Original Research Article

Response Surface Modelling of Effects of Extrusion Conditions on ~~s~~Some Anti-~~n~~Nutritional ~~c~~Composition of Water ~~y~~Yam ~~b~~Based Noodles Analogue~~.~~

ABSTRACT

A second order central composite response surface methodology was used to investigate the effect of extrusion process on proximate composition of noodles analogue from water yam, yellow maize, and African yam bean. Flour blend from water yam, yellow maize, and African yam bean were produced and was used to extrude noodles analogue using a brabender single screw laboratory extruder (Duisburg DCE 330 model) fitted with 3.0mm die nozzle diameter. A central composite rotatable design with three variables, namely barrel temperature, feed moisture content and screw speed and five level coded – a, -1, 0, +1,, +a, was used and data analyzed by regression analysis. Results showed that phytate ranged from 0.02 to 0.10; trypsin inhibitor ranged from 0.003 to 0.39% and tannin content ranged from 0.25 to 1.02%~~ respectively~~. The anti-nutritional composition of the noodles analogue were all at a safe level. The coefficient of determinations (R^2) were high and ranged from 0.9014 to 0.9522 at 5% levels. The response surface plots suggested that the models developed had a good fit and the CCRD was effective in explaining the effect of the process conditions on noodles analogue as influenced by barrel temperature, feed moisture content, and screw speed of the extruder. The data obtained from the study could be used for control of product characteristics. The study indicated that improved noodles analogue from available and cheap roots, cereal and legumes such as water yam, yellow maize, and African yam bean with safe anti-nutritional factors can be produced for possible projection for the commercial production of noodles analogue.

~~**KEY WORDS:**~~*Keywords:* **Extrusion, Noodles analogue, Anti-nutritional factors**

~~Introduction~~1. INTRODUCTION

Yam (*Dioscoreaspp*) are grown widely in tropical and subtropical region of the world. Yam is second only to cassava as the principal staple food and source of nutrient energy for millions of people in West Africa (Aniedu and Oti, 2011). Nigeria is the world leading producer of yam with an annual production of 36.5mt (AnieduandOti, 2011). One of the species, water yam (*D. alata*) contain starch between 70 and 80% of dry matter (Zhang and Oates, 2011). It is considered as the most amenable yam species for processing into wide range of confectioneries and

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other fabricated food because of its high starch content. It is the most widely distributed yam species, having comparatively better agronomic characteristics, such as ease of propagation and yields, higher nutritive value, and a longer storage life and this plays a very significant role when other foods crops are in short supply (Boume, 1990).

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Maize has been identified as a predominant cereal in Nigeria~~,~~.~~i~~It can be grown and harvested anytime, maturity is rapid, it contain useful vitamins, has about 65 – 84% starch; is tropical plant and is considered as a poor man’s cereal because ~~its~~It is highly nutritious, resistant to drought than wheat and rice. It can be prepared into so many dishes.

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African yam bean (*Sphenostylisstenocarpa*) is among the lesser known legumes in the tropics that grows wild throughout Africa and is common in central and Western Africa, especially in Southeastern Nigeria. African yam bean is a food legume that serves an important economic source of supplementary protein for population lacking animal protein. The seeds have crude protein levels varying from 21 to 29% with other nutrients, as well as anti-nutrients. The practice of blending locally grown tubers and legumes or cereal and legumes on the basis of nutrient complementarity is common in Nigerian food dishes.

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The simultaneous ingestion of yam, yellow maize and African yam bean in a singular product is desirable to provide nutrient balance. However, the utilization of these crops could be restricted due to lack of awareness of its nutritional composition to the general public and its content of anti-nutritional factors (Nair *et al.*, 2012)

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Anti-nutritional factors are those substances or chemical compounds found in raw foods generally, reduce nutrient intake, digestion, absorption, and utilization. They are known to adversely affect health through inhabitation of protein digestion, growth, iron, zinc absorption (Larson *et al.*, 1996) and healing due to low availability of nutrients (Agbaire and Emoyan, 2012). To improve on the nutritional availability by reducing anti nutritional factors of processed foods, many processing techniques such as drying, toasting, boiling, fermentation, and extrusion cooking have been in used

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Extrusion cooking has received great attention as one of the most effective and ~~fasted~~fastestgrowing food processing operation in reducing anti-nutritional factors in crop foods. Extrusion cooking process has become a highly trendy process in the cereal, snack ~~a~~and noodle industries. Its application in Nigeria has been reported for blends of cereals, root, tubers and low protein legumes (Iwe and Ngoddy, 1998). However, it has not been applied for the production of noodles from the blend of water yam, yellow maize, and African yam bean.

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Therefore the objective of this study is the effect of extrusion cooking on the anti-nutritional factors of noodles analogue from water yam, yellow maize, and African yam bean flour blend.

