OPTIMIZATION OF ROASTING CONDITIONS OF SOYA BEANS USING RESPONSE SURFACE METHODOLOGY

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Abstract
The processing conditions, roasting temperature (140, 170 and 200 ^oC), time (5, 10 and 15 min.) and soaking time (5, 7.5 and 10 sec.) of roasted soya bean flour were optimized by response surface methodology (RSM). A central composite rotatable experimental design with three factors and five levels (-1.4142, -1, 0, 1 and 1.4142) was used. Twenty roasting trials with six central points were performed. The relationship between the dependent and independent variables were determined by fitted second order polynomial equation. The result revealed moisture content, trypsin inhibitors and saponin content decreased with increase in roasting temperature and time. The values obtained for moisture, protein and fat content ranged from 6.45-14.82%, 11.23-13.33% and 20 - 65%, respectively. There was significant difference (p<0.05) in the values obtained for anti-nutrition properties and these showed a decreasing trend with increase in roasting temperature and time. Significant difference (p<0.05) existed in the values obtained for L and a*. These ranged from 74.03–84.73 and 0.7–5.97, respectively. The optimum roasting temperature, time and soaking time recorded were 170 ^oC, 10 min. and 8.99 sec. The desirability value for all the responses was approximately 0.8 at 10.64% (moisture content), 12.28% (protein content), 42.50% (fat content), 79.38 (L*), 3.34 (a*), 17.66 (b*), 0.18mg/100g (trypsin inhibitors) and 54.17mg/100g (saponin value). This implies that temperature and time combinations and varying these important processing condition have strong tendency to affect the general properties of soya beans and flours produced. The impact of roasting temperature and time were significantly indicated on the parameter analysed.*

Keywords: *Soya Beans, Roasting conditions, Roasting temperature, Roasting Time, Response surface modeling (RSM).*

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1. INTRODUCTION

Soya bean (*Glycine max)* is a versatile, unique pulse and an inexpensive source of protein supplemented in many cereals, roots and tubers based diets (Nwokolo, 1996; Iwe, 2003; Symolon *et al*., 2004). According to reliable reports, soya bean is credited to have a protein value addition close to animal origin and capable of supplying some essential amino acid and deficient protein in most diet for children and adults (Symolon *et al*., 2004;Fabiyi, 2006). Soya beans are sources of many products: oil, soymilk, soy flour, soya meal, texture vegetable protein (TVP) for vegetarian food, tempeh, soya lecithin, soya sauce and animal feeds (Faldet *et al.,*1992; Nwokolo, 1996; Iwe, 2003; Symolon *et al*., 2004; Fabiyi 2006). Its application is further established by the absence of cholesterol in the oil produced from soya beans (INTSOY, 1987).

Roasting is a unit operation which particularly involved dry heat: open flame, oven or other heat source (Vincent, 2004; Emily *et al*., 2009). Heat application has been severally employed in the processing of soya bean for many purposes (Faldet *et al.,*1992; Rafiee-Yarandi *et al.,* 2016., Reddy *et al.,*1993; Omafuvbe *et al.,* 2007; Amanlou *et al.,*. 2012). The ability of roasting to help released the enhanced flavor have been widely reported (Vincent 2004; Emily *et al*., 2009). Reduction in moisture content, texture and changes in colour during roasting were reported by some researchers (Emily *et al*., 2009; Vincent 2004; Cammerer and Kroh, 2009; Özdemir and Devres, 2000; Kahyaoglu and Kaya 2006; Bolaji *et al.,* 2018).
Most previous works on roasting of soya bean focused on formulation of food products, producing supplements protein and energy source for infants and livestock. However, the

optimized processing conditions (roasting temperature and time) were not reported. The quality characteristics of the roasted soya beans at this optimized processing conditions need to be studied. This will be necessary for predictions and design of related process and equipment.
Optimization of processing conditions is necessary in the development of efficient and economy of processing operations (Quoe, 2012). In this case, interaction between multiple processes variables are identified analyzed and need to be effectively communicated. Many processing of soya beans into formulation for food products, production of supplements protein and energy source for children and adults often involve roasting. This heat treatment (temperature) need to be optimally combined with roasting time and soaking period. The optimized processing conditions as indicted in this work were predicted by identified and analyzed multiple interactions of evaluated quality characteristics of the roasted soya beans.

