



Original Article

The effects of banana peel preparations on the properties of banana peel dietary fibre concentrate

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Abstract

Four different preparation methods of banana peel, dry milling, wet milling, wet milling and tap water washing, and wet milling and hot water washing were investigated on their effects on the chemical composition and properties of the banana peel dietary fibre concentrate (BDFC). The dry milling process gave the BDFC a significant higher fat, protein, and starch content than the wet milling process, resulting in a lower water holding capacity (WHC) and oil holding capacity (OHC). Washing after wet milling could enhance the concentration of total dietary fibre by improving the removal of protein and fat. Washing with hot water after wet milling process caused a higher loss of soluble fibre fraction, resulting in a lower WHC and OHC of the obtained BDFC when compared to washing with tap water. Wet milling and tap water washing gave the BDFC the highest concentration of total and soluble dietary fibre, WHC and OHC.

Keywords: banana peel, dietary fibre, wet milling, dry milling, functional properties

1. Introduction

Banana is one of the most common crops grown in almost all tropical countries, including Thailand. Banana plantations occupy approximately 106,947 ha (data from the Office of Agricultural Economics, Ministry of Agriculture, Thailand for the 2002 growing season); therefore it is an abundant and cheap agricultural product. Banana chip and banana fig are the main products from banana flesh produced by a number of small and medium factories located nationwide. As industrial by-products, peels represent about 30-40 g/ 100 g of fruit weight. This resulted in 200 tons of waste from banana peels in Thailand generated each day and this amount tend to increase annually (Pangnakorn, 2006).

The banana peels waste is normally disposed in municipal landfills, which contribute to the existing environmental problems. However, the problem can be recovered by utilizing its high-added value compounds, including the dietary fibre fraction that has a great potential in the preparation of functional foods.

Dietary fibre has shown beneficial effects in the prevention of several diseases, such as cardiovascular diseases, diverticulosis, constipation, irritable colon, colon cancer, and diabetes (Rodriguez *et al.*, 2006). The fruit fibre has a better quality than other fibre sources due to its high total and soluble fibre content, water and oil holding capacities, and colonic fermentability, as well as a lower phytic acid and caloric value content (Figuerola *et al.*, 2005). A high dietary fibre content of banana peel (about 50 g/ 100 g) is indicative of a good source of dietary fibre (Happi Emaga *et al.*, 2007). Happi Emaga *et al.* (2008) found that the maturation of banana fruits has shown to impact the dietary fibre composi-

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tions of banana peels. Cellulose, lignin, and hemicellulose contents of banana peels, the components of the insoluble dietary fibre fractions, varied from 7 to 12 g/100 g, 6.4 to 9.6 g/100 g and 6.4 to 8.4 g/100 g, respectively, whereas pectin contents, a component of the soluble dietary fibre ranged from 13.0 to 21.7 g/100 g. The concentrations of hydrogen cyanide, an extremely poisonous substance, and oxalate contents in banana peels were found to be 1.33 mg/g and 0.51 mg/g, respectively, falling within the safety limits (Anhwange, 2008). These results indicated that banana peels were safe and valuable functional ingredients for human consumption.

Several technological treatments applied to the fruit residue may affect dietary fibre compositions and functional properties (Lario *et al.*, 2004). Larrauri (1999) observed in fibre powders obtained from mango and orange peels that dietary fibre contents and water holding capacity affected by the time and temperature of washing of the peels. At present, there are no published studies on the suitable processes to produce dietary fibre from banana peel. Therefore, the overall objective of this study was to investigate the influence of different preparation methods of banana peels on the chemical compositions and properties of dietary fibre concentrate used as a raw material for functional foods.

2. Materials and Methods

2.1 Materials

Bananas (Musa ABB) at the color index of 1 (mature green) according to the CSIRO banana ripening guide (CSIRO, 1972) were purchased from the local market. The peels were removed from the flesh with a stainless steel knife. The commercial α -amylase Termamyl 300L Type LS, amyloglucosidase (AMG E) and neutral protease from *B. subtilis* (Neutrase®) were purchased from Novozyme (Krogshoejvej 36, 2880 Bagsverd, Denmark).

