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Exploring the Nutritional, Antioxidant, and Lipid-Lowering Properties of Saba Banana (*Musa acuminata x balbisiana* BBB Group) Peels

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This study investigated the nutritional and functional components of 'saba' banana peel (SBP) to determine its health-promoting potential for special food applications. SBP has undergone analyses measuring proximate composition, vitamin C, antioxidant activity, phytochemical content, estimated glycemic index (eGI), pancreatic lipase inhibition, and cholesterol micellar solubility inhibition. Data were processed using SPSS v20 and expressed as mean ± SD. Proximate analysis showed that SBP contained 83.83 ± 1.06% moisture, 6.74 ± 0.83% crude fat, 5.58 ± 0.24% crude protein, 9.97 ± 0.04% total ash, 9.91 ± 0.10% crude fiber, and 60.08% nitrogen-free extracts. Vitamin C content was found to be 72.15 ± 2.20 mg vitamin C/100 g fresh sample, whereas its antioxidant activity was 53.75 ± 1.29% DPPH inhibition. The eGI of SBP was 77.88 ± 1.42 and the phytochemical content analyses revealed that SBP contained total phenols at 135.61 ± 2.72 mg GAE, total flavonoids at 18.33 ± 0.65 mg catechin equivalent, and total tannins at 65.64 ± 1.97 mg quercetin equivalent. Finally, its pancreatic lipase inhibition was 35.34 ± 4.34%—almost 50% as effective as lipase inhibitor drug Orlistat. Its cholesterol micellar solubility inhibition was 71.40 ± 2.06%—almost 80% as effective as the cholesterol-lowering drug Cholestyramine. SBP had the highest phenolic content when compared with the published values of other fruit peels and far greater lipid-lowering enzyme inhibition effects than the healthy pigmented red and black rice varieties. These findings showed that SBP, which was considered as agricultural waste, contains nutritional properties and bioactive compounds, and can be utilized as food products and nutraceuticals with potentials in ameliorating obesity and associated disorders, providing banana farmers and processors additional revenue for their crops.

Keywords: antilipidemic, antioxidants, banana peels, functional property, nutrient composition

INTRODUCTION

Banana (*Musaceae*) is one of the world's most important fruit crops. According to FAO (2022), the output of bananas increased at a compound annual rate of 3.2% between 2000 and 2017 hitting a record of 114 MT in 2017, up from about 67 MT in 2000. Today's cultivation and domestication of edible desert bananas and plantains involve intricate hybridization and polyploidy between two diploid species, namely *Musa acuminata* "AA genome" and *Musa balbisiana* "BB genome". These sets of genomes may be combined ranging from triploid (AAA, BBB, AAB, ABB) to tetraploid blends to produce the sweet banana for dessert and the plantain usually used for cooking (Padam et al. 2014).

The Philippines is one of the world's leading banana and plantain producers together with India, China, Uganda, Ecuador, and Nigeria (Padam et al. 2014). In 2020, 'saba' banana was the second most popular banana cultivar produced in the Philippines at 2.51M MT, corresponding to 27.7% of the total banana production for this year (PSA 2021). Although being the world's second largest fruit crop, edible bananas are cultivated mainly for their fruits. Thus, banana farms and processing industries

tend to generate several tons of under-used by-products and wastes such as pseudo-stems, stalks, leaves, and peels.

Collectively, a single banana plant produces waste materials of up to 80% of the total plant mass. Particularly for 'saba' banana, fruit peels comprise 40% waste of the total weight of fresh banana (Nagarajaiah and Prakash 2011). At present, banana peels are not being used for any other purposes and are mostly dumped as solid waste at large expenses (Ragab et al. 2016).

Banana peels can be turned into highly profitable outputs that can improve the overall economics of processing units, particularly for the small- to medium-scale banana industry (Padam et al. 2014). It was already reported that banana peels can be used to develop various food products with acceptable sensory qualities and improved nutritional properties, including meat products, bread, cookies, and biscuits (Zaini et al. 2022). With these, this study characterized a mature unripe all green stage SBP in terms of its nutritional and functional properties *in vitro*. The findings of this study can improve the current economic usage of SBP particularly in special food applications, which in turn can potentially help reduce concerns on its disposal and provide additional income for banana farmers and processors.

