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Review Article

UTILIZATION OF BANANA PEEL AND PULP AS A
FUNCTIONAL INGREDIENT IN PRODUCT
DEVELOPMENT: A REVIEWChaitali Chakraborty^{2*}, Arunima Mukherjee¹, Bornini Banerjee¹, Shubham Mukherjee¹
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The banana is an edible fruit, botanically a berry, produced by several kinds of large herbaceous flowering plants in the genus *Musa*. *Musa* species are native to tropical Indomalaya and Australia, and are likely to have been first domesticated in Papua New Guinea. They are grown in at least 107 countries. The peel of banana represents about 40% of the total weight of fresh banana and has been underutilized. Peels form about 18-33% of the whole fruit are a waste product. It is thus significant and even essential to find applications for these peels as they can contribute to real environmental problems. Banana is a good source of polyphenols, carotenoids and rich in dietary fiber, proteins, essential amino acids, polyunsaturated fatty acids and potassium. The raw and ripe banana peels were used for the development of products such as bread and noodles. The study suggests that peel extracts of these banana varieties could be useful to combat free radical mediated diseases. The antioxidative property of polyphenols will also prevent lipid oxidation in the food products which causes rancidity, off flavour which leads to reduction of shelf life and nutritive value of food.

Keywords: Banana, Banana peel, Polyphenol, Antioxidant

INTRODUCTION

Banana (*Musa spp.*) is tropical fruit belonging to the Musaceae family. It is the fourth world's most important food crop after rice, wheat and corn (Mahajan *et al.*, 2010). Banana is grown in small scale farms in developing countries where it contributes highly to socioeconomic gain of the farmers because of its long production period. The banana is an edible fruit, botanically a berry,

produced by several kinds of large herbaceous flowering plants in the genus *Musa*. Bananas are one of the most important tropical fruits in the world market. Global production of bananas is estimated to be around 48.9 MT. India is the largest producer of banana with a production figure of 39 thousand tons. The states of Maharashtra and Gujarat in Western India, Karnataka in Southern India and Assam in the

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northeast are large banana growers. Short shelf life and increased production necessitates development of non-conventional products from banana such as chips, puree/pulp, powder, jams, juice, bar, biscuits, wine, etc. The main by-product of the banana processing industry is the peel, accounting 30% of the fruit which constitute environmental hazard. Banana peels, equivalent to 40% of the total weight of fresh banana. At present, these peels are not being used for any other purposes and are mostly dumped as solid waste at large expense. It is thus significant and even essential to find applications for these peels as they can contribute to real environmental problems. Potential applications for banana peel depend on its chemical composition. Banana peels are rich in fibre, vitamin B6, vitamin C, potassium and magnesium. Peel is low in calories, sugar, fats and cholesterol.

Banana has good nutritional and therapeutic value; therefore it may be possible to produce functional food from it. The high value of organic content (lipids, proteins and carbohydrate) indicates that banana peels are good source of carbohydrates and fibers. High fiber content also indicates that the peels could help treat constipation and improve general health and well being. As banana grows in humid low lands to upload tropical areas (Banerjee *et al.*, 2010). Being as a tropical plant, banana protects itself from the oxidative stress caused by strong sunshine and high temperature by producing large amount of antioxidants (Mokbel and Hashinaga, 2005). Nguyen *et al.* (2003) reported the total amount of phenolic compound in banana (*Musa accuminata*, *colla* AAA) peel ranges from 0.90 to 3 g/100 gm of DW. Someya *et al.* (2002) identified gallic acid in banana peel at a concentration of 160 mg/100 g DW. Variation in

ripening and growth stages causes certain changes in polyphenolic content. She has evaluated the antioxidant activity in banana peel, measured as the effect of lipid auto-oxidation, in relation to its gallic acid content. Mokbel and Hashinaga (2005) reported that unripe banana peel displayed high antioxidant activity as increasing the polarity, the extracts exhibited stronger antioxidant activity. Banana peel extract is classified as non-toxic to normal human cells criteria established by the National Cancer Standard Institute. Someya *et al.* (2002), therefore, it can be safely utilized as a natural source of antioxidants and enzyme to cure disease.