2.2 Preparation of banana peel powders

Banana peel powder was prepared utilizing four methods: dry milling (DM), wet milling (WM), wet milling and tap water washing (WM-TW), and wet milling and hot water washing (WM-HW). For the dry milling method, banana peels were dried at 50°C in a hot-air oven overnight, ground by using Udy cyclone mill (Udy cooperation, Colorado USA) and passed a 1 mm screen. The banana peels to water ratio of 1: 5 were blended in a commercial blender and screened through a 1 mm sieve in a wet milling process (WM). After wet milling, the banana peels prepared by WM-TW and WM-HW were washed with tap water and hot water at 95°C in the same amount as used in the WM process for 5 min, respectively. The peel samples were dried at 50°C in a hot air oven for 12 hrs and ground to obtain the banana peel powder with a particle size of less than 1.0 mm.

2.3 Extraction of dietary fibre

Dietary fibre from banana peel was extracted using the method of Yoshimoto *et al.* (2005). The banana peel powder samples were defatted for 12 hrs using hexane as a solvent (5 ml/g sample). The residue was dried at 50°C in a hot air oven to assure complete removal of the solvent. The defatted peel powder was mixed with water (1: 20 w/v ratio). The pH was adjusted to 5.8 by adding 1 N HCl solution. An alpha-amylase was added (0.1 ml/ g sample). The sample was incubated at 95°C for 30 min. after cooling down to 60°C, the pH was adjusted to 7.5 by adding 1 N NaOH. Neutrase® was then added (10 mg/ g sample) and incubated for 30 min at 60°C. After that, the pH was adjusted to 4-4.5 by using 1 N HCl solution. An amyloglucosidase solution was added (0.1 mg/ g sample) at 60°C for 30 min. Finally, the mixture was filtered through Whatman No.4 filter paper and dried in the hot air oven at 50°C for 12 hrs. The dried samples were then powdered in an Udy cyclone mill (Udy cooperation, Colorado USA) using a 1 mm sieve.

2.4 Chemical analysis

Moisture content was determined by using a moisture meter at 105°C. Ash, protein, and lipid content were analyzed according to AACC methods 08-01, 46-13 and 30-25, respectively (AACC, 2000). Total dietary fibre (TDF), insoluble dietary fibre (IDF), and soluble dietary fibre (SDF) contents were determined by enzymatic and gravimetric method of AOAC (Prosky *et al.*, 1988), using a TDF-100 kit obtained from Sigma chemical company, U.S.A.

Water activity was measured by a water activity meter at 25°C (AquaLab Series 3-Decagon).

Color measurements of the banana peel dietary fibre were carried out instrumentally using a color meter (Chroma, CR200, Japan). The CIE chromaticity coordinates (L^* , a^* and b^*) were measured. The L^* values gives a measure of the lightness of the product color from 100 for perfect white to zero for black. The redness/ greenness and yellowness/ blueness are denoted by the a^* and b^* values, respectively.

To evaluate the water holding capacity (WHC) and oil holding capacity (OHC). of the dietary fibres, the amount of water and oil released after centrifugation was quantified according to the modification of centrifugation method of Larrauri *et al.* (1996). The dietary fibre samples of 0.5 g were stirred in 10 ml of water or soybean oil and left at 30°C for 20 min. After that, the mixture was centrifuged at 3,000 \times g for 20 min and the residue was weighed and WHC and OHC calculated as g water or oil per g of dry sample, respectively.

2.5 Statistical analysis

Banana peel dietary fibre concentrate preparation and all analyses were performed in triplicate. Data were

Table 1. Proximate composition of banana peel used for preparation of dietary fibre.

Items	Content (g/100 g dry matter)
Protein	8.6±0.1
Fat	13.1±0.2
Starch	12.78±0.9
Ash	15.25±0.1
Total dietary fibre	50.25±0.2

subjected to analysis of variance (ANOVA) test followed by Duncan multiple range test to compare means at the 5% significance level.