MATERIALS AND METHODS

Selection and Preparation of Materials

The study used unripe mature all green stage SBP obtained from banana chip processing industries in Lipa City, Batangas and Sta. Cruz, Marinduque, Philippines (Fig. 1). The maturity of the 'saba' banana is determined mainly by its color and appearance as follows: all green (stage 1), green but turning yellow (stage 2), greenish yellow (stage 3), yellow with green tips (stage 4), and yellow with brown flecks (stage 5) (Reginio et al. 2020). All SBP used were of the same maturity and variety. The peel samples were washed initially with tap water to minimize microbial load and remove adhering contaminants such as soil and leaves. The peels were then dried in a drying oven (Memmert GmbH + Co. KG, Germany) at 50°C for 24 h, powdered using an electric grinder (Oster, US), and sieved using 80 mesh to achieve uniform particle size at the Institute of Food Science and Technology—College of Agriculture and Food Science, University of the Philippines Los Baños (UPLB). These samples were used for experiments requiring dried samples.

Fig. 1. Unripe mature all green stage 'saba' banana (left), fresh 'saba' banana peels (middle), and powdered 'saba' banana peels (right).

Proximate analysis was done in an accredited analytical service laboratory in Lipa City, Batangas while the rest of the experiments were conducted in the BioAssay Laboratory of the Institute of Human Nutrition and Food and in the Biochemistry Laboratory of the Institute of Plant Breeding, UPLB. All chemicals and reagents used were of analytical grade and were purchased from Sigma-Aldrich (Singapore).

Proximate Analysis

Proximate composition analysis of SBP included determination of the moisture, crude fat, crude protein, total ash, crude fiber, and nitrogen-free extracts (computed by difference) of the samples. The following experiments were analyzed in triplicates following standardized protocols of the AOAC (2016). Specifically, the protocols used were moisture (930.04), total ash (930.05), crude protein (978.04), crude fiber (930.10), and crude fat (930.09).

Analysis of Vitamin C Content

To determine the vitamin C content of the sample, the method of Ishiwu et al. (2014) was used. Briefly, 1 g of fresh unripe SBP was macerated with 20 mL of 0.40% oxalic acid solution, and then followed by filtration. One mL of filtrate was added with 0.20 mL of 0.01% methylene blue solution and 1 mL of acetate buffer. The solution was diluted to 5.0 mL and the absorbance of the solution was read at 450 nm using a spectrophotometer (Labtronics, India). The calculated slope of vitamin C was 0.0693. The vitamin C content of the sample was calculated using the equation:

Vitamin C (mg/100mL) = mean absorbance x dilution / slope

Analysis of Antioxidant Activity

The following analysis was based on the standardized protocols of Sultana et al. (2008) and, Singh and Prakash (2015) with some modifications. In this analysis, 100 mg of dried powdered SBP was added with 5 mL of 50% methanol solution. The solution was mixed intermittently in a vortex mixer for 10 min (Thermolyne - Marshall Scientific, US) and then filtered. One mL of the prepared extract was added with 4.0 mL distilled water and 1 mL of freshly prepared 1.0 mM diphenyl picrylhydrazyl (DPPH) radical methanolic solution and incubated for 30 min. The absorbance readings were read at 517 nm using

a spectrophotometer (Labtronics, India). Percent DPPH scavenging activity was computed as follows:

% DPPH scavenging activity = [1- (test sample abs / DPPH abs) x 100]

Analysis of Phytochemical Content

Total Phenolic Content (TP)

Total phenolic (TP) content of SBP was measured using only Folin-Ciocalteu reagent (Sigma-Aldrich, Singapore), modified from the method of Alothman et al. (2009). Briefly, 50 mg of dried, powdered SBP was added with 5.0 mL absolute methanol, mixed in a vortex mixer for 30 min, and centrifuged (Kokusan H-103N Series, Japan) at 3000 rpm for 10 min. Then, 0.2 mL of supernatant was obtained and added with 2.8 mL distilled water, 1.0 mL 0.2 M Na_2CO_3, and 0.2 mL of Folin-Ciocalteu phenol reagent. The solution was mixed thoroughly, placed in a boiling water bath for 15 min, cooled, and then read absorbance at 710 nm using a spectrophotometer (Labtronics, India). The standard used was gallic acid (Sigma-Aldrich, Singapore) at 0.10 mg mL^{-1}.

