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Review
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Review

Bioactive compounds in banana fruits and their health benefits

Jiwan S. Sidhu and Tasleem A. Zafar

Department of Food Science & Technology, College of Life Sciences, Kuwait University, 13060-Safat, Kuwait

Correspondence to: Jiwan S. Sidhu. E-mail: jiwan.sidhu@yahoo.com

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Abstract

Banana is an edible fruit and is herbaceous flowering plant belonging to the genus *Musa* and the family *Musaceae*. Banana is also eaten as cooked vegetable (and is then called plantains). All the edible banana fruits are seedless (parthenocarpic) and belong to two main species, *Musa acuminata* Colla and *Musa balbisiana* Colla. The hybrid from these two species *Musa* x *paradisiaca* L. is also available nowadays. Although banana is native to Indomalaya and Australia, Papua New Guinea was the first to domesticate this fruit. Banana has now spread to almost 135 countries around the world. As per 2016 data, nearly 28 per cent of the total world's banana production comes from India and China. Cavendish group banana, being the main export item from the banana-exporting countries, usually refers to soft, sweet, and dessert banana in the Western countries, but the plantain bananas have firm, starchy fruit which is suitable for cooking as a vegetable. Banana is known to be rich not only in carbohydrates, dietary fibres, certain vitamins and minerals, but is also rich in many health-promoting bioactive phytochemicals. General composition including various bioactives and their health contributions has been reviewed in this paper.

Key words: banana fruit; nutritional value; phytochemicals; bioactives; phenolics; biogenic amines.

Introduction

The consumption of fruits and fruit products is known not only to promote general good health but also lower the risk of various chronic diseases, such as heart diseases, stroke, gastrointestinal disorders, certain types of cancer, hypertension, age-related macular degeneration, cataract of the eye, skin conditions, lowering of low-density lipoprotein (LDL) cholesterol, and improved immune function. To promote healthy eating lifestyle, the USDA recommends filling up half the plate with fruits and vegetables, because these provide a good amount of dietary fibres, certain vitamins (*e.g.* ascorbic acid, folic acid, and vitamin A precursors), many minerals (*e.g.* potassium, magnesium, iron, and calcium), and many other important phytochemicals having strong antioxidative properties. Fruits make an important part of the balanced diet adopted by the humans. USDA recommends daily five servings of fruits to obtain most of the health benefits. Depending upon their origin and production area temperature, fruits are classified into temperate fruits, sub-tropical fruits, and tropical fruits. Banana belongs to the tropical fruits as it grows more profusely in tropical rain forest areas. Interestingly, banana fruit has flesh not only rich in starch which changes into sugars on ripening but is also a good source of resistant starch. Banana is known to be rich in carbohydrates, dietary fibres, certain vitamins, and minerals (Table 1). The presence of various bioactive phytochemicals and their nutritional significance has been discussed in this review paper (Figure 1).

Antioxidant Compounds in Banana Fruits

The reactive oxygen species (ROS) and reactive nitrogen species (RON), such as hydroxyl radicals, superoxide ions, nitric oxide radicals, and singlet oxygen and hydrogen peroxide, have now been implicated in the causation of many disorders like arthritis, diabetes, arteriosclerosis, age-related macular degeneration, certain types of cancer, inflammation, genotoxicity, and Alzheimer disease. The exact mechanism is not known but the reaction of these ROS and RNS species with biomolecules such as lipids, proteins, and DNA may be the cause of these disease conditions (Shukla *et al*., 2009; Septembre-Malaterre *et al*., 2016). Kandaswamy and Aradhya (2014) have

Table 1. Chemical composition of banana fruit (as is basis per 100 g)

Constituent	Amount µg, mg, g, or percent daily value
Energy	371 kJ (89 kcal)
Water	74.91 g
Carbohydrates	22.84 g
Sugars	12.23 g
Dietary fibre	2.6 g
Vitamins	
Pantothenic acid (B5)	0.334 mg, (7%)
Pyridoxine (B6)	0.4 mg, (31%)
Choline	9.8 mg, (2%)
Vitamin C	8.7 mg, (10%)
Minerals	
Magnesium	27 mg, (8%)
Phosphorus	22 mg, (3%)
Potassium	358 mg, (8%)
Sodium	1 mg, (0%)
Zinc	0.15 mg, (2%)

Adopted from: Wikipedia, Internet, USDA databases.