2. MATERIALS AND METHODOLOGY

Matured soybean seeds were obtained from Sabo market in Ikorodu, Lagos State, Nigeria. An oven (Model: 6960553(*PM0201*) with temperature capacity of up to 260^{o}C was used to roast the soybean. A 3-phase (Q-Link) blender was used to mill the roasted soybean seeds into flour while a stopwatch was used to monitor the time of soaking and roasting. Portable water for cleaning, and low density polyethylene (LDPE) bags for packaging of the roasted soybean flour were used.

Experimental Design and Modeling for Optimization.

Response surface modeling (RSM) comprising of central composite design with three factors and level was used. The three independent variable factors were roasting temperature (X_1), roasting time (X_2) and soaking time (X_3) and the dependent variable responses were L* value, a* value, b* value, fat content, protein content, moisture content, trypsin inhibitor, saponin level.
Twenty (20) roasting trials were performed with five central points. The coded value of the independent variables and treatment schedule are reported in Tables 1 and 2.

Model Development

A second- order polynomial equation was fitted to determine the relationship between dependent variables and independent variables. The model proposed for the response (Yi) was:

$$Yi = b_0+b_1X_1+b_2X_2+b_3X_3+b_{11}X_1^2+b_{22}X_2^2+b_{33}X_3^2+b_{12}X_1X_2+b_{13}X_1X_3+b_{23}X_2X_3 \quad ... (1)$$

Where X_1, X_2 and X_3 are roasting temperature (^{o}C), roasting time (min.) and soaking time (sec.) respectively, b_0 is the value of the fitted response at the centre point of the design (i.e. regression coefficient for interception), b_1-b_3, b_{11}-b_{33} and b_{12}- b_{23} are regression coefficients for linear, quadratic and interaction (i.e. cross product terms), respectively. Y(i=8) is the predicted response for L, a*, b*, fat content, protein content, moisture content, trypsin inhibitor level and saponin level, respectively (Shamaei *et al.,* 2012).
Raw soya bean was placed in a wire mesh and soaked at varying time as designed. The sample was drained and roasted in the oven at different temperature and time combination within the range of 140-200^{o}C and 5-15min as designed as shown in Tables 1 and 2, respectively. The roasted samples were dehulled, cleaned and milled into flour and packaged in low density polyethene (LDPE) bags. The soybean flour were then analysed for proximate composition (protein, fat and moisture content), colour and anti-nutritional (trypsin inhibitors and saponin) contents.

Chemical Composition Determination

The crude protein, fat and moisture content were determined by the method described by AOAC (2005), while colour was determined by the method described by Mridula *et al.* (2007), and the anti-nutrients : trypsin inhibitor and saponins were determined by the method described by Kakade *et al.* (1974).

Table 1: Coded Values of the Independent Variables

	-α	-1	0	+1	+α
X_1(^{0}C)	127.57	140	170	200	212.43
X_2(Min.)	2.93	5	10	15	17.07
X_3(Sec.)	3.97	5	7.5	10	11.04

α = 1.4142
X_1 = Roasting Temperature
X_2 = Roasting Time
X_3 = Soaking Time

Table 2: Treatment Schedule

TRIAL		ROASTING TEMPERATURE (°C)	ROASTING TIME (min.)	SOAKING TIME (sec.)
1	Block	170	10	7.5
2	Block	170	10	7.5
3	Block	187.84	12.97	8.99
4	Block	187.84	7.03	6.01
5	Block	170	10	7.5
6	Block	140	10	7.5
7	Block	170	10	7.5
8	Block	170	5	7.5
9	Block	170	10	5
10	Block	152.16	7.03	8.97
11	Block	170	10	7.5
12	Block	187.84	12.97	6.01
13	Block	200	10	7.5
14	Block	187.84	7.03	8.99
15	Block	152.16	12.97	8.99
16	Block	152.16	12.97	6.01
17	Block	170	10	10
18	Block	170	10	7.5
19	Block	152.16	7.03	6.01
20	Block	170	15	7.5

Determination of colour

The colour of soya bean flour samples were determined quantitatively with the aid of a handheld ColorTec-PCM/PSMTM1 meter. The colorimeter was first calibrated, and this process was repeated each time the instrument was used based on manufacturers guidelines.The colorimeter operates on the CIE (Commission Internationale de I'Eclairage) L*, a*, b* colour scheme. The colour of the sample was described by the lightness (*L*), redness (*a*), and yellowness (*b*). The sample was put in a transparent polythene bag and the colour meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly for L*. The instrument displayed three-dimensional colour difference in uniform colour space (Lab) co-ordinates.