Total Flavonoid Content (TF)

Total flavonoid (TF) content was determined according to the procedure of Sultana et al. (2008) with some modifications. One gram of fresh unripe SBP sample was macerated with 10 mL 50% methanol solution. The resulting methanolic extract of 0.20 mL was added with 2.0 mL distilled water and 0.30 mL 5.0% $NaNO_2$, and allowed to stand for 5 min, then add the 0.30 mL 10% $AlCl_3$, and allowed to stand for another minute, then added with 1.0 mL 1.0M NaOH. The absorbance was read at 510 nm using a spectrophotometer (Labtronics, India). One mg mL^{-1} catechin (Sigma-Aldrich, Singapore) was used as standard.

Total Tannin Content (TT)

Determination of total tannin (TT) content was modified from Karamac et al. (2007) using vanillin method. Fifty mg of the sample was added with 5.0 mL absolute methanol and mixed in a vortex mixer for 20 min. The solution was centrifuged at 3000 rpm for 10 min and the supernatant was collected. One mL aliquot was added with 5.0 mL 1.0% vanillin reagent and was incubated at 30°C for 30 min. The absorbance of the sample was read at 500 nm using a spectrophotometer (Labtronics, India). One mg mL^{-1} quercetin (Sigma-Aldrich, Singapore) was used as standard.

Estimated Glycemic Index (eGI)

The procedure for the estimation of glycemic index was based on the published paper of Goñi et al. (1997). In a 125 mL Erlenmeyer flask, 50 mg of the sample was added with 10 mL of HCl-KCl buffer (pH 1.5). Afterwards, 0.2 mL of a solution containing 1.0 g of pepsin in 10 mL of HCI-KCI buffer was added to the sample and then incubated at 40°C for 1 h in a shaking water bath. It was then added with Tris-Maleate buffer at pH 6.9 until it reached a volume of 25 mL. Addition of 5.0 mL solution of α- amylase in Tris-Maleate buffer containing 2.6 UI was done and then incubated at 37°C in a shaking water bath. From 0 to 180 min, an aliquot of 1 µL was taken every 30 min from the flask. The aliquot was placed in a tube at 100°C and vigorously shaken for 5 min to inactivate the enzyme. The solution was then refrigerated until the end of the incubation time.

Afterwards, 1 mL of 0.4 M sodium acetate buffer at pH 4.75 was added to each aliquot. Thirty µL of amyloglucosidase (from *Aspergillus niger*) was then added to hydrolyze the digested starch into glucose within 45 min at 60°C. Finally, the glucose concentration was measured using 3.0 mL glucose oxidase-peroxidase (GOPOD) kit, where the tubes were incubated at 50°C for 20 min and the absorbance was measured at 510 nm using a spectrophotometer (Labtronics, India) against the reagent blank. The glucose concentration from the sample was computed using the following formula:

D-glucose (µg/0.1mL) = (Absorbance (sample))/ (Absorbance (D-glucose standard [100µg])) x 100

The corresponding starch concentration was calculated by multiplying the glucose concentration by 0.9. The percentage of the total amount of starch hydrolyzed at various intervals of 30, 60, 90, 120, and 180 min was used to indicate the rate of starch digestion. The digestion curve was adjusted to the following non-linear equation established by Goñi et al. (1997) to describe the kinetics of starch hydrolysis:

$$C = C\infty\ (1-e-kt)$$

where C = is the percentage of starch hydrolyzed at time t (min) C∞ = is the equilibrium percentage of starch hydrolyzed after 180 min k = is the kinetic constant.

