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Research Article
Chemical and Functional Properties of Cavendish Jepara 30 (*Musa cavendishii*) Banana Pseudostem Flour after Blanching and Soaking in Sodium Bisulphite Solution

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Abstract

Background and Objectives: Cavendish Jepara 30 (*Musa cavendishii*) banana pseudostem in Indonesia is very abundant and has not been utilized because it is considered to be waste. The pseudostem contains dietary fibre, resistant starch (RS) and antioxidants that are strongly affected by several factors such as plant varieties and processing techniques. This study was conducted to investigate the effect of blanching and soaking in sodium bisulphite solution on changes in dietary fibre, resistant starch, antioxidants and the functional properties of Cavendish Jepara 30 banana pseudostem flour. **Materials and Methods:** Banana pseudostem of Cavendish Jepara 30 varieties were obtained from PT. Nusantara Tropical Farm Central Lampung, Indonesia. Preparation of the banana pseudostem flour included a blanching treatment at a temperature of 100°C for 10 min or soaking in 1% sodium bisulphite solution for 90 min. **Results:** The blanching treatment significantly increased the amount of soluble fibre by 3.55%, RS by 10.33%, total phenolic acids by 11.19 mg/100 g and antioxidant activity by 6.15% radical scavenging activity (RSA) but decreased the amount of insoluble fibre by 5.78%. The soaking treatment significantly increased the RS by 9.38% and the antioxidant activity by 12.5% RSA but decreased the insoluble fibre by 6.87%, the total fibre by 6.42% and the total phenolic acids by 17.52 mg/100 g. The blanching treatment also significantly increased the water holding capacity by10.81%, the swelling capacity by 13.87% and the cation exchange capacity was 9.75 meq kg^{-1}. The microscopic structure of the flour after the blanching treatment was more porous and hollower than the natural pseudostem flour. **Conclusion:** Blanching treatment significantly increased the soluble fibre, RS, total phenolic acid content, antioxidant activity, water holding capacity, swelling capacity and cation exchange capacity of banana pseudostem flour. Blanching had no effect on the oil holding capacity of flour.

Key words: Antioxidant, banana pseudostem flour, dietary fibre, resistant starch, soluble fibre

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Changes in lifestyle factors such as reduced physical activity, consumption of high cholesterol foods and low fibre intake have caused an increase in dyslipidemia[1]. Dyslipidaemia is a disorder of lipid metabolism characterized by an increase in LDL and total cholesterol, an increase in triglycerides and a decrease in HDL cholesterol in blood plasma[2]. The condition of dyslipidaemia must be treated immediately because it can trigger various diseases such as coronary heart disease[3]. At present, efforts to treat dyslipidaemia are still dominated by the use of statin drugs or other hypolipidaemic drugs[2]. The use of these dyslipidaemia drugs has been declared clinically safe but they can cause adverse side effects. Another alternative to improve the condition of dyslipidaemia, especially hypercholesterolemia, is the consumption of foods that contain a lot of bioactive components such as dietary fibre, resistant starch (RS)[1] and antioxidants[4-5]. Utilization of dietary fibre, RS and antioxidants in improving hypercholesterol conditions is very feasible because of their ease of availability and safety. Most parts of plants and fruits contain dietary fibre and natural antioxidants.

One part of the plant that contains a lot of edible fibre, RS and antioxidants is the Tender Core of the Banana Pseudostem (BP), which is currently considered to be a waste product of banana plants. A previous study reported that the Tender Core of the Banana Pseudostem of Cavendish Jepara 30 (CBP) waste at PT. Nusantara Trofical Farm (NTF) banana plantation in Central Lampung reached 240,000 stems/month. Currently, CBP is not being processed because it is considered waste. In other countries such as India and Malaysia, BP has long been consumed after undergoing processing such as cooking[6]. Its utilization has begun to vary as it has become a fibre source in the pulp and energy producing industries[7]and the latest possible use of BP is as a source of dietary fibre and antioxidants. This utilization is closely related to the bioactive components of BP, especially its dietary fibre and antioxidants contents. Some previous studies have stated that BP has a very high total fibre and phenolic acid content (46.09% and 1245 mg GAE/100 g dry weight, respectively)[8]. In addition, BP also contains high resistant starch (RS) at 12.81%[9]. Based on its composition, BP has the potential to be used as a new source of food fibre and antioxidants. Furthermore, processing it into a more practical form such as flour is believed to increase its value as a fibre-enriched flour full of antioxidants that have physiological effects on human health, such as improving the condition of dyslipidaemia by lowering cholesterol[4]. However, its content of fibre, nutrients and antioxidant compounds is affected by soil factors, climate, collection time, botany and specific banana variety[10].