Banana is a highly perishable and bulky fruit, which requires processing into a more stable and convenient form. Drying brings about a substantial reduction in weight and volume; thereby minimizing packaging, storage and transportation cost and also enable storability of the product under ambient temperature especially in developing countries (Senadeera *et al.*, 2005). Dried fruits are unique, tasty and nutritious. They are easy to handle and can be easily incorporated during food formulation and preparation. Dried fruit can be eaten as a snack or added to cereals, muffins or ice cream (Etsey *et al.*, 2007; and Reynolds, 2007). Drying is a complex process accompanied by physical and structural changes. There is a continuous change in the dimensions of differently shaped food particulates during drying as a result of water removal and internal collapse of the particulates (Senadeera *et al.*, 2005). Shrinkage is one of the major changes taking place during the drying process and it is observed as changes in the outer dimensions of foods. The present manuscript depicts, the studies carried out to utilize banana pulp and peel

for product development utilize its high antioxidant activity and high fibre content for nutraceutical purpose.

Antioxidant Activity of Banana Pulp and Peel Flours

Lipid oxidation in food components is known as the main undesirable reaction which causes rancidity, polymerization and off-flavor compounds that eventually leads to reduction in shelf life and nutritive value of food. To minimize lipid deterioration, food industries have been relying on synthetic antioxidants such as 2,6-di-tert-butyl-p-hydroxytoluene (BHT), tertbutyl-4-hydroxyanisole (BHA) and Propyl Gallate (PG) to extend the shelf life of their products. The main drawback of using synthetic antioxidants is their potentials of causing health hazards. Thus, safer and natural alternatives of antioxidative compounds are desirable. In this respect, various types of fruit by-products with antioxidant properties have been demonstrated. For example, residues from banana peel (Gonzalez-Montelongo *et al.*, 2010a) have been evaluated as inexpensive sources of antioxidants.

Banana peel represents about 40% of total weight of the fresh fruit (Anhwange *et al.*, 2008). The total amount of phenolic compounds in banana peel has been reported from 0.90 to 3.0 g/100 g dry weight (Someya *et al.*, 2002; and Nguyen *et al.*, 2003). Gallic acid is identified at a concentration of 160 mg/100 g dry weight (Someya *et al.*, 2002). Other phytochemicals such as anthocyanin, delphinidin, cyanidin (Seymour, 1993) and catecholamines (Kanazawa and Sakakibara, 2000) have been identified in ripe banana pulp and peel.

Recent studies demonstrated that banana peel generally include higher phenolic compounds

than that of banana pulps (Someya *et al.*, 2002; Kondo *et al.*, 2005; and Sulaiman *et al.*, 2011). Subagio *et al.* (1996) reported carotenoids such as β -carotene, α -carotene and different xanthophylls in the range of 300-400 μ g lutein equivalents/100 g. Someya *et al.* (2002) attributed antioxidant properties of banana peel to its gallic acid content.

Montelongo *et al.* (2009) found that banana peel extracts obtained in this work had a high capacity to scavenge 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and 2, 2'-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS+) free radicals, and they were also good lipid peroxidation inhibitors. Acetone:water extracts were found to be considerably more effective (compared with methanol, ethanol, acetone, water, methanol:water or ethanol:water) at inhibiting the peroxidation of lipids in the β -carotene/linoleic acid system or scavenging free radicals. Banana peel contained large amounts of dopamine and L-dopa, catecholamines with a significant antioxidant activity. However, ascorbic acid, tocopherols or phytosterols were not detected in the different extracts.

(Saifullah *et al.*, 2012) studied the influence of variety (Cavendish and Dream), stage of ripeness (green and ripe) and parts (pulp and peel) on antioxidative compounds and antioxidant activity of banana fruit.

DIFFERENT TYPES OF BANANA PEEL PRODUCTS

Xylitol from Banana Peel

Xylitol is the first rare sugar that has global market due to having beneficial health properties and being an alternative to current conventional sweeteners. Xylitol is naturally found in low concentrations in the fibers of many fruits and

vegetables, and can be extracted from various berries, oats, and mushrooms, as well as fibrous material such as corn husks and sugar cane bagasse. A study compared xylitol to other artificial sweeteners found that xylitol had fewer or no side effects, had fewer calories, and was less likely to cause cavities (that is, had lower cariogenicity) than sucrose.