Statistical Analysis

Analysis of Variance (ANOVA) was performed to check the adequacy and accuracy of the fitted models (Changrue *et al.,* 2008). The significance of regression coefficients was accessed by p-value at 0.1 significant levels. Plotting responses as a function of two factors drew response surface plots, but the third factor was set to its medium (Simurina *et al.,* 2012).

Optimization of roasting conditions of soya beans, the use of a desirability function of response surface modeling (RSM) which combines all responses into one measurement was employed. This is based on the idea that the "quality" of a product or process with complex characteristic is not acceptable when one of its parameters is outside of "desired" limits (Shamaei *et al.,* 2012).

3. RESULT AND DISCUSSION

The results of the experimental design for Yi (i=1-8), that is, the responses and X_1-X_3 (the conditions) are shown in Table 3. The responses ranged from 20-65% (fat), 6.45 - 14.82% (moisture), 11.23 - 13.33% (protein), 74.03 – 84.73 (L* value), 0.7 – 5.597 (a* value), 6.88 – 28.43 (b* value), 0–0.35mg/100g (trypsin inhibitor) and 15–93.33mg/100g (saponin). The graphical relationship between the factors and the protein, fat and moisture are shown in Figure 1, 2 and 3, respectively. The eight responses under different temperature - time combinations as defined in the design (Table 1 and 2) were analyzed using the analysis of variance (ANOVA) at $p<0.05$ significant level and shown in Table 3 and 4, respectively. The responses for the model had regression coefficient of $R^2<0.71$ as it ranges from 0.23 to 0.65 and F-value ranges from 0.33 to 2.02 (Table 5). The quadratic model with $R^2=0.65$ described the changes in moisture content of soya beans during roasting. The result obtained, temperature and time were functions of moisture content and this was consistent with the report of Shakerardekani *et al.* (2011) who worked on the effect of roasting conditions on hardness, moisture content and colour of pistachio kernels. Increase in roasting temperature and time decreased the moisture content of soya beans. Similar trend was reported by some researchers (Mridula *et al,* 2007; Wahidu and Tajul, 2013). According to Raji and Famurewa (2008), protein retention is a function of thermal treatment. Over heating produces changes in the chemical structure of many amino acids and may decrease the nutritive value (Marcela *et al.,* 2013). The crude protein of the roasted soya beans ranged from 11.23-13.33% and was within range reported by Muhammed *et al.* (2012) for date bars.