In addition, the processing of BP into flour or other products can affect its colour and dietary fibre, RS and antioxidant content as well as its general nutritional value. Soaking in sodium bisulphite solution could minimize its brown colour that is caused by the activity of the latent polyphenol oxidase (LPPO) enzymes and Maillard reactions[11-12]. The appropriate use of heat, in addition to improving the colour of the product, could also improve the fibre, RS and antioxidant content[13-15]. The dietary fibre content and RS are closely related to its functional properties such as its water holding capacity (WHC), its oil holding capacity (OHC), its swelling capacity (SC) and its cation exchange capacity[16], which in turn affect the nature of the hypercholesterol effect of BP flour.

However, there are currently no studies related to changes in chemical properties such as dietary fibre, RS, antioxidants and functionalities such as WHC, OHC, SC, or the cation capacity of local Indonesian Cavendish BP flour. The purpose of this study was to determine the effect of blanching and soaking in sodium bisulphite solution on changes in dietary fibre, resistant starch and antioxidants content and the functional properties of CBP flour.

MATERIALS AND METHODS

Materials: The waste of the Tender Core of Banana Pseudostem of Cavendish Jepara 30 (CBP) was obtained from a banana plantation, the PT Nusantara Tropical Farm (NTF) Terbanggi Besar, Lampung, Indonesia. The freshest BP waste was selected, which was ±1 days post-harvest of the bananas. All chemicals used were derived from the type of chemical intended for analysis (analytical grade).

CBP flour processing: CBP flour production followed the CBP flour making procedure carried out by previous researchers with a slight modification[17]. CBP was cut with a 7-inch stainless knife Zebra cleaver Smart into 20-60 cm pieces. Then, the CBP was cleansed with tap water and divided into 3 groups according to the variations in the processing procedures, namely:

- Natural CBP (CBPA),
- CBP blanching temperature 100°C for 10 min (CBPB10)
- CBP soaked in 1% sodium bisulphite solution for 90 min (CBPS90)

Furthermore, the CBP was thinly sliced into ±2 mm with a J23-Maksindo vegetable slicer machine and for the CBPA was put into a plastic basin container without water, for the

CBPB10 it was placed in a plastic basin container containing clean water for ±10 min, drained then heated at 100°C for 10 min. Meanwhile, after slicing, the CBPS90 was placed in a plastic basin container containing 1% sodium bisulphite solution and soaked for 90 min. Subsequently, the CBPA, CBPB10 andCBPS90 slices were dried in an oven at a temperature of 55°C for ±96 h. The dried CBPA, CBPB10 and CBPS90 slices were then ground finely with a milling machine from *Mitra Usaha Mandiri* and sifted through an 80-mesh sieve. The final result was CBPA, CBPB10 and CBPS90 flour packaged in airtight plastic bags and then stored at 4°C before use.

Chemical analysis: Chemical analysis of the CBP flour was carried out in three replications according to the AOAC procedure, including moisture content, ash content, micro-Kjeldahl crude protein, crude fat Soxhlet extraction and total carbohydrate calculated based on percentage differences[18].