Rehman *et al.* (2013) used banana peel as a substrate for xylitol production. Hydrolysate was detoxified by neutralization, activated charcoal treatment and vacuum evaporation. Effect of pH was tested for *C. tropicalis* at three different levels and pH value of 2.5 was found to be the best; producing 24.7 g L⁻¹ xylitol.

Rusks were prepared by replacing sucrose with xylitol at different levels. Physicochemical analysis of rusks at different intervals of storage was carried out. The increase in moisture content and decreasing trend in other parameters with storage were observed in rusks.

Xylitol has low calorific value as compared to sucrose so it can be incorporated into dietetic foods which may help in controlling sugar level in diabetic patients.

Ethanol from Banana Peel

Fuel is the basic need of any country. Rising concerns with the contribution of fossil fuels to global warming coupled with their global depletion trends provide added impetus to the research for alternative fuels that are environment friendly. Continued utilization of these fuels and poor regeneration practices of traditional sources of fuels are the major challenges for the fast growing human population (Cattalo *et al.*, 2002; and Malgwi *et al.*, 2003). Now a day, due to high industrial growth, the fossil fuel sources are rapidly disappeared and day by day, cost of petrol,

diesel and natural gas increases due to high demand and scarcity of sources. In last 10 years, the fuel cost increases approximately 150%, so scientists are move toward the sources of renewable energy. Biofuel is one of them. Bioethanol and Biodiesel are the example of Biofuel.

Ethanol is widely viewed as a viable alternative. This is particularly so, because in addition to its use in boosting the transport sector and ensuring environmental quality, it can also catalyze agricultural productions. More so, it has other economic implications as it can be put to many uses. Ethanol can be used as an organic extractant in many chemical industries (Kosaric, *et al.*, 1990). Thus, it can be used as solvent in detergents, paints, printing inks and dyes. It can also be useful in latex processing and photochemical applications. It can also be used as food in beverages and it is a constituent of pharmaceutical and medicinal preparation such as cough syrup, mouthwash and other disinfectants. In the recent years, cellulosic biomass from agricultural residues is in focus. This can to a large extent reduce the ethanol production costs (Nwabueze Tu *et al.*, 2006; and Sharma *et al.*, 2007). Today for the production of Bioethanol various substrate are used like sugarcane bagasses, sugarcane molasses and cellulosic substrates. Due to high utilization of the substrate, they are rapidly disappeared so, it's time to find out the new substrate which may be useful for the fermentation industry. Banana peel is one of them (Tanaka *et al.*, 1999; and Paramanik *et al.*, 2005). Nutrient composition of Banana peels (Ranzani *et al.*, 1996; and Anonymous *et al.*, 2001 and 2005) is given in Table 1.

Element	Concentration (mg/g)
Potassium	78.10 ± 6.58
Calcium	19.20 ± 0.00
Sodium	24.30 ± 0.12
Iron	0.61 ± 0.22
Manganese	76.20 ± 0.00
Bromine	0.04 ± 0.00
Rubidium	0.21 ± 0.05
Strontium	0.03 ± 0.01
Zirconium	0.02 ± 0.00
Niobium	0.02 ± 0.00

Source: Ranzani et al. (1996) and Anonymous et al. (2001 and 2005)

Banana Peel Flour

Ranzani *et al.* (1996) conducted chemical and biological evaluation of ripe banana peel, aiming its potential use as a source of dietary fiber in human nutrition. Banana peel flour revealed to be an important source of fiber (NDF), corresponding about 32% of its dried weight. The addition of this flour to a basal casein diet lowered its protein digestibility and increased the fecal bulk of the rats, which are the known effects of dietary fiber. However, it did not alter the protein quality, since there was no difference in the PER values of the diets studied; in addition, the growth of the rats fed diets containing banana peel did not differ from those fed control diet. These results suggest the feasibility of technological studies aiming the development of food products with banana peel.

Alkarkhi *et al.* (2011) prepared banana pulp and peel flour from green and ripe Cavendish banana which were assessed for physicochemical properties such as pH, Total Soluble Solids (TSS), Water Holding Capacity (WHC) and Oil Holding Capacity (OHC) colour values, Back Extrusion

Force (BEF) and viscosity. Data obtained were analysed by MANOVA, discriminant analysis and cluster analysis. All statistical analyses showed that physicochemical properties of flour prepared from pulp and peel, and green and ripe banana were different from each other.

