played an important role to the reduction of first-pass metabolism.

Dopamine, when undergoes high intestinal and hepatic first pass metabolism following oral administration, has good bioavailability following nasal administration (Dahlin et al., 2000, 2001). In addition, intranasal drug delivery offers the advantage over the oral route administration of higher permeability for polar molecules (Gervasi et al., 1991). Dahlin et al. (2001) investigated the levels of [^{3}H]dopamine in blood, cerebrospinal fluid (CSF), and brain tissue of rats. The nasal absorption of [^{3}H]dopamine was achieved in 15 min after administration. The [^{3}H]dopamine levels after nasal administration were about 2.3 times higher than after intravenous administration (75 ± 19 dpm and 32 ± 4 dpm, respectively) in the CSF and about 6.8 times higher (184 ± 68 dpm and 27 ± 10 dpm, respectively) in the right olfactory bulb. Metabolism of [^{3}H]dopamine in the olfactory mucosa was not extensive and therefore the metabolism to dihydroxyphenylacetc acid must have occurred during the transfer to or in the CSF. This results showed significantly higher amounts of unchanged dopamine in brain tissue samples after nasal administration of [^{3}H]dopamine to rats than after intravenous administration, indicating a direct pathway for this drug from the nasal cavity into the brain of the animals.

Chemuturi and Donovan (2006) also studied the role of nasal mucosal metabolism of dopamine by this route of administration. Dihydroxyphenylacetc acid (less than 0.5% of the initial amount of dopamine placed into the system) was the only metabolite detected in the in vitro assay, likely due to saturation of monoamine oxidase (MAO) localized in the submucosal region of the nasal explants from bovines. However, at low concentrations of dopamine its transport and metabolism reduce. Nasal dopamine transport across the epithelial layer has been shown to be mediated by cellular-based protein carriers DAT and the OCT family (Amenta et al., 2001; Eisenhofer, 2001). The high systemic bioavailability of dopamine and its apparent preferential transport into the central nervous system, following intranasal administration, is the combination of the limited dilution of dopamine solution, the activity of multiple uptake transporters, and the rapid saturation of MAO in the submucosal tissues (Dahlin et al., 2001). Chemuturi and Donovan (2006) and Dahlin et al. (2001) suggest that intranasal administration of dopamine is a promise mode of delivery along the olfactory neurons this neurotransmissor directly to the brain.

Recently, Wang et al. (2013) designed as a dipeptide mimetic prodrug of dopamine named as D-phenylglycine-L-dopa (D-PhG-L-dopa), which has 31-fold higher oral bioavailability than L-dopa in rats. After intravenous administration, both D-PhG-L-dopa and L-dopa entered the brain rapidly (T_{max} 1 min). D-PhG-L-dopa demonstrated 1.97-fold higher systemic bioavailability than L-dopa, probably due to its lower clearance rate and larger volume of distribution. The terminal half-life of brain dopamine upon D-PhG-L-dopa administration was 2.51 times longer than that upon L-dopa administration.D-PhG-L-dopa, as a dopamine prodrug, prevents or prolongs the fast decarboxylation process of L-dopa and works as a sustained dopamine-releasing system usefulness for treating Parkinson's disease.

5. Conclusion

Bananas and plantains are largely consumed all over the world as food staples and for medicinal purposes as they are interesting sources of bioactive secondary metabolites. Bananas and plantains belong to the genus *Musa* and according to peculiar morphogenetic characteristics their cultivars are distributed into four sections: *Eumusa, Rhodochlamys, Australimusa*, and *Callimusa* and classified according to their genomic group, subgroup, fruit usage, and geographic distribution.

Phytochemical and pharmacological studies of bananas and plantains have received much interest because it has been demonstrated that *Musa* spp extracts present pharmacological activities attributed to their phenolic, carotenoid, and amine constituents. However, despite of the continuous progress on the phytochemical and pharmacological potential of those species, the development of a phytomedicine or even an allopathic medicine from *Musa* spp biomasses such as fruit peels (e.g.) requires a more detailed investigation. For example, in Brazil, there is a growing interest in developing a banana-based phytomedicine for wound healing taking into account the ethnopharmacological data available, as well as for Parkinson's disease treatment. For that, relevant issues of the usage of *Musa* spp extracts, especially focusing on the scientific support for quality control, efficacy, safety, and toxicity, shall be addressed in both preclinical and clinical studies. Finally, considering the genetic diversity of *Musa* spp and its adaptation to a wide range of environmental conditions all over the world, one could expect that future rational and ethnopharmacological-oriented researches will provide the suitable support for clinical employment of *Musa* spp secondary metabolites in modern medicine.

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