shown the banana rhizome to be a rich source of many polyphenolic compounds having antioxidant activities. Pazmino-Duran *et al.* (2001) have suggested the use of anthocyanins from banana bracts (florets) as natural colourants. They identified various anthocyanins such as cyanidin-3-rutinoside (main one as 80 per cent of total pigments, being 32.3 mg/100 g) and 3-rutinoside derivatives of delphinidin, pelargonidin, peonidin, and malvidin. Interestingly, the addition of heat-treated onion extract was found to inhibit the polyphenol oxidase (PPO) during ripening of banana fruit at room temperature (Lee, 2007). Even the Maillard reaction products (MRP) significantly affected the banana PPO activity. The phytochemistry and pharmacology of wild banana (*Musa acuminata* Colla) have been reviewed by Mathew and Negi (2017) and they suggested the use of banana pulp and peel for the development of drugs and use in functional foods.

Not only banana pulp, but pseudo stem and banana fruit peel have been found to be the good sources of antioxidants (Table 2). Aziz *et al.* (2011) have analysed the native banana pseudo-stem flour (NBPF) and tender core of pseudo-stem flour (TCBPF) for chemical and functional properties. They found higher content of polyphenols, flavonoids, total dietary fibre, insoluble dietary fibre, lignin, hemicellulose, cellulose, antioxidant capacity, and free-radical scavenging

Figure 1. Banana tree and banana fruits of various maturities. (Source: Internet Wikipedia.)

capacity in NBPF than TCBPF. In exhaustive reviews, Pereira and Maraschin (2015) and Singh *et al*. (2016) have reported that banana is rich in many bioactive compounds, such as carotenoids, flavonoids, phenolics, amines, vitamin C, and vitamin E having antioxidant activities to provide many human health benefits. Recently, Vu *et al*. (2018) have also reviewed the phenolic compounds and their potential health benefits coming from banana peel. They have suggested the use of this valuable by-product from banana fruit processing industry in food and pharmaceutical industry. Anyasi *et al*. (2018) have analysed the essential macro and trace minerals as well as phenolic compounds in unripe banana flour obtained from the pulp of four cultivars treated with ascorbic, citric, and lactic acids before drying in a forced air dryer at 70°C. Results of their liquid chromatography-mass spectrometry-electrospray ionization (LC-MS-ESI) assay of phenolics revealed the presence of two flavonoids, epicatechin and 3-O-rhmnosyl-glucoside in varying concentrations. Among the essential minerals, zinc had the lowest concentration of 3.55 mg/kg, but the potassium was the highest, 14746.73 mg/kg in these cultivars.

Carotenoids

Carotenoids is a class of compounds having some 600 members in this family. Some of these are precursors for vitamin A, and others are known to have strong antioxidant capacity to scavenge ROS. Among the carotenoids present in banana fruit, α-carotene, β-carotene, and β-cryptoxanthin have provitamin A activity, but others like lycopene and lutein have a strong antioxidant capacity (Erdman *et al*., 1993). Lycopene is known to provide protection against prostate cancer among men, and lutein offers human health benefits to serve as an inhibitor of age-related macular degeneration (Davey *et al*., 2006). Later, Davey *et al*. (2009) have analysed 171 different genotypes of *Musa* spp. for provitamin A carotenoids and 47 genotypes for two minerals (iron and zinc). They found a great variability in provitamin A among the various cultivars, but a low variability in iron and zinc, irrespective of the soil type and growing environmental conditions. They suggested the use of high provitamin A and trace mineral cultivars as development strategies to improve the nutritional health and alleviation of micronutrient deficiencies among the *Musa*-consuming populations.

Yellow- and orange-fleshed banana cultivars are known to be richer in trans-β-carotene content (Englberger *et al*., 2006). Carotenoid content of some of the banana cultivars is presented in Table 3. Consumption of fruits rich in carotenoids is reported to boost immunity and reduce the risk of various diseases, such as cancer, type II diabetes, and cardiovascular problems (Krinsky and Johnson, 2005). Certain banana cultivars rich in provitamin A carotenoids can be grown and consumed by the poor population of the world that is having serious vitamin A deficiency, and the consumption of such banana fruit would alleviate vitamin A deficiency (Fungo and Pillay, 2013).

Phenolic Compounds

Phenolics present in banana fruit are the major bioactive compounds having antioxidant properties and are known for providing health benefits (Table 4). Various phenolics present in banana have been identified as follows: gallic acid, catechin, epicatechin, tannins, and anthocyanins. Banana rhizome is used as food and for medicinal properties as well in South India as it is very rich in phenolics (Kandasamy and Aradhya, 2014). Russel *et al*. (2009) have detected many phenolics in banana, such as ferulic, sinapic, salicylic, gallic, p-hydroxybenzoic, vanillic, syringic, gentisic, and p-coumaric acids as major components.

