Original Research Article

Effect of Extrusion Process on Proximate Composition of Water Yam based Noodles Analogue – A Response Surface Analysis

ABSTRACT

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 mixture. 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 proteins of noodles analogue ranged from 12.40 to 22.16%; fat content ranged from 2.98 to 6.07%; fibre content ranged from 1.80 to 2.52%; ash content ranged from 6.21 to 9.50%; moisture content ranged from 11.05 to 12.47% and carbohydrate content ranged from 48.31% to 63.65% respectively.The coefficient of determinations (R^2) were high and ranged from 0.9106 to 0.9747 at 5% level. The response surface plot 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 produced from available and cheap roots, cereal and legumes such as water yam, yellow maize, and African yam bean can be produced for possible projection for the commercial production of noodles analogue.

KEY WORDS: Extrusion, Noodles analogue, Proximate Composition

Introduction

Noodles, which are pasta,are categorized as convenience food which is basically a product of extrusion process. Noodles are one of the staple foods consumed in many part of the globe, including Nigeria.Data from the World Instant Noodles Association (WINA) shows that Nigeria is currently among the largest consumers of instant noodles, with 1.92 million serving as of May, 2020, ranking 11th position on the global demand for noodle ranking. Within Nigeria, the noodle Market has continued to grow in leaps and bounds amidstfierce competition among noodle producers for supremacy in the market place.

Presently, there are about 16 noodle brands in the Nigerian market competing for attention of consumers and striving for growing market.Noodle has become an important part of human diet for all age bracket. It is made from durum wheat, which is the most nutritious type of wheat, yet its primary contribution to the human diet is carbohydrate, which is considered not balanced for healthy living. Furthermore, there has been a steady rise in the cost of production of noodles, due to the long standing ban on the importation of wheat flour into Nigeria since 1987. This has resulted in several attempts in the development of alternative solution by researchers and the food industry to tacklethese problems of poor nutritional value and hike in price. One of the solution developed was the binary or ternary mixing of flour from other sources such as cereal, roots, tubers, and enriched with legumes with or without wheat flour(Tharise et al., 2014)

A complete replacement of wheat in some food formulation has been reported (Ylimaka, 1989). Food enrichment and supplementation using food-based approaches to could offer a good pathway for improving the nutritional quality of commonly consumed convenience foods. This has led to the suggestion that the addition of legume based products are essential in our daily diet for leading a healthy life (Boye*et al*., 2010).

The production of noodles analogue using water yam, yellow maize enriched with African yam bean, may offer solution to the needed improvement in noodle production. This non-wheat flour product will equally address the need of patience with celiac disease. This has not been exploited, hence a colossal omission from the view point of efforts in the production of improved noodles for the teeming consumers in Nigeria. It was on this premise that this study on the effect of extrusion process on proximate composition of noodles analogue from water yam, yellow maize and African yam been was engaged in the present study.

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.

Flour production: According to (Kalu*et al*., 2019) water yam tubers were washed, peeled manually with a stainless steel knife under water containing 0.20% solution of sodium metabisulphate. The peeled yam were transferred into another container containing a potable water of the same concentration 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 1hunder 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.

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 3h at room temperature and dehulled. The dehulled grains were dried at 60^{o}C for 10h in a Chirana type air convention oven (HS201A) and milled with Brabender roller mill (Model 3511A) to pass 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.

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

Experimental design

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 composition 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 time at the center point (0, 0, 0) of the design to generate a total of 20 experimental runs used.

Statistical analysis

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

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

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

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.

Noodles analogue formulation

Every 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.

Extrusion cooking

A single screw Brabender laboratory extruder (Model DCE 330, New Jersey) 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 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 foranalysis

Proximate composition analysis: Proximate composition of the noodles analogue was determined in triplicates according to AOAC (2005) methods. Total carbohydrate was determined by difference.

RESULTSAND DISCUSSION

Table 1: Effect of barrel temperature, feed moisture content and screw speedonthe Proximate composition of Noodles analogue.

Run	BT(°C)	FMC (%)	SS(rpm)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Moisture (%)	CHO (%)
1	90	18	120	12.40	4.16	1.80	6.28	12.47	62.89
2	200	18	120	21.12	4.33	2.06	6.39	12.14	53.96
3	90	30	120	12.45	4.21	2.00	6.31	11.58	63.45
4	200	30	120	21.17	3.06	2.18	7.61	12.01	53.97
5	90	18	180	12.50	2.98	2.23	6.21	12.23	63.85
6	200	18	180	21.68	3.90	2.29	6.68	11.23	54.22
7	90	30	180	13.02	3.98	1.96	6.48	11.59	62.97
8	200	30	180	22.05	5.09	2.37	7.64	11.49	51.36
9	52.5	24	150	14.25	5.10	2.30	8.09	12.19	58.07
10	237.5	24	150	22.16	5.19	2.70	9.50	12.14	48.31
11	145	13.91	150	14.82	6.07	2.22	7.34	12.91	56.64
12	145	34.09	150	14.86	4.88	2.19	7.98	11.86	58.23
13	145	24	99.55	14.80	4.18	2.32	6.81	11.95	59.94
14	145	24	200.45	14.89	4.20	2.52	6.58	11.05	60.76
15	145	24	150	14.79	4.81	2.37	6.61	12.02	59.37
16	145	24	150	15.01	4.80	2.50	6.52	12.17	59.00
17	145	24	150	15.12	4.84	2.40	6.48	12.14	59.02
18	145	24	150	15.09	4.65	2.35	6.60	12.04	59.27
19	145	24	150	15.07	4.70	2.38	6.59	12.07	59.19
20	145	24	150	15.14	4.83	2.39	6.49	12.06	59.09
CMV				16.12	4.50	2.28	6.96	11.97	58.18

BT = Barrel temperature, FMC = feed moisture content, SS = screw speed, CMV = calculated mean value, CHO = carbohydrate

Table 2: Proximate Composition regression coefficients of the fitted second order polynomialrepresenting the relationship between the response and the process variable

