EXTRACTION AND UTILIZATION OF WATER-SOLUBLE DIETARY FIBRE (SDF) FROM BANANA PEEL

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Abstract

Development of food supplement plays an important role in functional food processing and it becomes a challenge among people and manufacturers. In this research, water-soluble dietary fibre (SDF) was extracted from banana peels of Hpi Kyam (*Musa chiliocarpa* Backer) and Thi Hmwe (*Musa acuminata* Colla). The extracted SDF was included in wheat noodle formulation. This makes not only innovation but also gets new beneficial products. Cellulase enzyme was utilized in the extraction of SDF. Conventional acid treatment method was also carried out in SDF extraction. The functional properties of extracted SDFs were evaluated. The SDF obtained from banana peel (Hpi Kyam) by cellulase treatment had better characteristics and higher yield percent than that of the banana peel (Thi Hmwe) by acid treatment method. Both SDFs contained minerals such as iron and manganese. The FTIR results showed that SDFs composed of the functional groups which held to enhance the solubility of food. The physico-chemical characteristics of SDF supplemented wheat noodle were determined. In the formulation of noodle making, among the sixteen formulations, a formula of 86.5 % of wheat, 10 % of potato starch, 1.5 % of SDF, 1 % of sodium chloride and 1 % of sodium bicarbonate gave the best results and its characteristics and these nutritional properties were superior than those of the others.

Keywords: water-soluble dietary fibre, acid treatment, cellulase enzyme treatment, noodle formulation

Introduction

Nowadays, consumers become interested in the nutrition and health benefit from the food they eat. This has led to new detections about the linkage between food and health. The basic tendency of human beings has always been to prefer natural foods. Ready-to-eat foods have now moved into the essential point and onto the interest of modern consumers and new living style of people. Banana is one of the most common crops grown in almost all tropical countries, including Myanmar. Banana normally has a short shelf life and starts deteriorating just after plucking. The most widely used part of banana is the flesh of the fruit; meanwhile, the outer skin is only used for animal feed and organic fertilizer. Plantain and unripe banana are cooked as vegetable, chips, snacks, powder etc., whereas, banana is eaten raw. In recent years, banana peel has been utilized for various industrial applications including bio-fuel production, bio-sorbents, pulp and paper, cosmetics, energy related activities, organic fertilizer, environmental cleanup and biotechnology related processes (Benjamin and Ugye, 2008). The banana peel is richer in phytochemical compounds than its pulp. The antifungal, antibiotic properties of banana peel can be put to good use. The banana peels are waste and normally disposed to municipal landfills, which contributes to the existing environmental problems. The best way to solve the waste problem for banana peels is to produce value added compounds, including the dietary fibre fraction that has a great potential in the preparation of functional foods (Prashanthi, 2020). 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

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high total and soluble fibre content, water and oil holding capacities (Figuerola et al., 2005). A high dietary fibre content of banana peel (0.5 g)

is indicative of a good source of dietary fibre. Happi Emaga et al. (2007) found that the maturation of banana fruits has shown its impact on the dietary fibre composition of banana peels.

This research was objected to extract SDF by cellulase enzyme and acid treatment methods. The resulting SDFs were incorporated in the formulation of wheat noodle. Functional groups and mineral contents of SDFs were analyzed by FTIR (Fourier-transform Infrared Spectroscopy) and AAS (Atomic Absorption Spectroscopy). Nutritional properties of processed noodle were also evaluated.

Materials and Methods

Raw Materials

Banana peels were collected from banana-based product shops. They were cleaned and dried in an oven at 70 °C for 6 h. The dried peels were ground by using a grinder and screened with 20 mesh sieve to obtain banana peel powder (+20 mesh). In this research, two types of banana varieties (Hpi Kyam, *Musa chiliocarpa* Backer) and Thi Hmwe, *Musa acuminata* Colla) were used for the extraction of water-soluble dietary fibre. The enzyme *Aspergillus niger*, was purhased from Baodeli Inc. (Henan, China) and other required chemicals were purchased from Empire chemical shop, Pabedan Township, Yangon Region.