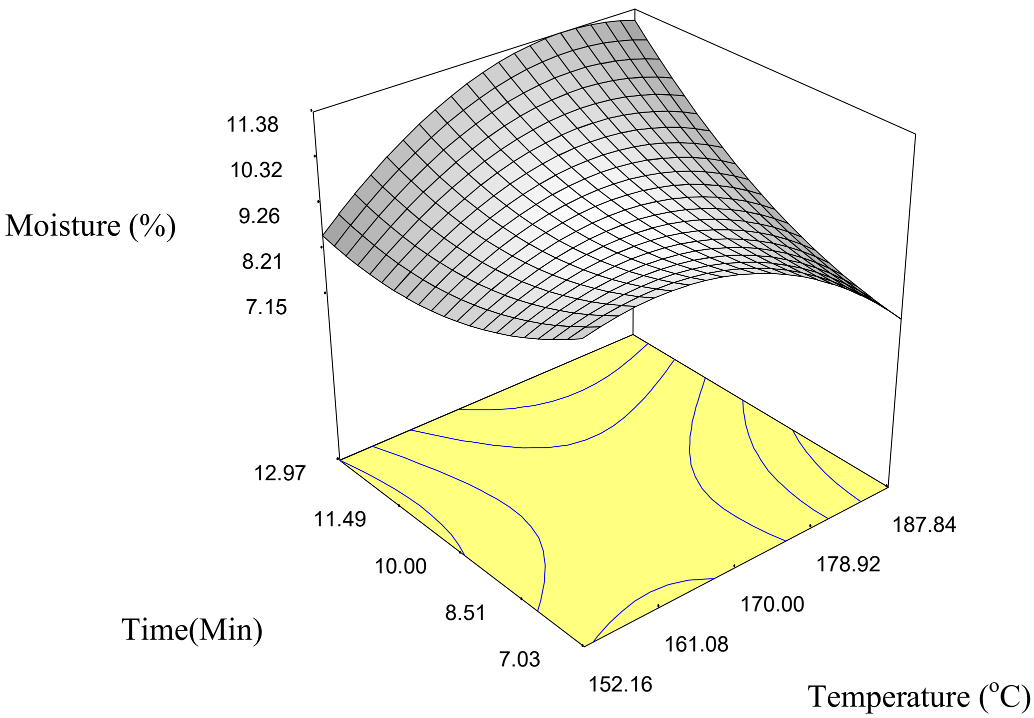


Fig. 1: Response plot of moisture content at varying roasting temperature and time condition

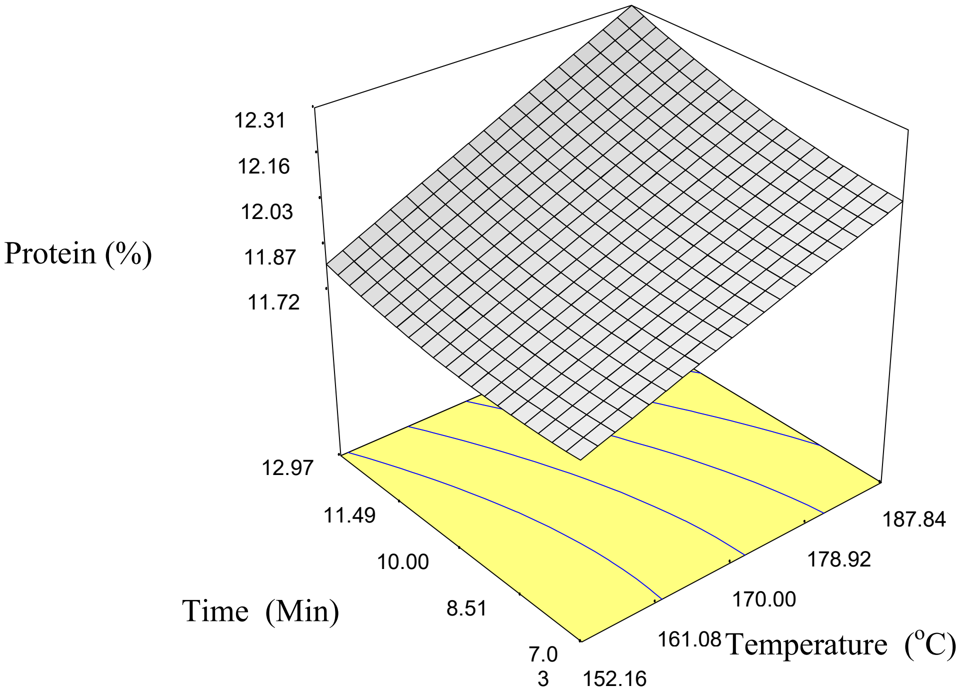


Fig. 2: Response plot of roasting temperature and time on protein content of soya beans

