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Optimization of Improved Instant Noodle from Bambara Groundnut (*Vigna subterranea)* Flour in Terms of Chemical and Texture Characteristics Using Response Surface Methodology (RSM)

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ABSTRACT

Response Surface Methodology (RSM) in conjunction with central composite design (CCD) was used to analyze effects of the combination water and Bambara groundnut flour towards the instant Bambara noodle. The experiments were run with different blends of Bambara groundnut flour (BF) and wheat flour (WF). The ratios for the BF incorporated with WF were 10%, 20% and 30 % respectively. The 100% Wheat Flour (WF) noodle was served as control. Selection of the optimal formulation was based on the hardness of the noodle with the desirability of 1. An optimized formulation was obtained, at where BF replaced WF for 20% at 48g of water that produced the optimum value of noodle hardness at 92.24g. Results of chemical analysis for the optimum selected instant Bambara noodle showed a significant increase in protein (11.2%), crude fibre (0.5%) and ash contents (3.1%). However, there was a significant decrease in moisture (2.9%) and carbohydrate contents (78.5%) of the Bambara noodle blends. Meanwhile, in texture profile analysis, the optimum instant noodle shows increase values in hardness, springiness, gumminess and chewiness but yet decreased value in cohesiveness compared to control noodle. Last but not least, the sensory evaluation for overall acceptance of the instant Bambara noodles by using hedonic scale, scored as the second highest among the other two samples.

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INTRODUCTION

Instant noodles are widely consumed throughout the world and it is a fast growing sector of the noodle industry (Owen, 2001). This is because instant noodles are convenient, short cooking time, diverse tastes, low product cost and have a relatively long shelf-life. Flour of hard wheat (*Triticum aestivum L.)* is the main primary ingredient (Crosbie *et al*., 1998) which usually low in fiber and proteins as well in essential amino acids, lysine. Alkaline salts are usually added into it to help strengthen the structure and hence improve the firmness of the noodle (Hou *et al*., 1998). Thus, in order to derive this demand for instant noodles, effort need to be made in improving the functional quality attributes of existing products and also introducing new products into the market that satisfy the potential needs of current health-conscious consumers. Bambara groundnut (*Vigna subterranea*) has found to have some properties similar to wheat flour and also provide other nutrition properties that beneficial. Bambara groundnut (BG) is the untraditional seeds, the new cultivated and promising underutilize crop. They contain 7.2% moisture, 18 to 24% protein, 6.0 to 7.0% fat and 60 to 63% carbohydrates (Okonkwo and Mary, 2010). The seed grain has a good balance of essential amino acids with relatively high proportion of lysine (6.6%) and 1.3% methionine (Elegbede, 1998). Stephens (2003) noted that BG contains higher amount of an essential amino acid, methionine than other grain legumes while the oil content is less than half of that found in legume like peanuts and calories of about 36 to 414 Kcal/ 100 g. As a result of its high nutritive value, this legume has a potential to influence the nutritional profile of food (Sripriya *et al*., 1997).Thus, in this study, Bambara groundnut (*Vigna subterranea*) was prepared and incorporated into the formulation of instant fried noodles using Response Surface Methodology (RSM). The effect of BG on the quality attributes of the noodles was investigated in terms of chemical and textural characteristics.

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Methodology:

A. Preparation of Bambara Groundnut Flour:

Bambara groundnut (*Vigna subterranea*) was procured at Padang Besar Market near Thailand-Malaysia Border and kept in polyethylene bags on dry placed until used. Bambara Groundnuts were washed and rinsed in water at room temperature (25±2°C). The seeds were boiled at a temperature of 100ºC for 20 min, dehulled manually and sun-dried for 2-3 days. The dried seed were then dry-milled into flour by grinding, passes through a 150 mm mesh sieve. The flour was stored in polythene bags and kept in a refrigerator at 4°C before use (Mbata *et al*., 2009).