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~~Materials and Methods~~2. MATERIALS AND METHODS

The water yam TDA 297 was bought at National Root Crop Research Institute (NRCI), Umudike, Abia State, Nigeria. The yellow maize and the cream coloured African yam bean were identified and bought at National Institute of Horticulture (NIHOT) Mbato sub zone, Okigwe, Imo state. Xanthan gum (G 1253, sigma – Aldrich USA) was procured from pharmaceutical shop in Onitsha~~,~~.Dangote iodized table salt was purchased from a super market in Afikpo, Ebonyi state, Nigeria.

2.1 Flour production: Water yam tubers was washed, peeled manually with a stainless steel knife under water containing 0.20% solution of sodium metabisulphate. The peeled yam was transferred into another container of the same concentration of solution of sodium metabisulphate and allowed to stand for 5 min and then were sliced manually in (2 mm x 3 mm) sizes. They sliced water yam were removed and allowed to drain for 1h under air current and dried at 60^{o}C for 6h in a Chirana type air convention oven (HS201A). Dried chips were cooled for 2h at room temperature under air current and milled using Brabender roller mill (Model 3511A). The flour sample was sieved through 0.50mm mesh size,packaged and sealed in polyethylene bag for further use.

Yellow maize grain were sorted, and cleaned in an aspirator (Model: OB 125 Bindapst Hungary) located at the Food Processing Laboratory of Federal Polytechnic, Mubi. The cleaned maize grains were conditioned by manually sprinkling of clean potable water at interval of 15 min and the moisture content was maintained at 21 to 22 % for 30 min in a stainless steel container. The grains were dried at 60^{o}C for 6h to 15 % MC in a Chirana type air convention oven (HS201A)and then cracked and milled with Brabender roller mill (Model 3511A). The seed coats were removed to obtain the maize flour to pass through a screen with 0.50mm openings. The flour was stored in an air tight plastic container at room temperature for further use.

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Creamcoloured African yam bean grain were sorted to eliminate contaminants, cleaned in an aspirator (Model: OB 125 Bindapst Hungary) ~~and washed~~ located at the Food Processing Laboratory of Federal Polytechnic, Mubi. Cleaned grains were soaked for 3 h at room temperature and dehulled. The dehulled grains were dried at 60^{o}C for 10 h in a Chirana type air convention oven (HS201A) and milled with Brabender roller mill (Model 3511A) to pass

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through a screen aperture with 0.50 mm openings. The flour was stored in an air tight plastic container at room temperature for further use.

2.2 Flour blending ratio

Flour samples were blended in the ratio of 60% water yam, 10% yellow maize, and 30% African yam bean based on preliminary result

2. 6 Experimental design

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A central composite rotatable design (CCRD) for three variable was employed to examine the response pattern of the effects of barrel temperature, BT (^{o} C), feed moisture content, FMC (%) and screw speed, SS (rpm) on ~~proximate~~ antinutrientcomposition of the noodles analogue. Each variable was evaluated as shown in Table 2 and 3. Each variable were at five levels, namely -α -1, +0, +1 and +α gave 15 variable combinations in which the 15th combination was replicated 5 times at the center point (0, 0, 0) of the design to generate a total of 20 experimental runs ~~used.~~

2.7 Statistical analysis

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The data obtained from triplicate run using Central Composite Rotatable Design was analyzed statistically using Response Surface Methodology, so as to fit the quadratic polynomial equations generated using Design Expert software version 8.0.7.1 (Stat-ease Inc., USA).

A second order polynomial equation was used to fit the experimental data given in Table 2. The model proposed for the response (Yi) was shown in equation 1 and 2

$$Y_1 = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 \beta_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3 + \quad \ldots (1)$$

$$Y_1 = \beta_o + \beta_1 BT + \beta_2 FMC + \beta_3 SS + \beta_{11} BT^2 + \beta_{22} FMC^2 + \beta_{33} SS^2 + \beta_{12} BTFMC + \beta_{13}BTS\ \beta_{23}FMCSS + \beta_{123}BTFMCSS \quad .... (2)$$

Where Y_1 is the predicted response for proximate composition, β_o (intercept) is the value of the fitted response at the enter point of the design, βi, $\beta_{ii,}$ β_{ij}(regression coefficient term) being the linear, quadratic and cross product terms respectively and e is the random error term. In order to deduce workable optimum conditions, a graphical technique was used (Floros and Chinnan, 1988; Giovanni, 1983). To visualize the relationship between the responses and experimental levels for each of the factors the fitted polynomial equation was expressed as surface contour plots.