Dietary fibre measurement: Soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) were measured in the following way[19]: 1 g of sample and a duplicate were weighed to an accuracy of 0.1 mg and put in a 500 mL Erlenmeyer flask and then, we added sodium phosphate (25 ml, 0.1 M, pH 6.0) and Termamyl 120 L (100 µL, Novo US industry) and the container was covered with aluminium foil. Afterwards, the container was incubated at 80°C for 15 min with shaking. The container was cooled, then 20 mL of aquadest water was added and the pH was lowered to 1.5 with 4 M HCl. Then, 100 mg pepsin was added to the container and the container was closed and incubated in a 40°C water bath with shaking for 60 min. After the container was cooled, 20 mL of aquadest water was added and the pH was increased to 6.8 by adding 4 M NaOH. Next,100 mg of pancreatin was put into the container and the container was closed and incubated at 40°C in a water bath with shaking for 60 min. Then, the pH was reduced to 4.5 with HCl and the solution was filtered through a crucible containing 500 mg celite and washed with 10 mL of aquadest water twice. The residual IDF was washed with 10 mL of 94% ethanol twice, cured at 105°C overnight (D1), then weighed and heated at 550°C overnight (I1). SDF was measured after adding 400 mL of 94% warm ethanol (60°C) to the filtrate and the precipitate was left to form for 1 h. The solution was filtered as before and then washed with 10 mL 78 and 94% ethanol twice. The precipitate (SDF) was dried at 105°C overnight (D2) and then weighed as in the IDF sample (I2). Blanks were treated according to the same procedure without adding samples. Dietary fibre content could be obtained using the formulae:

$$IDF = \frac{(D1 - I1 - B1)}{W} \times 100\% \quad (1)$$

$$SDF = \frac{(D2 - I2 - B2)}{W} \times 100\% \quad (2)$$

Total fibre content = (1)+(2)

Where

D = Weight of sample in (g) after the oven
I = Weight of sample(g) after precipitation
B = Weight (g) ash free blank
W = Sample weight (g)

Resistant Starch (RS) measurement: RS was measured using the method of Goni *et al.*[20]. A 100 mg sample of BP flour was placed in a centrifuge tube and then, 10 mL of KCl-HCl pH 1.5 buffer was added, followed by200 µL of pepsin solution (500 mg pepsin/5 mL KCL-HCl buffer) and vortexing to mix. Then, the container was put in a 40°C waterbath for 60 min with constant shaking. Next, the container was cooled to room temperature. After cooling, we added 9 mL of 0.1 M Tris maleate buffer pH 6.9 and 1000 µL of α-amylase solution (40 mg α-amylase per 1000 µL of Tris maleate buffer). Then, the container was placed for 16 h in a 37°C water bath with constant shaking. Next, it was centrifuged at 2500 g for 20 min and then, the supernatant was discarded and the precipitate was subsequently washed with 10 mL of aquadest water. Then, it was centrifuged again and the supernatant was removed. Next,3 mL of aquadest water was carefully added to the precipitate followed by 3 mL of KOH 4M. The container was placed for 30 min in a 37°C waterbath with constant shaking. Then, we added 5.5 mL of HCl 2M and 3 mL sodium acetate buffer 0.4 M with a pH of 4.75 followed by 80 µL of amyloglucosidase; it was mixed well and placed in a 60°C water bath for 45 min with constant shaking and then centrifuged at 2500 g for 20 min. The supernatant was taken and stored in a volume tube. Then, the residue was washed with 10 mL of aquadest water and centrifuged again. Next, the supernatant was collected and aquadest water was added up to 50 mL.

A standard curve was made from a glucose solution 10-60 ppm from ki GOD PAP. Next, 0.5 mL of each sample, water and the standard were placed into the measurement tubes. Then, we added 1 mL of the GOD PAP reagent kit and incubated it in a 37°C water bath for 30 min. Furthermore, it was monitored at 510 nm against the blank (5 min after incubation). RS was calculated using the standard glucose curve. RS was expressed as glucose×0.9.