Acid Treatment Extraction of Soluble Dietary Fibre (SDF)

20 g of banana peel powder were subjected to extraction by adding 400 mL of distilled water, and pH was adjusted to pH 3.5 with 98 % (36.8 N) sulfuric acid solution by using pH meter (Consort C1010). The mixture was heated at 80 ºC for 4 h with magnetic stirring, and then filtered. The filtrate was concentrated to half of it, and cooled to room temperature. The concentrate was precipitated into 70 % ethanol solution. The ethanol precipitation process lasted for 1 h, and SDF was collected after filtration, and then dried at room temperature. The yield was calculated as a percentage of the obtained SDF to banana peel powder used. The effects of pH on SDF yield were studied by varying the pH of (1.5, 2.5, 3.5, 4.5 and 5.5) and the resulting yield % of SDFs were recorded.

Enzymatic Extraction of Soluble Dietary Fibre (SDF)

In this research work, the cellulase enzyme from *Aspergillus niger*, was used to extracted both SDFs. The enzymatic hydrolysis of banana peel powder was conducted by preparaing (4 % w/v) sodium acetate solution to which 0.02 % (based on peel powder weight) cellulase enzyme was added. The hydrolysis was carried out at 50 °C for 3 h with magnetic stirring, and then filtered. The filtrate was concentrated to become half of its volume, and cooled to room temperature. The concentrate was precipitated into 70 % ethanol solution. The ethanol precipitation process was taken for 1 h, and SDF was collected after filtration, and then dried at room temperature. The yield was calculated as a percentage. The effects of cellulase enzyme concentration on SDF yield were also studied by using (0.005, 0.01, 0.02, 0.03, 0.04) % of cellulase enzyme and the resulting yield % of SDFs were recorded.

Formulations for Wheat Noodle Including SDF

Sixteen experimental runs were conducted for the formulation of noodle processing according to the design arrangement. Design expert version 11 (Analysis of Variance, ANOVA) was applied for the formulation of noodle processing.

About 86.5 % of wheat flour, 10 % of potato starch powder, 1.5 % of SDF, 1 % of salt, and 1 % of sodium bicarbonate were mixed in a container. Then, 55 mL of water was added for making dough. The constituents were mixed at room temperature, and the mixing time was 15-20 min. The dough produced in this process was composed of a fine mesh structure and formed the glutinous dough. The dough was placed into the noodle extruder. Before the dough was extruded, the dough was sometimes aged for a period of time. In this process, the dough was made strong, and uniform. The dough was extruded directly into the boiling water. The noodles were boiled in water for 10 min. The resulting wet noodle were filtered with stainless steel screen, and then dried in an oven at 70 °C for 4 h.

Observation of Surface Morphology

Surface morphology of banana peel powder and SDFs were observed by using Scanning Electron Microscopy (SEM), (JSM- 5610 LV) at the Universities' Research Center, University of Yangon.

Analysis of Functional Groups in SDF by FTIR

FTIR analysis was carried out to qualitatively examine the functional groups of SDFs by using FTIR (PerkinElmer Spectrum, Version 10.5.2) at the National Analytical Laboratory, Department of Research and Innovation, No.6 KabaAye Pagoda Road, Yankin, Yangon Region.

Determination of Mineral Contents in SDF by Atomic Absorption Spectroscopy

The concentrations of individual mineral contents were determined by Atomic Absorption Spectroscopy (AAS, PerkinElmer, PinAAcle 900F) at the National Analytical Laboratory, Department of Research and Innovation, No.6 KabaAye Pagoda Road, Yankin, Yangon Region.

Sensory Evaluation of Processed Wheat Noodle Including SDF

The sensory evaluation was carried out to assess the overall acceptability of the SDF powder enriched noodles. The sample noodles were cooked in boiling water for 15 min and the quality attributes (Colour, Taste and Texture) of prepared noodles were evaluated for overall liking of the samples by 10 well trained persons using a nine-point hedonic scale.

Statistical Analysis

By using D-optimal mixture design, the optimum amount of ingredients used in noodle formulations was determined based on the most acceptable like on taste, colour and texture of the resulting noodles.

Determination of Nutritional Characteristics of Noodle

The nutritional characteristics such as the protein, fat, crude fibre, carbohydrate, sugar, moisture, ash content, cooking weight, cooking loss of resulting Noodle including SDF and without SDF were determined. The energy value of resulting noodle was also determined by using the following formula.

