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Extrusion Parameters Impact on Cooking Qualities of Plantain-Wheat Instant Noodles

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Abstract

This study investigated extrusion parameters impact on the cooking qualities of instant noodle produced from plantain-wheat composite flours. The plantain-wheat composite flours were produced using documented procedures and its blends in ratios 0:100; 5:95; 10:90; 15:85; 20:80 and 25:75 were further used for production of instant noodles using a laboratory model rotating screw extruder at different extrusion conditions considering barrel temperature (60-100^{o}C) and screw speed (85-125 rpm). The cooking properties such as optimum cooking time, cooking weight and cooking loss, fat uptake content of the instant noodles were investigated and data obtained were analyzed using Design Expert Software. The results showed that extrusion parameters investigated affected cooking properties of the plantain-wheat instant noodles. Optimum solutions data were provided by optimizing the solution analyzed. Therefore, the data obtained will provide valuable information for industries in process control and design of plantain-wheat instant noodle.

Keywords

Plantain, Composite Flour, Extrusion Parameters, Instant Noodles, Cooking Properties

1. Introduction

Instant noodle has become an important food item globally, with annual production of 101,420 million packs in 2012, and a steady increase of 3% annually since 2010 [1]. Most instant noodles are made of wheat as the base material, thus instant noodle consumption led to dependency on massive importation of wheat in non-wheat producing countries Nigeria inclusive. Apart from high cost of wheat importation, excessive consumption of wheat has been associated with allergy, diabetics, asthma, autoimmune response, or gluten sensitivity [2] in some parts of the world. Several works have been done on composite flour instant noodle using different flours, although rice flour seems to be the best replacement for its small granule sizes to benefit noodle textural characteristics [3-5]. Some other raw materials for composite flour instant noodle include sorghum[6], and corn starch [7, 8] or corn flour [9]. Lately, pigeon pea and rice [4], pseudo-cereal such as amaranth flour in combination with cassava starch [10] have also been incorporated. The weakening of protein matrix in composite flour instant noodle often adversely affects noodle quality; hence composite flour instant noodle requires treatment to improve its consumers' acceptability. In process control and design, processing data are very useful for evaluating performance during processes such as mixing, sheeting, proofing and baking [11-13]. This information also predicts functionality, acceptability and storability of the product. Consequently, in this work, impact of extrusion parameters on cooking quality of instant noodles produced from plantain and wheat flours are investigated with the view to providing baseline information on the production of instant noodles from plantain fruits.

2. Materials and Methods

2.1 Source of Materials

Freshly harvested bunches of plantain fruit (Plate 1) at stage one maturity using colour as basis of clarification [14-16] were obtained from Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Other materials such as white wheat flour (Dangote brand), iodized table salt (Dangote brand), potato starch, guar gum, potassium carbonate (food grade), sodium carbonate (food grade) and sodium tripolyphosphate (STTP, food grade) were bought from a local market in Ile-Ife, Osun State. The chemicals used for analysis were of analytical grade.

Plate 1. A freshly harvested matured plantain (*agbagba*) fruits.

2.2 Preparation of Musa spp flour

About 10 kg of freshly harvested debunched plantain fruits were immersed in a plastic bowl containing potable water on individual variety basis for 5 min. The fruits were removed from the bowl and peeled with the aid of a stainless kitchen knife. The pulp was sliced into cylindrical discs with thickness of about 5 mm and dipped in citric acid (CIT) (1% w/v) for 1 min to prevent enzymatic browning reaction [16]. Accumulation of moisture on the sliced surface as a result of the pretreatment was drained with a cheese cloth before samples was transferred to dryer set at 70°C [17].

The citric acid treated sliced plantain fruits were dried in an air-oven set at 70°C (±1°C) using convective air flowing at a velocity of 2.2 m/s [16, 17]. Prior to loading of the sliced fruits, the dryer was ran for 30 min to reach the set drying air temperature conditions. The drying of the sliced fruits was done in a thin layer form so as to ensure effective drying. The initial weight of sliced fruits was recorded by means of the digital balance before loading into already set oven. The sliced fruits were dried for 48 h and subsequently, the sliced fruits weight was measured at interval of 30 min until its weight was constant. At this point, the dried chips were considered to have attained its equilibrium moisture content (EMC) of the drying conditions. The dried chips were milled using laboratory milling machine (sieve size) 500 µm aperture) and stored in an air tight bottle until the time of use (Figure 1).

2.3 Blend formulation of plantain-wheat composite flour

The processed plantain flour was blended with wheat flour at 0, 5, 10, 15 20 and 25% replacement [18] using a Kenwood food processor (Model 49074, Kenwood Ltd, Hants, UK) operated at full speed for 10 min. The blends were stored in high density polyethylene bags (0.77 mm thick) prior to use.

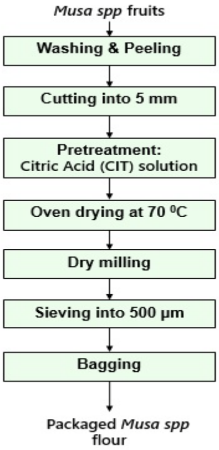


Figure 1. A flow chart showing production of plantain flour [17].