Table 2. Antioxidant activity, total polyphenol, and individual polyphenolic compounds present in organic acid treated (20 g/l) unripe banana flour

Antioxidant and phenolic content	Cultivar	Ascorbic acid	Citric acid	Lactic acid
DPPH (mg GA/g DW)	Luvhele	$0.84^{c} \pm 0.01$	$0.90^{d} \pm 0.04$	$0.95^{e} \pm 0.01$
	Mabonde	$0.81^{e} \pm 0.00$	$0.89^{f} \pm 0.01$	$0.96^{g} \pm 0.02$
Total polyphenols (mg GAE/100g DW)	Luvhele	$777.83^{de} \pm 56.41$	$707.87^{c} \pm 12.62$	$769.24^{cd} \pm 18.68$
	Mabonde	$1081.54^{h} \pm 23.18$	$856.46^{f} \pm 18.01$	$929.36^{g} \pm 9.32$
Epicatechin (µg/g DW)	Luvhele	$3.49^{a} \pm 0.67$	$4.05^{a} \pm 0.76$	$4.24^{a} \pm 0.84$
	Mabonde	$1.35^{a} \pm 0.18$	–	–
Myricetin-3-O-rhamnosyl glucoside (µg/g DW)	Luvhele	$17.08^{a} \pm 1.97$	$13.91^{bc} \pm 1.61$	$9.91^{b} \pm 1.58$
	Mabonde	$13.69^{a} \pm 1.61$	$5.68^{bc} \pm 1.04$	$8.20^{b} \pm 0.96$

Means with different letters across rows are significantly different at $P < 0.05$. Values are Means ± SE of triplicate measurements. DPPH, 1,1-diphenyl-2-picryl-hydrazyl. (Adopted and modified from Anyasi *et al*., 2018.)

Table 3. Carotenoid content of different banana cultivars (µg/100 g)

Cultivar	Trans-α carotene	Trans-β carotene	Total carotenoid content	Reference
Hung Tu ripe pulp	1849 FW	5653 FW	7760 FW	Beatrice *et al*., 2015
To'o ripe pulp	2055 FW	5267 FW	7765 FW	
Sepi ripe pulp	4728 FW	5611 FW	10,067 FW	
Apantu ripe pulp	3287 FW	6387 FW	10,056 FW	
Bungaoisan ripe pulp	779 FW	857 FW	1675 FW	
Aibwo	2358 FW	5945 FW	9400 FW	Englberger *et al*., 2010
Fagufagu	1524 FW	3428 FW	5054 FW	
Ropa	3682 FW	1324 FW	5218 FW	
Gatagata	79 FW	695 FW	774 FW	
Toraka Parao	250 FW	526 FW	776 FW	
Red banana peel and pulp	ND	123 and 29.6 DW	200 and 250 DW	Arora *et al*., 2008

Source: Adopted and modified from: Singh *et al*., 2016.

However, ferulic acid content was the highest (69 per cent of cinnamic acids) among these phenolics. Banana peel is also a rich source of phenolic compounds. Tsamo *et al*. (2015) analysed banana pulp and peel from nine plantain cultivars and two dessert banana cultivars. According to their results, hydroxycinnamic derivatives, such as ferulic acid-hexoside, were the major ones (4.4–85.1 µg/g DW) in plantain pulp. They observed large variations in the phenolic contents among the cultivars tested. In the peel from plantain cultivars, rutin was the most abundant flavonol glycoside (242.2–618.7 µg/g DW). Thus, the banana peel and pulp both are good sources of health-promoting phenolic compounds. Among the flavonoids detected in banana are as follows: quercetin, myricetin, kaempferol, and cyanidin which provide health benefits mainly because they act as free radicals, ROS, and RNS scavengers (Kevers *et al*., 2007). Most of these phenolics are known to also exhibit antibacterial, antiviral, anti-inflammatory, antiallergenic, antithrombotic, and vasodilatory activities (Cook and Sammon, 1996). Sulaiman *et al*. (2011) have determined the total phenolic and mineral contents in pulp and peel from eight banana (*Musa* spp.) cultivars grown in Malaysia. With a few exceptions, the peel extracts had the higher total phenolics and total antioxidant activities than the pulp. Among minerals, potassium was the major element found in both the peel and pulp followed by phosphorus, magnesium, and sodium.