From the digestion curves obtained during the starch hydrolysis, the area under the hydrolysis curve (AUC) was calculated for the sample using the equation:

$$AUC = C\infty\ (t_f - t_0) - (C\infty/k)\ [1-exp\ [-k(t_f - t_0)]]$$

where t_f = final time (180 min), t_0 = initial time (0 min).

The hydrolysis index was obtained by dividing the area under the hydrolysis curve of each sample by the corresponding area of the reference sample (fresh white bread, GI=100) obtained from Goñi et al. (1997). Then, prediction of the estimated glycemic index (eGI) was calculated using the formula:

$$eGI = 39.71 + (0.549 \times HI)$$

Pancreatic Lipase Inhibition

The pancreatic lipase inhibition assay was carried out using the methods of Chedda et al. (2016). Orlistat was used as the reference control for this assay.

Buffer preparation. A 1100 mM potassium phosphate buffered saline was prepared with 150 mM of sodium chloride. A 0.5% (v/v) of Triton - X-100 was be added with pH set to 7.2.

Enzyme preparation. A porcine lipase enzyme solution was prepared through a gentle vortex by dissolving 6 mg of the enzyme in a 10 mL buffer solution.

Substrate preparation. A p-nitrophenyl butyrate (PNPB) was used as the substrate. The working solution for PNPB was prepared in a vial with 8.493 µL of PNPB stock solution and volume was made up to 10 mL by acetonitrile.

In vitro pancreatic lipase inhibition assay. The total volume of the assay was 200 µL. The mixture contained 25 µL of the test solution, 50 µL enzyme solution, 100 µL buffer solution, and 25 µL substrate solution. Lipase inhibition activity was determined by an enzyme-linked immunosorbent assay (ELISA) 96-well plate reader to measure PNPB hydrolysis to *p*-nitrophenol at 400 nm using a spectrophotometer (Agilent, USA). Percent inhibition was calculated using:

$$\% \ Inhibition = ((B-S)/B) \times 100$$

where, B = absorbance of blank, S = absorbance of sample.

Cholesterol Micellar Solubility

The inhibition of cholesterol micellar solubility was performed using the method of Boungoura et al. (2009). Cholestyramine was used as the reference for this experiment.

For sample preparation, the cholesterol micellar solution was composed of 10 mM sodium taurocholate, 0.4 mM cholesterol, 1 mM oleic acid, 132 mM NaCl, and 15 mM potassium phosphate buffer with the pH of 7.4. The solution was then sonicated for 20 min. The Zak's reagent used was composed of 100 mg ferric chloride dissolved in 1 mL of glacial acetic acid, made to volume in a 100 mL flask using sulfuric acid. The reference control was 1 mg mL^{-1} of cholestyramine. The cholesterol standards were 250 µg mL^{-1}, 125 µg mL^{-1}, 62.50 µg mL^{-1}, 31.25 µg mL^{-1}, and 20 µg mL^{-1}.

Standard calibration curve preparation. The cholesterol with glacial acetic acid standards were prepared with the following concentrations: 20 µg mL^{-1}, 25 µg mL^{-1}, 30 µg mL^{-1}, 35 µg mL^{-1}, 40 µg mL^{-1}, and 45 µg mL^{-1}. Absorbance was recorded at 560 nm using a spectrophotometer (Agilent, USA) and a standard curve was prepared.

In vitro cholesterol micellar solubility inhibition assay. Four hundred µL of the cholesterol micellar solution was added with 50 µL of the buffer and 50 µL of the sample. The solution was incubated at 37°C for 24 h. It was then subjected to centrifugation at 12 000 rpm for 30 min at 37°C. The supernatant was collected and used for cholesterol concentration determination.

Done in triplicates, 80 µL of the sample was pipetted into a 96-well microplate. One hundred µL of glacial acetic acid was added and followed by the addition of 120 µL of Zak's coloring reagent. It was mixed by pipetting the solution. Eighty µL of micellar solution was then added to the control. The solution was incubated for 30 min and its absorbance was measured at 560 nm. The cholesterol binding capacity (%CBC) was calculated from the resulting cholesterol concentrations using:

$$\% \ CBC = ((B-S)/B) \times 100$$

where, B = calculated concentration of blank, S = calculated concentration of sample.