3. Results and Discussion

3.1 Chemical composition

The main components of banana peel used for preparation of dietary fibre were listed in Table 1.

The dry matter of banana peel sample was 11 g/100 g sample, which was similar to the values reported by Happi Emaga *et al.* (2007) (9.5 g/100 g sample). The banana peel had higher fat, ash, and total dietary fibre content, but lower protein and starch content than those of the banana peels at stage 1 of ripeness reported by Happi Emaga *et al.* (2007) (4.2, 12.8, 37.3, 3.6 and 9.5 g/100 g dry matter, respectively). This might be due to the differences in varieties and due to geographical factors. In comparison with the peels of other fruits, the protein and fat content of the banana peel were greater than those of lemon peel (7 and 2.5 g/100 g dry matter, respectively) and sweet orange peel (9.1 and 2.6 g/100 g dry matter, respectively). On the other hand, it had lower total dietary fibre content than fibre obtained from different sources of fruit industrial by-products (60-78 g/100 g dry matter) as reported by Figuerola *et al.* (2005), Llobera and Canellas (2007), Marin *et al.* (2007). Therefore the removal of the fraction of fat, protein, and starch from the banana peel powders prepared by the different prepara-

tion methods was performed in this study in order to enhance the content of the dietary fibre and lower the content of fat, starch, and protein to obtain the low caloric value products. Moreover, fat and protein trapped inside the fiber matrix have the evidence to retard the water hydration properties of dietary fibres (Raghvendra *et al.*, 2004; Yamazaki *et al.*, 2005).

3.2 Yield

Yields after the removal of protein, starch, and fat from banana peel powder prepared by the different banana peel preparation methods were shown in Table 2. The banana peel dietary fibre concentrates (BDFC) prepared by DM had significantly higher yield than those prepared by the other methods ($P \leq 0.05$). In this method, no water washing was performed, therefore, there was no loss of undesired components associated to dietary fibre, such as sugar washing out with water. This result was in accordance with the results of the orange peel dietary fibre preparation reported by Larrauri (1999). Hot water washing caused significantly higher loss than tap water washing ($P \leq 0.05$) due to the additional loss in the low molecular weight carbohydrate from the thermal degradation, the leaching to the processed water, and the solubilization of insoluble dietary fibre components (Nyman *et al.*, 1987).

3.2 Chemical composition

Chemical compositions of BDFCs prepared by different methods are shown in Table 2. Protein contents of the banana peel dietary fibres were in the range of 2.09-3.04 g/100 g dry matter, indicating that 55-76 g/100 g of the protein content in banana peel was removed by neutral protease extraction. The methods of preparation significantly affected the protein content left in the BDFCs ($P \leq 0.05$). The protein content of BDFC prepared by wet milling tended to be higher than that prepared by dry milling, although no significant difference was observed. The protein contents in the BDFCs prepared by WM-TW and WM-HW were signifi-

Table 2. Chemical compositions of the banana dietary fibre concentrates prepared by different methods.

Preparation Methods	Yield (g/100 g dry weight of banana peel)	Chemical composition (g/100 g dry matter of dietary fibre)						
		Protein	Fat	Starch	TDF	SDF	IDF	IDF/SDF
DM	44.0	3.86±0.03b	1.43±0.01c	4.62±0.01c	83.00±0.28a	12.84±0.13a	70.16±0.27a	5.46:1
WM	41.9	3.44±0.04b	0.73±0.18b	4.08±0.02b	87.77±0.35b	17.10±0.30c	70.67±0.37a	4.13:1
WM-TW	37.3	2.09±0.04a	0.66±0.01b	4.08±0.02b	89.21±0.85c	17.84±0.13c	71.37±0.63ab	4.00:1
WM-HW	35.6	2.04±0.04a	0.74±0.07b	2.71±0.01a	89.35±0.62c	16.29±0.00b	73.06±0.62b	4.48:1

Values are means ± standard deviations of three replicate measurements. Treatments followed by same letter (a, b, ...) in a column were not significant different ($P > 0.05$).