Energy Value= (4 kcal/g × Protein) + (4 kcal/g × Carbohydrate) + (9 kcal/g × Fat)

The resulting noodle was stored in air-tied plastic bag and stored in room temperature and there was no change in conditions (colour, odor and texture) of both SDFs and noodle during 6 months.

Results and Discussion

Figure 1 shows the resulting values of acid treatment extraction method. The effect of pH on the yield percent of SDF was conducted by varying pH. The optimum pH that gave the maximum amount of yield was 3.5, and beyond this pH the yield percent became lower. The yield percent was not significantly lower but the higher concentration of acid gave the odor of SDF with pungent smell. Below pH 3.5, the treatment was not enough for disruption of walls of banana peels.

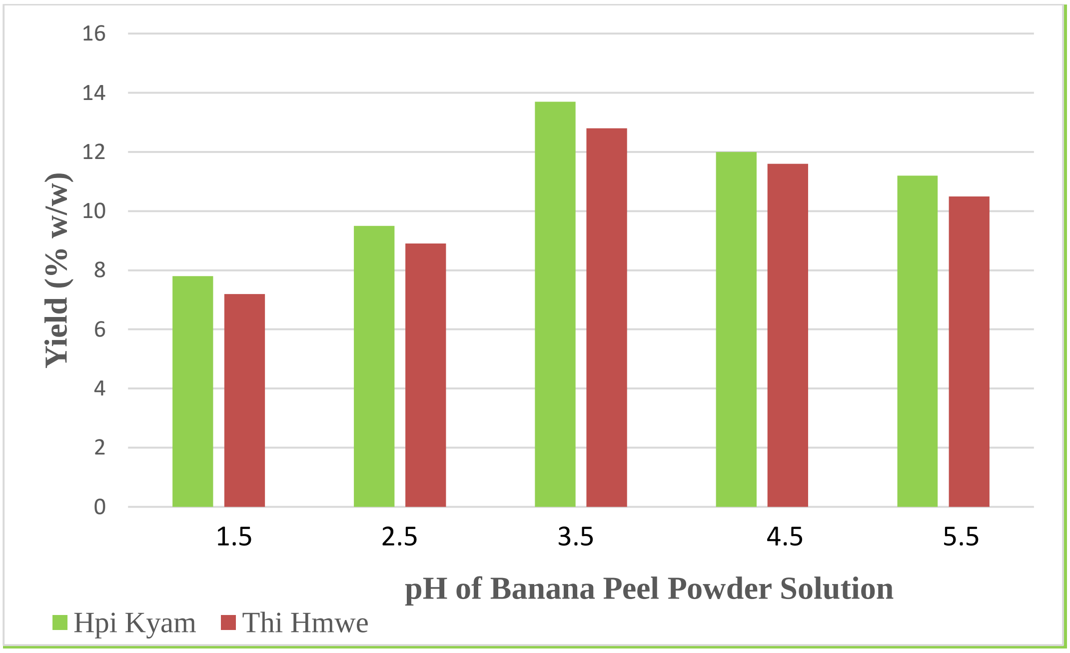


Figure 1: Effect of pH on the Yield Percent of SDFs by Acid Treatment

The effect of cellulase concentration on the yield percent of SDF was studied. As shown in Figure 2, it was found that the maximum amount of SDF was obtained at 0.02 % of cellulase, and the lower amount of enzyme gave the lower amount of SDF. The enzyme action was found to be optimum in 0.02 %, and it gave the yield percent of 13.7 % in Hpi Kyam, and 12.4 % in Thi Hmwe respectively. 0.02 % of cellulase enzyme concentration was effective substrate to enzyme ratio to obtain the maximum SDF extraction.