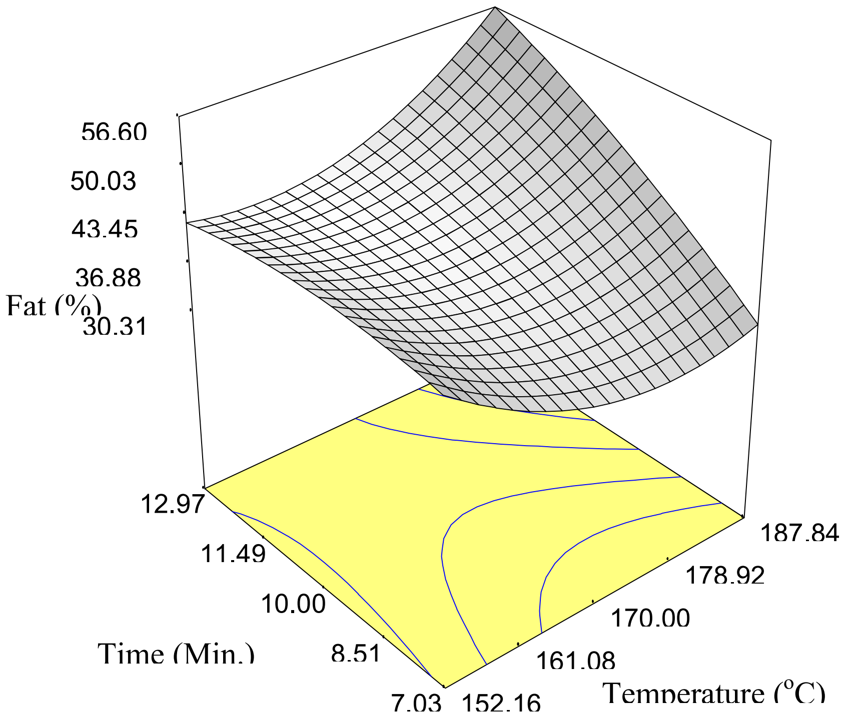


Fig. 3: Response plot of roasting temperature and time on fat content of soya beans

The protein value reported for mangrove legume seeds, roasted on a sand bath was found to be higher (29.6%), (Seena *et al.*, 2005) and these values were within the range of values reported for legumes (Reddy *et al.*, 1984). Raji and Famurewa (2008), presented almost similar range of values 20.86-37.46% for undehulled soya bean flour and 24.53-40.73% for dehulled soya bean flour at different moisture content (8.1- 22.1%). Also

Akaninwor and Okechukwu (2004) reported protein content between 45.83 and 46.16% for soya beans with soaking time, drying temperature and time of 12h, 70°C and 24h, respectively. The variation in values may be unconnected with botanical sources and processing conditions.

As presented in Table 4, there was no significant difference (p>0.05) in values reported for fat content however.

Table 3: Analysis of variance and model fitting for response parameters of roasted soya beans flour

	DF	Fat	Protein	Moisture	L* Value	a* Value	b* Value	Trypsin Inhibitor	Saponin
Sequential Model Sum of Squares:									
Regression									
Linear	3	500.63	15.96	0.76	12.86	1.13	91.29	0.023	927.32
Quadratic	3	698.84	56.06	0.030	4.45*	8.31	22.19**	0.039	2521.23
Interaction	3	525.00**	36.12	0.89	40.34*	12.98*	139.00	0.059	1602.87
Residual Error	6	2556.16	40.11	3.09	49.57	16.71	336.04	0.16	2384.46
Lack of fit									
Linear	11	3779.37	113.15	5.10	128.95	45.34	337.52	0.18	7505.14
Quadratic	5	2555.53**	20.97**	4.18**	84.15*	24.05*	176.33**	0.081**	3381.04**
Interaction	8	3254.37**	77.03	4.21	88.60	32.36	198.52	0.12	5902.27
Pure Error	5	1200.00	38.41	1.42	10.18	2.99	301.18	0.093	1926.08

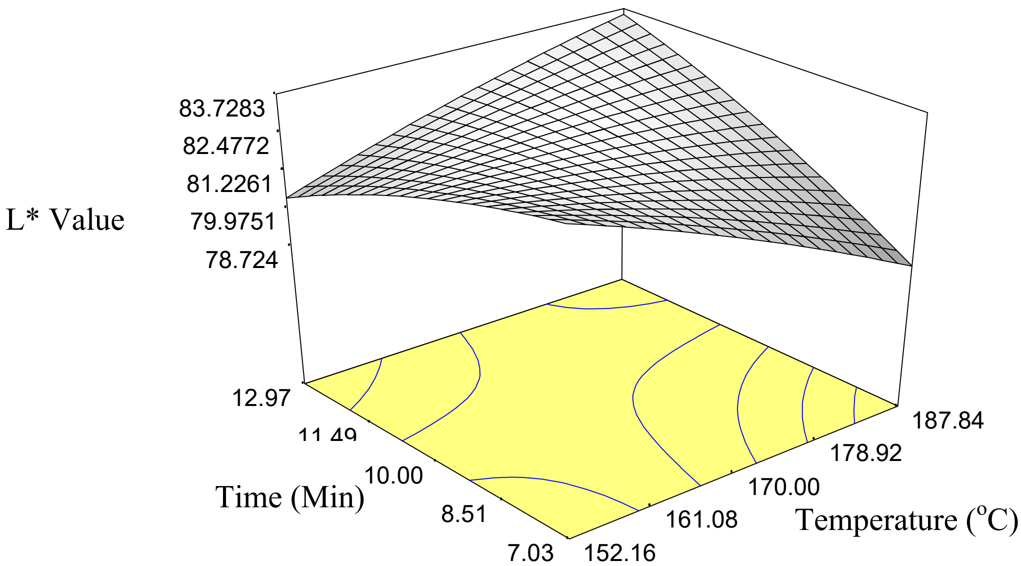
Foot note: * - significantly different at p<0.05
** - Not significantly different at p<0.05
DF – Degree of Freedom