2.3 Noodles analogue formulation

According to (*Kalu et al.,* 2019) each one hundred grams (100g) of flour was mixed in the desired water level according to the experiment design (Table 1). 1g Iodized salt and xanthan gum 0.5 g each respectively was added for thickening and stability (Gambus*etal.,* 2007) and thoroughly mixed using Hobeart mixer (Model: A:200; English). Thereafter, the mixture was subjected to extrusion cooking.

2.4 Extrusion cooking

A single screw Brabender laboratory extruder (Model DCE 330, New Jersey, USA, Plate iv) located at the Food Processing Laboratory of Federal Polytechnic, Mubi, Nigeria, was used for the cooking. The extruder feed hopper equipped with auxiliary auger-screw rotating at variable speed on vertical axis was set at 60rpm for all the sample runs. The extruder was allowed to run to stabilization over a period of 30 min at screw speed of 40 to 45rpm during which time the noload torque and temperature and pressure regimes were displayed on the control panel before the experimental runs commenced for each set of conditions. The moisture content of flours, barrel temperature and screw speed were adjusted according to the experimental design (Table 1). The feedwas introduced gradually but continuously into the feed hopper and were received at the die end with of 3.00mm diameter as dried strands or pellets. The samples were allowed to cool and packaged in a polythene bag for further use.

2.5 Anti-nutritional factors analysis: Anti-nutritional properties of raw and extruded samples determined were phytate, trypsin inhibitor activity, and tannin according to methods reported in literature for phytate (Young and Greaves,1940), trypsin inhibitor activity (Kakade et al., 1974), and tannin (Pearson, 1976)

3. RESULTS AND DISCUSSION

Table 1~~:~~. The effect of barrel temperature, feed moisture content and screw speed on the anti-nutrient factor contentand percentage (%) reduction in noodles analogue.

RUN	BT(^{0}C)	FMC(%)	SS(rpm)	Phytate		TIA		Tannin	
				NA	%RE	NA	%RE/IN	NA	%RE/IN
1	90	18	120	0.100	77.27[a]	0.019	84.17[a]	0.41	37.50[a]
2	200	18	120	0.085	80.68[a]	0.157	30.83[b]	1.02	59.38[b]
3	90	30	120	0.065	85.23[a]	0.074	38.33[a]	0.38	40..63[a]
4	200	30	120	0.060	86.36[a]	0.054	55.00[a]	0.37	- 42.19[a]
5	90	18	180	0.087	80.23[a]	0.024	80.00[a]	0.38	40.63[b]
6	200	18	180	0.065	85.23[a]	0.014	88.33[a]	0.72	12.50[a]
7	90	30	180	0.064	85.45[a]	0.009	92.50[a]	0.32	50.00[a]

8	200	30	180	0.063	85.68[a]	0.015	87.50[a]	0.36	43.75[a]
9	52.5	24	150	0.082	81.36[a]	0.324	170.00[b]	0.37	42.19[a]
10	237.5	24	150	0.079	82.05[a]	0.016	86.67[a]	0.25	60.94[a]
11	145	13.91	150	0.087	80.23[a]	0.224	86.67[b]	0.39	39.06[a]
12	145	34.09	150	0.020	98.45[a]	0.005	95.83[a]	0.25	60.94[a]
13	145	24	99.55	0.082	81.36[a]	0.390	225.00[b]	0.41	35.94[a]
14	145	24	200.45	0.080	81.82[a]	0.003	97.50[a]	0.30	53.13[a]
15	145	24	150	0.081	81.59[a]	0.291	142.50[b]	0.28	56.25[a]
16	145	24	150	0.081	81.59[a]	0.330	175.00[b]	0.35	45.31[a]
17	145	24	150	0.081	81.59[a]	0.389	224.17[b]	0.34	46.88[a]
18	145	24	150	0.082	81.36[a]	0.360	200.00[b]	0.35	45.31[a]
19	145	24	150	0.079	82.05[a]	0.322	168.33[b]	0.34	46.88[a]
20	145	24	150	0.050	88.64[a]	0.330	175.00[b]	0.25	60.94[a]
RFB value				0.440		0.120		0.64	

Where BT= barrel temperature; FMC= feed moisture content; SS= screw speed; TIA= trypsin inhibitor; a= % reduction (RE); b = % increase (IN); NA= noodle analogue. RFB = raw flour blend.

