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Phenolic compounds within banana peel and their potential uses: A review

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ABSTRACT

A large quantity of bananas is produced annually and its peel, which accounts for about one third of the fruit weight, is mostly discarded as waste. The peel has been traditionally used for the treatment of various ailments. This by-product is rich in phenolics with over 40 individual compounds identified. However, composition and levels of these compounds are influenced by various factors, including varieties, maturity, cultivation conditions, and pre-treatments. Phenolics within banana peels have been found to possess potent antioxidant and antimicrobial properties, and linked with various health benefits. Therefore, it is worthwhile to recover phenolics from this by-product for further utilisation in food and pharmaceutical industries. This review comprehensively highlights the phenolic compounds as well as major factors affecting their presence within the banana peel, reviews the current applications of this by-product, outlines its potential uses in food and pharmaceutical industries and finally proposes a trend for future studies.

1. Introduction

The banana is one of the most popular fruits, and has a high nutritional content (Aurore, Parfait, & Fahrasmane, 2009). The fruit is usually consumed fresh or processed into different products at small and industrial scales, such as dried fruit, chip, smoothie, ice-cream, bread, flour, wine and ingredients for functional foods (Jackson & Badrie, 2003; Ramli, Alkarkhi, Shin Yong, Min-Tze, & Easa, 2009; Sodchit, Tochampa, Kongbangkerd, & Singanusong, 2013). Recently, the use of banana as an ingredient for functional foods has garnered significant interest. This is particularly due to the banana carbohydrates (starch and non-starch) having low digestibility, which makes it an excellent ingredient to add to food (Mohapatra, Mishra, & Sutar, 2010).

A large quantity of banana (102 million tonnes of fresh fruit) is produced annually (FAOSTAT., 2012). The peel accounts for about 35% of the whole fruit weight (Vu, Scarlett, & Vuong, 2016b), therefore approximately 36 million tonnes of banana peel is generated every year and this is a potential material for further utilisation. However, most of the banana peel is usually discarded into landfill or with general waste (Schieber, Stintzing, & Carle, 2001).

The peel has been traditionally used as medicinal material for the treatment of various ailments such as burns, anaemia, diarrhoea, ulcers, inflammation, diabetes, cough, snakebite, and excess menstruation (Fries, Nicholas, & Waldron, 1950; Gore & Akolekar, 2003; Kumar, Bhowmik, Duraivel, & Umadevi, 2012; Pereira & Maraschin, 2015). It has been found to contain high levels of dietary fibre and phenolic compounds (Anjum, Sundaram, & Rai, 2014). Moreover, the material has been demonstrated to exhibit potent antioxidant capacity, antimicrobial and antibiotic properties (Chabuck, Al-Charrakh, Hindi, & Hindi, 2013; Fidrianny, Kiki Rizki, & Insanu, 2014; Oliveira & Furlong, 2008; Vijayakumar, Presannakumar, & Vijayalakshmi, 2008). As such, it is a promising material for further applications in the nutraceutical and pharmaceutical industries.

Phenolics are important secondary metabolites, and are found in high levels in banana peel compared to other fruits (Lim, Lim, & Tee, 2007). Phenolic compounds have been linked with various health benefits, such as prevention of cardiovascular diseases, cancer, diabetes and obesity (Boots, Haenen, & Bast, 2008; Cheng, Dai, Zhou, Yang, & Liu, 2007). They have been effectively used as functional ingredients in foods as they can prevent lipid oxidation and prevent moulds and bacterial growth (Aziz, Farag, Mousa, & Abo-Zaid, 1997; Chen & Ho, 1997). Therefore recovery of these secondary metabolites from banana peel can generate functional ingredients, and consequently add more value to the banana industry. To effectively recover and utilise phenolic compounds from banana peel, it is necessary to understand its chemical profile (especially individual phenolics), factors affecting the levels of phenolic compounds in the peel, and potential use of these metabolites as food ingredients or therapeutic agents. This review comprehensively highlights phenolic compounds which have been identified from within banana peel, reviews its traditional uses as food and medicine, outlines the current applications of this by-product and finally proposes a trend for future studies on banana peel.

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2. Botany and production

Banana belongs to the family Musaceae, including a number of hybrids in the genus *Musa* (Pereira & Maraschin, 2015). The genus *Musa* was further divided into four sections including Eumusa, Rhodochlamys, Australimusa, and Callimusa. The genomes of Eumusa and Rhodoclamys have eleven chromosomes (2n = 22), while the genomes of Callimusa and Australimusa have ten chromosomes (2n = 20). Eumusa is the most geographically widespread section, followed by Australimusa. The other two sections do not produce edible fruit (Pereira & Maraschin, 2015).

The banana plant is known as one of the largest herb groups in the world that can grow up to 15 m and its fruit can be categorised as climacteric (Cordenunsi & Lajolo, 1995). The banana is commonly known as the dessert cultivar, while plantain is referred to as the cooking cultivar (Padam, Tin, Chye, & Abdullah, 2014). There are diploid, triploid, and tetraploid hybrids composed from subspecies of *Musa acuminata* (A) Colla, and between *Musa acuminata* Colla and *Musa balbisiana* (B) Colla. The haploid contribution of the respective species to the cultivars are marked with the letter A and B, which are linked with characteristics of the fruits. For example, fruits from subspecies AA and AAA are dominant cultivars available in the markets and are found to be sweeter than other cultivars. Whereas, cooking bananas or plantains are hybrid triploid cultivars marked as AAB, ABB or BBB containing higher starch content as compared to other cultivars (Pereira & Maraschin, 2015).