Green Banana Peel Flour Noodle

Studies have been conducted to investigate banana peel, including the production of banana peel flour (Ranzani *et al.*, 1996), the effects of ripeness stage on the dietary fibre components and pectin of banana peels (Emaga *et al.*, 2008) and the chemical composition of banana peel, as influenced by the maturation stage and varieties of banana (Emaga *et al.*, 2007). As these studies indicated a high content of dietary fibre in the peel, it would be possible to utilize the peel as a functional ingredient in starch-rich products such as the yellow noodles.

Saifullah *et al.* (2009) prepared Banana Peel (BP) noodles by partial substitution of wheat flour with green banana peel flour. Cavendish banana peel flour was assessed of parameters such as pH, color, tensile strength and elasticity, and in-vitro Hydrolysis Index (HI) and estimated Glycemic Index (GI). BP noodles was found to have lower L* (darker) and b* values (less yellow) but higher tensile strength and elasticity modulus than control noodles.

Following an in-vitro starch hydrolysis studies, it was found that GI of BP noodles was lower than control noodles. Partial substitution of green banana peel into noodles may be useful for controlling starch hydrolysis of yellow noodles.

BP noodles had a lower estimated glycemic indices, higher tensile strength and elasticity values as compared to control noodles. The modified noodle product described in this study

may broaden the range of low glycemic index foods and increase innovation of products from banana peel flour.

Banana Peel Flour Cake

Celiac Disease is an autoimmune disorder affecting primarily the small intestine that occurs in people who are genetically predisposed ("Celiac Disease". NIDDKD, June 2015). Coeliac disease is caused by a reaction to gluten, which are various proteins found in wheat and in other grains such as barley, and rye (Di Sabatino *et al.*, 2009; Penagini *et al.*, 2013; and Tovoli *et al.*, 2015).

The only known effective treatment is a strict lifelong gluten-free diet, which leads to recovery of the intestinal mucosa, improves symptoms, and reduced risk of developing complications in most people (See *et al.*, 2015). Most gluten-free food product on the market is rich in starch but poor in terms of other nutrients, functional and health beneficial ingredients. Green (unripe) banana is a good source of resistant starch, non-starch polysaccharides including dietary fiber, antioxidants, polyphenols, essential minerals such as potassium, various vitamins, e.g., provitamin A, carotenoid, B1, B2, C which are important for human health (Türker *et al.*, 2016).

Türker *et al.* (2016) developed nutritious and functional gluten free cake formulations by substituting Green Banana Peel Flour (GBPF) with rice flour (5%, 10%, 15% and 20%) and to investigate physical properties of GBPF substituted cakes. As a result, GBPF substituted gluten free cakes were successfully produced. Physical analyses of gluten free cakes showed that 5% and 10% GBPF substitution did not affect gluten free cake volume, specific volume, density and baking loss negatively. 5% and 10% GBPF

substituted cakes were not different from control cake statistically ($p > 0.05$). However, substitution levels of 15% and 20% resulted in poorer physical properties. Sensory analysis indicated that all GBPF substitution levels were acceptable, as determined by hedonic scale tests. By developing a nutritious gluten free cake alternative, it is expected to provide an alternative in the dietary diversity of individuals with celiac disease.

Banana Peel Flour Donuts

Futeri *et al.* (2014) used of banana peel flour with different concentrations to prepare donuts. It turned out to affect the organoleptic properties of the donut. Of hedonic organoleptic test, the results of the average value of the ratio between wheat flour with flour banana skin that gave the best results for color, aroma, and flavor that is a donut with banana peel flour ratio of 0% to 100% wheat flour and donuts with banana peel flour ratio 10% with 90% wheat flour, but the texture will be best results are donuts of banana peels can be made by substituting wheat flour with flour banana skin at 10%.

DIFFERENT TYPES OF BANANA PULP PRODUCTS

Banana Flour

Banana flour is an excellent alternative to minimize postharvest losses and to retain the nutritive value of fresh bananas. Unripe banana flour is rich in resistant starch, dietary fiber, and aids in colon health. Ripe banana flour contains high amount of iron calcium, potassium and reducing sugars which helps in better blood circulation and also aids in curbing the craving for nicotine, caffeine.