Total phenolic level measurement: Total phenolic levels were measured using the method of Senter *et al.*[21]. The preparation of the standard gallic acid solutions was as follows: (a) Making gallic acid stock solutions of 20 mg/100 mL, (b) Placing the stock solution at 2, 1.6, 1.2, 0.8, 0.4 and 0 mL into 6 consecutive test tubes, (c) The addition of distilled water to bring the volume of each tube in sequence up to 2 mL, (d) Taking as much as 0.2 mL from each dilution, (e) Adding 1 mL of the Folin reagent with 0.8 mL of a 7.5% Na_2CO_3 solution and 3 mL of distilled water to each tube then mixing using a vortex, (f) Incubation for 30 min, (g) Measuring the absorbance at 750 nm. For determination of the total phenolic acid levels: (a) We took 1 mL of the BP flour samples, (b) Added 1 mL of the Folin reagent, 0.8 mL of a 7.5% Na_2CO_3 solution and 3 mL of distilled water then mixed it using a vortex, (c) Incubated it for 30 min, (d) Measured the absorbance with a spectrophotometer at λ750 nm, (e) calculated the total phenolic levels using the standard gallic acid curve. The total phenolic levels were expressed in terms of mg/100 g of ingredients.

Measurement of antioxidant activity: Antioxidant activity was measured using the DPPH free radical scavenging activity method of Hatano *et al.*[22] in Yen and Chen[23]. First, 200 mg of sample was mixed with 5 mL of methanol, then extracted by vortexing for ±1 h. Then, 200 µL of this was added to 5 mL of a methanol solution and 1 mL of a 0.1 mM DPPH solution; then, the mixture was placed in a closed glass test tube and incubated in a 37°C water bath for 30 min. Then, the absorbance was measured in a spectrophotometer at λ517 nm. The antioxidant activity was expressed in units of % radical scavenging activity or % RSA.

Determination of the best treatment: Determination of the best treatment based on colour, soluble fibre content and antioxidants was conducted by applying the principles of the DeGarmo method[24] as described in Diniyah *et al.*[25]. The weighting system was carried out based on the physical and chemical properties. Before being given a weight, a score was assigned to the physical properties test with criterion 3 for the brightest one and 1 for the darkest one. Assessment of the chemical properties test was given for the results of the food fibre and antioxidant tests with a value of 3 for the highest level and a value of 1 for the lowest level. Then, we proceeded by giving a weight to each attribute and its value was adjusted according to the importance of the role of the attributes in the selection. The weighted values for colour, dietary fibre and antioxidants were 30, 40 and 30%, respectively.

Water holding capacity (WHC): A total of 1 g of sample was placed in a closed centrifuge tube container; then, 10 mL of distilled water was added and stirred for 24 h at room temperature. Then, the sample was centrifuged at 3000 g for 30 min. The supernatant was separated and its volume was measured. The WHC was expressed as millilitres of water absorbed by one gram of dry sample according to the method of Chau and Huang[26].

Oil holding capacity (OHC): As much as 1 g of sample was placed in a centrifuge tube; then, we added 10 mL of maizena oil and stirred for 30 min at room temperature. The sample was then centrifuged at 3000 g for 30 min. The supernatant was separated and the volume was measured. OHC was expressed as millilitres of vegetable oil held by the sample based on the method of Chau and Huang[26].

Swelling capacity (SC): A total of 100 mg of sample was placed in a volumetric tube and then, we added 10 mL of distilled water and left it at room temperature for 18 h. The samples were then centrifuged at 2500 g for 15 min and the volume of the supernatant was measured. SC was expressed as millilitres of volume of water absorbed per milligram according to the Robertson *et al.*[27] method.

Cation exchange capacity (CEC): A total of 500 mg of sample was put into a closed Erlenmeyer flask and then, we added 25 mL of 2N hydrochloric acid and incubated it for 24 h with continuous stirring. The suspension was centrifuged at a speed of 2500 for 15 min and then, the residue was washed several times with distilled water until the pH of the supernatant was above 4. The acid residue had 25 mL of sodium chloride 0.3 M added with blanks treated with water followed by stirring and centrifugation. The resulting supernatant was titrated with 0.01 N sodium hydrochloride. The CEC was expressed as meq g^{-1} dry weight according to the Jimenez *et al.*[28] method.

Microscopic image: The samples (flour CBPA and CBPB10) were prepared in the form of a 1% suspension by dissolving the samples in acetone. One drop of the acetone samples suspension was placed on a microscope slide. Then, the samples were put into a specimen holder with double-sided Scotch tape and sputter-coated for sample preparation by the Jinglin *et al.*[29] method. Then, the sample images were taken with an SEM (SU 1510, Hitachi, Japan)using an acceleration voltage of 20 kV at a magnification of 5000×, following the method of Chen *et al.*[30].