Cleaning
↓
Soaking (1hr)
↓
Boiling (100ºC for 20min)
↓
Removing the outer skin
↓
Drying (48hr)
↓
Milling
↓
Storage

Fig. 1: Flow process for the production of Bambara Groundnut flour

B. Preparation of Instant Noodle:

The basic ingredients used for making noodles were: wheat flour (100g), water (50g) and sodium chloride (1.5g). The salt was first dissolved in the water and this solution was added to the flour and then mixed manually by hands for about 2 minutes. The dough was then rest for 15 minutes. Noodles were prepared in the laboratory following the procedures of Bui and Small (2007). For making instant noodles, the dough sheet formed was further pressed through the noodle machine with the roller gap gradually reduced to 1mm. The dimension was 2mm in width and 1mm in thickness for each strand. The resulting noodle strip was placed into the steam pan. The steam pan was put into the preheated (100°C) steamer, and cooked for 2 min until the noodle strip was in smooth surface and had become elastic in texture. The next and final step is hot air drying. The steam noodle was dried by blowing a hot air stream at a temperature of 120° C to 160° C onto the noodle at a stream speed of 30 m/s to 70 m/s for a period of 3 to 15 minutes in the oven and the noodles are then cooled to room temperature for 2 h and stored in a plastic bag until further testing. Control dried noodles were prepared from 100% wheat flour. Additional dried noodle samples were prepared by substituting wheat with 10, 20 and 30% Bambara Groundnut flour. Noodle samples were cooked by placing nine strands of noodles into 400 ml boiling water in a 500ml beaker.

Dough Sheeting
↓
Cutting
(2mm wide, 150mm length)
↓
Steaming
(100°C for 2 minutes)
↓
Hot-air Drying
(120° C-160° C for 3 to 15 minutes)
↓
Cooking
(Boiling)

Fig. 2: Flow of the process of non-fried Instant Noodle production

C. Response Surface Methodology (RSM) analysis:

An RSM was used to determine the experimental design and the optimal ingredients levels in producing air dried instant Bambara noodle. A three coded levels; two-factor central composite (face-centered) design was constructed using the Design Expert version 8.0.7.1 software as shown in Table 3.2. The two basic ingredients were incorporated with wheat flour as follows; water (10–30%) and Bambara groundnut flour (10–30%). The three coded levels of water: −1 (10%), 0 (20%), 1(30%) and Bambara groundnut flour: −1 (10%), 0 (20%), 1(30%) were incorporated into the design and were analyzed in 13 combinations. The central point of the design was repeated five times to calculate the reproducibility of the method. The effect of these two independent variables *x*1 and *x*2 on the responses (*Y*) was modeled using the second-order polynomial response surface. The equation derived using RSM for the prediction of the response variables is as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x^2{}_1 + \beta_{22} x^2{}_2 + \beta_{12} x_{12} x_2 \quad (1)$$

where $\beta 0$ is the value of the fixed response at the central point of the experiment that is the point (0,0); $\beta 1$and $\beta 2$ are the linear, $\beta 11$ and $\beta 22$ are the quadratic and $\beta 12$ are the interactions regression terms.

Table 1: Level of ingredients for central composite design

Factor	Low	High
Water	46g	50g
BG flour	10g	30g

D. Noodle Texture Analysis:

The textural properties of cooked noodles are immediately followed after noodles finished cooked by instrumental method. The texture analyzer (TA-XT2i) was used to determine the Texture Profile Analysis (TPA) of the noodle .Three replicates of cooked noodles at each level of Bambara Groundnut flour were prepared.

E. Proximate Analysis:

The noodle sample was blended prior to analysis. The noodles were analyzed for moisture, ash, fat, protein (N x 6.25) and crude fibre according to AOAC method (2000). Carbohydrate content was estimated by difference. Caloric value was measured by calculation. The results were triplicated and reported on dry weight basis.

F. Sensory Evaluation:

The sensory evaluations of the noodles are conducted by 30 respondents. The sensory evaluation is conducted using the nine-point hedonic scale. The three different food samples are prepared in identical sample containers, coded with 3-digit random numbers and each sample was presented with different number. The randomized order of the sample was presented once at a time to each respondent. Respondents were asked to evaluate the coded noodle samples for each sensorial parameter including color, aroma, crunchiness, and overall acceptance based on their degree of liking (1 = like extremely; 2 = like vey much; 3 = like moderately; 4 = like slightly; 5 = neither like nor dislike; 6 = dislike slightly; 7 =dislike moderately; 8 =dislike very much; 9 =dislike extremely) (Lazaridou *et al*., 2007 and Sabanis *et al*., 2009).