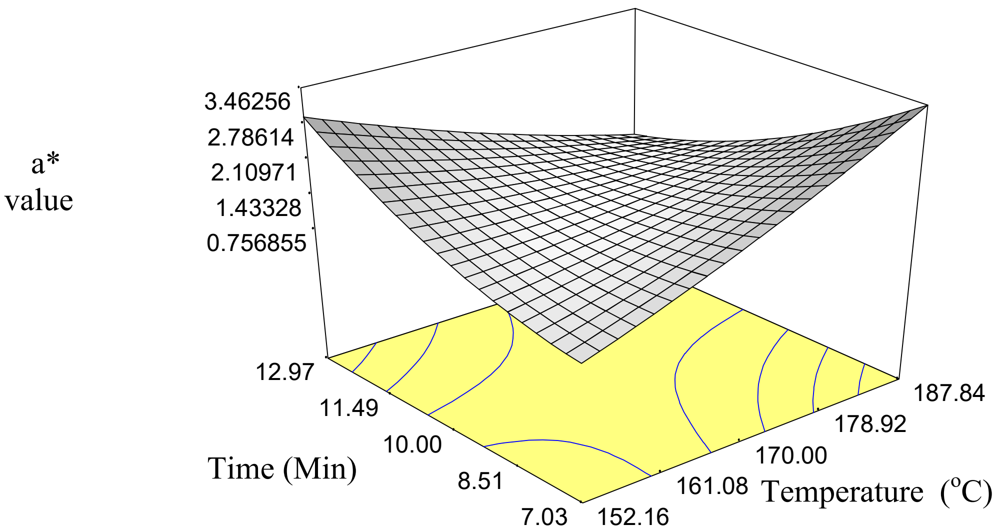
Table 4: Coefficient of Regression

Coefficient	L* value	a* value	b* value	Fat	Protein	Moisture	Trypsin inhibitor	Saponin
Model	102.54	-2.59	143.59	484.09	4.37	-22.57*	4.76	-631.68
Linear								
$X_{1\,(Temp)}$	-0.16	0.12	-0.83	-6.26	0.07	1.19	-0.02	9.09
$X_{2\,(Time)}$	-4.02	2.22	12.59	-15.91	-0.57	-8.41	-0.17	-16.10
$X_{3\,(Soaking\ time)}$	4.58	-4.88	5.90	41.29	0.79	-7.96	-0.50	3.14
Quadratic								
X_{11}	-0.00	0.00	-0.00	0.02	-0.00	-0.00	-0.00	0.04*
X_{22}	-0.04	0.04	0.08	-0.21	0.00	0.08	-0.00	0.89
X_{33}	0.185	0.32*	0.27	-0.83	0.01	0.56	0.01	-0.01
Interaction effect								
X_1X_2	0.04*	-0.02*	0.04	0.12	-0.00	0.03	0.00	0.24
X_1X_3	0.00	0.00	0.09	-0.19	-0.00	0.02	0.00	0.11*
X_2X_3	-0.21	0.09	0.54	0.29	0.05	0.35*	0.00	-1.13
R^2	0.38	0.45	0.35	0.32	0.23	0.65	0.41	0.49
F-Value	0.68	0.92	0.59	0.92	0.33	2.02	0.77	1.06

Significant Level: * means p< 0.1
** means p<0.01

The colour of a food product contributes to consumers' decision about a product. Roasting may encourage colour changes as indicated in this work. There may be possible caramelisation reactions (Shakerardekani *et al.,* 2011; Seena *et al.,* 2001; Revathy *et al.,* 2008). The shapes of the surface plot and contour for L* value and a* value are similar to each other just that the surface plot is in reverse to the other, as shown in Figure 4. The shapes of L* value and b* value gradually increased with increase in temperature and time. The quadratic and interaction term of regression due to sum of squares for L* value was significantly different ($p<0.05$). The significant influence of temperature on colour were widely reported by many researchers (Demir *et al.,* 2012; Ozdemir and Devres, 2000; Shakerardekani *et al.,* 2011).