Experimental design: The dietary fibre content, RS, total phenolic content and antioxidant activity were measured in triplicate. The data were analysed using one-way analysis of variance (ANOVA), followed by Fisher's Least Significant Difference Test using SPSS version 20.0.

RESULTS AND DISCUSSION

Chemical composition: The chemical composition of the CBPA, CBPB10 and CBPS90 flours Table 1. In general, the chemical composition in regards to the water content, lipid content and carbohydrate content are similar to a previous study about pseudostem flour but the ash and protein content in this study are higher. The moisture content of the CBPA, CBPB10 and CBPS90 flours are presented in Table 1. The recommended moisture content for flour is a maximum of 14%[31]. The levels of ash in the CBPA, CBPB10 and CBPS90 flours varied and were significantly different. This high ash content indicated that all three flours contained a high mineral content. The lipid content of the CBPA, CBPB10 and CBPS90 flours were also significantly different except that the lipid content of the CBPB10 flour was not different compared to the CBPA flour; the lipid levels of the CBPS90 flour were significantly lower compared to the others. This finding was not surprising due to the preparation process, especially the long soaking time. Meanwhile, the protein levels of the CBPA, CBPB10 and CBPS90 flours varied but were not significantly different. The CBPA protein content was higher than the other two flours, probably due to loss (leaching) during the process of preparation, boiling and soaking[14]. Another possibility is that the boiling treatment during processing could dissolve the water-soluble proteins[32]. The carbohydrate levels (by difference) (% d.b.) of the CBPA, CBPB10 andCBPS90 flours were also varied but the differences were not significant. The highest carbohydrate content was obtained from the CBPB10 flour, 59.69%. This was allegedly due to boiling. The level of bisulphite residue in the EBP90 flour was 37.55 ppm. This value was still in the safe category because it is below the limit permitted by The National Agency of Drug and Food Control of Republic of Indonesia (BPOM), which is 70 ppm[33].

Dietary fibre content and RS: Analysis results of the insoluble dietary fibre, soluble dietary fibre and total dietary fibre were varied and significantly different among the CBPA, CBPB10 and CBPS90 flours as presented in Table 2. The lowest content of insoluble dietary fibre was in the CBPS90 flour and the highest was in the CBPA flour. The treatment process involving blanching at 100°C for 10 min for the CBPB10 flour and soaking in a 1% sodium bisulphite solution for the CBPS90 flour could reduce their insoluble dietary fibre content. The results of this study are similar to a previous study stating that the content of insoluble fibre of banana pseudostem flour was 46.09%[8]. The decrease in the content of insoluble fibre in this study is likely due to some of the constituent components of the insoluble fibres, such as cellulose, hemicellulose and lignin, being turned into simple carbohydrates via immersion or cooking, as reported by several previous researchers[10,34]. A decrease in insoluble food fibre content was also reported in a study of bulb onion skin heat treatment. A decrease in the insoluble fibre from the bulb onion skin was due to some insoluble parts of the fibre, such as uronic acid and cellulose, that were damaged or changed[35].

Unlike the insoluble dietary fibre content, the average content of soluble fibre in this study increased. Table 2 shows

Table 1: Chemical composition of natural CBP flour (CBPA), 10 min CBP blanching flour (CBPB10) and CBP flour soaked for 90 min in a sodium bisulphite solution (CBPS90)

Chemical composition (% d.b)	CBPA	CBPB10	CBPS90
Water content (%.w.b)	7.97±0.04^{b}	6.19±0.12^{a}	9.34±0.03^{c}
Ash	31.20±0.03^{a}	26.01±0.01^{b}	30.65±0.17^{a}
Lipid	0.82±0.01^{a}	0.89±0.03^{a}	0.49±0.01^{b}
Protein	7.31±0.08^{a}	7.22±0.06^{a}	6.48±0.18^{a}
Carbohydrate (by difference)	54.30±0.55^{a}	59.69±1.89^{a}	53.04±0.30^{a}
Bisulphite residue (ppm)	-	-	37.55