Response coefficients	Protein content (%)	Fat content (%)	Fibre content (%)	Ash content (%)	Moisture content (%)	CHO content (%)
	Coefficient	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Linear						
β_o	20.69472	-1.00986	-4.25053	-1.07077	9.07134	76.64089
β_1	-0.12265*	-7.93844E3	1.70503E3*	-0.0076609	-3.67576E5	0.20901*
β_2	-0.08765*	-0.35918	0.29761	-0.080144	-0.37502*	0.60216
β_3	-0.087654	0.14369	0.034414*	0.17715	0.12038*	-0.45289
Interaction						
β_{12}	-5.68182E5	-4.28030E4	1.02273E4	7.12121E4	6.28788E4*	-958333E4 -2.14394E4
β_{13}	5.83333E5	2.28030E4	2.27273E6	1.66667E5	-9.09091E5	-2.99306E3
β_{23}	5.48611E5	2.36806E3*	-3.54167E4	-1.38889E5	4.44444E4*	-8.17615E4*
Quadratic						
β_{12}	6.49373E5*	-4.87595E5	-7.66324E4	2.23387E4*	1.83058E6	-8.17615E4*
β_{11}	5.99150E5	1.19523E3	-5.37499E3*	5.68118E4	3.68207E3*	-6.23138E4
β_{33}	2.71735E5	-7.76519E4	-7.70770E5	-5.96323E4	-420445E4*	
R^2	0.9747	0.9106	0.9436	0.9123	0.9299	0.9395
Adj. R^2	0.9520	0.6501	0.9029	0.7634	0.8668	0.8850

*Significant at 5% level

B=Barrel temperature (BT); β_2=Feed moisture content (FMC); β_3 = Screw speed (SS): β_{12} = BT* FMC; β_{13}= BT*SS; β_{13}= BT*SS; β_{23}=FMC*SS; = BT_2; β_{22} = FMC^2 = FMC^2; β33 = SS^2 CHO = carbohydrate

Six responses, namely protein content (Y_1), fat content (Y_2) fibre content (Y_3), ash content (Y_4), moisture content (Y_5) and carbohydrate content (Y_6) which described the proximate composition of the noodles analogue are shown below. The coefficients for the actual functional relation for predicting Y_i are presented in Table 3. The non-significant terms from the model were omitted in the equations based on students T- ratio (Khuri and Cornell, 1987). The contour plot for the proximate composition are shown in the discussion.

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

	Sum of squares						
	Df	**Protein (%)**	**Fat (%)**	**Fibre (%)**	**Ash (%)**	**Moisture (%)**	**CHO (%)**
Regression							
First order terms	3	185.585^{b}	0155082^{b}	0.280715^{b}	3.0512^{b}	1.489^{b}	421.32^{b}
Second order terms	6	27.0522^{b}	6.303^{b}	0.339969^{b}	5.6390215^{b}	1.691214^{b}	87.99^{b}
Total	9	212.6372	6.458082	0.620683	8.69021	3.180214	509.3102
Residual							
Lack of fit	5	5.48^{a}	2.78^{a}	0.12^{a}	5.05^{a}	0.22^{a}	4.86590^{a}
Pure error	5	0.083	0.030	0.014	0.017	0.017	0.014723
Total error	10	5.56	2.81	0.13	5.07	0.23	4.880626
Grand total	19	18.1972	9.268082	0.750683	13.76022	3.410214	325.7485

^{a} Significant at $p< 0.005$
^{b} Not significant at $p> 0.05$

Protein contentof noodles analogue

The values of protein content of the noodles analogue varied from 12.40 (at barrel temperature of 90℃, feed moisture content of 18% and screw speed of 120rpm) to 22.16% (at barrel temperature of 237.50^{o}C, feed moisture content of 24%, and screw speed of 150rpm) indicating increase in protein contents of the noodles analogue with increase in barrel temperature, feed moisture content and screw speed in this study. (Table 1).The observed values in this study were comparable to earlier reported values (Danbaba*et al*., 2016).Furthermore, values observed in this study were comparable to the report by earlier researchers on the use of composite flour in extruded products.The protein content in this study fell within the recommended minimum protein requirement for supplementary mixtures by FAO/WHO/UNU (1985) and FAO (2002) as reported by Filli*et al.* (2012).Protein requirement is the amount of protein or its constituent’s amino acids or both that must be supplied in the diet in order to satisfy the metabolic demand and achieve nitrogen equilibrium. The square of barrel temperature (quadratic effect) was positively and significantly affected the protein at 5% level. The linear effect of feed moisture content and screw speed, the interaction effects of all the independent variables and quadratic effect of feed moisture content and screw speed respectively were not significant at 5% level. (Table 2). The first and second order terms were not significant at 5% level. However the lack of fit was significant at 5% level (Table 3). The R^2 (Coefficient of determination) value was 0.9747 (97.47%), implying that 97.47% of the total variation in protein content was explained by the model. This meant that the model had a perfect fit. The model equation developed for predicting protein was shown in equation 1.

Protein = $20.69472 - 0.12265BT + 6.49373E5BT^2$. (1)

Fat contentof noodles analogue

The values of fat contentof the noodles analogue ranged from 2.98 (at barrel temperature of 90^{o}C, feed moisture content of 18%, and screw speed of180 rpm) to 6.07% at barrel temperature of 145^{o}C, feed moisture content of 13.91%, and screw speed of 150 rpm. This indicate that there were increases in fat content of the noodles analogue with increase in barrel temperature, as the feed moisture content and screw speed decreases respectively in this study (Table 1). The fat content observed in this study were higher than the reported value by earlier researchers (Danbaba*et al.,* 2016). Sabota*et al.* (2010) reported increase in fat content when feed moisture content increased from 14% – 29%. However, the fat content in this study increase at a lower feed moisture content and screw speed at higher barrel temperature. The interaction effect of feed moisture content and screw speed and the quadratic effect of screw speed positively and significantly affected the fat content at 5% level. The linear effect of all the independent variables; the interaction effect of barrel temperature and feed moisture content and barrel temperature and screw speed respectively were not significant at 5% level. Quadratic effect of barrel temperature and feed moisture content were also not significant at 5% level. (Table 2).The first and second order terms were not significant at 5% level. However, the lack of fit was significant at 5% level (Table 3).The model equation developed for predicting fat was shown in equation 2.

Fat= $-1.00986 + 2.36806E{-}3FMC*SS - 7.76519E{-}4SS^{2}$ (2)

Fibre content of noodles analogue

The fibre content of the noodles analogue ranged from 1.80 (at barrel temperature of 90℃, feed moisture content of 18%, and screw speed of 120 rpm) to 2.52% (at barrel temperature of145^{o}C, feed moisture content of 24% and screw speed of 200.5 rpm). The result revealed that the fibre content of the noodles analogue increased with increase in barrel temperature, feed moisture content and screw speed respectively in this study. (Table 1). The values observed in this study were comparable to values on cereal – pulses based extruded (Shadan*et al*., 2014). Naval *et al.* (2015) and Vavantha*et al.* (2002) reported that extrusion cooking increased the total fibre of wheat flour with increasing barrel temperature. This is in agreement with the present findings.