2.4 Instant noodle preparation

Instant noodle formulations, production flow chart and products developed were given in Table 1, Figure 2, and Plate 2, respectively. A laboratory model rotating screw extruder was used for development of the extrudate (Plate 3). The barrel diameter and length-diameter (L/D) ratio were 37 mm and 27:1, respectively with screw configuration standardized for processing flour-based products was used. The plantain-wheat composite dough extrusion was conducted at a range of extrusion conditions: barrel temperature, 60-100°C and screw rotation, 85-125 rpm.

Table 1. Formulation of instant noodle from *Musa* spp-wheat composite flour

	Formulations					
Ingredients	0% NOD	5% NOD	10% NOD	15% NOD	20% NOD	25% NOD
Wheat flour, g	100	95	90	85	80	75
Musa spp flour, g	0	5	10	15	20	25
Water, ml	34	34	34	34	34	34
Salt, g	1.6	1.6	1.6	1.6	1.6	1.6
Potato starch, g	12	12	12	12	12	12
Guar gum, g	0.2	0.2	0.2	0.2	0.2	0.2
Potassium carbonate, g	0.12	0.12	0.12	0.12	0.12	0.12
Sodium carbonate, g	0.8	0.8	0.8	0.8	0.8	0.8
STTP, g	0.1	0.1	0.1	0.1	0.1	0.1

0% NOD (Control) =100% wheat flour; 5% NOD = 95% wheat+ 5% *Musa spp* flour; 10% NOD = 90% wheat+ 10% *Musa spp* flour; 15% NOD = 85% wheat+ 15% *Musa spp* flour; 20% NOD = 80% wheat+ 20% *Musa spp* flour and 25% NOD = 75% wheat+ 25% *Musa spp* flour [3] (Hou et al., 1997).

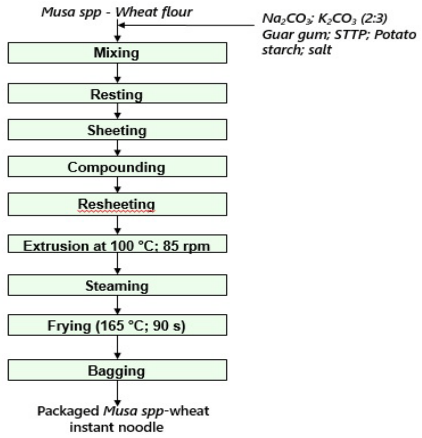
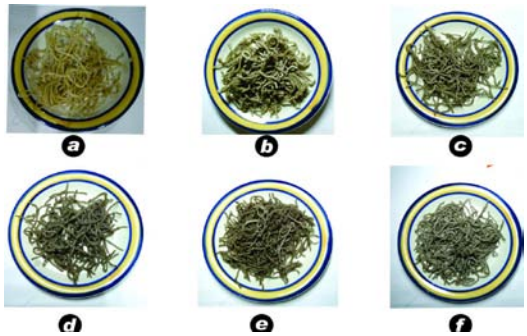


Figure 2. A schematic diagram showing production of fried instant noodle.



(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25% plantain flour + 75% wheat flour instant noodle again. The percentage weight loss during cooking was obtained by gravimetry. Values reported are average of five replications.

Plate 2. Fried instant noodles produced from plantain-wheat flours.

Plate 3. A laboratory model rotating screw extruder.

2.5 Determination of optimum cooking time

The optimum cooking time was determined following the method of [19]. About 10 g of instant noodle was boiled in 1,000 ml of boiling distilled water and after each minute of cooking for the first 2 min, noddle was removed and squeezed between clear glass slides. This procedure was then repeated by removing the noodles every 15 s until the white core disappeared. Therefore, the time taken for the white core to disappear when the noodle strand was boiled in the distilled water is referred to as the optimum cooking time.

2.6 Determination of cooking weight and cooking loss

Cooking weight and cooking loss were determined by methods of [20] and [21], respectively. Instant noodle (10 g) was cooked in 300 ml of distilled water in a beaker to their optimum cooking time, rinsed with distilled water, drained and left to cool for 5 min at room temperature. The cooled cooked noodles were then reweighed and results recorded as % increase on cooking. Residual water was removed by drying in the oven at 100°C until no traces of water in the beaker, cooled and weighed. Results are reported as % weight loss during cooking.

$$C_w = \frac{W_C - W_D}{W_D} \times 100 \quad (1)$$

Where:
C_W = Cooking weight (%)
W_C = Weight of cooked instant noodle, g;
W_D = Weight of dried instant noodle, g.

$$C_L = \frac{W_L}{W_D} \times 100 \quad (2)$$

Where:
C_L = Cooking loss, %
W_L = Weight of loss solid, g

2.7 Determination of Fat Content

Ground instant noodle (3 g) was put into a thimble and extracted with n-hexane for about 6 h using soxhlet extractor. The solvent was removed from the extracted oil by evaporation. The oil was further dried in a hot-air oven at 100°C for 30 min. to remove residual organic solvent and moisture. The oil was allowed to cool in a dessicator and weighed. The quantity of oil obtained was expressed as percentage of the original sample weight used.