No. followed by different superscript letters on the same row indicate a significant difference ($p<0.05$)

Table 2: Natural dietary fibre and resistant starch (% db) of CBP flour (CBPA), 10 min CBP blanching flour (CBPB10) and CBP flour soaked for 90 min in a sodium bisulphite solution (CBPS90)

Components (% d.b)	CBPA	CBPB10	CBPS90
Insoluble dietary fibre	43.7±0.50^{a}	37.92±0.62^{b}	36.83±2.06^{b}
Soluble dietary fibre	2.35±0.72^{b}	5.90±0.27^{a}	2.74±0.36^{b}
Total dietary fibre	46.11±0.57^{a}	43.82±0.36^{a}	39.69±2.00^{b}
Resistant starch	2.8±0.08^{c}	13.13±0.32^{a}	12.18±0.30^{b}

Different superscript notations behind the average standard deviation value on the same row show significant differences ($p<0.05$)

Table 3: Total phenolic and antioxidant activity of CBP flour (CBPA), 10 min CBP blanching flour (CBPB10) and CBP flour soaked for 90 min in a sodium bisulphite solution (CBPS90)

Components	CBPA	CBPB10	CBPS90
Total phenolic (mg/100 g)	121.62±1.15[b]	132.81±2.14[a]	104.10±0.46[c]
Antioxidant activity (% RSA)	11.89±0.27[c]	18.04±0.23[b]	24.39±1.22[a]

RSA: Radical scavenging activity, Different superscript notations behind the average standard deviation values on the similar row show significant differences ($p<0.05$)

the CBPB10 soluble fibre content increased by 3.55% compared to the CBPA soluble fibre. The increased levels of soluble dietary fibre are thought to be due to heat treatment resulting in the rupture of the glycosidic bonds from the polysaccharides so that they could release oligosaccharides, which caused an increase in the soluble dietary fibres[34,36].

Meanwhile, the treatment with a blanching temperature of 100°C for 10 min or soaking in sodium bisulphite solution for 90 min decreased the total dietary fibre in the CBP flour. CBPB10 flour that was subjected to the heat treatment had a decrease of 2.29% and the EBP90 flour had a decrease of 6.42% compared to the total dietary fibre of the CBPA flour. The decrease in total dietary fibre in both flours is thought to be due to a decrease in the content of the insoluble fibre, which is part of the total dietary fibre. The total dietary fibre is the combination of insoluble dietary fibres and soluble dietary fibres. Dietary fibre damage during a heating process has been previously reported by Rehinan *et al.*[10].

The RS content (% db) of the CBPA, CBPB10 and CBPS90 flours are presented in Table 2. The results show that the treatment of blanching at 100°C for 10 min (CBPB10) and soaking in 1% sodium bisulphite solution for 90 min (CBPS90) increased the RS content. The results of this study are similar to a previous study about the RS of the pseudostem flour[8].The increase in RS content in CBPB10 flour is thought to be due to the heat treatment (blanching at 100°C for 10 min), drying at 55°C and cooling at room temperature for ±30 min. Heat treatment of food followed by cooling can cause gelatinization and retrogradation of starch[37]. The retrogradation process could possibly increase the content of the food ingredients[14].

The increase of the RS content in the CBPS90 flour is suspected to be due to the immersion treatment in the 1% sodium bisulphite solution for 90 min followed by drying at 55°C. Soaking and cooking significantly increases the resistance of starch[38]. Starch granules experienced bubbling during immersion and undergo gelatinization and retrogradation during heating[39].

Antioxidant activity: Table 3 shows the results of the total analysis of starch phenolic CBPA, CBPB10 and CBPS90 that were significantly different. The highest phenolic totality (132.81%) was found in the CBPB10 flour. The increased total phenolic content in the CBPB10 flour is thought to be due to boiling at 100°C for 10 min[40]. Heat treatment could increase the total phenolic content because it can break the bonds between phenol compounds and polysaccharides[41]. Meanwhile, the lowest total phenolic content was found in the CBPS90 flour at 104.10%. Immersion in the sodium bisulphite solution for a long time is suspected to have dissolved a portion of the total phenolic content, considering that phenol compounds are soluble in water.