Potential value added products such as cookies from unripe banana flour and bread from ripe banana flour can prepared to determine the

utilization of banana flour as functional food ingredient. The development of nutraceutical ingredients is of current interest for the food industry.

Singham *et al.* (2014) studied the comparative effect on physico-chemical, re-constitutional and sensory qualities of prepared unripe and ripe banana pulp flour during the storage of sixty days at ambient conditions. Water absorption capacity of unripe banana flour was found to be greater than ripe banana flour. Due to presence of sugars in ripe banana flour, its hygroscopicity was much higher than unripe banana flour.

Rodríguez *et al.* (2007) prepared a fibre-rich powder (FRP) by liquefaction of raw banana flour (RBF) and its chemical composition, water- and oil-holding capacity, and antioxidant capacity were evaluated.

Total Dietary Fibre (TDF) was found to be higher in FRP than in the RBF, but the Total Starch (TS), potentially Available Starch (AS) and Resistant Starch (RS) contents were lower in the processed product, since the liquefaction process involves granular disruption and starch hydrolysis, resulting in reduced TS and AS and increased TDF. The reduced RS content is also explained by (Rodríguez *et al.*) by the loss of granular integrity, which is the main factor responsible for the indigestibility of native banana starch. Total indigestible fraction content of FRP was found to be relatively high, the soluble fraction being lower than the insoluble portion. A very fast reduction of DPPH was observed in the presence of FRP, indicating that polyphenols in this preparation efficiently quench free radicals. Tested at various temperatures, the FRP and RBF exhibited similar water- and oil-holding capacities. The main difference was observed in water-holding capacity

at 80 °C, where FRP was less efficient than the raw material, a fact associated with starch gelatinization in RBF treated at that temperature. FRP might be a potential ingredient for development of products with high TDF and indigestible fraction contents, as well as important antioxidant capacity.

Banana Bread

Banana Flour (BF) was obtained from unripe banana (*Musa paradisiacal*L.) and characterized in its chemical composition.

Experimental bread was formulated by (Juarez *et al.*, 2006) with BF flour and the product was studied regarding chemical composition, Available Starch (AS), Resistant Starch (RS) and rate of starch digestion *in vitro*. The chemical composition of BF showed that total starch (73.36%) and dietary fiber (14.52%) were the highest constituents. Of the total starch, available starch was 56.29% and resistant starch 17.50%.

BF bread was found to have higher protein and total starch content than control bread, but the first had higher lipid amount. Appreciable differences were found in available, resistant starch and indigestible fraction between the bread studied, since BF bread showed higher resistant starch and indigestible fraction content. HI-based predicted glycemic index for the BF bread was 65.08%, which was significantly lower than control bread (81.88%), suggesting a “slow carbohydrate” feature for the BF-based goods. Results revealed BF as a potential ingredient for bakery products containing slowly digestible carbohydrates.

Extruded Products

Gamlath (2008) investigated the physical, nutritional and sensory properties of different

ripening stages of banana during extrusion processing in combination with rice flour to develop quality snack products. Dehydrated banana flours at ripening stages 4, 5 and 6 (peel colour) were mixed separately at 40% banana to 60% rice flour levels. The mixtures were extruded through a twin-screw extruder at 120 °C barrel temperature, 220 and 260 r.p.m, screw speed and 12% feed moisture. Increase in ripeness indicated negative effect on expansion and water absorption capacity while increasing the water solubility index and moisture retention (wet basis) of the products. Protein and mineral (except for zinc and copper) content of the products were significantly different ($P < 0.05$) from 4 to 6 of the ripening stages. Most of the essential amino acids in the extruded products increased significantly ($P < 0.05$) at the ripening stage of 6. All the products were within the acceptable range in the 9-point Hedonic scale showing the best texture and flavour scores for stage 4 and 6, respectively. The extruded products show potential as snack products because of their nutritional quality and sensory acceptability.

Banana Chips

Abd Elmoneim Elkhalfifa *et al.* (2014) studied the characteristics of banana chips through baking and frying and to assess nutritive value and the acceptability of this product. Fried banana chips were found to be better quality and acceptability when compared to potato chips. Baked banana chips were found to be lower in quality and had weak acceptability compared with both fried banana chips and fried potato chips.