$$\%\, CF = \frac{W_{oil}}{W_{sample}} \times 100 \quad (3)$$

Where:

CF = Crude fat content , %
W_{oil} = Weight of extracted oil, g
W_{sample} = Weight of sample, g

Statistical Analysis

The data obtained will be analyzed descriptively and inferentially using Turkey's post test procedures of GraphPad Prism version 4.00 for Windows

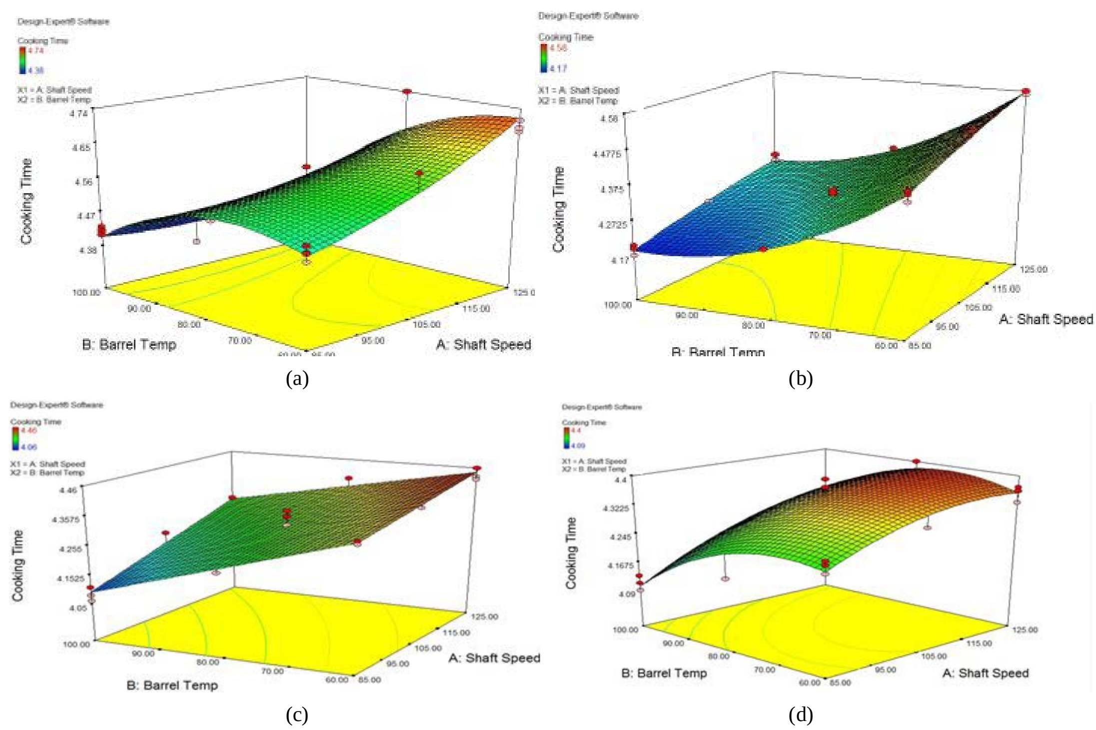
3. Results and Discussion

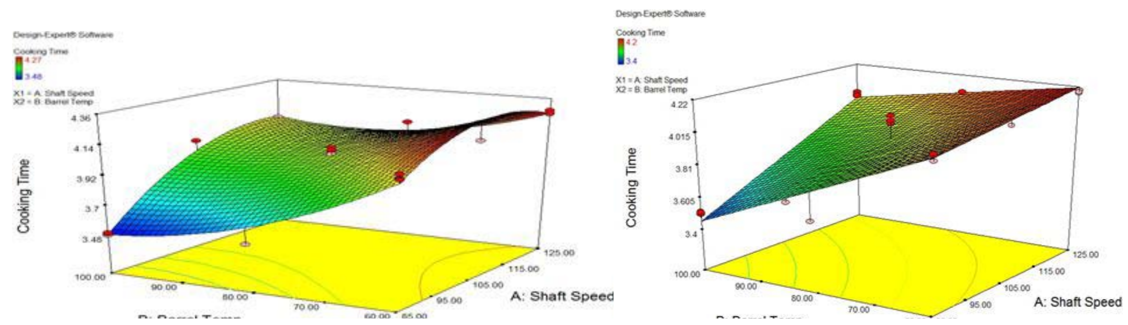
Effects of extrusion parameters on quality assessment of fried instant noodle: The quality assessments such as cooking time, cooking loss, cooking gain, moisture and fat uptakes are evaluated as affected by extrusion parameters on plantain-wheat instant noodles. Extrusion parameters have been documented to be essential to the quality of the final product as it is thought to contribute to color, water and fat uptakes and the textural properties of the product [22-23].