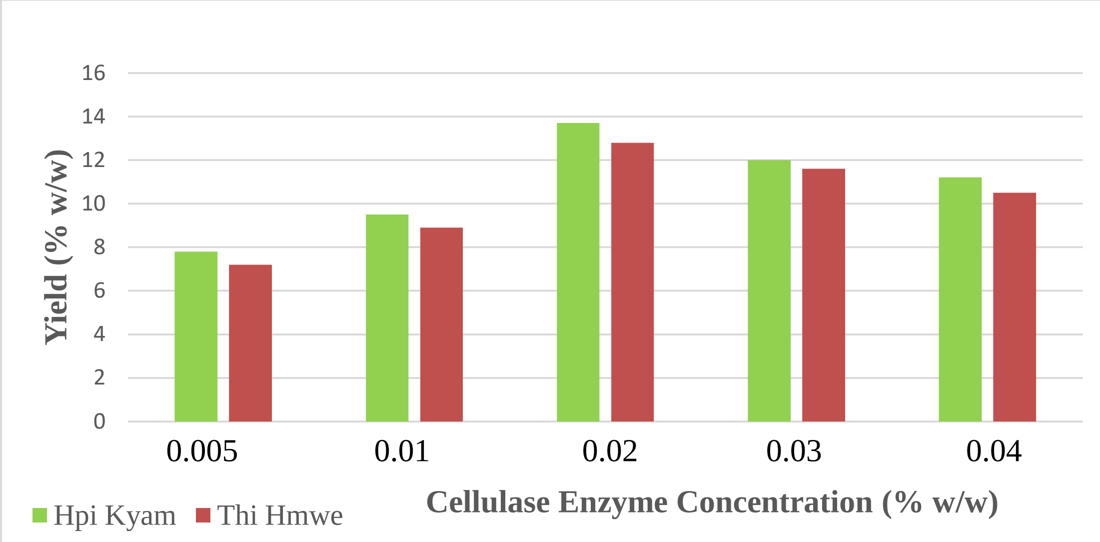
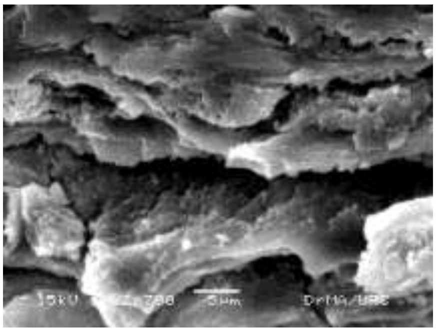
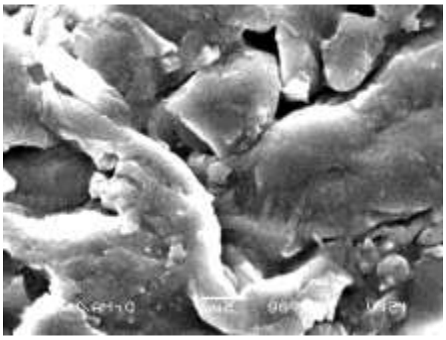


Figure 2: Effect of Cellulase Concentration on the Yield Percent of SDFs by Enzyme Treatment

Surface morphology of raw banana peel powder, and its products SDFs were observed by scanning electron microscope (SEM) and the results are shown in Figures 3 and 4. The surface morphology was highly influenced by the presence of cellulose materials in the banana peel. According to the SEM images, the heterogeneous nature was observed at the surface of which indicate the amorphous structure of materials.



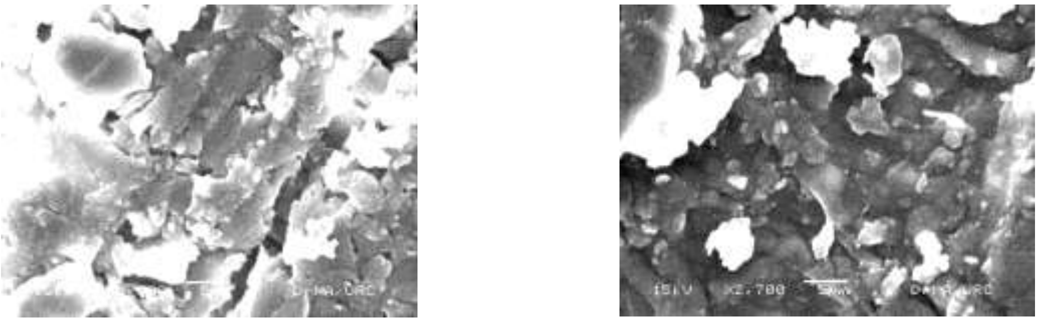
(a)