Statistical Analysis

Results were expressed as mean ± standard deviation (SD) using Statistical Package for the Social Sciences (SPSS) software version 20.

RESULTS

Proximate Composition of SBP

Proximate composition allows the determination of the nutritional value of SBP through quantitative evaluation of its macronutrient contents and other main components such as ash, crude fiber, and moisture. This valuable nutrition information is useful for the consumers in making healthy food choices and for the manufacturers in developing products from SBP with nutritional and health values. The results showed that SBP contains 83.83 ± 1.06% moisture, 6.74 ± 0.83% crude fat, 5.58 ± 0.24% crude protein, 9.97 ± 0.04% ash, 9.91 ± 0.10% crude fiber, and 60.08% nitrogen-free extracts (NFE) (Table 1). Most of the proximate values obtained from this study were

Table 1. Proximate composition of unripe mature 'saba' banana peels.

Proximate Parameters	Dried Sample (% per gram)
Moisture	83.83 ± 1.06 (in fresh sample)
Crude fat	6.74 ± 0.83
Crude protein	5.58 ± 0.24
Total ash	9.97 ± 0.04
Crude fiber	9.91 ± 0.10
Nitrogen-free extract*	60.08

*calculated by difference

comparable with values reported by several studies characterizing banana peels in Egypt. Reported moisture content ranges from 88.1% – 90.88%, crude fat from 5.52% – 10.44%, crude protein from 5.21% – 7.57%, and ash content from 12.44% – 13.42% (Aboul-Enein et al. 2016; Ragab et al. 2016).

Conversely, SBP contains relatively higher proximate composition compared with the plantain peels in Nigeria, specifically in terms of moisture, crude protein, crude fat, ash, and NFE content (Adamu et al. 2017). The same is true with banana peels in India (Khawas and Deka 2016) wherein proximate composition differs with that of SBP, particularly in terms of crude fat, crude fiber, and NFE content. These variations in proximate composition of banana peels may be due to fruit varieties, maturity stages, geographical conditions (Arun et al. 2015) and efficiency of extraction methods (Aybastier et al. 2013).

Vitamin C Content of SBP

The vitamin C content of the SBP in the present study was found to be at 72.15 ± 2.20 mg vitamin C per 100 g fresh sample (Table 2). This value was relatively comparable with the values reported in USA and Indian varieties of banana peel having 60.70 mg and 91.30 mg vitamin C per 100 g peel powder, respectively (Puraikalan 2018). The present value, however, was evidently lower than the values obtained by González-Montelongo et al. (2010), wherein Grande Naine and Gruesa cultivars in Spain have vitamin C content as high as 2000 mg and 1900 mg per 100 g sample, respectively.

Table 2. Vitamin C, antioxidant activity, phytochemical content, and estimated glycemic index of unripe mature 'saba' banana peels.

Parameters	Value
Vitamin C	72.15 ± 2.20 mg
Antioxidant activity	53.75 ± 1.29% DPPH scavenging activity
Phytochemical	
Total phenols (TP)	135.61 ± 2.72 mg gallic acid equivalent (GAE)
Total flavonoids (TF)	18.33 ± 0.65 mg catechin equivalent
Total tannins (TT)	65.64 ± 1.97 mg quercetin equivalent
Estimated glycemic index	77.88 ± 1.42

Vitamin C is important for proper cell growth and functioning and in strengthening the immune system. The vitamin C content of SBP is more than twice than the vitamin C content of raw 'saba' flesh which is 32 mg per 100 g (DOST-FNRI 2020). The value is also comparable with two of the commonly consumed fruits in the Philippines, namely ripe papaya and unripe Indian mango (DOST-FNRI 2022), with 74 mg and 61 mg vitamin C per 100 g edible portion, respectively (DOST-FNRI 2020). If utilized in food applications and product development, this amount of vitamin C from 100 g of fresh SBP could contribute to meeting the vitamin C recommended nutrient intake (RNI) of Filipino adults, which is 60 mg for males and 70 mg for females (DOST-FNRI 2018).