The linear effects of barrel temperature and screw speed,positively and significantly ($p<0.05$) affected thefibre in noodles analogue. The quadratic effect of feed moisture content, positively and significantly affected thefibre content at 5% level. The linear effect of feed moisture content and the interaction effects of all the independent variables were not significant at 5% level. The quadratic effect of barrel temperature and screw speed were also not significant at 5% level of significance (Table 2). The first and second order terms were not significant at 5% level of significance. However the lack of fit was significant at 5% level (Table 3).The test for the fit was significant with R^2 value of 0.9436. This meant that 94.36% of the total variation in moisture content was explained by the regression model. The model equation developed for predicting fibre was shown in equation 3.

Fibre =$– 4.25053 + 1.70503E–3BT + 0.034414\ SS – 5.37499E–3FMC^2$. (3)

Ash content of noodles analogue

The values of ash content of the noodles analogue varied from 6.21 (at barrel temperature of 90^{o}C, feed moisture content of 18%, and screw speed 180rpm) to 9.50% (at barrel temperature of 237.50^{o}C, feed moisture content of 24%, and screw speed of 150 rpm) which showed increase in the value of ash content with increase in barrel temperature and feed moisture content and decrease in screw speed respectively in this study. Many researchers (Muhammed*etal* 2012) reported high ash content in their respective studies. However, other several studies had reported much lower values on the ash content of starch based extruded products (Danbaba*et al.*, 2016) when compared to the present study.The level of ash in food is an important nutritional indicator for mineral density.

The quadratic effect of barrel temperature positively and significantly ($p<0.05$) affected the ash content of the noodles analogue. The linear and interaction of all the independent variables were not significant fit 5% level.The quadratic effect of both the feed moisture content and screw sped were not significant at 5% level of significance. (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 model equation developed for predicting ash was shown in equation 4.

Ash = -$1.07077 + 2.23387E–4BT^2$. (4)

4.7.1.5 Moisture content of noodles analogue

The moisture content of the noodles analogue ranged from 11.05 (at barrel temperature of 145°C feed moisture content of 24%,, and screw speed of 200.45rpm) to 12.47% at barrel temperature of 90°C, feed moisture content of 18%, and screw speed of 120rpm). This indicates that there were increases in the moisture content of the noodles with decrease in barrel temperature, feed moisture content and screw speed respectively in the study. Chaiyakul*et al*., (2009) reported that higher barrel temperature reduced extrudate moisture on rice- based snack.Similar observation was observed in this study. However, the values of the moisture content of the noodles analogue in this study were higher than the values reported by many researchers (Samaila and Nwabueze, 2013; Jiddere and Filli, 2016) on extrudates.Product moisture is the index presumed as one of the most important determinant of the shelf – stability of food products (Asare*et al*., 2004).

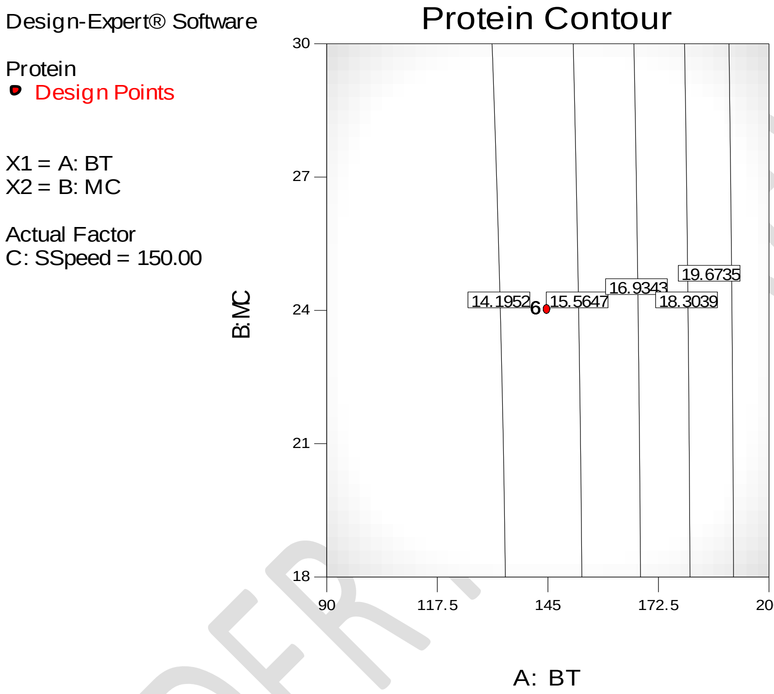
The linear effect, quadratic effect of moisture content and screw speed respectively, negatively and significantly ($p<0.05$) affected the noodles analogue. The interaction effect of barrel temperature and moisture content respectively, negatively and significantly ($p<0.05$) affected the noodles analogue. The quadratic effect of feed moisture content and screw speed positively and negatively respectively affected the moisture content at 5% level of significance. The linear and quadratic effects of barrel temperature were not significant at 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. The test for the fit was significant with R^2 value of 0.9299. This meant that 92.99% of the total variation in moisture was explained by the regression model (Table 3). The model equation developed for predicting moisture was shown in equation 5

Moisture = $9.07134 - 0.37502FMC + 6.28788E{-}4\ BT{*}FMC - 9.09091E{-}5\ BT{*}SS + 4.44444E{-}4FMC{*}SS + 3.68207E{-}3FMC^2 - 4.20445E{-}4SS^2$. (5)