(b)

Figure 3: Surface Morphology of Raw Banana Peel Powders

(a) Hpi Kyam (b) Thi Hmwe



(a) **(b)**

Figure 4: Surface Morphology of Extracted SDFs from
(a) Hpi Kyam (b) Thi Hmwe

FTIR sepctrum of SDFs are shown in Figures 5 and 6 and their band assignments are tabulated in Table 1. It was found that the sharp intense band at 3330 cm^{-1} and 3329 cm^{-1} indicates C-H stretching, and it will be the hydrogen bonded O-H stretching vibration. The medium intensity C=C stretching bend occurred near 1639 cm^{-1} and 1640 cm^{-1}. The observed pattern of figer-like bands further suggested disubstituded or trisubstitude groups that were present in the resulting SDF. There was also a weak absorption at 1413 cm^{-1}, and it was constituent with C=C-H in plane bending vibration of the terminal $=CH_2$ group. The conjunction with aliphtatic asymmetric, and symmetric C-H in plane banding vibration at 1450 cm^{-1}, and 1552 cm^{-1} indicated the presence of alkyl group. There was also C-O stretching vibration at 1020 cm^{-1} and 1021 cm^{-1} indicates the ester and amines groups presence in both SDFs. The FTIR analysis of both SDFs show the presence of 4-(2,3-Dihydroxypropyl), 2-Isononenylsuccinate and Pama Dendrimer compounds that can enhance the solubility of resulting products.

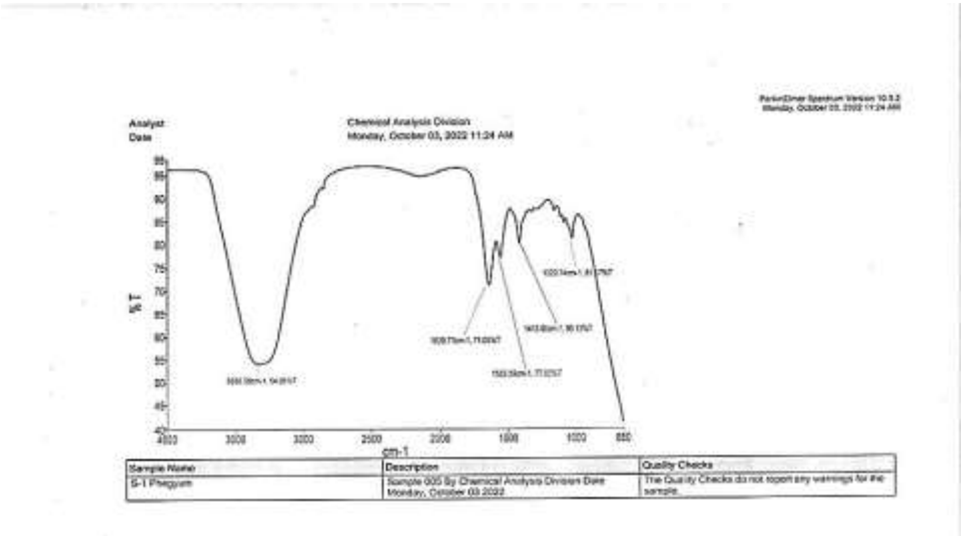


Figure 5: FTIR Spectrum of SDF (Hpi Kyam)

