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Original Research Article

Utilisation of Banana Peel as Functional Ingredient in Product Development

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Abstract: The agro-food industry's exponential growth of plant waste production is a critical global issue, taking into account its storage, disposal, environmental impact and potential health risks. However, by-product utilisation of agricultural waste for the retrieval of added-value compounds offers new avenues for industrial production and waste management. Bananas waste primarily the peels are potentially a useful source for the substitution of value added products such as dietary fibres, bioactive components, including carotenoids, polyphenols, pro-vitamins as well as essential minerals. This project describes the types and the composition of raw banana peel wastes and the bioactive components of the peel, the processing methods and the possible application of banana peel flour (BPF). Of particular interest, the proximate analysis and physicochemical properties of potential BPF and the properties of the by-product are discussed. This information was then used to identify types of food that is suitable for the production industry. Then, the utilisation of banana peel flour in waffle ice cream cones and yellow noodles were chosen. The formulations of BPF were prepared in three different formulations: 10%, 20% and 30% for banana peel noodles and 5%, 10% and 20% for waffle cones, respectively. Overall, BPF substitutions in these food products have affected and improved the cooking properties, nutritional values, colour, texture and sensory characteristics compared to control without any substitution.

Keywords: banana peel waste, banana peel flour (BPF), waste management, banana peel, banana peel yellow noodles, banana peel waffle cones

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1. Introduction

Banana is one of the popular food crops in more than 100 countries especially in tropical and subtropical regions and is believed to play a crucial role in the economy and food security. In addition, bananas are powerful in providing an energy source that is inexpensive and easily processed. Bananas are also rich in some minerals and vitamins A, C and B6. Not only that, the crop can be cultivated in a variety of climates and processing systems, providing a nutritious staple food and a significant revenue stream during the year. Small-scale farmers produce about 87 % of all bananas grown worldwide for home consumption or sale on local and national markets. Based on (Shahbandeh, 2021), banana produced worldwide was around 30460 thousand metric tonnes per year where India is the leading producer followed by China, Indonesia and Brazil. However, many of the edible bananas are cultivated primarily for their fruit, which means that banana farms will produce many tons of underused by-products and waste such as banana leaves, pseudostem, and peels where waste management has tremendous environmental consequences, which can cause severe problems. The fibrous banana peels are usually thrown away after their fruits are taken. Similar to its flesh nutrients, banana peels also offer various beneficial components where it should be something to be utilised instead of landing them in landfills. It may not be normal to eat a banana especially its peeling parts, but people around the world consume it as it is absolutely edible (Szalay, 2017). Also, it is important to remember that the banana peels are not poisonous and they are not toxic either. Studies have also shown that banana peels are an excellent source of fibre, calcium, potassium, and fatty acids (Sampath Kumar, *et al*., 2012). Since this study has revealed a high dietary fibre content in the banana peel, it can be used as a functional ingredient in rich starch products. Therefore, the substitution of BPF can be used in the making of banana peel waffle cones and banana peel noodles.

Hence, the objective of this project also is to study the physicochemical properties of yellow noodle and waffle cones prepared by partial substitution of wheat flour with banana peel flour (BPF). Some parameters including pH, texture, colour, tensile strength, and nutritional values need to be studied in order to define the acceptance of waffle cones and banana noodles. Additionally, the texture of the food must also be noted, as it can affect the processing and storing of the food. However, it also depends on how the food is consumed where the strength will cause changes in the shape and texture of foods. This paper, therefore, aims to study the potential substitution of wheat flour in the processing of banana by-products and wastes which focused more on their peels as well as the complexities of making such by-products a viable asset for the future.

2. Selection of Samples

2.1 Selection of Stage 2 and Stage 5

The selection of banana peels for Stage 2 was from the waste products of banana chips made by small and middle-size enterprises (SMEs), Seri Kembangan while for Stage 5, the banana peels were selected from the waste from a banana stall, Taman Seri Serdang.