4.7.1.6 Carbohydrate contentof noodles analogue

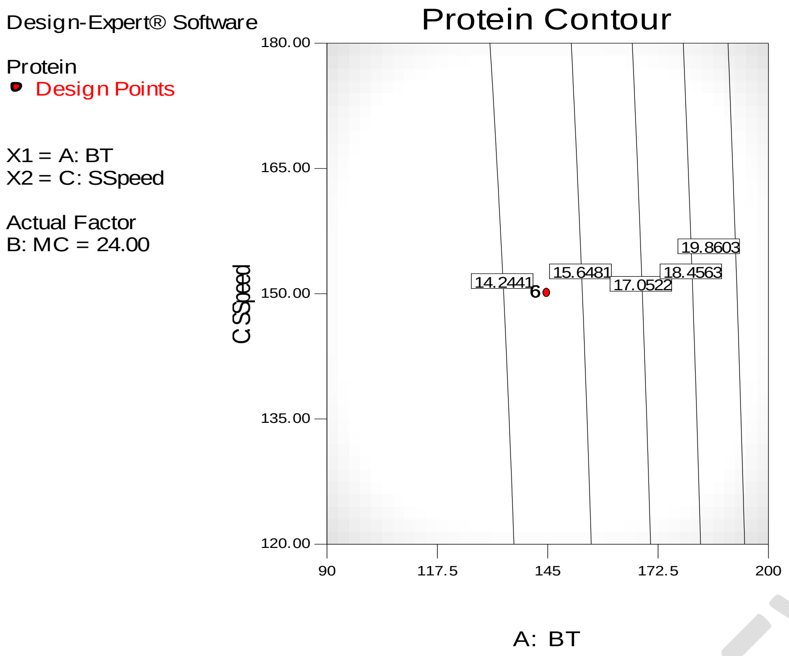
Carbohydrate content of the noodles analogue ranged from of 48.31 (at 237.50℃ barrel temperature, feed moisture content of 24% and screw speed of 150 rpm to 63.85% (at barrel temperature of 90^{o}C, feed moisture content of 18%, and screw speed of 180 rpm). The result indicated increase in carbohydrate content in the noodles analogue with decrease in barrel temperature and feed moisture content with increased screw speed respectively. The observed values in this study fell within the range of earlier reported values (Samaila and Nwabueze, 2013; Danbaba*et al.*, 2016; Shadan*et al.*, 2014) on starch based extruded productsDanbaba et al. (2016) reported increase in carbohydrate content of extrudate with reduction in temperature. Similar observation was made in this study. It could be explained based on the conversion of sucrose to glucose and fructose (reducing sugar) and loss of these sugars duringbrowning reactions and subsequent reduction in carbohydrate at higher temperature.The linear effect of barrel temperature positively and significantly ($p<0.05$) affected the carbohydrate content in the noodles analogue. The quadratic effect of feed moisture content and screw speed negatively and positively respectively affected the carbohydrate content at 5% level of significance. The linear effect of feed moisture content and screw speed, the interaction effect of all the independent variables and the quadratic effect of feed moisture content respectively were not significant at 5% level of significance. The first and second order terms were not significant. However, lack of fit was significant at 5% level of significance (Table 3).The model equation developed for predicting carbohydrate was shown in equation 6.

Carbohydrate $=76.64089+0.20901BT-8.17615E-4BT^2+0.184505E-3SS^2$ (6)



1a.

1b.



1c.

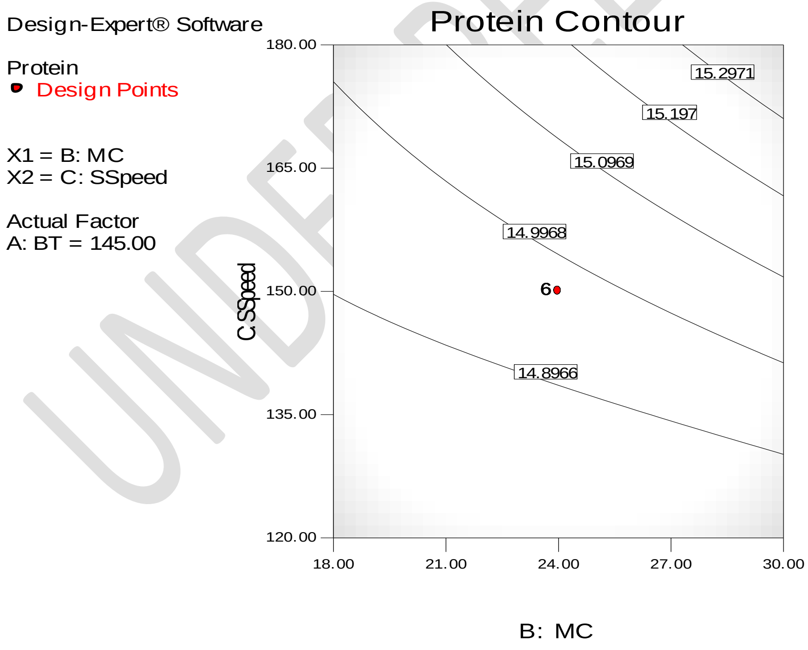
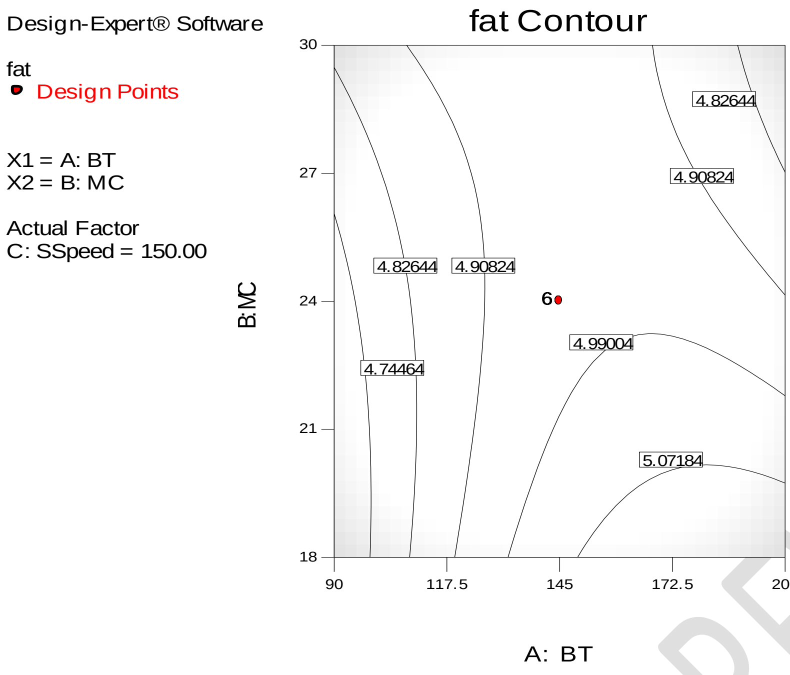


Fig 1a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on protein content.