DM = Dry milling, WM = Wet milling, DM-TW = Wet milling and tap water washing, and WM-HW = Wet milling and hot water washing.

antly lower than those prepared by DM and WM ($P \leq 0.05$). The wet milling process was known to effectively separate protein-containing and non-protein-containing products by softening the plant tissue for milling, helping breakdown the protein, and also removing certain soluble constituents (Adejuyitan *et al.*, 2008). The washing process allows for the soluble proteins to be removed from fibres, especially hot water washing, which additionally solubilized more proteins to water by denaturing and made more susceptible to enzyme.

Fat contents of the banana peel dietary fibre concentrates ranged between 0.66 and 1.43 g/100 g dry matter; were lower than fat contents in dietary fibre concentrates derived from grape fruit (3.24 g/g dry matter), lemon (1.89 g/100 g dry matter), and apple (2.44 g/100 g dry matter) found by Figuerola *et al.* (2005) and Llobera and Canellas (2007). The methods of banana peel preparation had significant influence on fat content in the BDFCs. Dietary fibre prepared from dry milling process had significantly higher fat content than those prepared from wet milling processes ($P \leq 0.05$). It might be due to the removal of some types of fats during water treatment. Christie (2003) pointed out that most complex lipids are slightly soluble in water and at least form micellar solutions, and lipids such as polyphosphoinositides, lysophospholipids, acyl-carnitines, and coenzyme A esters are especially soluble in water.

Starch contents in the BDFCs were in the range of 2.71 g/100 g dry matter and 4.62 g/100 g dry matter, indicating that 64-78 g/100 g of starch in the banana peel was removed by amylase enzyme. The BDFC prepared by dry milling process had significantly higher starch content left in the product than those prepared by wet milling processes ($P \leq 0.05$). In wet milling, the plant fibres were hydrated, resulting in a differential swelling and making the starch separation more effective (Cabrales *et al.*, 2006). The washing by hot water could produce the BDFCs with significantly lower starch content than the others ($P \leq 0.05$). It might be due to the fact that hot water washing caused the starch to gelatinize, involving the dissolution of hydrogen bonds among and within starch molecules to open the molecules up to hydration and enzymatic hydrolysis (Hall, 2003).

Table 2 shows the total dietary fibre (TDF), insoluble dietary fibre (IDF), soluble dietary fibre (SDF) contents of the BDFCs, and ratio between IDF and SDF. The BDFCs had more than 80 g/100 g dry matter of TDF. According to Femenia *et al.* (1997) and Larrauri (1999), these products could be considered as a rich source of dietary fibre. The BDFCs had higher TDF content than found in the dietary fibre concentrate from processing by-products of fruits and greens (35.8-38.8 g/100 g dry matter) reported by Grigelmo-Miguel and Martin-Belloso (1999b), and in the lemon peel dietary fibre (66-70.4 g/100 g dry matter) reported by Ubando-Rivera *et al.* (2005).

IDF was the predominant fraction in all samples. The insoluble dietary fiber ranged between 70.16-73.06 g/100 g dry matter. IDF in banana peel fibre as reported by Aregheore