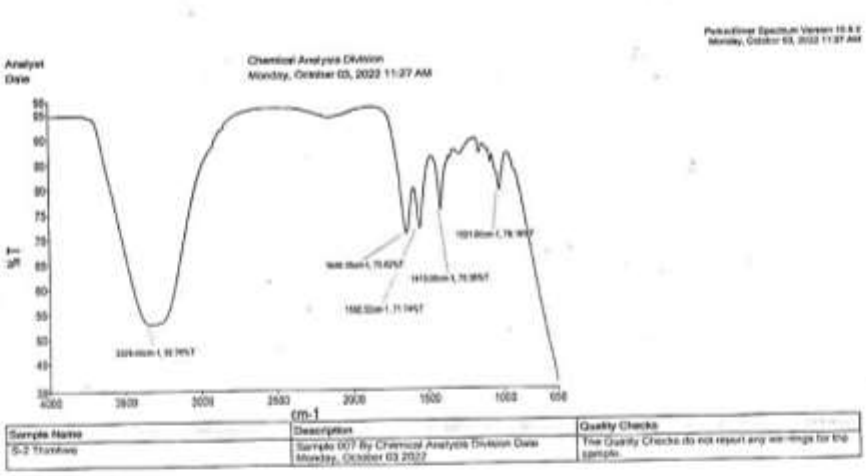


Figure 6: FTIR Spectrum of SDF (Thi Hmwe)

Table 1: FTIR Absorption Bands and Assignments of Extracted SDFs

Sr. No.	Experimental Frequency (cm^{-1})		Literature Frequency (cm^{-1})	Band Assignments	Types of Identified Functional Groups
	Hpi Kyam	Thi Hmwe			
1	3330.58	3329.45	3500-3200	O-H stretch, C=O stretch	Alcohol , Phenol
2	1639.77	1640.15	1670-1620	C=C stretch, C=O stretch	Trisubstituted Groups
3	1563.59	1552.32	1800-1260	C=CH stretch, =CH stretch	Asymmetric and Symmetric Alkyl Group,
4	1413.86	1413.08			
5	1020.74	1021.60	1260-1000	C=C stretch, O-H bends, C-N stretch	Ester, Aliphatic amines, Aromatic ring, Alcohol, Phenol
The identical compounds found in Extracted SDF 4-(2,3-Dihydrioypropyl) 2-Isononenylsuccinate, Pama Dendrimer					

(Noh *et al.*, 2017), (Maobe M.A.G. *et al*., 2013)

Table 2 shows that the mineral contents of SDFs and it was found that both SDFs contained high amount of iron (Fe) content, and manganese content. When compared, SDF from Thi Hmwe contained a little high mineral contents than that of Hpi Kyam. This agreed with the findings of Akinyosoye (1991), and Anhwange *et al*, (2009) that pointed as banana peel can serve as one of the major source of iron and manganese ions.

Table 2: Mineral Contents of Extracted SDFs by Atomic Absorption Spectroscopy

Elements	Concentrations (mg/g)	
	SDF (Hpi Kyam)	SDF (Thi Hmwe)
Calcium	0.09	0.19
Iron	16.85	19.24
Manganese	7.01	9.37
Potassium	0.20	0.21
Sodium	0.99	1.39

Table 3 shows the experimental runs and sensory scores of formulated 16 samples of SDF enriched noodle. It was found that the taste, colour and texture of sample with 86.5 % of wheat flour, 10 % of potato starch, 1.5 % of extracted SDF, 1 % of NaCl and 1 % of $NaHCO_3$ were superior to the others. The amount of SDF in best formulation was 1.5 % (w/w) and it was in acceptable range for human diet.

Table 3: Sensory Scores of Formulated Noodle Including SDF

Run	Ingredients						Sensory Score		
	Wheat Flour (%)	Potato Starch (%)	SDF (%)	$NaHCO_3$ (%)	NaCl (%)	Distilled Water (mL)	Taste R_1	Colour R_2	Texture R_3
1	77.875	19.125	1	1	1	55	6.5	6.45	6.2
2	50	47.5	0.5	1	1	55	5.8	6.4	4.8
3	87.5	10	0.5	1	1	55	6.7	5.92	6.4
4	85.5	10	2.5	1	1	55	6.9	5.68	6.5
5*	86.5	10	1.5	1	1	55	7.2	7.81	6.9
6	50	45.5	2.5	1	1	55	5.7	6.12	5.2
7	59.125	36.875	2	1	1	55	5.7	6.65	4.9
8	68.75	28.75	0.5	1	1	55	6.4	6.5	5.4
9	68.75	28.75	0.5	1	1	55	6.4	6.5	5.4
10	87.5	10	0.5	1	1	55	6.9	5.9	5.9
11	50	46.5	1.5	1	1	55	5.5	4.89	4.5
12	85.5	10	2.5	1	1	55	6.4	5.7	6.4
13	50	45.5	2.5	1	1	55	5.9	6.2	4.9