2a.


Design-Expert® Software
fat
Design Points
X1 = A: BT
X2 = B: MC
Actual Factor
C: SSpeed = 150.00
fat Contour
30
27
24
21
18
B: MC
90
117.5
145
172.5
200
A: BT
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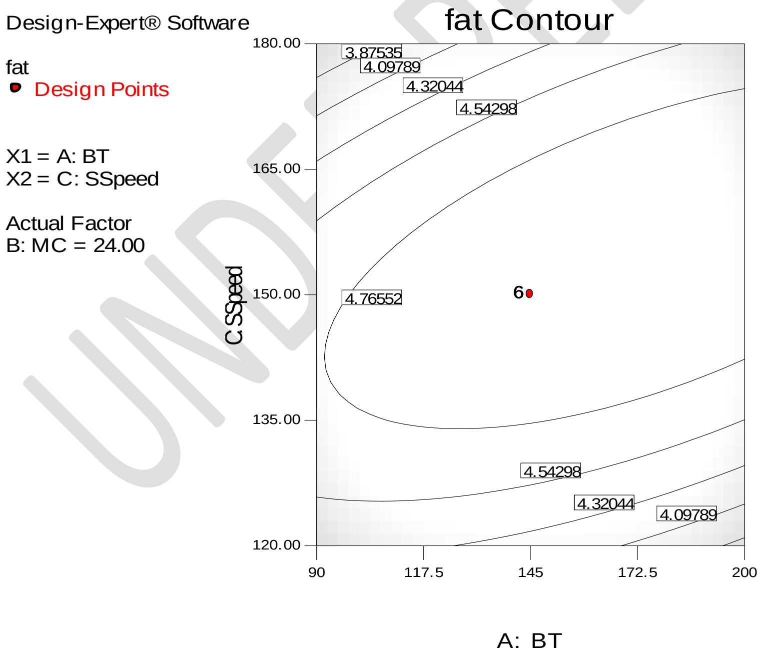
4.90824
4.82644
4.90824
6
4.99004
4.74464
5.07184

2b


Design-Expert® Software
fat
Design Points
X1 = A: BT
X2 = C: SSpeed
Actual Factor
B: MC = 24.00
fat Contour
180.00
165.00
150.00
135.00
120.00
C: SSpeed
90
117.5
145
172.5
200
A: BT
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4.09789
4.32044
4.54298
4.76552
6
4.54298
4.32044
4.09789

2c.

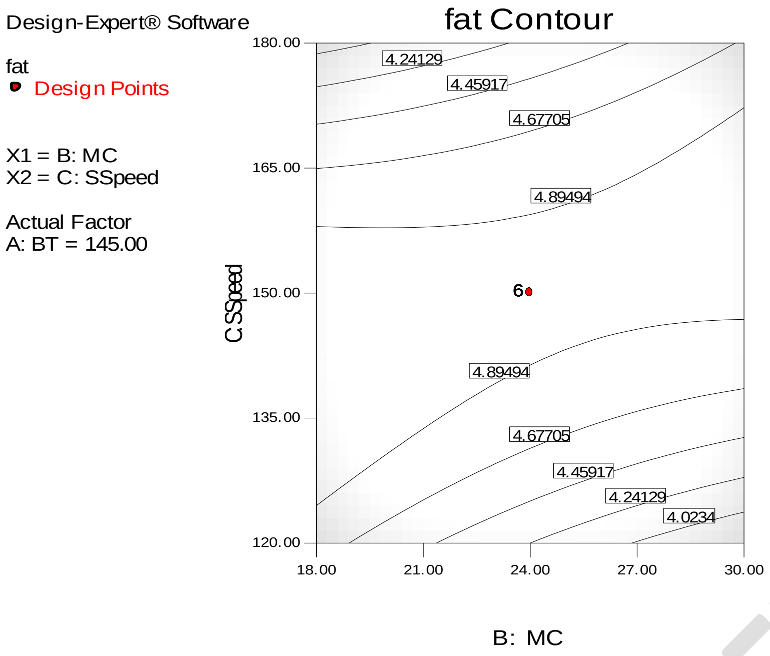
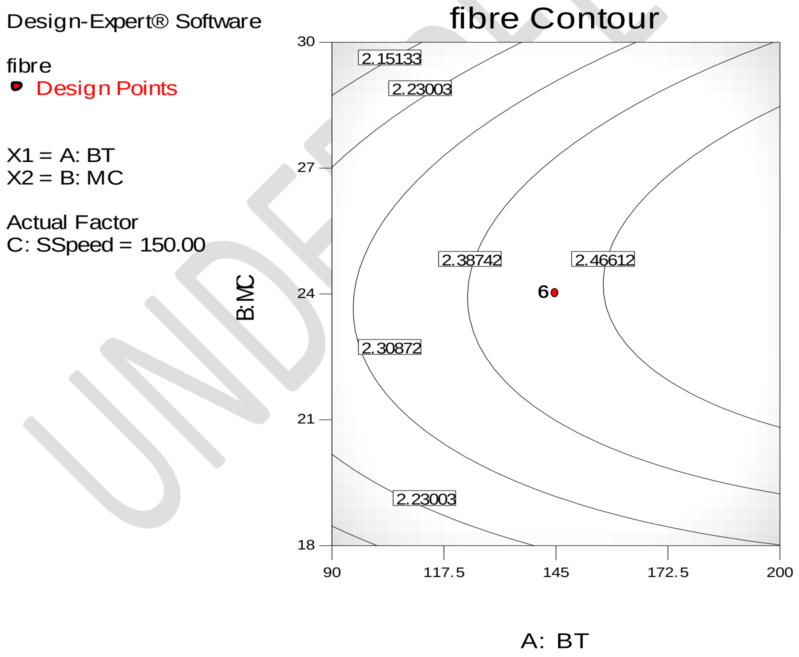
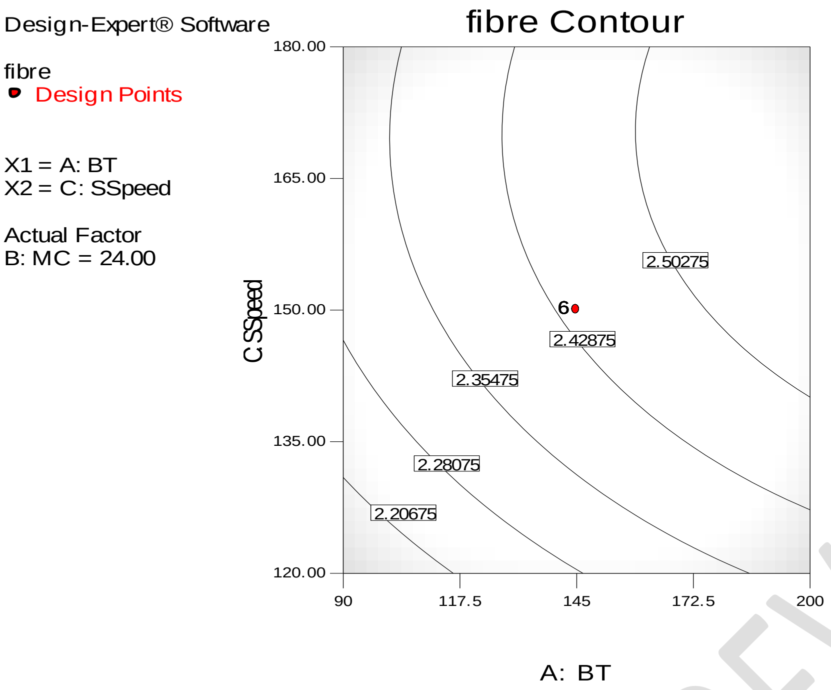