Effect of extrusion parameters on optimum cooking time: Figure 3 showed the effect of extrusion parameters (barrel temperatures and conveying shaft speeds) on cooking time of plantain-wheat instant noodles at different levels of substitution. The cooking time ranged from 4.38-5.4 min; 4.17-4.58 min; 4.06-4.46 min; 4.09-4.40 min; 3.38-4.27 min and 3.40-4.40 min for the instant noodle samples 0% NOD; 5% NOD; 10% NOD; 15% NOD; 20% NOD and 25% NOD, respectively. The values showed that as conveying shaft speed increased, there was a corresponding increase in cooking time. Whereas, increase in barrel temperatures led to a decrease in cooking time of the instant noodles. There is significant difference ($p < 0.05$) among the instant noodles cooking time at all levels of substitution. The interactive effects between conveying shaft speed and barrel temperature on cooking time is positive. The minimum cooking time was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient (R^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9602 and desirability of 0.972. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on cooking time of the instant noodle is shown in Equation 4:

$$CT = 4.854 - 1.238E - 3u + 0.0115T + 5.83E - 5\,uT \tag{4}$$

Where:
CT = cooking time, min
u = conveying shaft speed (rpm) and;
T = barrel temperature, °C.





(e) (f)

(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25% plantain flour + 75% wheat flour instant noodle.

Figure 3. Effect of conveying shaft speed and barrel temperature on optimum cooking time of plantain-wheat instant noodle.

The optimum solution (cooking time of 4.19 min) is found at 100 °C barrel temperature and 85 rpm conveying shaft speed. The cooking time values of plantain-wheat instant noodle compared favourably with 3.11-4.77 min for breadfruit-konjac-pumpkin-wheat instant noodle; 4.5-8.29 min for plantain-wheat instant noodle and 4.3-5.41 min for corn-tapiocal-wheat instant noodles [24-26] but lower than 5.6-6.6 min reported by [27] for malted and fermented cowpea-wheat instant noodle; 7.33-8.67 min for sago starch-wheat instant noodle [28]; 7.30 min for defatted rice bran-soy-wheat instant noodle [29] and 7.16-9.36 min reported for raw jackfruit-wheat instant noodle [30]. The decline in cooking time values of plantain-wheat instant noodles obtained as substitution proportion increased is due to discontinuity within the gluten matrix and results in weak dough properties [31-32].

Effect of extrusion parameters on cooking gain: Figure 4 showed effect of extrusion parameters (barrel temperatures and conveying shaft speeds) on cooking gain of plantain-wheat instant noodles at different levels of substitution. The cooking gain values ranged from 183.55-197.02%; 173.78-187.58%; 173.68-182.03%; 173.45-182.93%; 169.68-181.02% and 168.11-179.11%; for the instant noodle samples coded 0% NOD; 5% NOD; 10% NOD; 15% NOD; 20% NOD and 25% NOD, respectively. The values showed that as conveying shaft speed increased, there was a reduction in cooking gain of the instant noodles. Whereas, increase in barrel temperatures led to increase in cooking gain of the instant noodles. There is significant difference ($p< 0.05$) among the instant noodles cooking gain. The interactive effects between conveying shaft speed and barrel temperature on cooking gain is positive. The maximum cooking gain was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient (R^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9941 and desirability of 0.984. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle cooking gain is then shown in Equation 5:

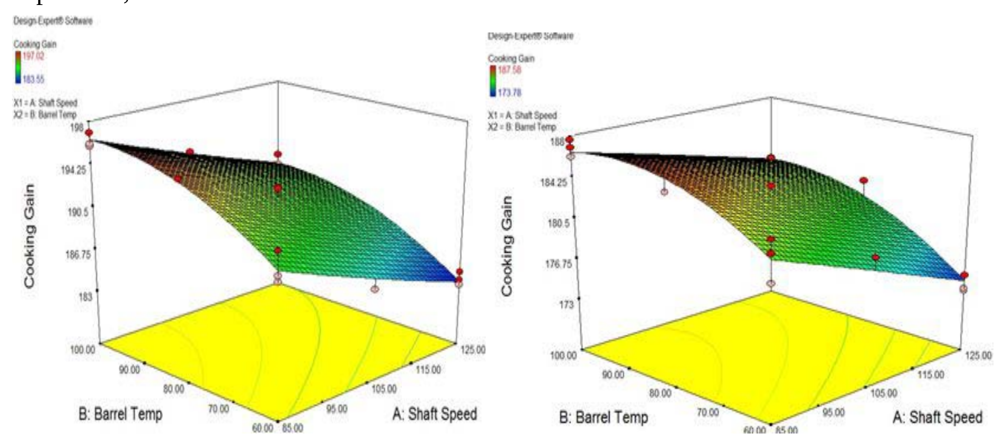
$$CG = 164.98 + 0.166u + 0.533T - 5.81E - 0.004uT + 3.478E - 5u^2 + 2.315T^2 \tag{5}$$

Where:

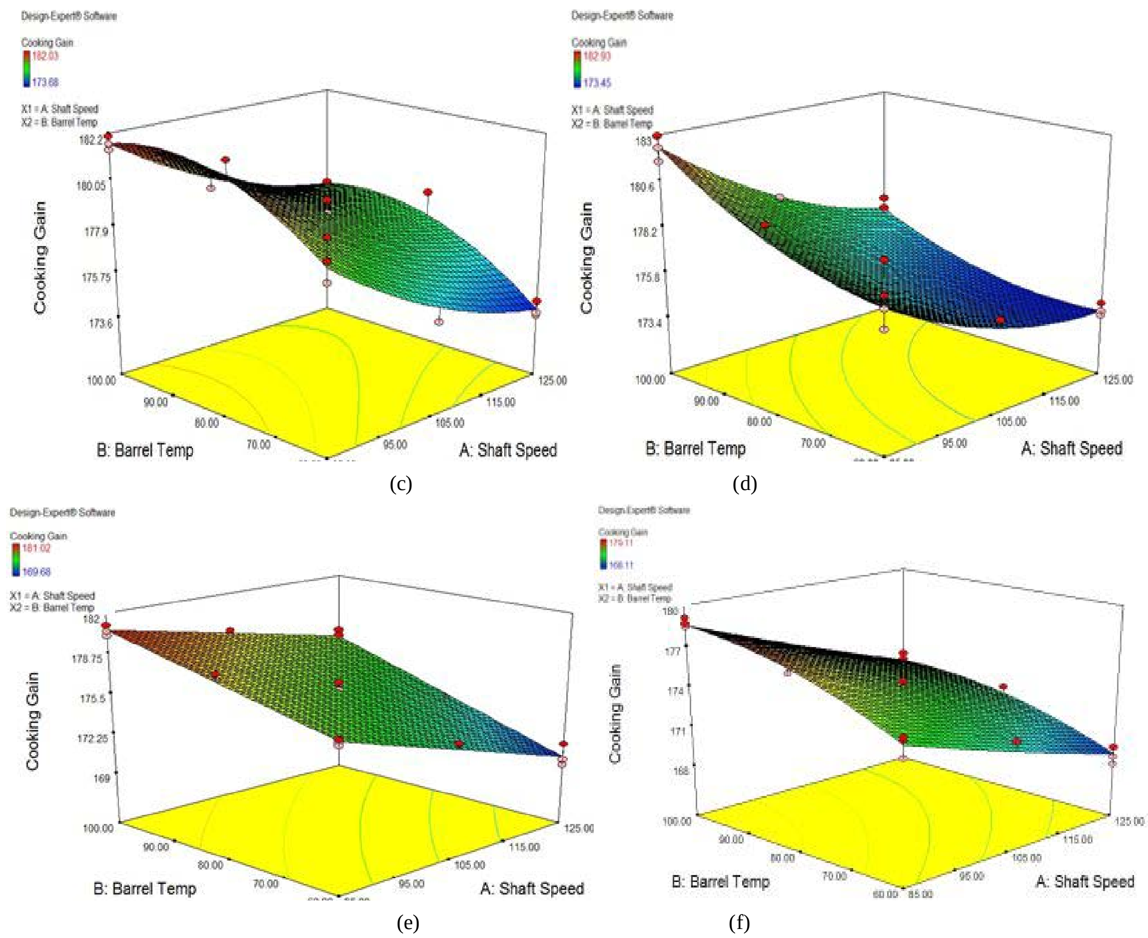
CG = cooking gain, %

u = conveying shaft speed (rpm) and;

T = barrel temperature, °C.



(a) (b)



(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% Musa spp flour + 80% wheat flour instant noodle; (f) 25% Musa spp flour + 75% wheat flour instant noodle.

Figure 4. Effect of shaft speed and barrel temperature on cooking gain of plantain-wheat instant noodle.

The optimum solution (cooking gain of 181.73%) is found at when 100°C and 85 rpm conveying shaft speed. The results obtained compared favourably with 120.7-160.3% reported [27] for malted-fermented cowpea-wheat instant noodle but lower than 252-379% and 287-362% reported by [28] for sago starch-wheat instant noodle and [33] for soy protein isolate-wheat instant noodle, respectively.

Effect of extrusion parameters on cooking loss: Figure 5 showed the effect of extrusion parameters (barrel temperatures and conveying shaft speeds) on cooking loss of plantain-wheat instant noodles at different levels of substitution. The cooking loss values ranged from 5.51-6.92%; 6.31-7.15%; 6.31-7.15%; 7.19-7.94%; 7.65-8.43% and 7.61-8.87% for instant noodle samples 0% NOD; 5% NOD; 10% NOD; 15% NOD; 20% NOD and 25% NOD samples, respectively. The values showed that for all level of substitution, as shaft speed increased, there was an increase in cooking loss. This is associated with incomplete gelation of the noodle starch as a result of low residence time of the dough in the extruder. Whereas, increase in barrel temperature leads to reduction in cooking loss. The interactive effect of conveying shaft speed and barrel temperature is quadratic. The minimum cooking loss was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient (R^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9796 and desirability of 0.980. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle cooking loss is then shown in Equation 6:

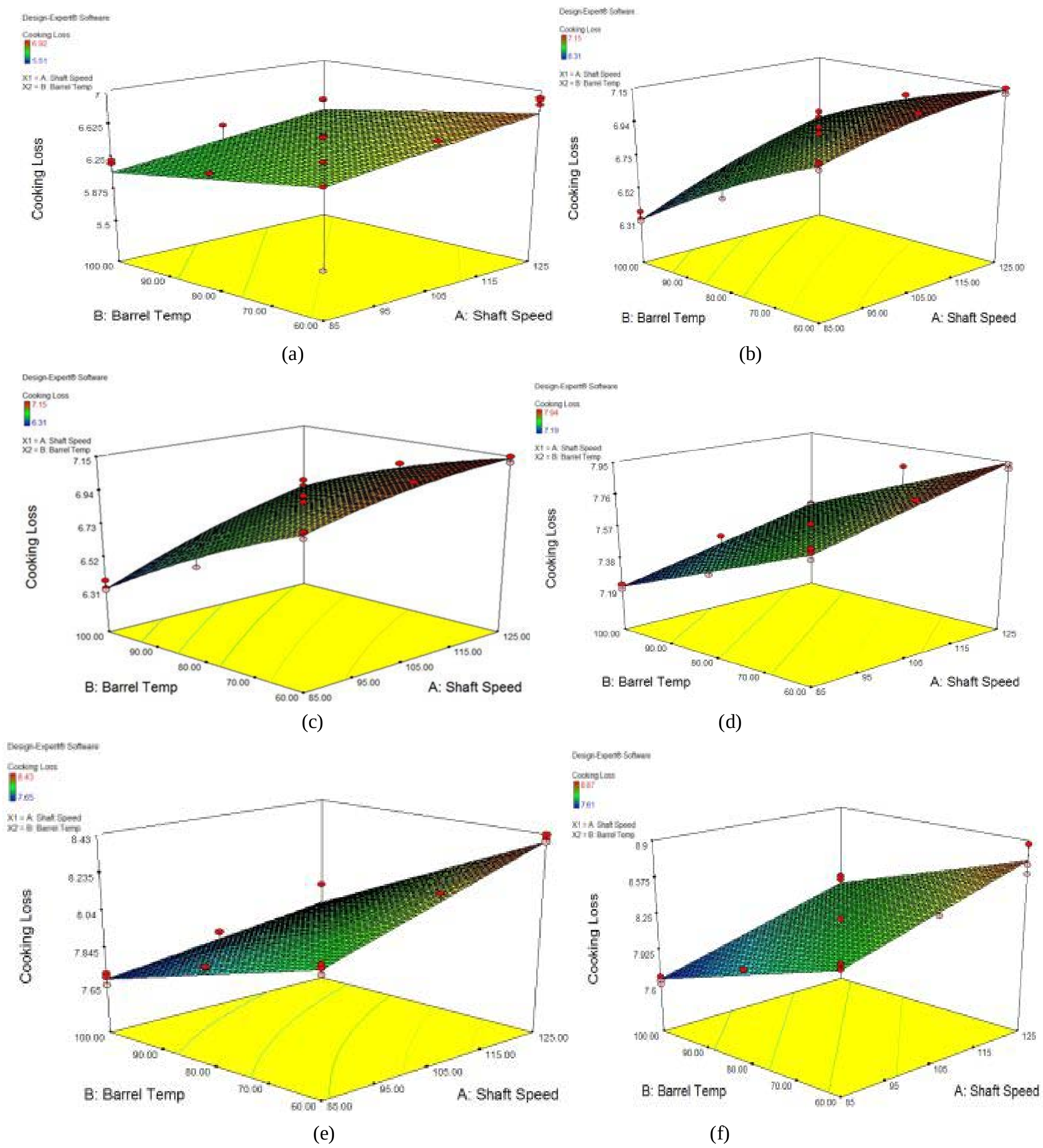
$$CL = 6.951 + 0.0137u - 4.812E - 3T - 7.083E - 3uT \quad (6)$$

Where:

CG = cooking loss, %

u = conveying shaft speed (rpm) and;

T = barrel temperature, °C.



(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25% plantain flour + 75% wheat flour instant noodle.

Figure 5. Effect of shaft speed and barrel temperature on cooking loss of plantain-wheat instant noodle.

The optimum solution (cooking loss of 7.03%) is found at barrel temperature of 100°C and 85 rpm conveying shaft speed. The cooking loss results obtained compared favourably with 6.39-10.40% reported by [25] for cassava-wheat instant noodle but higher than 0.93-1.63% and 2.01-6.19% reported by [27] for malted-fermented cowpea-wheat instant noodle and [28] for sago starch-wheat instant noodle, respectively. It reported that cooking loss of instant noodles from blends of breadfruit, konjac, pumpkin and wheat flours, ranged from 12.45-17.04% [24]. These results are in the agreement with the study of [33] who reported that partial or complete substitution of durum wheat semolina with fibre material can result in negative changes to pasta quality, including increased cooking loss. The high cooking loss recorded by plantain-wheat instant noodle as substitution increases is due to a weakening of the protein network by the presence of plantain (non-gluten protein) flour which allows more solids to be leached out from the noodles into the cooking water [23, 34].