The analysis of the antioxidant activity in the CBPA, CBPB10 and CBPS90 flour is presented in Table 3. The antioxidant activity of the CBPB10 and CBPS90 flour increased, with the highest value achieved by the CBPS90 flour, at 24.39%. The high antioxidant activity of the CBPS90 flour is thought to be derived from the total phenolic content of the flour and because it could have additional antioxidant activity derived from the sodium bisulphite, which could act as an antioxidant[42,43]. Sodium bisulphite is classified as an easily oxidized compound similar to sulfite, which can be oxidized to sulfate by large numbers of compounds that use oxygen to oxidize it[44]. Thus, the protected compound is inhibited from the oxidation process. Whereas the increase of the CBPB10 flour activity compared to the CBPA flour is thought to be due to its higher total phenolic levels. Total phenolic levels are positively correlated with antioxidant activity[45].

The best treatment based on colour, fibre content and antioxidants: Determination of the best treatment used the principles of DeGarmo *et al.*[24] in Diniyah *et al.*[25]. Determination of the best treatment in this study was based on the selection of observational parameters that matched the priorities of the study, which included determination of the weight, the worst value and the best value. As shown in Table 4, the best treatment was the CBPB10 flour with a total value of 270.

Functional properties: Table 5 shows the results of the analysis of the functional properties of the CBPA and CBPB10 flour. Their water holding capacity (WHC) was lower when compared to the results of a study reported by previous researchers for banana pseudostem flour (1828%)[8].

The increased water holding capacity of theCBPB10 flour compared to the CBPA flour was thought to be due to its being boiled for 10 min[8].

Table 4: Determination of the best treatment based on colour, fibre content and antioxidants

	Parameters*		
Treatments	Color	Soluble fibre	Total phenolics
CBPA	1	1	2
CBPB10**	2	3	3
CBPS90	3	2	1

CBPA: Natural CBP flour, CBPB10: CBP blanching flour 10 min and CBPS90: CBP flour soaked for 90 min in a sodium bisulphite solution, *colour weight 30, food fibre dissolves 40, phenolic total 30, 1: Lowest value 2: Moderate value 3: High value, **best

Table 5: Functional properties of the CBP flour (CBPA) and 10 min CBP blanching flour (CBPB10)

Functional properties (%)	CBPA	CBPB10
Water holding capacity	433.16±1.54^{b}	443.97±0.97^{a}
Oil holding capacity	300.40±0.55^{a}	297.25±2.44^{a}
Swelling capacity	855.27±1.90^{b}	869.14±2.07^{a}
Cation exchange capacity (meq kg^{-1})	67.24±1.15^{b}	76.99±1.15^{a}

Different superscript notations behind the average standard deviation value on the similar row show significant differences ($p<0.05$)

The results of the analysis of the functional OHC flours CBPA and CBPB10were varied and not significant (Table 5). These OHC values were smaller than that reported in a previous studyon pseudostem flour (388%) but they were larger than the OHC of gayam flour, which ranged from 58-71% and white sword koro flour, which ranged from 106-116%. The OHC of the CBPB10 flour decreased in capacity by 3.15%, from 300.40-297.25%, when compared to the CBPA flour ; this decrease was statistically insignificant. This decrease in the OHC value is similar to the study conducted byWijanarka *et al.*[46]. The decrease in the OHC capacity of the CBPB10 flour is thought to be due to a lower protein content so that the hydrophobic chains of the CBPB10 flour were also lower. The hydrophobic chains of the proteins could integrate with the lipid hydrocarbon chains[47].