(2005) includes hemicellulose (10.1 g/100 g), cellulose (25.6 g/100 g), and lignin (12.3 g/100 g). This class of dietary fiber is insoluble in water. It is possible that the BDFCs have pronounced effects on intestinal regulation and stool volume, which are related to the consumption of IDF (Grigelmo-Miguel *et al.*, 1999a). The BDFCs prepared by wet milling process and subjected to hot water washing had the highest IDF content, followed by the BDFC prepared by WM-TW, DM, and WM. This may be explained by a concentration effect. The SDF fraction in the banana fibres ranged between 12.84-17.84 g/100 g dry matter, which was greater than the previously described values for dietary fibre from residues from juice extraction of grape fruit (4-6 g/100 g dry matter), lemon (6-9 g/100 g dry matter), orange (10 g/100 g dry matter) reported by Figuerola *et al.* (2005), and DF concentrates from processing by-products of apple (13.8 g/100 g dry matter), pear (14.1 g/100 g dry matter), orange (13.6 g/100 g dry matter), peach (9.71 g/100 g dry matter), artichoke (10.4 g/100 g dry matter), and asparagus (10 g/100 g dry matter) reported by Grigelmo-Miguel and Martin-Belloso (1999b). Soluble dietary fiber in banana peels includes pectin (Madhav and Pushpalatha (2002), Happi Emaga *et al.*, 2008), fructans (Rodriguez *et al.*, 2006), oligosaccharides and arabinoxylan (Zhang *et al.*, 2004). This type of dietary fiber is soluble in water. The result suggests that the BDFCs could possibly be used as a good source of soluble DF in many food applications. The BDFC prepared by dry milling process showed the lowest SDF due to a higher content of impurities such as fat, starch, and protein, which are higher than other samples subjected to wet milling and water washing. No significant difference was found between the BDFCs prepared from WM and WM-TW, which had DF with higher SDF than those subjected to wet milling and hot water washing. It is due to the fact that hot water treatment caused the solubilization of polysaccharides, resulting in the loss of the dietary fibre components, especially in the low molecular weight carbohydrates (Larrauri, 1999; Tatjana *et al.*, 2002).

There were found different IDF/ SDF ratios in the samples studied ranging between 4:1 in BDFCs obtained using wet milling and tap water washing and 5.46:1 in BDFC obtained using dry milling process. These values are lower than those in lemon (9.9:1) and apple (12.9:1) but are comparable to the values of grape fruit (5.9:1) and orange (5.3:1) reported by Figuerola *et al.* (2005). The ratio values from the banana peel DF are close to the well-balanced values according to the recommendation of Spiller (1986) (1.0-2.3:1) in order to obtain the physiological effect associated with both the soluble and insoluble fractions. No significant effect of the preparation methods on the IDF/SDF ratio was observed.

3.4 Water holding capacity (WHC) and oil holding capacity (OHC)

WHC and OHC are important properties of DF from both a physiological and technological point of views. The

BDFCs had high WHC (9.25-10.52 g water/g dry matter) except the sample prepared from dry milling process (Table 3). This is in accordance with the results reported by Lario *et al.* (2004). The lower values of WHC found in the BDFC prepared by DM in comparison with the other methods of preparation could be attributed to the lower content of soluble DF comprising some components in the plant tissue materials having the ability to hold water such as pectin, fructan, and arabinoxylan (Stephen and Cummings, 1979; Marin *et al.*, 2007) and the higher content of protein and fat retarding hydration capacity of dietary fibers (Raghvendra *et al.*, 2004; Yamazaki *et al.*, 2005). Moreover, dry milling affected its physical structure by breaking pores and therefore, the increasing fiber density and so reducing WHC (Cadden, 1987). The WHC values of the BDFCs in this study presented a great value in comparison with peach dietary fibre concentrate (9.2-9.3 g water/g fibre) reported by Grigelmo-Miguel *et al.* (1999). The high WHC of the BDFCs indicates the potentiality to be used as a functional ingredient to avoid syneresis and to modify the viscosity and texture of formulated products (Grigelmo-Miguel *et al.*, 1999).

OHC is another functional property of some ingredients used in formulated food (Kuntz, 1994). Ingredients with high OHC are useful as emulsifiers for high fat food products. OHC was significantly influenced by the preparation methods ($P \leq 0.05$) (Table 3). The DM resulted in the lowest OHC, while no significant difference was found among the other three methods of preparations. The preparation methods of banana peels may have an influence on the factors affecting the OHC of dietary fibre, including surface properties, overall charge density, thickener, and hydrophobic nature of the fibre particle (Femenia *et al.*, 1997). The values of OHC of the BDFCs were much higher than those of peach DF (1 g oil/g fibre) reported by Grigelmo-Miguel *et al.* (1999) and orange fibre DF concentrate (1.2 g oil/g fibre) reported by Grigelmo-Miguel and Martin-Belloso (1999a). The high OHC of the BDFCs suggests their potential use as fibre-rich ingredient in food-stuffs requiring oil retention and cholesterol absorption.