Antioxidant Activity of SBP

Antioxidant substances in food can prevent or slow down the oxidative damage caused by free radical accumulation in the body, which in turn supports disease prevention. The percent DPPH scavenging activity of SBP was 53.75 ± 1.29% (Table 2). This finding is comparable with the values reported by Aquino et al. (2016), showing that methanolic extracts from 15 banana peel cultivars in Brazil have % DPPH inhibition ranging from 54.75 – 89.64 %. Conversely, the antioxidant activity of SBP was relatively higher than the % DPPH scavenging activity in the peels of two banana cultivars in Spain namely Grande Naine and Gruesa at 44% and 42%, respectively (González-Montelongo et al. 2010). Same trends were seen in banana peels from India, having at most 45.76% DPPH inhibition (Aboul-Enein et al. 2016).

It is important to note that the DPPH scavenging activity of SBP is at par with some plant-based foods with reported health benefits, including *Curcuma longa* L. or turmeric (Yu et al. 2020) and *Carica papaya* or red lady papaya (Galang et al. 2016).

Phytochemical Content of SBP

Phytochemicals are essential for the prevention and treatment of several diseases due to its antioxidant, anti-inflammatory, anti-carcinogenic, antihypertensive, and cardioprotective properties (Thakur et al. 2020). Table 2 shows the results of the phytochemical content analysis of unripe mature SBP.

Total Phenolic Content (TP)

In this study, the TP content of SBP was found to be at 135.61 ± 2.72 mg GAE per gram of dried sample. The TP obtained from the SBP was in agreement with the *Musa acuminata* peel extracts from Egypt having TP content at 142.5 ± 0.10 mg GAE g^{-1} sample (El Zawawy 2015). On the other hand, the TP of SBP was higher as compared with peels from various banana varieties in Iraq (Niamah 2014), Ecuador (Santacruz and Espinosa Borrero 2017), Egypt (Aboul-Enein et al. 2016), and in Brazil where 15 peels from different banana cultivars have TP values ranging only from 29.02 mg to 61.0 mg GAE g^{-1} sample (Aquino et al. 2016).

Compared with other fruit peels, banana peels had the highest phenolic content when compared to oven-dried peels of pineapple, papaya, passion fruit, watermelon, and melon (Morais et al. 2015). In terms of utilization, the TP content of SBP is more than four-fold higher than some of the common fruits in the Philippines including velvet apple (mabolo), lolly fruit (santol), Jamaica cherry (aratilis), and Chinese laurel (bignay) (Recuenco et al. 2016).

Total Flavonoid Content (TF)

The TF content of SBP was measured to be at 18.33 ± 0.65 mg catechin equivalent per gram of fresh sample. This value was comparable with that of Aboul-Enein et al. (2016), wherein banana peels from Egypt have TF content of 21.04 mg per gram of sample. Conversely, a higher TF value of banana peels at 55.44 mg/g sample was reported in Iraq (Niamah 2014). Nonetheless, TF of SBP was seen to be higher than TF in banana peels from India having only 11.37 mg catechin equivalent/g sample for unripe peels and 8.35 mg catechin equivalent/g sample for ripest peels (Khawas and Deka 2016). Researchers in Egypt even reported TF values of banana peels to be as low as 0.45mg/sample (El Zawawy 2015). This TF value of SBP is significantly higher than some of the common fruits in the Philippines, including lolly fruit (santol), sugar apple (atis), mandarin orange (dalanghita), tamarind (sampalok), jambolan (duhat), dragon fruit, guava (bayabas), and durian with TF less than 3.5 mg CE per gram of fresh sample (Recuenco et al. 2016).

Total Tannin Content (TT)

The TT content of SBP was 65.64 ± 1.97 mg quercetin equivalent per gram of dried sample. This particular TT value of SBP was higher than the TT content of different varieties of banana peels such as in Egypt having only 24.21 mg g^{-1} of sample (Aboul-Enein et al. 2016) to 50.60 mg g^{-1} sample (El Zawawy, 2015), and in Ecuador with only 10.56 mg g^{-1} of sample (Santacruz and Espinosa Borrero 2017).