The results of the analysis of the swelling capacity (SC) of CBPA and CBPB10 flour varied and were significant (Table 5). The second SC value of this flour was lower than the previous SC value of pseudostem, which was 1382%[8]. However, it was higher (416%) when compared with pre-gelatinization gayam flour. The increase in the swelling capacity by 13.44% of the CBPB10 flour is thought to be due to the boiling process. Heat treatment could increase the particle size of dietary fibre so that it could increase the capacity of swelling[13]. The hydration properties of dietary fibres (WHC and SC) are strongly affected by particle size, porosity and dietary fibre density[35]. In addition, heat treatment also causes the dissolution of amylase during starch gelatinization so that the swilling ability by the starch also increased[48]. The results of the analysis of the cation exchange capacity varied

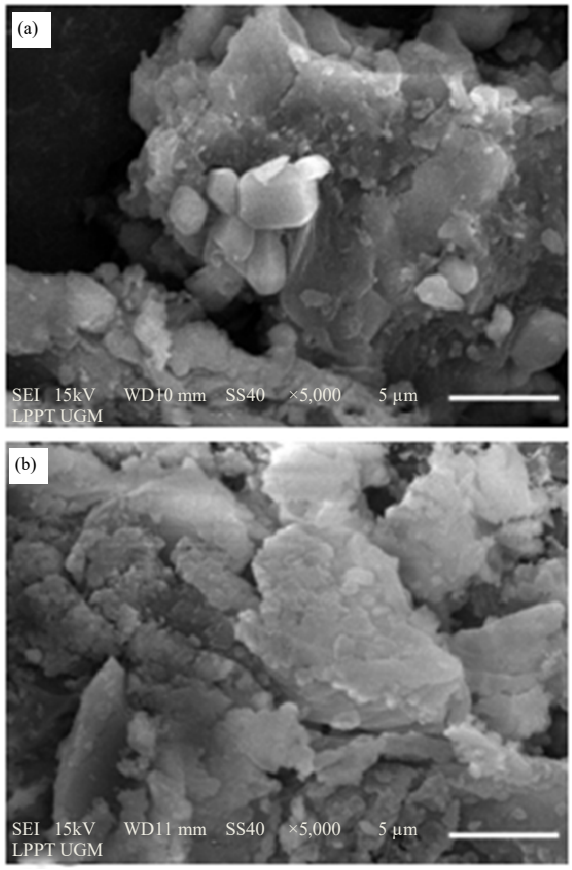

Fig. 1(a-b): Scanning electron microscopic of banana stem flour (a) Natural Cavendish banana pseudostem (b) Blanching Cavendish banana pseudostem

and were also significant for the CBPA and CBPB10 flour (Table 5). The value of the cation exchange capacity (CEC) was lower when compared to the CEC of white sword karo flour that had been treated with autoclaving-cooling, which was 85 meg kg^{-1} but it was higher compared to natural white sword koro at 29 meg kg^{-1} [13]. The increase in the CEC of CBPB10 flour was 9.75 meg kg^{-1} when compared to that of the CBPA flour, allegedly because boiling treatment could increase the amount of acid polysaccharides with free -COOH groups, such as pectin and lignin that could bind to minerals such as Fe[16]. The carboxyl groups and uronic acids in the sugar residue of the fibre constituent components were able to exchange with the surrounding cations[49].

Microscopic image: The microscopic structure of the CBPA and CBPB10 flour are presented in Fig. 1. The microscopic structure of the CBPB10 flour was more porous and hollower when compared to the microscopic structure of the CBPA

flour. This structural change is thought to increase the ability of the CBPB10 flour to bind more water (WHC), oil (OHC), cations and have an increased swelling capacity (SC). Polysaccharides that are subjected to a high heat treatment could cause the structure to change to become more porous and hollower so that it could increase its capacity to hold water, WHC, OHC and SC[50]. Starch granules of gayam flour that were subjected to heat treatment produced a rough surface and a heterogeneous size compared to that from a natural untreated source[46].

CONCLUSION

Blanching at 100°C for 10 min (CBPB10) significantly increased the soluble fibre (3.55%), RS, total phenolic acids and antioxidant activity of the banana pseudostem flour. Immersion in 1% sodium bisulphite solution for 90 min (CBPS90) significantly increased its RS levels and antioxidant activity. Blanching at 100°C for 10 min (CBPB10) significantly increased its WHC, SC, CEC and reduced its OHC but this change was not significant compared to the untreated banana pseudostem flour. These results showed that CBPB10 banana pseudostem flour is potent as a new source of dietary fibre and antioxidants.

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