Table 2:.Estimated regression coefficients of the fitted second order polynominalrepresenting the relationship between the response and the process variable

Response Coefficients	Phytate		TIA		Tannin	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Linear						
β_0	0.25353		-2.52579		2.82547	
β_1	-7.45297E4	0.2751	6.54016E3	0.1231	7.81812E3	0.0676
β_2	7.03505E3*	0.0017	0.12477	0.0869	-0.064741*	0.0105
β_3	-2.21524E3	0.4275	0.016406*	0.0073	-0.027744	0.2172
Interaction						
β_{12}	1.17424E3	0.3829	1.09848E5	0.9019	-3.52273E4*	0.0208
β_{13}	-2.27273E7	0.9314	3.71212E6	0.8351	-1.74242E5	0.5131
β_{23}	2.43056E5	0.3271	1.4231E4	0.3925	1.73611E4	0.4780

Quadratic						
β_{11}	1.45869E6	0.3550	-2.79100E5*	0.0205	1.57576E5	0.3188
β_{22}	-3.10442E4*	0.0339	-3.23530E3*	0.0035	1.48445E3	0.2667
β_{33}	5.22358E6	0.3258	-7.68088E5*	0.0482	8.18306E5	0.1361
R^2	0.9437		0.9522		0.9014	
Adj.R^2	0.8131		0.9192		0.7448	

*Significant at 5% level
Where TIA= trypsin inhibitor, β_1= Barrel temperature; β_2 = Feed moisture content; β_3 = screw speed;
β_{12} = BT* FMC; β_{13} = BT*SS; β_{23} = FMC*SS; β_{11} = BT^2; β_{22} = FMC^2; β_{33} = SS^2

Three responses, namely, phytate content (Y_1), trypsin inhibitor content (Y_2) tannin content (Y_3), which described the anti-nutritional properties of the noodles analogue were evaluated. The coefficients for the actual functional relation for predicting *Yi* are presented in Table 4. The non-significant terms from the model were omitted in the equations based on students T- ratio (Khuri and Cornell, 1987).The contour plots for the anti-nutrient content are shown in discussion.

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Table 3~~:~~. Analysis of variance for the fitted second order polynomial model as per CCRD

	Sum of squares			
	Df	**Phytate**	**TIA**	**Tannin**
Regression				
First order terms	3	0.002907 [b]	0.117 [a]	0.225 [b]
Second order terms	6	0.001434 [b]	0.183658 [b]	0.198425 [b]
Total	9	0.004341	0.300658	0.423425
Residual				
Lack of fit	5	0.000647 [b]	0.060 [b]	0.13 [a]
Pure error	5	0.0007953	0.005672	0.009083
Total error	10	0.001442	0.060	0.14
Grand total	19	0.005783	0.360658	0.563425

[a] Significant at P< 0.005
[b] Not significant atP> 0.05, Where TIA= trypsin inhibitor,

3.1 Phytate~~C~~content of ~~N~~noodles analogue

The values of the phytate content of the noodles analogue varied from 0.02% (at barrel temperature of 145°C, feed moisture content,of 34.09%, and screw speed of 150rpm) to 0.10% (at barrel temperature of 90°C, feed moisture content of 18%, screw speed of 120rpm) indicating increase in phytatecontent of the noodles analogue with decreasing barrel temperature, feed moisture content and screw speed respectively and were comparable to the values observed by earlier researchers (Anuonye*et al*. 2012; Samaila and Nwabueze, 2013) on extruded products. The range of percentage reduction in the phytate content in noodles analogue (Table 1) were higher than the values reportedby(Anounye*et al*. 2012; samaila and Nwabueze 2013)Samaila and Nwabueze [ ] and Anounye et al. [ ].

Phytic acid has 12 irreplaceablereplaceablehydrogen atomsic with which it could form insoluble salts with metals such as calcium, iron, zinc and magnesium. The formation of these insoluble salts renders the metals unavailable for absorption into the body (Anuonye*et al.*, 2009). Phytic acid is also associated with increased cooking time in most legumes and can also affect digestibility by chelating with calcium or by binding with substrate or proteolytic enzyme. However, the local methods of food processing used in Nigeria minimized the concerns posed by metal chelation and protein-binding action brought about by the phytate naturally present in food materials of plant origin (Osagie, 1998). Conventional food processing methods have been reported to reduce the phytatecontent such as fermentation (Gernah*et al*., 2011), and germination (Ugwu, 2008). Nevertheless, the percentage reduction in this study was higher compared to other methods of food processing. It could be suggested that extrusion cooking reduces phytate more than other methods of food processing(Attaugwu*et al.*, 2016). It would be expected that lowering this compound should enhance the bioavailability of such minerals as zinc and iron in the noodles analogue as phytic acid has been implicated in making these minerals unavailable as

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reported by Anuonye*et al.* [ ]~~,(2009)~~. Again, the samples had phytate content below the recommended safe level of 3010 mg/kg (Heaney *et al.*, 1991). The feed moisture content linearly, positively and significantly affected thephytate in noodles analogue at 5% level. The square (quadratic effect) of feed moisture content negatively and significantly affected the phytate content in noodles analogue at 5% level.The linear effect of barrel temperature and srew speed, interaction effect of all the independent variables, quadratic effect of barrel temperature and screw speed respectively were not significant at 5 % level (Table 2). However, the (first and second order) terms and the lack of fit were not significant at 5 % level (Table 3). The R^2 value was 0.9437 indicating that 94.37% total variation in phytate content was explained by the regression model implying a perfect fit. The model equation developed for predicting phytatecontent~~was~~is shown in ~~e~~Equation 1.