The banana is thought to originate from the tropical regions in Southern Asia, and it is now cultivated throughout the world (Anhwange, 2008). It has been reported to be the most popular fruit, which accounts for 16.8% of all the world's fruit production, followed by apple and orange, sharing 11.4% (FAOSTAT., 2013). The world production of banana has increased steadily over the last 20 years from approximately 46 million tonnes in 1993 to around 105 million tonnes in 2013 (Fig. 1). Asia has remained the largest banana producing continent with approximately 57.3% of the total world production. It is followed by Americas, then Africa. Oceania and Europe have the lowest production, which accounts for approximately 0.3% of the total world production (FAOSTAT, 2013). The increase in banana production can be explained by the higher demand due to population growth as well as the increase in cultivated area and productivity. Among the banana producing countries, India ranks first with cultivated area of 722 thousand ha and production of 26.51 million tonnes annually. It is followed by China, the Philippines, Ecuador, Brazil and other five countries as shown in Fig. 2. These top ten countries accounted for approximately 74.5% of the total world banana production (FAOSTAT, 2013). In general, the trend of banana production is on the rise.

3. Phenolic compounds derived from banana peel

Banana peel is a rich source of phenolic compounds (Table 1), with total phenolic content ranging from 4.95 to 47 mg garlic acid equivalent/g dry matter (mg GAE/g DM) (González-Montelongo, Lobo, & González, 2010a; Hernández-Carranza et al., 2016). This level is 1.5–3 times higher than that recorded in the flesh (Sulaiman et al., 2011). In comparison with other fruit peels, such as avocado, pineapple, papaya, passion fruit, water melon and melon, banana peel ranks second in terms of phenolic content (Morais et al., 2015). Banana peel also possesses higher radical scavenging activity and reducing ability when compared to other fruit peels (Morais et al., 2015), with several studies identifying a strong correlation between the level of phenolic content and oxygen radical absorbance capacity, free radical scavenging and ferric reducing ability (Babbar, Oberoi, Uppal, & Patil, 2011; Vu et al., 2016b).

With regards to individual phenolics, more than 40 compounds have been identified from banana peel. They can be broadly classified into four subgroups; including hydroxycinnamic acids (Table 2), flavonols (Table 2), flavan-3-ols (Table 3) and catecholamines (Table 3). Among the identified flavonols, rutin and its conjugates were the most dominant components (Passo Tsamo et al., 2015a; Rebello et al., 2014). Especially the conjugates with hexoses, flavonoid glycosides, mainly 3-rutinosides and predominantly quercetin-based structures were detected in significant quantities (Passo Tsamo et al., 2015a; Rebello et al., 2014). Furthermore, within hydroxycinnamic acids, ferulic acid tends to dominate over other compounds. The hydroxycinnamic acids present in either the acid form or is conjugated with sugars, or with each other (Passo Tsamo et al., 2015a; Waghmare & Kurhade, 2014).

The flavan-3-ols were the largest group of phenolics found in banana peel (Rebello et al., 2014), consisting of monomers, dimers and polymers (tannin) (Table 3). The polymers, known as proanthocyanidins, presents at the highest total concentration of 3952 mg/kg, as (+)-catechin equivalents, followed by dimers, which accounted for around 126 mg/kg as (+)-catechin equivalents (Rebello et al., 2014). Among the monomers, gallocatechin was found in a greater amount (158 mg/100 g DM), which was 5 times higher than found in the fruit pulp. Of note, this compound has been reported to be associated with the potent antioxidant capacity of the banana extract (Someya, Yoshiki, & Okubo, 2002). Moreover, the presence of large amounts of dopamine and L-dopa, catecholamines with significant antioxidant activity, in banana peel has been reported by several studies (González-Montelongo et al., 2010a; Kanazawa & Sakakibara, 2000; Riggin, McCarthy, & Kissinger, 1976). Dopamine is a strong antioxidant and is believed to be significantly attributed to the antioxidant activity of the banana extract (Kanazawa & Sakakibara, 2000). Studies have also reported that the dopamine content in the peel (80–560 mg/100 g) was many times higher than found within the pulp (2.5–10 mg/100 g)

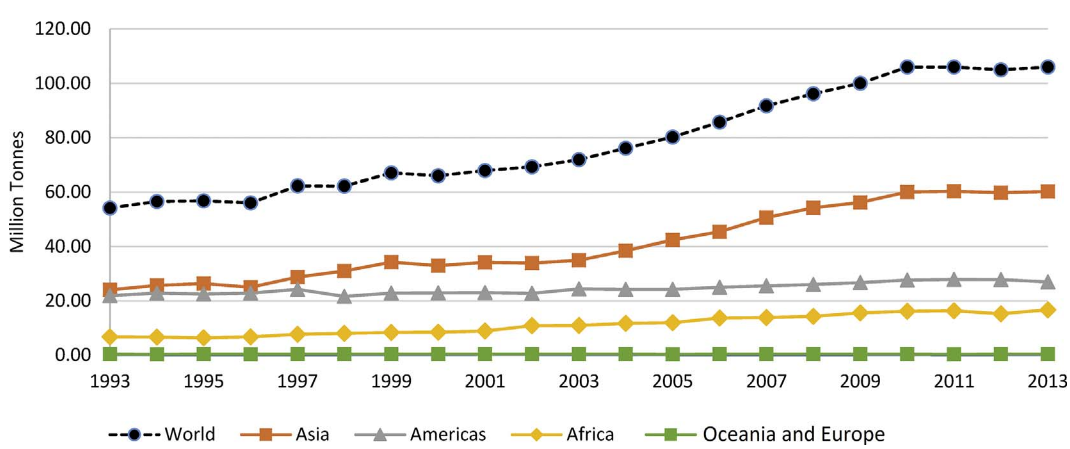

Fig. 1. Banana world production by years (FAOSTAT, 2013).