Fig 2a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on fat content.

3a.



3b.



3c

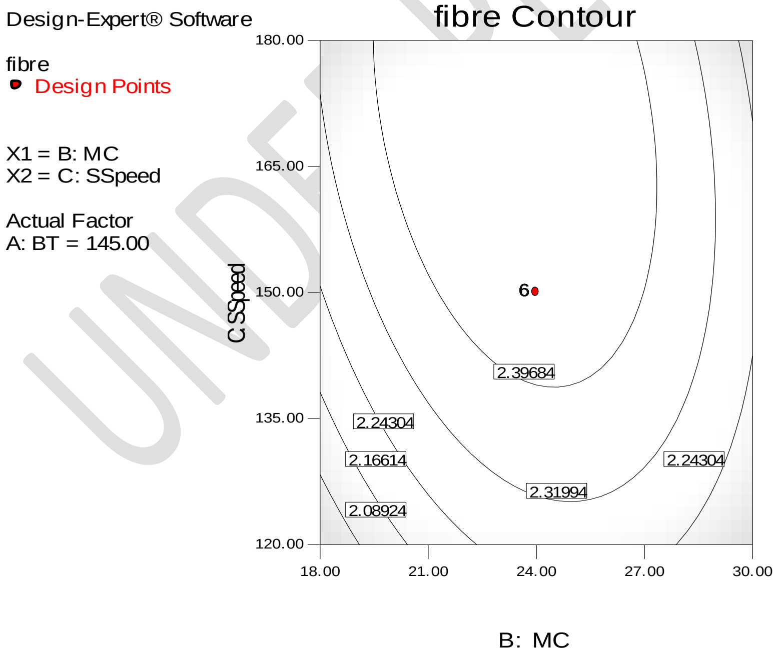
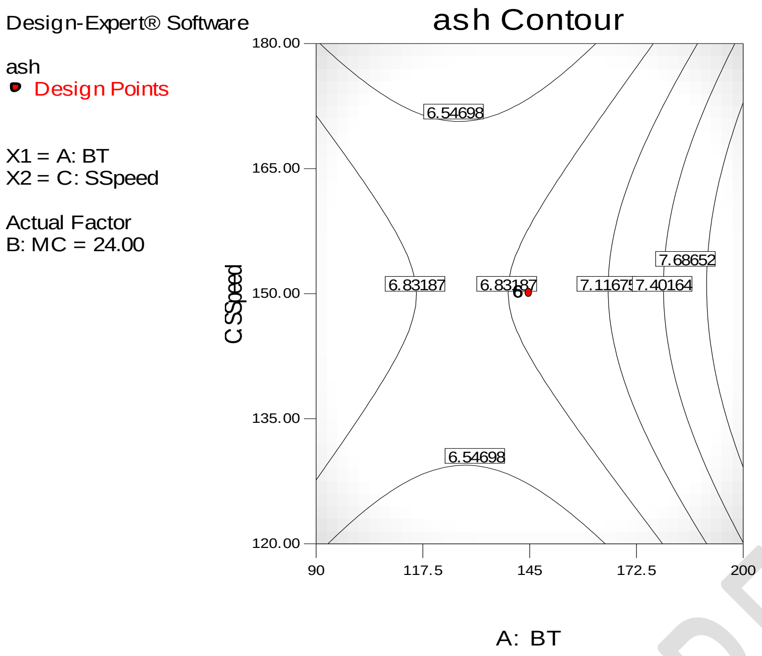
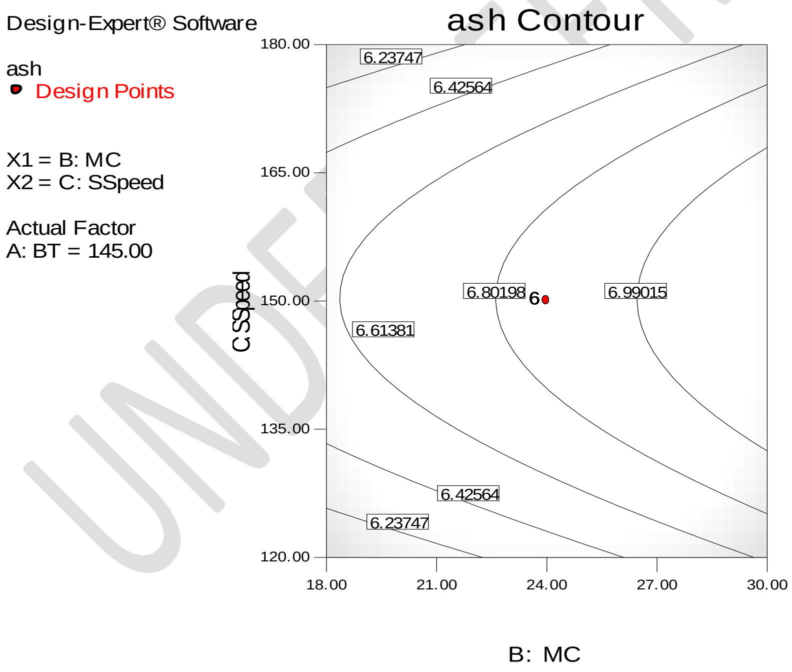


Fig 3a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on fibre content.