Phytate= 0.25353+7.03505E–5FMC – 3.10442E–4FMC^2.(1)

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3.2 Trypsin ~~I~~inhibitors (TIA) of noodles analogue

The trypsin inhibitor ranged in values from 0.003% (at barrel temperature of 145^{o}C, feed moisture content of 24%, 200.45rpm) to 0.39% (at barrel temperature of 145^{o}C, feed moisture content ~~34.09~~24%, and screw speed of~~150~~99.55rpm) indicating that increasing feed moisture content and decreasing screw speed favoured increase in trypsin inhibitor content of the noodles analogue. There was no clear effect of barrel temperature on the trypsin content in this study.The value of trypsin inhibitor observed in this study were lower than reported values by earlier researcher on extruded snack (Oluwole*et al.*, 2013; Anuonye*et al.*, 2012; Samaila and Nwabueze 2013). High barrel temperature and feed moisture content has been known to reduce trypsin inhibitor (Bjorck and Asp, 1983; Samaila and Nwabueze, 2013). This is in agreement with the observation in this study looking at the barrel temperature employed in this study. Bjorck and

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Asp(1983) observed that high extrusion temperature, longer residence time and high feed moisture content are the key variables for the destruction of trypsin inhibitors.~~s~~Similar observation was made in this study with respect to feed moisture content. Thermal treatment of proteinous anti nutritional factorse has proved valuable for the inactivation of protein inhibitors (Rackis*et al.*, 1986). Extrusion cooking has been reported to reduce TIA by 78 – 98% (Ukachukwu, 2015). This agrees with the percentage TIA reduction in this study whichranged from38.33% to 97.50 % (Table 1~~5~~) and were close to the observations of (Anuonye*et al.* 2007;Anuonye*et al.*, 2012; Singh *et al.* 2000). Trypsin (Protease inhibitor) causes pancreatic enlargement and growth depression (Aletor, 1993). The inactivation of trypsin inhibition activity may be due to the denaturation of heat labile proteins of seeds. This couldimply that protein digestibility will not be hampered when the product is consumed. The screw speed linearly, positively and significantly ($P<0.05$) affected the trypsin inhibitor in noodles analogue. The quadratic effect of the three independent variables negatively, and significantly affected the trypsin inhibitor in noodles analogue at 5% level. The linear effect of barrel temperature and feed moisture content and the interaction effect of all the independent variables were not significant at 5 % level (Table 2). The first order term was significant at 5 % level. The second order term and lack of fit respectively were not significant at 5 % level (Table 3). The R^2 value was 0.9522, indicating that 95.22% of total variation in trypsin inhibitor was explained by the regression model implying a perfect fit. The model equation developed for predicting trypsin inhibitor content was shown in equation 2.

Trypsin inhibitors $= -2.52579 + 0.016406\,SS - 2.79100E{-}5BT^2 - 3.23530E{-}3FMC - 7.68088E{-}5SS^2$.(2)

3.3 Tannin ~~C~~content of ~~N~~noodles analogue

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The tannin content ranged from 0.25% (at barrel temperature of 145^{o}C, 237.50^{o}C, feed moisture content of 24%, 34.09% and screw speed of 150rpm) to 1.02% (at barrel temperature of 200^{o}C, feed moisture content of 18% and screw speed of 120rpm). The result revealed that the tannin content of the noodles analogue increased with decreased in barrel temperature, feed moisture content and screw speed respectively.The observed values of tannin content in this study was comparable to the earlier reported values (Ugwu, 2008). Mukhopadhyay and Bandyopadhyay, (2003) reported that tannin reduction is greatly influence by screw speed and barred temperature. However, in this study, screw speed and barrel temperature did not demonstrate strong relation with the tannin content reduction.The percentage tannin reduction in this study was 39.06% (Table 1) and was comparable to the value reported by ~~(~~Samaila and Nwabueze~~, 2013)~~ [ ]. However, earlier researchers had reported higher values (Anuonye*et al.*, 2012; Samaila and Nwabueze, 2013). Tannin, a phenolic derivative of flavone which occurs as glycosides in the natural states and forms complexes with the available protein thereby affecting the digestibility and palatability. Tannin causes decreased feed consumption in animals, bind dietary protein and digestive enzymes to form complexes that are not~~ready~~ readily digestible (Aletor, 1993; Uzoechina, 2007). Alonso *et al.* (2000) reported the effects of extrusion and traditional processing methods on anti-nutritional invitro digestibility of protein and starch in fiba and kidney beans. They assert that legumes extrusion was the best method to abolish trypsin, chymotrypsin, a-amylase inhibitors and haemagglutinating activity, without modifying protein content and effective in improving protein and starch digestibility when compared with dehulling, soaking and germination. The enzyme hydrolysis of protein is improved after extrusion cooking as a result of the inactivation and sometimes complete destruction of anti-nutritional factors in plant proteins. This suggests that extrusion considerably improved the