RESULTS AND DISCUSSION

A. Response Surface Methodology (RSM) Analysis:

Table 2: Analysis of variance (ANOVA) on the response variable (Hardness)

Source of variation	*% Sum of squares (SS)*	*Degree of freedom (DF)*	*Mean squares (MS)*	*F-value*	*p-value Probe >F*
Model	957.82	5	191.56	49.77	< 0.0001 (significant)
A-Water	1.50	1	1.50	0.39	0.5523
B-BFlour	0.17	1	0.17	0.043	0.8411
AB	0.25	1	0.25	0.065	0.8062
A^2	267.69	1	267.69	69.54	< 0.0001
B^2	324.83	1	324.83	84.39	< 0.0001
Residual	26.95	7	3.85		
Lack of fit	2.95	3	0.98	0.16	0.9156 (not significant)
Pure Error	24.00	4	6.00		
Cor Total	984.77	12			

Std. Dev. =1.96; Mean=82.69; C.V%=2.37; PRESS=57.92; R^2=0.9726; Adj R^2=0.9531; Pred R^2= 0.9412; Adeq Precision=16.210

Table 3: The Selected Results for the Optimization Hardness in BG Flour Noodle

Constraints Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: Water	Is in range	46	50	1	1	3
B: BFlour	Is in range	10	30	1	1	3
Hardness	Is in range	70	95	1	1	3
Solutions Number	Water	BFlour	Hardness	Desirability		
1	50.0	20.0	82.9	1		
2	46.0	10.0	70.6	1		
3	50.0	10.0	72.1	1		
4	48.0	20.0	92.2	1		

From the Table 3, the total number of starting points is 39 and out of which, 39 solutions have been identified with the optimized desirability of 1.00. The suggested fourth solution is selected and the results are below.

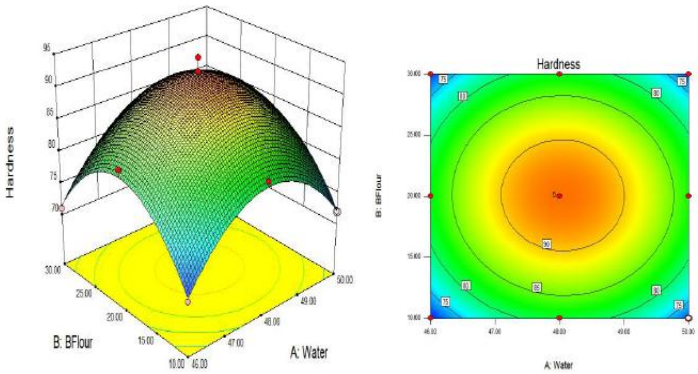

Fig. 3: 3D surface and contour plot of Bambara flour and water on the hardness of noodle after cooked.

Fig: 3, shows the effects of water and Bambara flour on the hardness of noodle after cooked. Form the 3D response plotted, the hardness of noodle after cooked increased with increasing Bambara flour and water in the range of 10-20 in gram and water of 46-48 in gram. However, the conversion rates were reduced for a further increase in Bambara flour and water after reach the optimum value of 20g in Bambara flour and 48g in water. Meanwhile, in contour plot, it shows that when the optimum Bambara flour is 20g and water is 48g, optimum hardness observed is 92.2414. The range color in the above figure indicates the high and low value; blue color as the lowest value and orange color as the highest value.

B. Validation Analysis:

Table 4: Comparison of experimental and predicted of optimum response

Run	*Water (g)*	*Bambara Flour (g)*	*Hardness*		*Percentage of error (%)*
			Experimental	Predicted	
1	48	20	94g	92.2414g	1.9065%
2	48	20	93g	92.2414g	0.822%
3	48	20	95g	92.2414g	2.9906%

Subsequent experiments were carried out to validate the predicted optimal process values derives from RSM design. These process parameters such as water and Bambara flour were set to optimal condition with 48g of water and 20g of Bambara flour. All experiments were performed in triplicates. Under these operating conditions, the model predicted 92.241 g of hardness as compared to experimental values 93g to 95g of hardness. The percentage of error between experimental and predicted values fell below 5%. These shows that it is possible to achieve the predicted response because percent error that fell within 5% indicated that the process of optimization by CCD was capable and reliable to optimize the process (Ayla, 2009).