Estimated Glycemic Index (eGI)

The glycemic index (GI) gauges how rapidly a food raises the blood sugar levels. Consumption of high GI foods results in a quick and high postprandial blood sugar or hyperglycemia which might cause serious health problems like diabetes if not treated. Lower GI foods, which are generally recommended for people with diabetes, have high amylose and resistant starch content. Amylose has long straight glucose molecules making it difficult to gelatinize and digest whereas resistant starch is a carbohydrate that resists digestions in the small intestine (Lal et al. 2021).

Plantain peels generally have high amounts of amylose and resistant starch (Nasrin et al. 2015), which helps slow down the pace of digestion and decreases the rate at which glucose is released and absorbed in the blood (Gbenga-Fabusiwa et al. 2022). In this study, the eGI of SBP was 77.88 ± 1.42 (Table 2), however, this value was relatively higher than the GI international value for banana peels in general which ranges from 28 to 44 (Gbenga-Fabusiwa et al. 2022).

Pancreatic Lipase and Cholesterol Micellar Solubility Inhibition

Table 3 revealed that SBP has 35.34 ± 4.34% pancreatic lipase inhibition, which is almost 50% as effective as the reference lipase inhibitor drug Orlistat (79.08 ± 0.72%). On the other hand, the cholesterol micellar solubility inhibition of SBP was 71.40 ± 2.06%. This value is almost 80% as effective as the cholesterol-lowering drug Cholestyramine (90.54 ± 1.25%), suggesting that SBP could be a potent ingredient in food formulations that can lower cholesterol. These values are far greater than the lipid-lowering potentials of considered healthy rice varieties such as red and black pigmented rice with an average percent inhibition of pancreatic lipase of red and black rice at 17.9% and 20.4%, respectively (Gabriel 2022).

Table 3. Comparison of the pancreatic lipase and cholesterol micellar solubility inhibition of unripe mature 'saba' banana peels against some reference drugs.

Lipid-Lowering Properties	'Saba' Banana Peels	Reference
Pancreatic lipase inhibition	35.34 ± 4.34%	Orlistat (79.08 ± 0.72%)
Cholesterol micellar solubility inhibition	71.40 ± 2.06%	Cholestyramine (90.54 ± 1.25%)

DISCUSSION

SBP could be considered one of the plant matrices with significant amounts of nutritional compounds including crude fat, crude protein, ash, and crude fiber. In fact, SBP has higher protein, fiber, and ash contents than some common fruits like papaya, tomato, mango, and flesh of various banana varieties including 'saba', latundan, and lacatan. As compared with white and brown rice, SBP also has higher fiber and ash contents and about ¾ of the rice protein content (DOST-FNRI 2020). These nutritional components were already established to have beneficial effects in humans and animals, including as main source of energy, building blocks of cellular structures, proper metabolism and organ functions, disease prevention, and immunity (Chen et al. 2018). Moreover, SBP has substantial vitamin C content, at par with common vitamin C-rich fruits like papaya, unripe mango, and strawberry (DOST-FNRI 2020). The vitamin C content of SBP could contribute to its antioxidant properties and other reported health benefits, especially since antioxidants scavenge free radicals, inactivate pro-oxidants, and minimize oxidative stress (Zaini et al. 2022). Aside from vitamin C, the antioxidant activity of banana peels could also be attributed to the other dietary compounds such as β-carotene, α-carotene, and different xanthophylls which are also naturally present in the peels (Kondo et al. 2005).

In terms of phytochemicals, the higher TP, TF, and TF contents of SBP as compared with other banana peels from different countries suggests that SBP could be a good functional ingredient for special food applications. Numerous studies have demonstrated the high bioactive content found in banana peels, which may help in prevention of chronic illnesses and in improving food quality (Hashim et al. 2023). In terms of nutrition, SBP generally has higher TP and TF than some of the common fruits in the Philippines such as lolly fruit (santol), Jamaica cherry (aratilis), sugar apple (atis), mandarin orange (dalanghita), tamarind (sampalok), guava (bayabas), and durian, among others (Recuenco et al. 2016). SBP also has higher antioxidant activity than some peels of other banana varieties in Spain and India (González-Montelongo et al. 2010; Aboul-Enein et al. 2016). Nevertheless, existing studies have showed that phenolics within banana peels possess potent antioxidant and antimicrobial properties and are linked with various health benefits (Vu et al. 2018).