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nutritive value of proteins (Singh *et al.*, 2000). All the noodles had tannin content below the recommended safe level of 1500 to 3000 mg/kg (Schiavone*et al.*, 2007). The feed moisture content linearly, negatively and significantly ($p<0.05$) affected the tannin content in noodles analogue. The interaction effect of barrel temperature negatively and significantly affected the tannin content in noodles analogue at 5% level. The linear effect of barrel temperature and screw speed, and interaction effect of barrel temperature and screw speed, feed moisture content and screw speed were not significant at 5 % level. Also the quadratic effect of all the three independent variables were not significant.Aat 5 % level (Table 2). The first and second order terms were not significant at 5 % level. However, lack of fit was significant at 5 % level (Table 3). The R^2 value was 0.9014, indicating that 90.14% of total variation in tannin was explained by the regression model implying a perfect fit. The model equation developed for predicting tannin content was shown in equation 3.

Tannin = 2.82547 – 0.064741FMC– 3.52273E–4BT*FMC (3)

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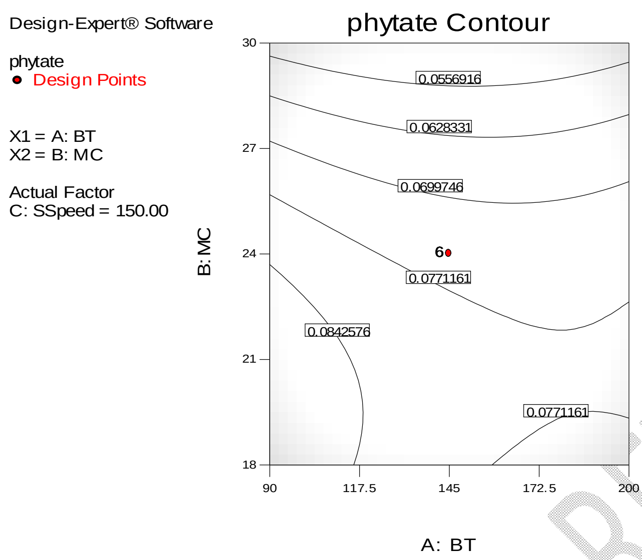
Design-Expert® Software
phytate
Design Points
X1 = A: BT
X2 = B: MC
Actual Factor
C: SSpeed = 150.00
phytate Contour
B: MC
A: BT
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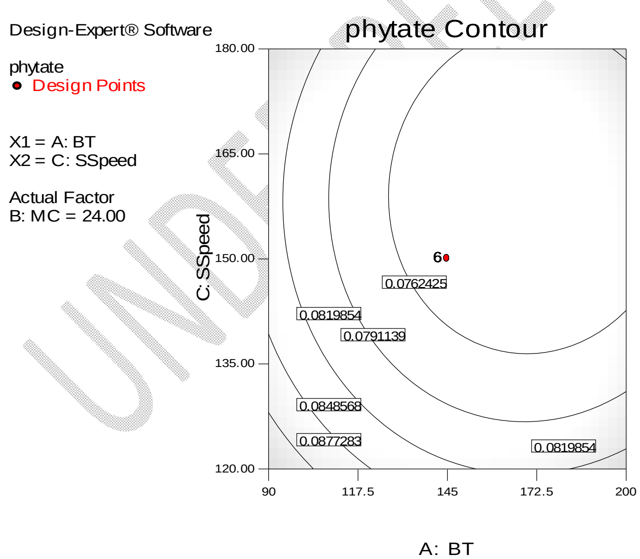
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Actual Factor
B: MC = 24.00
phytate Contour
C: SSpeed
A: BT
0.0762425
0.0819854
0.0791139
0.0848568
0.0877283
0.0819854
6
180.00
165.00
150.00
135.00
120.00
90
117.5
145
172.5
200

1c.