Health Benefits of Bioactive Components in Banana Fruits

Health benefits of phenolics

A flavonoid, leucocyanidin, has been identified as a predominant component of aqueous extract of unripe banana pulp that showed significant anti-ulcerogenic activity (Lewis *et al*., 1999). Thus, many flavonoids, especially leucocyanidin analogues, may offer immense therapeutic potential in the treatment of gastric disease conditions.

The structure–activity relationship of flavonoids indicates that their antioxidant capacity, scavenging free radicals, and chelating action are related to the presence of functional groups in their nuclear structure (Heim *et al*., 2002). They also attributed most of the health benefits from the consumption of flavonoids to their antioxidant and chelating properties. Because of these properties, flavonoids are also shown to exhibit antimutagenic and antitumoral activities (Rice-Evans *et al*., 1996). The flavonoids can also inhibit many enzymes, such as oxygenases (prostaglandin synthase), required in the synthesis of eicosanoids. Thus, the flavonoids inhibit hyaluronidase activity and help in maintaining the proteoglycans of connective tissues. This would prevent the spread of bacterial or tumour metastases (Havsteen, 2002). As the flavonoids get preferentially oxidized, they are reported to prevent the oxidation of body's natural water-soluble antioxidants like ascorbic acid (Korkina and Afanas'ev, 1997). Generally, after the consumption of banana fruit, the peel ends up as a feed for the animals only. The disposal of peel (pomace) and other by-products from banana-processing industry causes a serious environmental problem (Zhang *et al*., 2005). Banana peel is reported to be rich in many high-value health-promoting antioxidant phytochemicals, such as anthocyanins, delphinidin, and cyanidins (Seymour, 1993). In a recent study, Rebello *et al*. (2014) have also shown the banana peel extract to be a rich source of total phenolics (29 mg/g as GAE), which are responsible for the very high antioxidant activity. They also determined various other antioxidant compounds, namely, highly polymerized prodelphinidins (~3952 mg/kg), flavonol glycosides (mainly 3-rutinosides and predominantly quercetin-based compounds, ~129 mg/kg), B-type procyanidin dimers, and monomeric flavan-3-ols (~126 mg/kg).

Health benefits of biogenic amines

Banana peel and pulp are known to be good sources of certain biogenic amines (catecholamines) which are produced by the decarboxylation of amino acids or by the amination of aldehydes and ketones. Catecholamines include dopamine, serotonin, epinephrine, and norepinephrine and are reported to occur in many plants in considerable amounts (Ponchet *et al*., 1982). In animals, these biogenic amines are reported to work as neurotransmitters for the hormonal regulation of glycogen metabolism (Kimura, 1968). When banana is consumed by humans, serotonin present in the pulp (ranging from 8 to 50 µg/g)

Table 4. Uses and health benefits of bioactive compounds in banana

Bioactive compound	Health benefits	Reference source
Tannic acid	Applied as medicinal agents for the treatment of burns	Siang (1983)
Catechin	Resistance of LDL to oxidation, brachial artery dilation increased plasma antioxidant activity, and fat oxidation	Williamson and Manach (2005)
Gallic acid	Antioxidant and potential hepatoprotective effects	Rasool *et al*. (2010)
Cinnamic acid	Is a precursor to the sweetener aspartame by the means of enzyme catalysed amination to phenylalanine	Garbe (2000)
p-Coumaric acid	Antioxidant properties and potentially reduce the risk of stomach cancer	Ferguson, Zhu, and Harris (2005)
Gallocatechin gallate	Cholesterol reduction	Ikeda *et al*. (2003)
Quercetin	Promotes overall cardiovascular health by encouraging blood flow	Perez-Vizcaino and Duarte (2010)
Ferulic acid	Antioxidant, antimicrobial, anti-inflammatory, antiallergic, anticarcinogenic, modulation of enzyme activity, antiviral and vasodilatory actions	Kumar and Pruthi (2014)
Trans-α carotene	Precursor to vitamin A	Li *et al*. (2011)
Trans-β carotene	Reduce the risk of CVD and cancer	Li *et al*. (2011)
Violaxanthin	Used as a food colourant	
Cryptoxanthin	Food colourant might reduce the risk of lung cancer	DeLorenze *et al*. (2010)
Serotonin	Might contribute to feelings of well-being and happiness	Young (2007)
Dopamine	Reduce the plasma oxidative stress and enhance the resistance to oxidative modification of LDL	Yin *et al*., (2008)
Catecholamines	Increases blood pressure, glucose levels, and heart beat rate	Kuklin and Conger (1995)
β-Sitosterol	Potential to reduce blood cholesterol levels and benign prostatic hyperplasia (BPH)	Wilt *et al*. (1999)
Campesterol and stigmasterol	Reduces the absorption of cholesterol in the human intestines	Choudhary and Tran (2011)