The significant amount of fiber in SBP could have influenced the resulting eGI value. A recent study even showed that that partial substitution of unripe banana peel flour in making biscuits significantly decreased the starch digestion rate in a dose-dependent manner, lowering the eGI of biscuits from high eGI food to intermediate GI food (Bakar et al. 2020). This effect was linked to the added fiber from banana peel powder which traps available water, preventing proper starch swelling and gelatinization and, in turn, results in a poor digestibility rate. The GI value also indicates the antidiabetic potential of a certain food. As compared with low GI foods, high GI items are digested and absorbed into the bloodstream more quickly, resulting in significant, fast increases in blood sugar levels. The antidiabetic potential of banana peel extracts was documented by another study showing improvements in body weight along with reduction in diabetic complications in vivo (Vijay et al. 2022).

Furthermore, the pancreatic lipase inhibition of SBP could be due to the various dietary compounds inherently present in the peels. One probable reason for this observed health-promoting benefit is the presence of pectin, a type of soluble fiber, in the peels of 'saba' banana. It was already reported that various pectic polysaccharides influenced the activity of pancreatic lipase in both the static *in vitro* digestion and simplified models (Aguilera-Angel et al. 2018). Moreover, in a recent study by Estribillo et al. (2022), it was shown that pectin extracted from SBP inhibited pancreatic lipase in vitro but was relatively lower compared to previous studies, possibly due to the crude nature of the extracted pectin and the use of low concentrations of 20 – 60 μg mL^{-1}. The authors cited a study describing the probable mechanism of the inhibition where pectin protonates some portions of the lipase structure preventing the initiation of the lipase action. Other notable compounds to investigate include palmitic acid, 5-methyl-5-(4,8,12-trimethyl-tridecyl)-dihydro-furan-2-one, cycloeucalenol, and stigmasterol which were found to have pancreatic lipase inhibition properties as shown by the chromatographic fractionation of *Musa cavendishii* leaf extracts (Abdel-Raziq et al. 2022).

The cholesterol-lowering property of banana peels may be due to various dietary components namely saponins, tannins, and flavonoids (Berawi and Bimandama 2018). The authors mentioned that the mechanisms of action of these dietary components include inhibition of HMG CoA reductase enzyme, bile acid excretion, cholesterol and bile acid-binding, and antioxidant activity. Herewith, the presence of flavonoids and tannins in SBP could contribute to its observed cholesterol micellar solubility inhibition. Another notable mechanism is through the action of pectin, a soluble fiber. In a recent study, pectin extracted from SBP supplemented at 10% of w/w of the diet was shown to

lower body weight and blood total cholesterol of obese hypercholesterolemic mice mainly via cholesterol and bile acid binding pathways (Bagabaldo et al. 2022).

Given that several studies already showed that banana peels can be used to develop sensory acceptable food products (Zaini et al. 2022), the results of the present study suggest that SBP can be regarded as an ideal raw material for use in special food applications with higher nutritional value and added health benefits. Its utilization for product development and special food formulations can benefit both the supply and demand sides of the market. In particular, it can provide additional income for banana producers and at the same time introduce a cheap material that food manufacturers can use to improve the nutritional and functional health properties of their products. For the demand side, food products with SBP could be beneficial to address concerns related to metabolic syndrome, a cluster of conditions that coexist and raise the risk of heart disease, stroke, and type 2 diabetes.

CONCLUSION

This study revealed that 'saba' banana peel (SBP) has valuable nutritional, antioxidant, and lipid-lowering properties. The resulting nutritive values of SBP was at par or even higher when compared with the reported values from related studies. This suggested that SBP has huge potential to be used as a value-added raw material in developing food products with improved nutritional and functional properties. The findings can increase its commercial usage, help reduce problems in its disposal, and provide banana farmers and small-to-medium scale processors additional value for their crops.

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