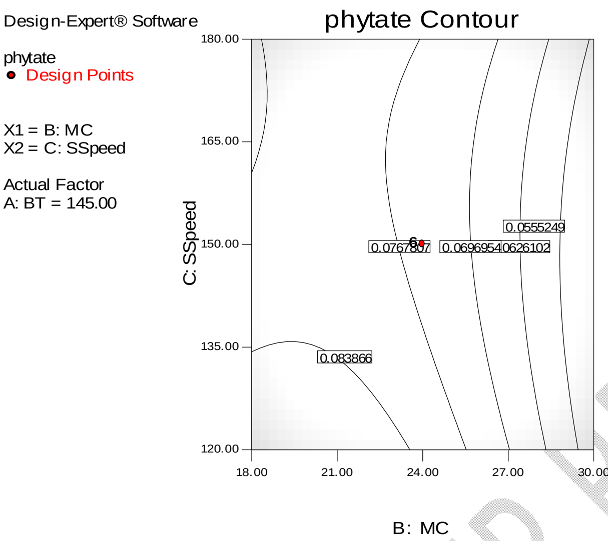
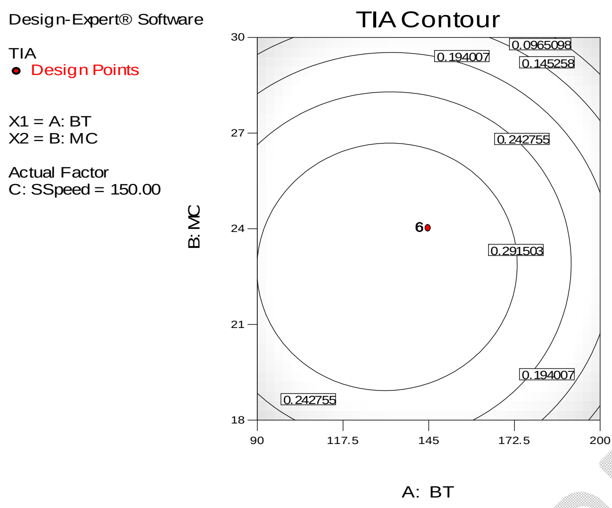
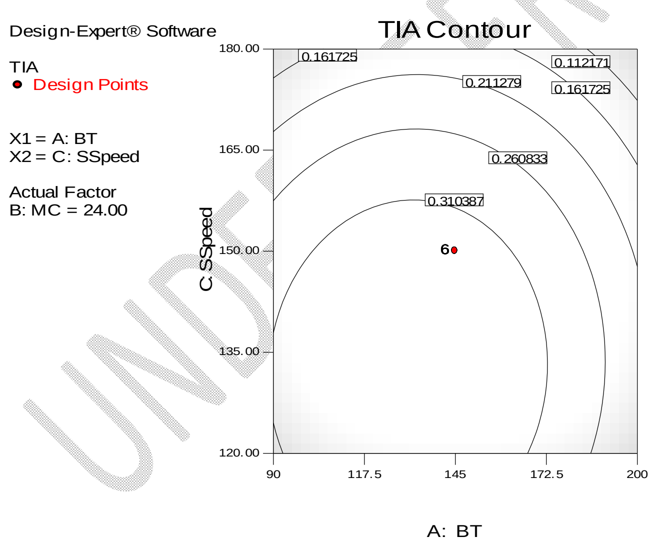


Fig 1a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on phytate content.

2a.


Design-Expert® Software
TIA
Design Points
X1 = A: BT
X2 = B: MC
Actual Factor
C: SSpeed = 150.00
TIA Contour
0.0965098
0.194007
0.145258
0.242755
0.291503
0.194007
0.242755
B: MC
30
27
24
21
18
90
117.5
145
172.5
200
A: BT
6

2b.


Design-Expert® Software
TIA
Design Points
X1 = A: BT
X2 = C: SSpeed
Actual Factor
B: MC = 24.00
TIA Contour
0.161725
0.112171
0.211279
0.161725
0.260833
0.310387
C: SSpeed
180.00
165.00
150.00
135.00
120.00
90
117.5
145
172.5
200
A: BT
6

2c.

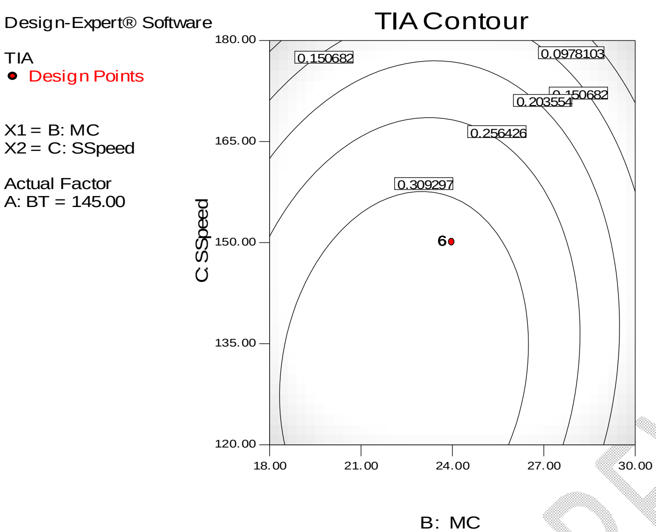
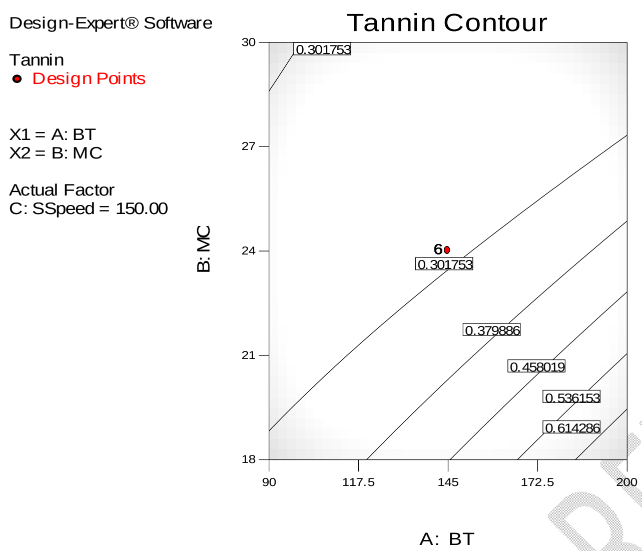