Run	Ingredients						Sensory Score		
	Wheat Flour (%)	Potato Starch (%)	SDF (%)	$NaHCO_3$ (%)	NaCl (%)	Distilled Water (mL)	Taste R_1	Colour R_2	Texture R_3
14	50	47.5	0.5	1	1	55	5.8	6.4	4.8
15	67.75	27.75	2.5	1	1	55	6.2	6.3	5.9
16	59.125	37.875	1	1	1	55	6.1	6.53	5.2

***** = the optimum formulation
R_1, R_2, R_3 = Responds for sensory evaluation (Taste, Colour, Texture)

Table 4 shows the predicted and experimental values of sensory scores for the optimized formulation. From the results of Table 4, there were no significant differences between the predicted and experimental scores of the responses for optimized formulation of SDF enriched noodle and also good agreement with the model used.

Table 4: Optimum Composition of Noodle Including SDF

Sr. No.	Ingredients	Composition (g)	Taste		Colour		Texture	
			P	E	P	E	P	E
1	Wheat Flour	86.5	6.8	7.2	7.8	7.81	6.4	6.9
2	Potato Starch	10						
3	SDF	1.5						
4	Water	55						
5	NaCl	1.0						
6	$NaHCO_3$	1.0						

P = Predicted value E = Experimental value

Table 5 shows the characteristics of SDF enriched noodle. It was found that the resulting noodle had higher protein content, carbohydrate content, energy value, and cooking weight. These characteristics are very good for human health, and there was a little cooking loss in noodle. The extracted SDFs were stored in airtight bottles in refrigerated storage. The resulting noodle was stored in airtight plastic bag and stored at room temperature. There was no change in colour, odor and texture of both SDFs and processed noodle during 6 months. From the results the noodle including SDF had high energy value and no fat content. The nutritional values of prepared noodle including SDF were high and achieved good organoleptic quality. Moreover, the SDF enriched noodle makes enhance lowering fat absorption and weight management. It promotes digestibility, lowering cholesterol and stabilizing blood sugar level than the normal noodle.

Table 5: Characteristics of Wheat Noodle Including SDF and Without SDF

Sr. No.	Characteristics	Wheat Noodle Including SDF	Wheat Noodle Without SDF	Literature Value*
1.	Protein (% w/w)	15.8	10.5	4.5
2.	Fat (% w/w)	N. D	0.94	2.06
3.	Crude Fibre (% w/w)	1.7	0.36	1.19
4.	Carbohydrate (% w/w)	76.6	74.88	25
5.	Sugar (% w/w)	3.29	3.0	0.375
6.	Moisture (% w/w)	5.9	< 14	5.6
7.	Ash (% w/w)	0.92	0.94	1.4
8.	Energy Value (kcal/100 g)	370	192	140
9.	Cooking Weight (% w/w)	200.0	189.0	-
10.	Cooking Loss (% w/w)	1.49	1.4	-
11.	Shelf Life (Months)	6	6	6

* (Kawaljit S.S, 2010)

(a)

(b)

(c)

Figure 7: (a) Solid SDF (b) Wet Noodle (c) Dry Noodle

Conclusion

Physical modification of foods is very important in several industries. Since the well proved nutritional benefits of dietary fibers, many efforts are being put in the improvement of their functionality by physical means. Banana peel was observed to be an excellent source of dietary fibre, and it was concluded that the waste banana peel could be used as a potential source of fibre. The characteristics of SDFs showed a drastic efficiency, and enzyme treatment provided the higher SDF yield than the acid method. The present study showed that extracted SDF from banana peel (Hpi Kyam) by cellulase enzyme treated method was a promising material for the development of noodle formulation. The studies on cooking quality such as colour, taste and texture revealed that the noodle incorporated with 1.5 % of SDF was the most acceptable in terms of both palatability and nutritional compositions. There were no significant differences between the predicted and experimental values of the responses for optimized formulation of SDF enriched noodle by statistical analysis. Formulation of such type of functional foods can impart positive results against many diseases like cancer, cardiovascular diseases, obesity, heart problems etc. So, these noodles can be a good source of nutraceuticals containing functional food from byproduct of banana food industries.

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