Abd Elmoneim Elkhalfifa *et al.* (2014) proved the possibility of promoting the use of banana that could had been wasted unnecessarily. The banana chips product was found to be a source

of energy and minerals such as potassium and phosphorous, and its processing as snack was found to be simple, environmentally clean and can be produced at family level given the necessary precautions.

Spicy Banana Muffins

According to (Rudrawar *et al.*, 2015) incorporation of mashed banana, cocoa powder, spices in refined wheat flour with appropriate proportions lead to increase in overall acceptability of final product. Colour characteristics of muffins were found to be affected by increased addition of cocoa powder. Banana pulp and spices are good source of energy, dietary fibres, potassium, amino acids, various vitamins and minerals which imparts special health benefits. It was found that cinnamon in product act as an antimicrobial agent.

Sensory evaluation was conducted and the overall acceptability for sample gaining highest sensory scores was selected for further production and chemical analysis. The chemical composition of muffins of fresh sample was analyzed and it was found that it contains carbohydrates 52.5, protein 4.99, fat 14.5, sugar 20.9 and energy value 360 kcal/100 gm.

Banana Liqueur

Banana beer is an alcoholic beverage made from fermentation of mashed bananas. In this alcoholic drink making process bananas fruits are used as source of carbohydrates and sugar. Banana wine or beer benefit from the good quality of banana juice to have a higher amount of carbohydrates and sugars, minerals and it also has a lower pH value.

According to (Gavimath *et al.*, 2012) the production of banana liqueur form beer bananas was done by incubation of mature green banana

at 20 °C for 4 days of ripening. After the ripe banana fruits were crushed with spear glass (*Impeta cylindrica*) to obtain juice which was pasteurized at 80 °C for 15 min. The wine produced was 9% (v/v) of alcohol content and then proceeded to distillation at 78-82 °C for the production of a brandy which was 89.5% (v/v) of alcoholic strength after check. The 30.19° Brix produced liqueur was checked for physicochemical properties and proved to have 40.5% (v/v) of alcoholic strength with the total acidity of 2.5 g/l, a volatile acidity of 1.03 g/l and a density of 1.045.

CONCLUSION

Banana is rich in resistant starch, dietary fiber, and aids in colon health. Ripe banana flour contains high amount of iron calcium, potassium and reducing sugars which helps in better blood circulation and also aids in curbing the craving for nicotine, caffeine.

Potential value added products such as cookies from unripe banana flour and bread from ripe banana flour can prepared to determine the utilization of banana flour as functional food ingredient. The development of nutraceutical ingredients is of current interest for the food industry.

Banana peel are rich in fibre, vitamin B6, vitamin C, potassium and magnesium. Peel is low in calories, sugar, fats and cholesterol. Banana has good nutritional and therapeutic value; therefore it may be possible to produce functional food from it. The high value of organic content (lipids, proteins and carbohydrate) indicates that banana peels are good source of carbohydrates and fibers. High fiber content also indicates that the peels could help treat constipation and improve general health and

well being. Banana peel extract is classified as non-toxic to normal human cells; therefore it can be safely utilized as a natural source of antioxidants. Though raw banana has many health benefits but due to its unfavorable taste it's not accepted by the people as their daily diet, so by converting the raw banana into products form we can easily provide it to them as a tasty nutritious food.

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APPENDIX

Table 2: Minerals Composition of Banana Peels	
Parameter	Concentration
Moisture (%)	6.70 ± 2.22
Ash (%)	8.50 ± 1.52
Organic matter (%)	91.50 ± 0.05
Protein (%)	0.90 ± 0.25
Crude Lipid (%)	1.70 ± 0.10
Carbohydrate (%)	59.00 ± 1.36
Crude Fiber (%)	31.70 ± 0.25
Hydrogen cyanide (mg/g)	1.33 ± 0.10
Oxalate (mg/g)	0.51 ± 0.14
Phytate (mg/g)	0.28 ± 0.06
Saponins (mg/g)	24.00 ± 0.27

Source: Ranžani et al. (1996) and Anonymous et al. (2001 and 2005)



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