2.2 BPF

2.2.1 Preparation of BPF

The banana peels were immersed in a 0.5% solution of citric acid. Then, after 10 minutes, the peels were sliced and dipped back into the citric acid solution and drained. Then the peels were dried in the oven (Memmert Oven, Model 55 internal dimensions 53 litres, 400 x 400 x 330 mm, Germany) at 60°C for around 72 hours until no further sap can be seen. Then, the dried banana peels were milled for about 30 minutes with a 10 minutes interval. The milled powder was then sieved with size distribution according to Table 1. The samples were then placed for further analysis in an air secure package at 5±2°C in a zip lock bag.

Table 1. Particle size range of 3 different sieving mesh values.

Sample	Size of particle range (μm)
A	≤125
B	126–250
C	≥251

2.2.2 Proximate analysis

The moisture content was determined using A&D MX50 moisture analyser. Protein crude, fat, and fibre were determined according to the methods from AOAC (2000). Next, the ash was analysed by putting 5 g sample at 600°C into the muffle furnace, until a greyish colour was obtained. Lastly, the total content of carbohydrates was calculated by difference.

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

One (1) g of each sample was weighed into centrifuge tubes. Then, 25 mL of distilled water or commercial palm oil cooking oil were added and simply stirred for uniform mixing. Then all the tubes were incubated at 40°C for 1 hour. Next, by using Centrifuge (Hettich® Universal 320/320R centrifuge, Merck, Germany), the tubes were centrifuged at 3000 rpm for 20 minutes. The supernatants were drained for about 10 minutes at 45°C and the residues were weighed. The WHC and OHC calculated were in the form of weight of water and oil hold for 1 g sample respectively (Quinn & Paton, 1979).

2.2.4 pH analysis

Using the weighing balance, 4% mass of banana peel powder was weighted. The powder was then poured into the centrifuge tube and 15 mL of distilled water was added to it. The mixture was then vortexed for 5 minutes and allowed to stand for another 30 minutes (Savlak *et al*., 2016). Using a pH meter, the supernatant's acidity was measured. The measurement was done in triplicates.

2.3 Application of BPF

The application of BPF was to make yellow noodles and waffle cones.

2.3.1 Materials

The basic ingredients for noodles and waffle cone preparation were obtained from the local supermarket. Other chemicals and reagents used in the analysis were of analytical grade.

2.3.2 Preparation of banana peel noodle

The noodle formulations used are shown in Table 2. Noodles have been formed using the process (Sirichokworrakit *et al*., 2015) defined. The basic formula for a control noodle was 100 g of wheat flour, 50 mL of distilled water, 1 g of salt and 1 g of Kansui reagent, respectively. Three additional samples of noodles were also prepared by replacing wheat flour with 10 %, 20% and 30% of BPF. The preparation stage of the noodles was the process of mixing, sheeting, cutting and boiling. In the first place, all the necessary ingredients were mixed and processed into noodles using a kitchen aid mixer. The mixer continued to run at a low speed and then proceeded on to a higher speed of 4. Then, slowly, the mixer was stopped to help clean the bowl and the beater. After the mixing process, all the mixed ingredients will be shaped into dough. The dough was prepared to rest for a few minutes. The dough was then sheeted several times through a small noodle machine with the roller distance slowly decreasing and the dough sheet was folded in between passes to achieve homogeneity. The final dough sheet was then cut with a noodle cutting roll with a thickness of 2 mm in width and 1 mm in thickness. The developed noodles were coated with a thin layer of flour to prevent them from sticking together. The noodles obtained were boiled or cooked by placing the noodles in a boiling water saucepan and boiled for 15 minutes. At the end, the cooked noodles were allowed to cool at room temperature for further study. The process was repeated by replacing wheat flour with BPF at different formulations (10% w/w of BPF, 20% w/w of BPF and 30% w/w of BPF).

Table 2. Formulations used for noodle preparation.

Ingredients	Type of noodles			
	Control	**10% w/w BPF**	**20% w/w BPF**	**30% w/w BPF**
Wheat flour (g)	100	90	80	70
Distilled water (ml)	50	50	50	50
Kansui reagent (g)	1	1	1	1
Salt (g)	1	1	1	1
BPF (g)	0	10	20	30

2.3.3 Preparation of waffle cone

The waffle cone formulations are shown in Table 3. The basic formula for waffles was 12 g wheat flour, 80 g sugar, 112 g white eggs, 2 g of salt, and 3 g of vanilla essence. Three further samples of waffles were prepared by replacing wheat flour with 5%, 10% and 20% of banana peel flour. Difference percentages of BPF were used because a decent mixture should have the consistency of waffle batter to be not so smooth and clumpy that it clings to your whisk, yet still not so runny that it's essentially water. First, white eggs and vanilla essence were stirred until bubbles were produced. After that, one by one of the dry and wet components were added starting from wheat flour, BPF, sugar, salt, and fresh milk were added in continuously. The parameters used in the study of batters were pH, density and viscosity. The analysis was done immediately following the mixing operation.