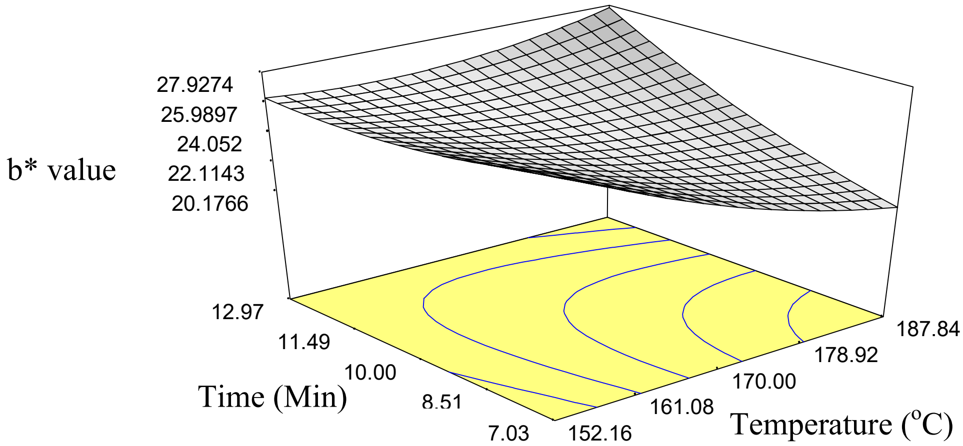
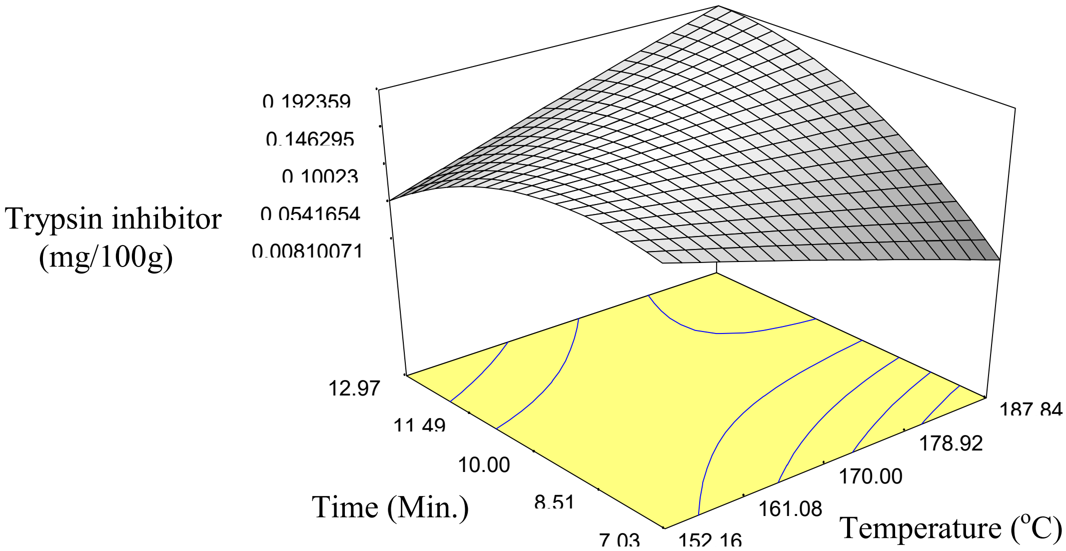


Fig. 4: Response plots of roasting temperature and time on L*, a* and b* values of roasted soya beans



Trypsin inhibitor is the primary anti nutritional factor in soya bean meal (Araba and Dale, 1990; Anderson- Hafermann *et al.,* 1992; Mian and Garlich *et al.,* 1995). It was reported that trypsin inhibitor can be reduced by 80-95% by heat processing (Gumbmann *et al.,* 1985). Unlike soya bean, Seena *et al.* (2005) reported that trypsin inhibitor was not detected in the seeds of mangrove legumes, *canavalia cathetica* from southwest coast of India roasted on a sand bath at 180^0C for 20 min. Also Nwosu *et al.* (2010) reported that roasting as a processing method eliminated trypsin inhibitor in "Oze" seed flour after 6min. of blanching and was totally eliminated after 8min. of heat treatment. The saponin content of the sample was relatively high (15- 93.33mg/ 100g) compared to the values obtained by Mbah *et al.* (2012) which ranged from 0.12-0.46mg/ 100g for saponin content of *Moringa* oleifera seeds. Nwosu *et al.* (2010) reported that 840mg/100g saponin was present in raw "Oze" seed flour and this was said to reduced by 92.86% (840-60mg/100g) by blanching for 6 min. while roasting for 45 min. eliminated saponin in the seed.