Effect of extrusion parameters on moisture uptake: Figure 6 showed the effect of extrusion parameters (conveying shaft speeds and barrel temperatures) on moisture uptake of plantain-wheat instant noodles at different levels of substitution. The moisture uptake ranged from 9.79-10.74%; 10.27-11.01%; 10.7-11.71%; 11.16-12.06%; 11.59-12.31% and 12.01-12.43% for instant noodle samples 0% NOD; 5% NOD; 10% NOD; 15% NOD; 20% NOD and 25% NOD, respectively. The values showed that at all levels of substitution, as the conveying barrel temperature increased, there was corresponding decrease in moisture uptake of the instant noodles as increased barrel temperature ensured complete gelation of noodle starch. In contrast, as conveying shaft speed increased, there is an increase in moisture uptake due to incomplete gelation of noodle starch in the barrel. The interactive effects of conveying shaft speed and barrel temperature on moisture uptake are both linear and quadratic. The minimum moisture uptake was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental data, predicted responses, their correlation coefficient (R^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9687 and desirability of 1.00. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle moisture uptake is then shown in Equation 7:

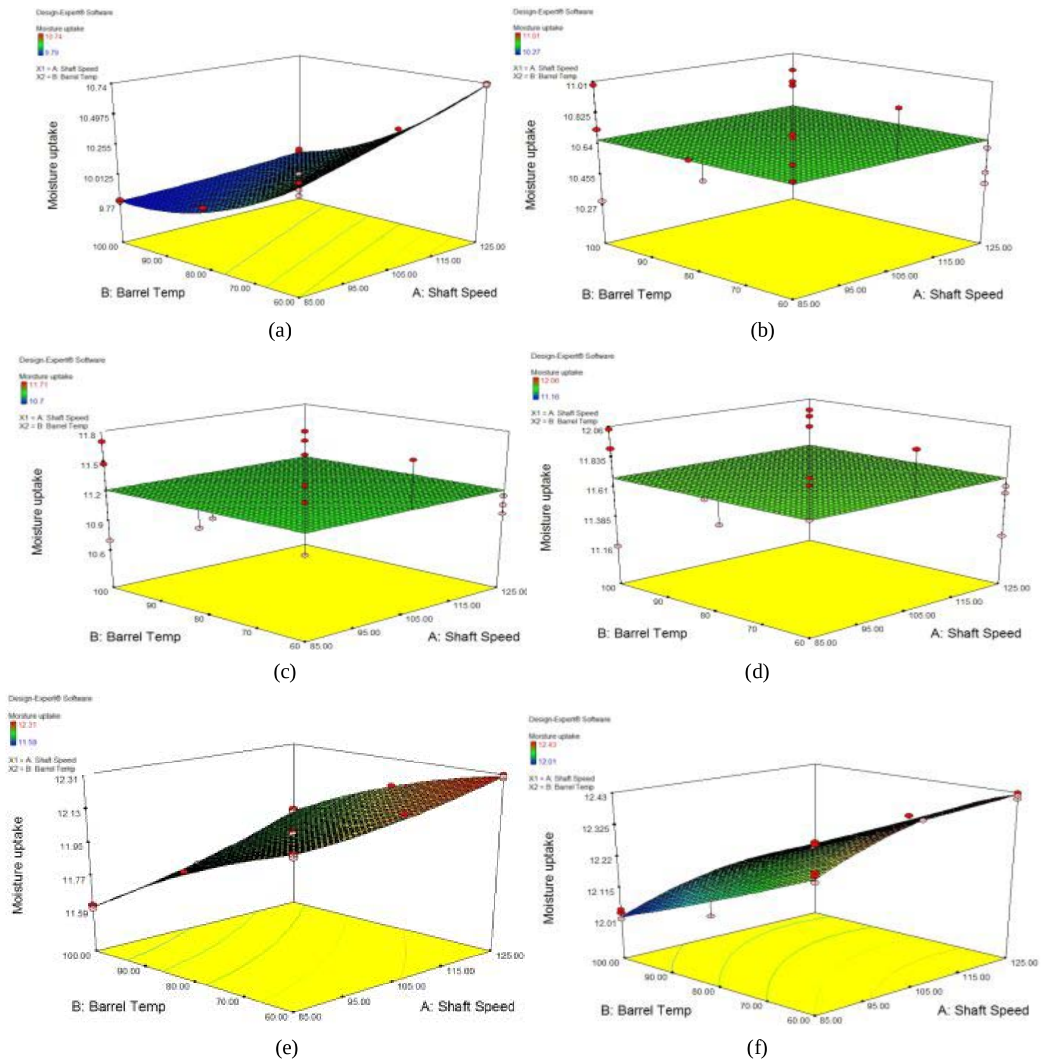
$$MU = 6.528 - 4.407E4u - 0.0218T + 1.104E - 4uT \quad (7)$$

Where:

MU = moisture uptake, %

u = conveying shaft speed (rpm) and;

T = barrel temperature, °C.



(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25%plantain flour + 75% wheat flour instant noodle.

Figure 6. Effect of shaft speed and barrel temperature on uptake moisture of plantain-wheat instant noodle.