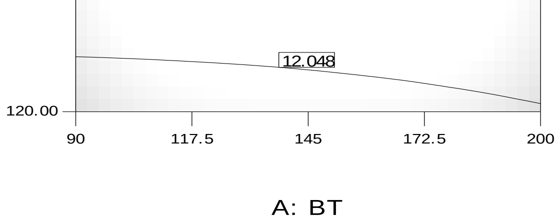
4a.


Design-Expert® Software
ash
Design Points
X1 = A: BT
X2 = C: SSpeed
Actual Factor
B: MC = 24.00
ash Contour
180.00
165.00
150.00
135.00
120.00
C: SSpeed
6.54698
6.83187
6.83187
7.11675
7.40164
7.68652
6.54698
6
90
117.5
145
172.5
200
A: BT

4b.


Design-Expert® Software
ash
Design Points
X1 = B: MC
X2 = C: SSpeed
Actual Factor
A: BT = 145.00
ash Contour
180.00
165.00
150.00
135.00
120.00
C: SSpeed
6.23747
6.42564
6.80198
6.99015
6.61381
6.42564
6.23747
6
18.00
21.00
24.00
27.00
30.00
B: MC

4c



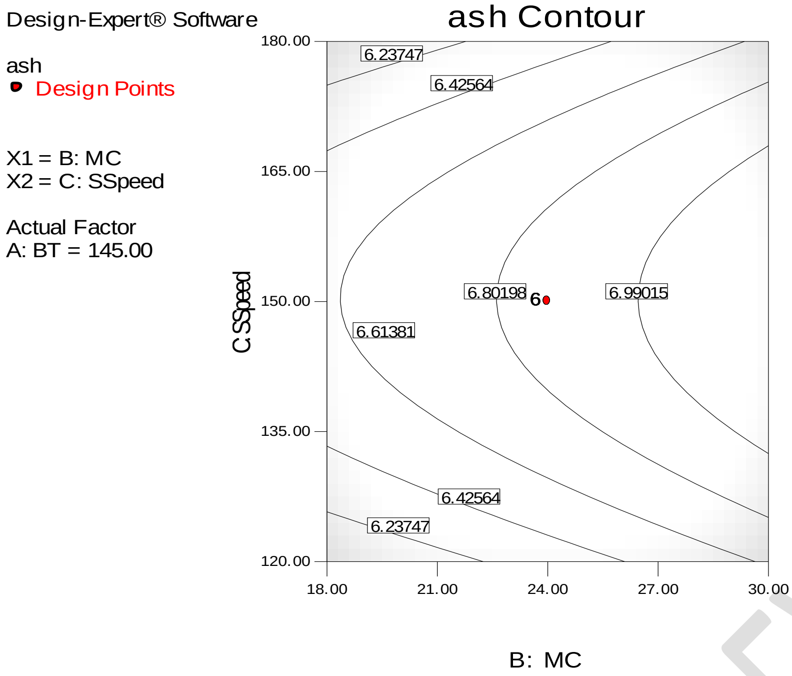
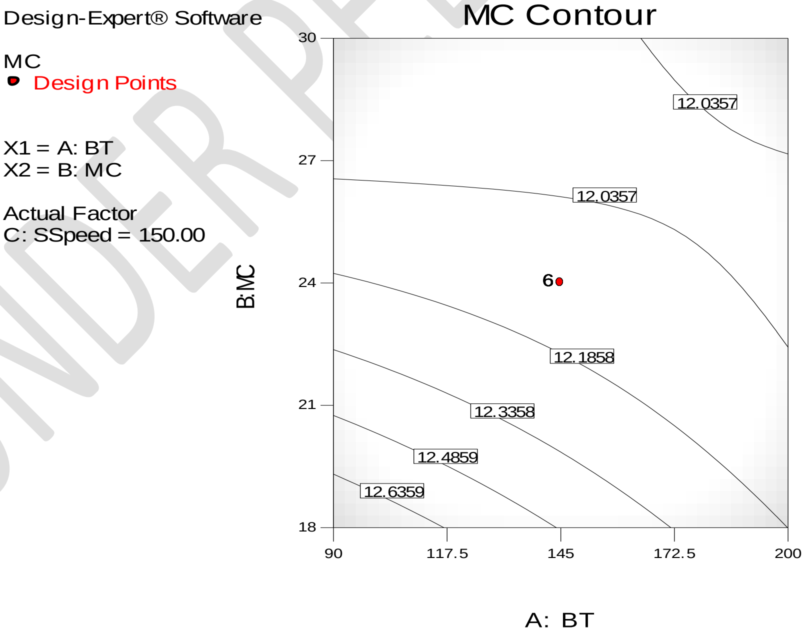
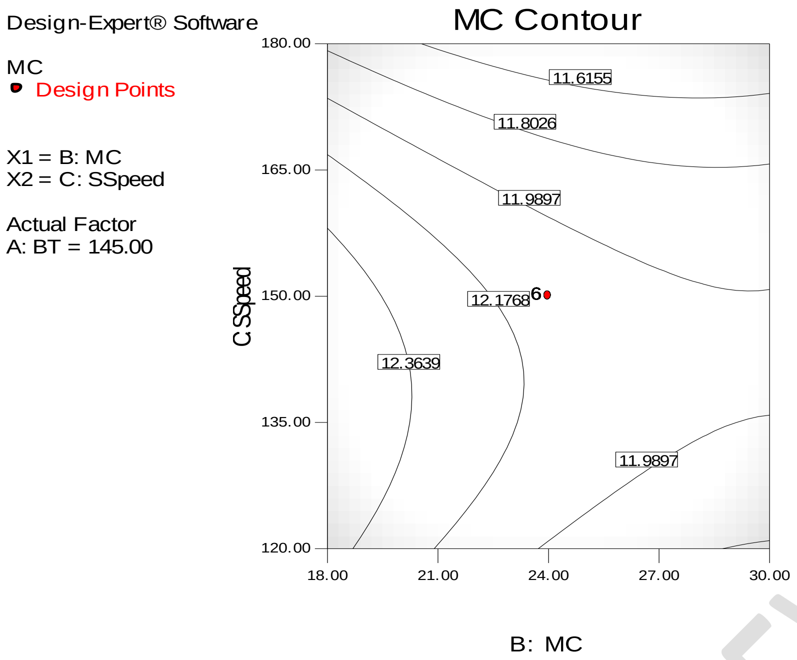


Fig 4a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on ash content.