C. Proximate Composition Analysis of BG Flour Instant Noodle:

Table 5: The Chemical Composition of Control Noodle and Optimized BG Flour Noodle

Component (g)	*Control noodle /100g*	*Bambara noodle/100g*
Moisture	3.6	2.9
Ash	1.8	3.1
Protein	10.1	11.2
Fat	2.8	4.3
Crude Fiber	ND(<0.1)	0.5
Carbohydrate	81.7	78.5
Calories	392kcal	398kcal

From the above data, the moisture content of control noodle is higher compared to Bambara noodle. The lowered moisture content in Bambara noodle might be due to water holding capacity of fibers and polysaccharides in Bambara flour during the dough formation. The lower moisture content is a desirable phenomenon, as it will enhance the keeping quality of the noodle since water for activity is low.

Besides that, there is increasing of ash content (3.1%) in the noodle once Bambara flour is added into it. Suryaningrum *et al*., (2003) reported that when there was an increased on ash content, there was also as well an increase of sulfate content. This explains that in Bambara noodle, there is a relatively high value of inorganic material such as minerals compared to control noodle which also due to high-protein of Bambara flours. The high protein content of the noodles sample relative to control could be attributed to the supplementation effect.

It has been shown that when legume proteins supplement those of cereals, a protein quality equal to or better than those of animal origin could be obtained (Mensah *et al*., 2003).

A small increase of fiber in Bambara noodle been traced. This is related to the outer layer of the seed coat, which is rich in fiber, being removed during the flour refinement. Besides, form the Table 4.4, there is a higher carbohydrate in control noodle (81.7%) compared to Bambara noodle (78.5%). This is because legumes store less carbohydrate than cereals as source of energy. It would make the Bambara noodle more desirable as weight management di*et al*ternative. Finally, there is an increasing value in calories of Bambara noodle (398kcal/100g) compared to control (392kcal/100g). The higher energy for Bambara groundnut than for control sample was because legumes store more energy in form of fat than cereals.

D. Textural properties of BG Flour Noodles:

Table 6: Data Texture Profile Analysis (TPA) of Control Noodle and Optimized Bambara Noodle

Texture Characteristic	*Control Noodle*	*Bambara Noodle*
Hardness (g)	119.00±2.00	202.00±2.64
Cohesiveness	0.43±0.03	0.32±0.03
Springiness (mm)	1.06±0.05	1.08±0.07
Gumminess (g)	87.00±65	95.33±2.56
Chewiness (mJ)	1.30±1.24	1.50±0.30

Hardness is a measure of the firmness of the noodles at the maximum peak of the first compression. From the result, the hardness value in Bambara noodle is higher compared to the control noodle indicates that the Bambara noodle is the hardest. The harder the noodles, the stronger protein network in it (Park *et al*., 2003, Huang and Morrison, 1988). There was significantly increased ($p<0.05$) of the noodle after modified with the addition of Bambara flour. In Bambara noodle, the springiness shows significant different ($P<0.005$) to control noodle. The springiness in Bambara noodle is more elastic to control noodle, which means, the Bambara noodle easy to bounce back to its original position. Gumminess is the energy required to disintegrate a semisolid food to a state ready for swallowing and is a combination of hardness and cohesiveness (Whistler *et al*., 1997). The gumminess in Bambara noodle is pastier than control noodle as there was significant difference between them.

Chewiness is a combination of hardness, cohesiveness, and elasticity. In this study, Bambara noodle is tougher than control noodle due to the significant existence between the control noodles. The Bambara noodles need to chew harder compared to control noodle.

E. Sensory Evaluation Analysis:

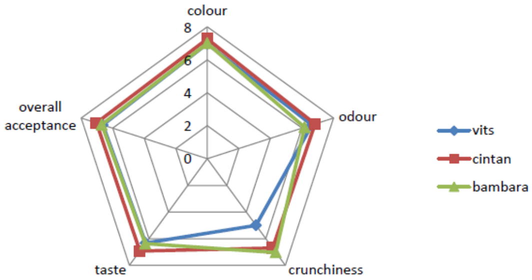

Fig. 4: The sensory analysis on the average scores of three different types of noodle in radar chart.

Sensory evaluation indicated that the noodle supplemented with BG flour was acceptable (Figure 4). of BG flour did not influence the colour of Bg flour noodle (slightly bright). An increased in crunchiness, taste overall acceptance was noted on the noodle supplemented with BG flour.

Conclusion:

Supplementation of bambara groundnut flour to wheat flour was found to increase the chemical especially in crude fibre and protein although there was a slightly decreased in moisture. The noodles were considered acceptable by the sensory panel. Thus, bambara groundnut flour can be added in noodle formulas as develop high fibre noodle and in order to increase the daily fibre intake.

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