Table 3. Formulation of waffle samples.

Ingredients (g)	Types of waffle			
	Control	**5% w/w BPF**	**10% w/w BPF**	**20% w/w BPF**
Wheat Flour	120	114	108	96
Sugar	80	80	80	80
Egg white	112	112	112	112
Salt	2	2	2	2
Essence vanilla	3	3	3	3
Milk	109	109	109	109
Banana peel flour	0	6	12	24

2.3.5 Colour analysis

Colour analysis of noodles and waffle cones was performed using the UltraScan PRO Spectrophotometer (Hunter Lab, Germany). For each sample, all measurements were done in triplicates at random locations on the surface.

2.3.6 Texture analysis

The texture properties of the banana peel yellow noodles and banana peel waffle cones were measured using a (Texture Analyser, TA. XTplusC, United Kingdom) with optimal test conditions. Measurements were performed at room temperature for 10 min after the noodles were cooked. Instrument settings were pull-to-break mode: test speed 1 mm/s. Two texture parameters were obtained: the tensile strength (maximum force; N) and the length of the break (maximum force distance; mm). Three replicates of noodles were determined for each substitution of banana peel flour (Sirichokworrakit *et al.*, 2015). Next, Ice Cream Cone Support Rig (A/ICC) was used to measure the force required to cause breakage and simulates the stress imposed when an ice cream scoop is forced into the cone. The parameters were obtained: hardness (g), brittleness (mm), toughness (g/sec), crispiness (F) for all ratios of BPF waffle cones tested for cone-shaped waffle and flat-shaped waffle.

3. Results and Discussions

3.1 Chemical composition of dried banana peels

Table 5. The chemical composition of dried banana peels based on their moisture, crude protein, fat and crude fibre.

Proximate component	Stage 2 of Saba Peel	Stage 5 of Saba Peel
Moisture (%w/w)	9.18	9.20
Crude Protein (%w/w)	4.4	5.4
Fat (%w/w)	4.8	3.8
Crude fibre (%w/w)	1.3	1.8

Table 5 shows the proximate composition of moisture, crude protein, fat and crude fibre for Stage 2 and Stage 5 of Saba banana peels. There were no significant differences in the properties between both samples, however, the Stage 2 peels was chosen for the subsequent study because it is an abundant source in the SME industry. The lower moisture content of Stage 2 and Stage 5 has made it suitable to be stored for a long time as it was also in the range of the standard moisture content of flour. Moreover, the quantity of crude fibre in the BPF of Stage 2 was much lower than Stage 5. Similar findings by Khawas & Deka (2016) found that the crude fibre content of banana peels increases as maturity increases. The crude protein content depends on the stage of ripeness. Ogbonna Obiageli *et al*. (2016) observed that as the maturity stage increases, the protein content in the banana peel of Saba also increases. The percentages of fat in both stages were influenced by the longer heating time. Not only that, the method of preparation of the dried banana peel does also affect the crude fibre degradation in the banana peel (Phatcharaporn *et al*., 2009).

3.2 BPF

The analysis of BPF and its properties.

3.2.1 WHC and OHC

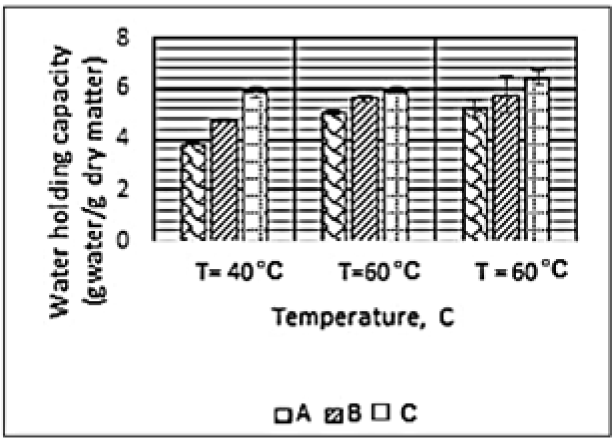

Figure 1. The water holding capacity of Saba banana peel powder for sample A, sample B, and sample C.