The optimum solution (moisture uptake of 5.25%) was recorded at 100°C barrel temperature and 85 rpm conveying shaft speed. *Effect of extrusion parameters on fat content*: Figure 7 showed the effects of extrusion parameters (barrel temperatures and conveying shaft speeds) on fat content of plantain -wheat instant noodles at different levels of substitution. The fat content values ranged from 9.37-9.99%; 9.94-10.42%; 10.01-10.69%; 11.17-12.02%; 12.47-13.32% and 12.82-13.85% for instant noodle samples 0% NOD; 5% NOD; 10% NOD; 15% NOD; 20% NOD and 25% NOD, respectively. The values revealed that for all levels of substitution, as shaft speed increased, there was a corresponding increase in fat content. Whereas, increase in barrel temperature leads to reduction in fat content. This may be associated with gelation rate of the instant noodle starch as there is complete gelation at high temperature and partial gelation at high conveying shaft speed due to low residence time of the dough in the extruder [32, 34]. Interactive effects of conveying shaft speed and barrel temperature are both linear and quadratic. The minimum fat content was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient (R^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9958 and desirability of 0.995. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle fat content is then shown in Equation 8:

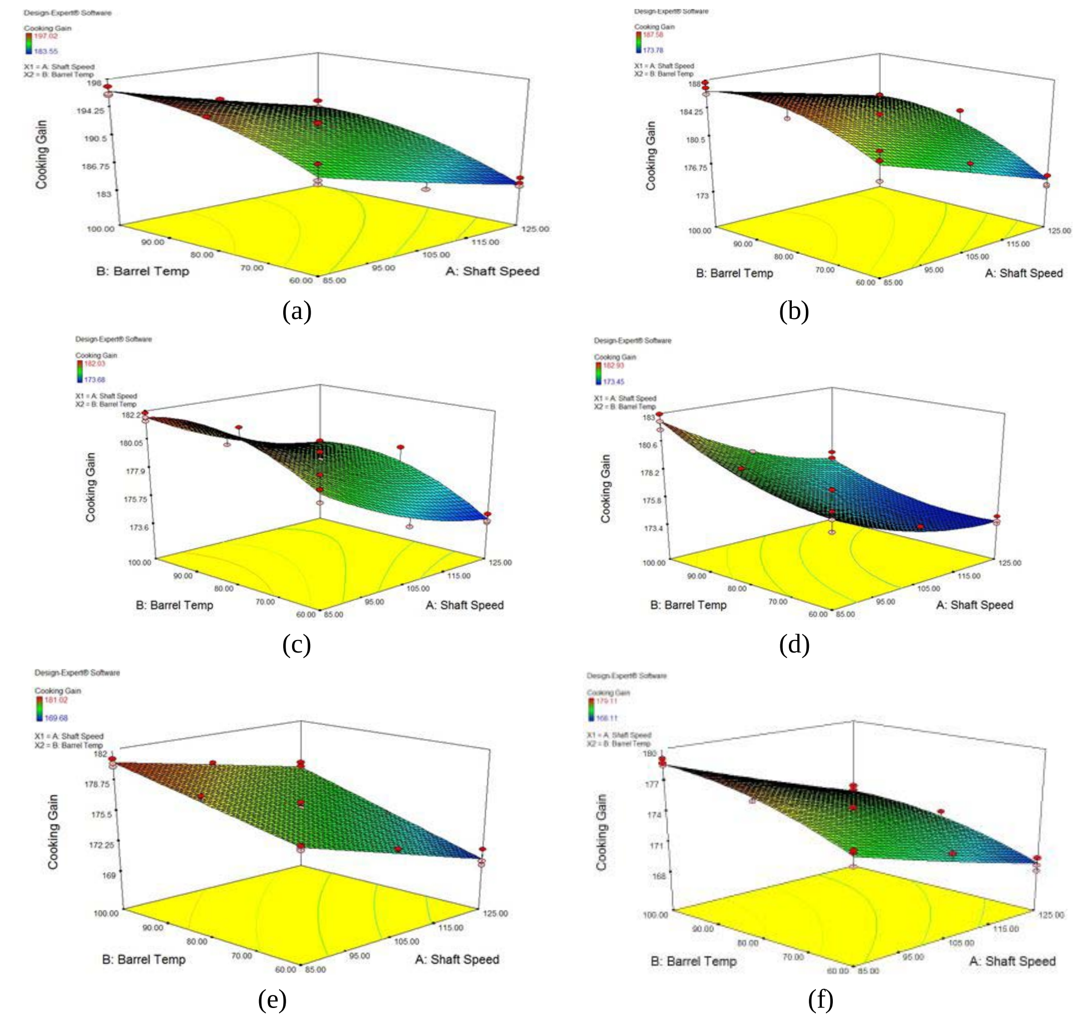
$$FC = 11.538 - 7.4E3u - 0.0148T - 6.25E - 6uT + 5.956E - 5u^2 + 2.21E - 5T^2 \tag{8}$$

Where:

FC = fat content, %

u = conveying shaft speed (rpm) and;

T = barrel temperature, °C.



(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25% plantain flour + 75% wheat flour instant noodle.

Figure 7. Effect of shaft speed and barrel temperature on fat content of plantain-wheat instant noodle.

The optimum solution (fat content of 10.02%) was recorded at 100°C barrel temperature and 85 rpm conveying shaft speed.

4. Conclusion

Impact of extrusion parameters on cooking quality of instant noodles produced from plantain-wheat composite flour has been documented. The cooking properties data also showed significant correlation between cooking properties and extrusion parameters considered. These data obtained provide baseline information for process control and design in industrial production of instant noodle from plantain fruits; thereby promising value addition to this important tropical food crop which hitherto has suffered enormous postharvest losses.

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