3.5 Water activity

Water activity (A_w) values of the BDFCs were in the range of 0.43-0.53 (Table 3). These values of A_w of all samples were lower than the minimum level at which micro-organism can grow (about 0.61) (Beauchat, 1981). The wet milling and washing previous to drying enhanced the A_w reduction compared with dry milling. These results are in agreement with those reported by Lario *et al.* (2004).

3.6 Color

All BDFCs presented brown color, which could be defined as yellow color with low lightness. The WM-HW resulted in the BDFC with lighter colors than the others, whereas WM and WM-TW yielded a darker color than the others (Table 4). The b^* value of the BDFC made by DM process was significantly lower than those of the samples prepared by the other three methods ($P \leq 0.05$), which agrees with the reports from Lario *et al.* (2004). These results might be attributed to the fact the wet milling caused the cell damage, resulting in the phenolic substrate available in the fruit coming into contact with the browning enzyme polyphenoloxidase.

4. Conclusions

Banana peel is a good source of dietary fibre exhibiting 50 g/100 g dry matter. The different preparation method had an influence on the properties of banana peel dietary fibre concentrate obtained subsequently after removal of fat, protein, and starch fraction. Dry milling process yielded the banana dietary fibre concentrates with significantly higher fat, protein, and starch residue than wet milling processes ($P \leq 0.05$), resulting in the lower dietary fibre concentration. Among the wet milling processes, washing with either tap or hot water contributed to the removal of protein fraction, enhancing the total dietary fibre concentration. Although the wet milling and hot water washing process could reduce

Table 3. Water Holding Capacity (WHC), Oil Holding Capacity (OHC) and Water activity (A_w) of the banana dietary fibre concentrates prepared by different methods.

Preparation method	WHC(g water/g fibre)	OHC(g oil/g fibre)	A_w
DM	6.57±0.15a	4.75±0.01a	0.53±0.00d
WM	9.62±0.03b	5.23±0.69b	0.46±0.00c
WM-TW	10.52±0.36c	5.77±0.01b	0.43±0.00a
WM-HW	9.25±0.35b	5.17±0.03b	0.45±0.01b

Values are means ± standard deviations of three replicate measurements. Treatments followed by same letter (a, b, ...) in a column were not significant different ($P > 0.05$). DM = Dry milling, WM = Wet milling, DM-TW = Wet milling and tap water washing, and WM-HW = Wet milling and hot water washing.

Table 4. Color of the banana dietary fibre concentrate prepared by different methods.

Preparation method	L*	a*	b*
DM	41.14±0.21b	5.67±0.18a	16.44±0.22a
WM	32.23±2.28a	7.94±0.36b	18.39±0.74b
WM-TW	35.50±2.20a	7.69±0.36b	18.19±0.86b
WM-HW	45.04±0.47c	5.24±0.11a	18.45±0.10b

Values are means±standard deviations of three replicate measurements. Treatments followed by same letter (a, b, ...) in a column were not significant different ($P>0.05$). DM = Dry milling, WM = Wet milling, DM-TW = Wet milling and tap water washing, and WM-HW = Wet milling and hot water washing.

higher starch fraction in the dietary fibre, the higher loss of soluble fibre fraction was observed. Wet milling and tap water washing gave the banana peel dietary fibre concentrate having the highest WHC and OHC. This results indicated that this treatment was the most effective method to provide an opportunity to enhance the functionality of dietary fibre concentrate and hence to use the banana peel dietary fibre concentrate as a low-caloric functional ingredient for fibre enrichment, although the incorporation of them within the food system may slightly affect the color of the final product.

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