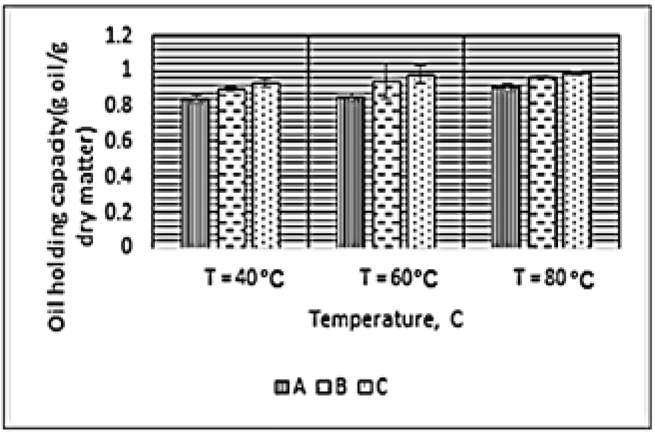

Figure 2. The oil holding capacity of Saba banana peel powder for sample A, sample B, and sample C.

Figure 1 shows the increasing water holding capacity for all the particle sizes as the temperature increases. Sample C which has the biggest sample of particle size, which was more than 250 μm, has the highest value of WHC. This is because as the size of particles gets bigger, the porosity of banana peel powder will become lower and have the ability to hold more water. Thus, we can conclude that the increase in the ability of the banana powder to retain water is due to the increase in particle size.

In Figure 2, Sample C has the highest mean value range (0.91 to 0.99g/sample) of OHC for particle size. The absorption of oil is based on the food's porosity. As the temperature increases, the porosity of the food becomes lower (Li *et al*., 2007). After that, oil is allowed to enter the food as the space of the micro structure creates very low positive vapour pressure. Therefore, sample C can offer the advantages of providing low oil absorption as it decreases the oil content of fried foods such as deep-fried coated food items.

3.2.2 pH Analysis

Table 6. The pH of Saba banana peel powder for sample A, sample B, sample C.

Sample	pH
A	6.16 ± 0.01
B	6.38 ± 0.02
C	6.46 ± 0.01

In the batter analysis, the results showed that the pH of all samples ranged from 6.16-6.46 which can be classified as acidic. Also, the pH of batter using BPF was almost the same as the range of controlled samples which was around 6.02. Therefore, we can consider that BPF has the ability to be a substitution of food products.

3.2.3 Proximate analysis of banana peel flour

Table 7. Proximate Analysis of Banana Peel Flour.

Parameter	[%]
Crude Fibre	16.6± 0.29
Dietary Fibre	35.9± 0.29
Carbohydrate	71.0± 0.27
Moisture content	8.9± 0.022
Ash content	7.0± 0.021
Fat	13.0± 0.02
Protein	6.5± 0.024

Table 7 summarises the results of proximate principles such as fibre, carbohydrate, moisture content, ash, fat and protein of BPF. Fat content in the banana peel was 13.0%. This value shows that the peel could be a great source of carbohydrates and fibre. In addition, the moisture content was found to be at 8.9%. This lower value will lengthen the banana's shelf life without the growth of molds. The amount of protein in the flour of the banana peel depends on the banana's level of maturity.

3.3 Banana Peels Yellow Noodles

The analyses of banana peel yellow noodles and their properties.

3.3.1 Noodle colour analysis

Table 8. Colour characteristics of noodles.

Sample	L*	a*	b*
Control noodle	68.50 ± 0.45	1.55 ± 0.27	22.55 ± 0.75
10% BPF noodle	46.82 ± 2.40	2.89 ± 0.70	9.96 ± 0.82
20% BPF noodle	40.35 ± 0.46	2.37 ± 0.20	7.53 ± 0.33
30% BPF noodle	37.33 ± 0.66	1.75 ± 0.26	5.89 ± 1.06

Figure 3. Control noodle.