5a.



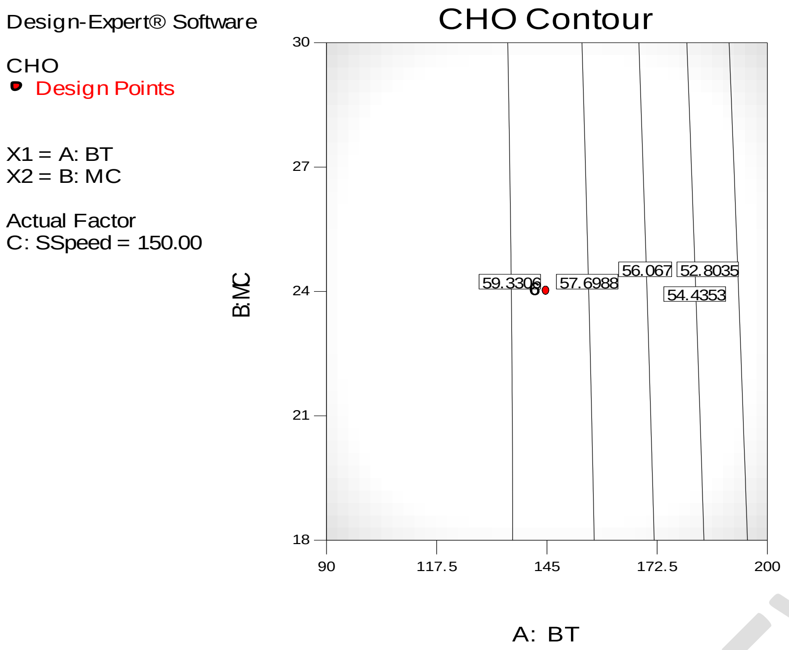
5b.



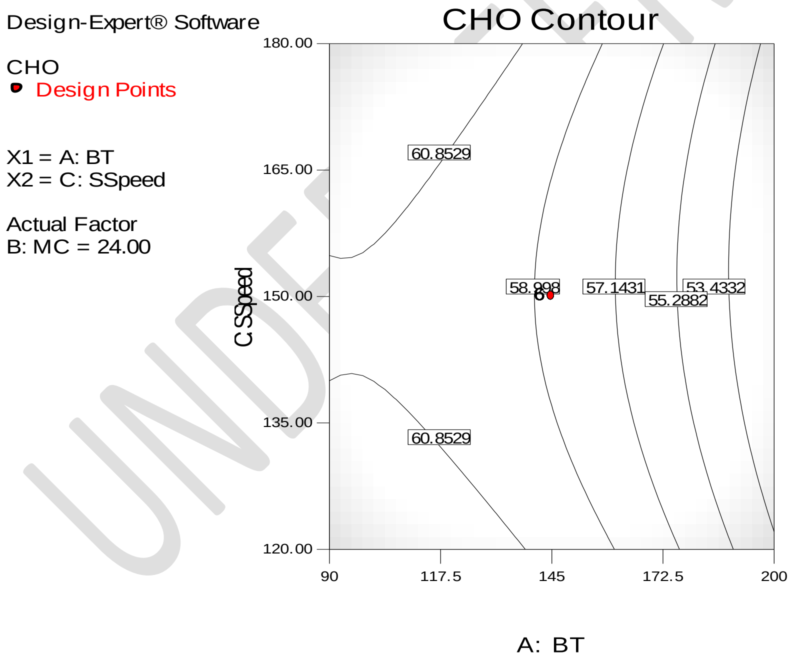
5c.

Fig 5a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on feed moisture content.

6a.


Design-Expert® Software
CHO
Design Points
X1 = A: BT
X2 = B: MC
Actual Factor
C: SSpeed = 150.00
CHO Contour
B: MC
A: BT
30
27
24
21
18
90
117.5
145
172.5
200
59.3306
6
57.6988
56.067
52.8035
54.4353

6b.


Design-Expert® Software
CHO
Design Points
X1 = A: BT
X2 = C: SSpeed
Actual Factor
B: MC = 24.00
CHO Contour
C: SSpeed
A: BT
180.00
165.00
150.00
135.00
120.00
90
117.5
145
172.5
200
60.8529
58.998
6
57.1431
55.2882
53.4332
60.8529

6c.

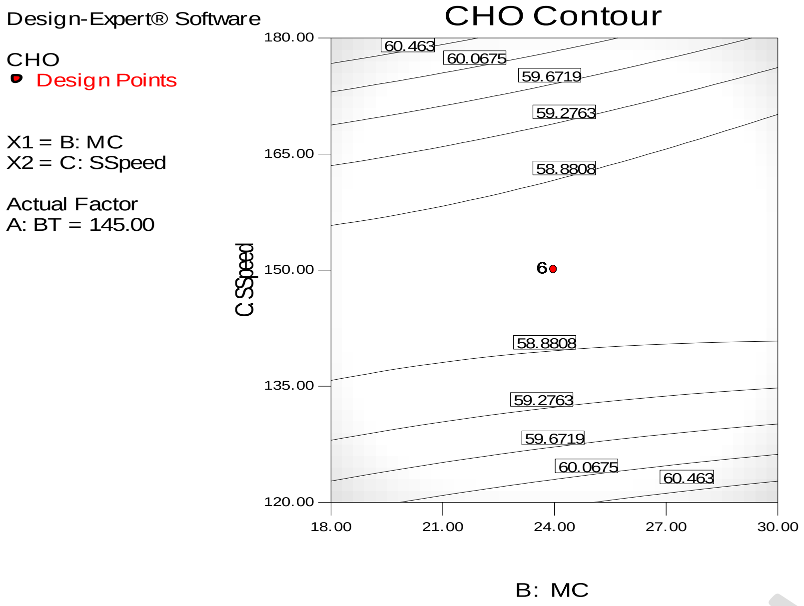


Fig 6a-c: contour plot showing the effect of barrel temperature, feed moisture content and screw speed on carbohydrate content.

Conclusion

The response surface methodology employed in this study clearly explained the effect of the processing variables in terms of linear, quadratic, and interaction on the proximate composition of an improved noodles analogue from blends of water yam, yellow maize, and African yam bean. 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 composition 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.

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