creates a feeling of well-being and happiness. Banana contains a large amount of dopamine and norepinephrine (Buckley, 1961). Waalkes *et al*. (1958) were the first to report the amount of various catecholamines in banana pulp as follows: serotonin, 28 µg/g; norepinephrine, 1.9 µg/g; and dopamine, 7.9 µg/g. The concentrations of dopamine in the pulp of yellow banana (*M. acuminata*), red banana (*Musa sapientum*), and plantain has been reported to be 42, 54, and 5.5 µg/g, respectively (Feldman *et al*., 1987). They highlighted the role of dopamine in human brain and body as a neurotransmitter having a strong influence on mood and emotional stability. Dopamine in the peel and pulp of commercially ripened *Musa* Cavendish is reported to range from 80 to 560 mg/100 g, and 2.5 to 10 mg/100 g, respectively (Kanazawa and Sakakhibara, 2000). Tryptophan being one of the precursors for the synthesis of dopamine, the presence of this amino acid in banana peel increases the interest in possibilities of preventing neurodegenerative diseases like Parkinson's using this by-product of food-processing industry by developing pharmaceutical formulations. However, the increase in dopamine content from unripe to the ripened stage in both the peel and pulp has been reported by many workers (Romphophak *et al*., 2005; Gonzalez-Montelongo *et al*., 2010). They also suggested that the decline in dopamine concentration during over-ripening stage may be due to its oxidation to quinones which may further polymerize to melanin pigments.

Using peroxide value and thiobarbituric activity determination, the antioxidant compounds present in water extract of banana peel have shown to suppress the autooxidation of linoleic acid by 65 to 70 per cent after 5 days of incubation (Kanazawa and Sakakhibara, 2000). When they compared dopamine with other natural antioxidants, such as ascorbic acid, reduced glutathione, and phenolic acids (*e.g.* gallocatechin gallate), the dopamine showed higher antioxidant activity *in vitro* (DPPH assay). Gonzalez-Montelongo *et al*. (2010) have reported the banana peel extracts to be rich in dopamine, L-dopa, and catecholamines with a significant antioxidant capacity. They found no significant difference in the antioxidant activity in the banana peel extracts from different cultivars. The biogenic amines are also shown to play an important role in offering plants' resistance to various invading pathogens through their interaction with phytohormones (*via* auxin oxidation), thus affecting the growth and development of plants (Newman *et al*., 2001; Roepenack-Lahaye *et al*., 2003).

Health benefits of phytosterols

These naturally occurring plant sterols have attracted the attention of food manufacturers to produce functional foods having higher health benefits. Because of their structural similarity with cholesterol, they compete with cholesterol for absorption in the gut, thus lowering the blood cholesterol levels (Marangoni and Poli, 2010). They reported that a daily intake of 3 g of phytosterols results in marked reduction of LDL cholesterol levels. Various phytosterols reported in the banana peel are stigmasterol, -sitosterol, campesterol, 24-methylene cycloartenol, cycloeucalenol, and cycloartenol (Knapp and Nicholas, 1969). Now the health professionals recommend the consumption of plant sterols–rich diet to lower the LDL cholesterol in patients who do not tolerate cholesterol-lowering statin drugs (Ostlund *et al*., 2003). Banana fruit has been shown to contain a good amount of phytosterols both in the peel and pulp (Akihisa *et al*., 1986). The phytosterols content in unripe banana in the range of 2.8 to 12.4 g·kg DW has been reported by Vilaverde *et al*. (2013). According to their results, the *Musa balbisiana* cultivars, such as 'Dwarf Red' and 'Silver', had higher amounts of phytosterols than the *M. acuminata* cultivars. The lipophilic extract of ripe banana pulp from several cultivars of the *M. acuminata* and *M. balbisiana* species has been found to be a source of ω-3 and ω-6 fatty acids, phytosterols, long-chain aliphatic alcohols, and α-tocopherol, thus offering well-established nutritional and health benefits (Vilela *et al*., 2014).

Summary

The above discussion brings out the importance of consuming banana fruits for obtaining various health benefits. It is not only the banana fruit pulp, but also the peel of this fruit is known to contain many important phytochemicals and offers many health benefits. More research is needed to be carried out to find ways of using banana fruit peel in the development of many new functional foods.

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