Fig 2a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on trypsin inhibitor content.

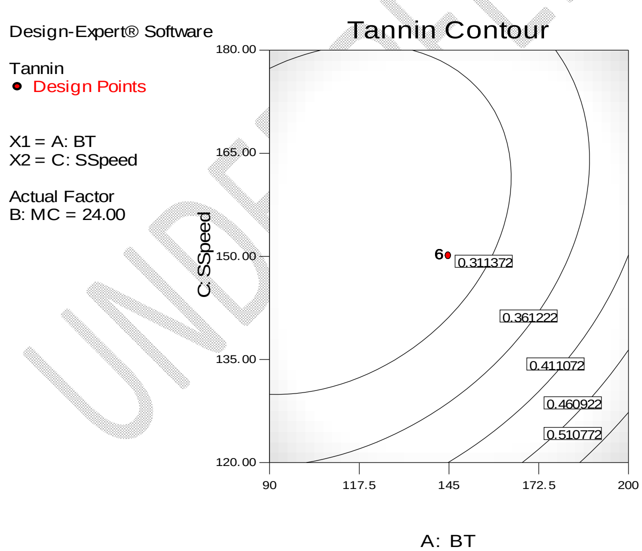
3a.

.



Design-Expert® Software
Tannin
Design Points
X1 = A: BT
X2 = B: MC
Actual Factor
C: SSpeed = 150.00
Tannin Contour
B: MC
A: BT
0.301753
0.379886
0.458019
0.536153
0.614286
6

3b



Design-Expert® Software
Tannin
Design Points
X1 = A: BT
X2 = C: SSpeed
Actual Factor
B: MC = 24.00
Tannin Contour
C: SSpeed
A: BT
0.311372
0.361222
0.411072
0.460922
0.510772
6

3c.

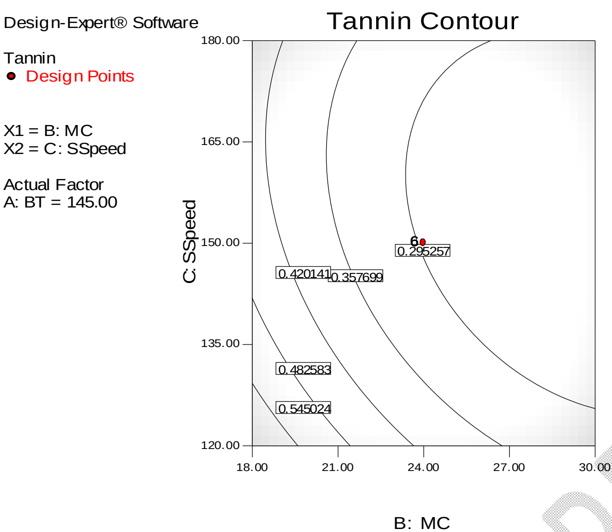


Fig 3a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on tannin content.

The figures were not discussed. You need to briefly discuss the figures to enable the readers understand what you are talking about.

~~Conclusion~~4. CONCLUSION

The response surface methodology employed in this study clearly explained how an extrusion processing of blends of water yam, yellow maize, and African yam bean would give an improved noodles analogue by reduction in the anti-nutrient content. The models equation developed were adequate because of high coefficients of determinations (R^2) and can be used for predictive purposes. This could be a good news for an intended commercial production of noodles analogue. It is recommended that more process variables other than ~~proximate~~antinutrientcomposition could be investigated. Furthermore, other extrusion types and sizes could be used to study product quality and extruder performance for possible product scale up to commercialization.

Comment [U51]: Your conclusion should be able to indicate the best extrusion condition for the blend.

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Comment [U52]: Follow the Journal reference format in all.

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