Figure 4. 10% banana peel noodle.

Figure 5. 20% banana peel noodle.

Figure 6. 30% banana peel noodle.

The colour characteristics of the noodles are shown in Table 8. Based on the result obtained, it was reported that the colour of the control noodle had higher L * and b * values than the noodles with the replacement of BPF. The noodles with BPF were darker in colour compared to the control noodles. The dull colour may be caused by certain enzymes found in banana peels that lead to the enzymatic browning and also during the drying process of banana peels. This is an acceptable reason, as the enzymatic browning of bananas is a well-known problem (Ramli *et al*., 2009).

3.3.2 Noodle texture analysis

Table 9. Texture characteristics of noodles.

Sample	Tensile Strength (N)	Breaking Length (mm)
Control noodle	0.18 ± 0.40	14.58 ± 0.34
10% BPF noodle	0.17 ± 0.23	12.73 ± 0.20
20% BPF noodle	0.16 ± 0.20	11.86 ± 0.23
30% BPF noodle	0.13 ± 0.21	10.94 ± 0.32

The texture characteristics of the control noodle and the banana peel noodle are compared in Table 9. The noodle texture parameters are based on its tensile strength and the maximum length of breakage. It showed that with the increasing substitution for BPF, the tensile strength of the noodles and their breaking lengths were markedly different where the increase in the substitution of BPF decreased the tensile strength and the breaking length. This is because of the properties of BPF where the protein content is lower than wheat flour. According to Kovacs *et al*. (2004), the low protein content can decrease gluten formation thermostability, which then leads to noodle texture's strength and firmness.

3.4 Waffle Cone

The analysis of banana peels cone-shaped waffles and flat-shaped waffles with their properties.

3.4.1 Colour analysis

Table 10. Colour characteristics of waffle cones.

Sample	Average		
	L*	**a***	**b***
Control	53.45 ± 0.2	13.24 ± 0.2	31.81 ± 0.2
5% BPF	46.75 ± 0.1	12.72 ± 0.4	25.4 ± 0.2
10% BPF	38.09 ± 0.2	12.67 ± 0.2	20.49 ± 0.1
20% BPF	34.61 ± 0.2	10.56 ± 0.1	16.92 ± 0.2

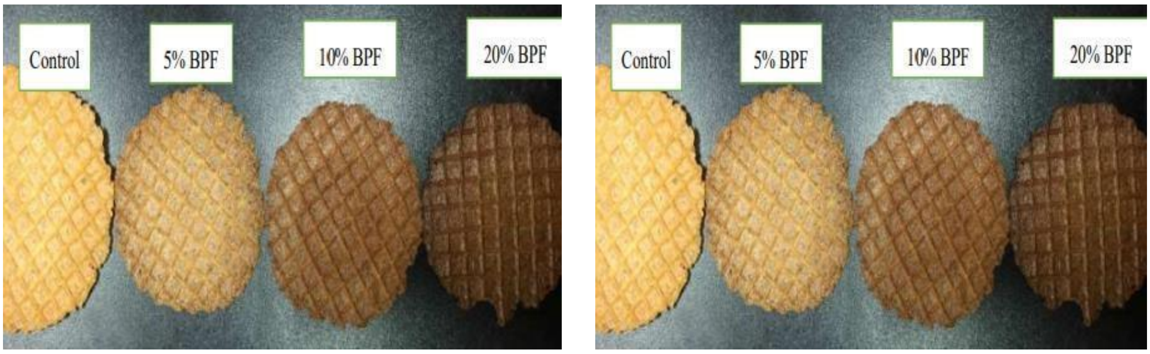

Figure 8. Analysis for Flat-Shaped Waffle.

Colour is one of the most important factors in the determination of market acceptance. In the analysis of colour cones, we found that the addition of BPF would also change the colour of the waffle batter significantly. The L* value of the cone sample ranged from 34 to 53. L* value indicates the range between lightness and darkness (Black, L=0; White, L=100). The reading shows that the control cone has the highest L* value which described it as lighter in colour compared to other samples. The cone with a high fibre content which was 20% BPF could absorb water more and decreased the L* value of the cone which subsequently be a reason for fibre to display a darkening effect. Moreover, the b* values which indicate the yellow or blue coordinates were ranged from 16 to 32. These positive values denoted how yellow the sample were where the result clearly showed that the control sample has the highest b* value compared to the rest. Meanwhile, the a* values were ranged from 10 to 13 indicating the redness of the product sample. These values tell us that the control sample cone was more red due to the large value of a* than other cone samples. The results of a* and b* values also were significantly affected by the presence of fibre content where the addition of BPF could influence those colour coordinate readings**.**

3.4.2 Texture analysis

3.4.2.1 Cone-shaped waffle

Table 11. Texture characteristics of cone- shaped waffle cone.

Sample	Control	5% BPF	10% BPF	20% BPF
Hardness (g)	186.75	392.07	538.21	286.8
Brittleness (mm)	6.86	8.37	6.02	5.99
Toughness (g/sec)	370.15	689.76	596.01	407.74
Crispiness (F)	18.67	14.8	17.67	24.33
Standard Deviation	6.03	4.09	1.53	3.21

3.4.2.2 Flat-sheet waffle

Table 12. Texture characteristics of flat-sheet waffle cone.

Sample	Control	5% BPF	10% BPF	20% BPF
Hardness (g)	880.29	457.88	759.89	438.06
Brittleness (mm)	0.3	0.53	0.42	1.03
Toughness (g/sec)	64.03	60.73	89.38	103.62
Crispiness (F)	5.33	2.33	4.67	4.00
Standard Deviation	4.04	0.58	2.89	1.00

In the texture analysis for cone-shaped and flat-sheet waffles, hardness and firmness are the most commonly evaluated parameters for texture analysis, which has been defined as the required force to achieve a given deformation. The tensile strength of these samples favours the composition of 5% and 10% BPF due to the ability to the maximum load that a material can support without fracture when being stretched. The amount of waffle hardness was dependent on the incorporated compound contents such as fibre and ash content. Besides, hardness increment may be related to the moisture content and density in a sample. Moreover, the crispiness evaluation shows that all of the samples have similar prospects as the control sample where the values are suitable for ice cream cone texture. It is best to have a high value of crispiness analysis as crispiness is defined as a product's most flexible single texture parameter because it was uniformly liked, improved or contrasted texture, and was the popular texture attribute synonymous with high quality cooking.

3.4.3 Sensory Evaluation

Table 13. Sensory evaluation of waffle cones.

Sample Labelled	Colour	Aroma	Taste	Texture	Overall acceptability
Sample Control	4.10	3.67	3.89	4.22	4.11
Sample with 5% BPF	4.11	4.22	3.89	4.67	4.67
Sample with 10% BPF	4.33	4.33	4.11	4.78	4.67
Sample with 20% BPF	4.67	4.67	4.67	5.00	4.80

Sensory evaluation helps to define the product properties that are influential about the customer's product acceptability. In determining the sensory quality of the final product, sensory properties such as taste, aroma, mouth-feel, texture and general acceptability were considered. The percentage of BPF affects the sensory properties of different types of waffle samples. Sample with 20% BPF has the highest rating of all the evaluations where it showed a lot of consumer love to colour, aroma, taste and texture offered by it. Not only that, consumers seemed to prefer functional foods with potential health benefits because of their increased nutrition information.

4. Conclusions

Based on this study, BPF can be utilised to produce value-added food such as waffle cones, and yellow noodles. The high water holding capacity of BPF can lower the tensile strength of wafer cones and fulfil the need for a water binding agent in the bakery and processed meat products industry. Its characteristics of high WHC suit the need of food products such as bread, waffle, cake, biscuit, and cookies in restoring their moisture. Moreover, the utilisation of BPF can provide alternative solutions to reduce oil absorption during the frying of fried food due to its low OHC. Also, the utilisation of BPF in processed food can reduce the dependency on wheat flour in Malaysian food products and improve the development of low gluten foods based on our indigenous resources. Hence, the substitution of BPF into noodles is accepted as the banana peel itself has a good value in WHC and OHC. The enrichment of waffle cones with unripe BPF is an effective way to enhance the nutritional and physiological aspects.

Conflicts of Interest: The authors declare no conflict of interest.

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