Omizu *et al.* (2011) worked on determination of saponin content in raw soya beans and fermented soya beans. The researchers reported that about 401.8– 686.9mg/100g were obtained in raw soya bean. The values obtained for roasted soya bean flour in this work were significantly lower however higher than values reported by Mbah *et al.* (2012) for *Moringa oleifera* seed at constant temperature and time interval.

Optimization

The desirability functions of RSM were used to determine the optimum roasting conditions of roasted soya beans flour. The use of desirability functions help in the transformation of different responses to one measurement which is simple and quick(Singh *et al*., 2010). The responses were used as the control parameters for determining the optimum quality characteristic with respect to roasting temperature, roasting time and soaking period. The Selected points for optimization of responses are as shown in Table 5. The optimum proximate composition (moisture, protein and fat content) were 5.26 – 12, 11-13.33 and 20.01 - 65 respectively. Also for optimum colour parameter (L*, a* and b* value), the data obtained were 74.03 – 84.73, 0.7 – 5.97 and 6.88 – 22.43, respectively while anti nutritional factors (trypsin inhibitors and saponin values) were 0 – 0.35 mg/100g and 15 – 70.33 mg/100g, respectively. The Figure 6 indicates the desirability. The point with highest possible desirability (0.8) function that could be taken as the optimum condition for roasting temperature and time combination of soybeans was found to be 170^{o}C and 10 min, respectively, with soaking time of 8.99 sec.

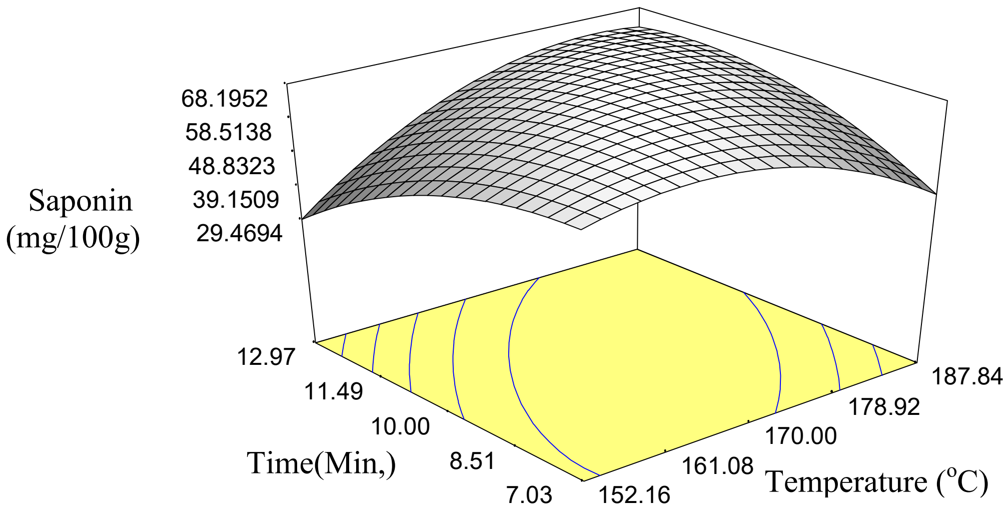


Fig. 5: Response of roasting temperature and time on Trypsin and saponin values of roasted soya beans

Table 5: Selected point for optimization of responses

Response	Goal	Target	Lower Limit	Upper Limit	Weight
Moisture content	Is target	10.64	5.26	12.00	1
Protein content	Is target	12.28	11	13.33	1
Fat content	Is target	42.50	22.01	65.00	1
L* value	Is target	79.38	74.03	84.73	1
a* value	Is target	3.34	0.70	5.79	1
b* value	Is target	17.66	6.88	28.43	1
Trypsin inhibitors	Is target	0.175	0.00	0.35	1
Saponin content	Is target	54.16	15.00	70.33	1

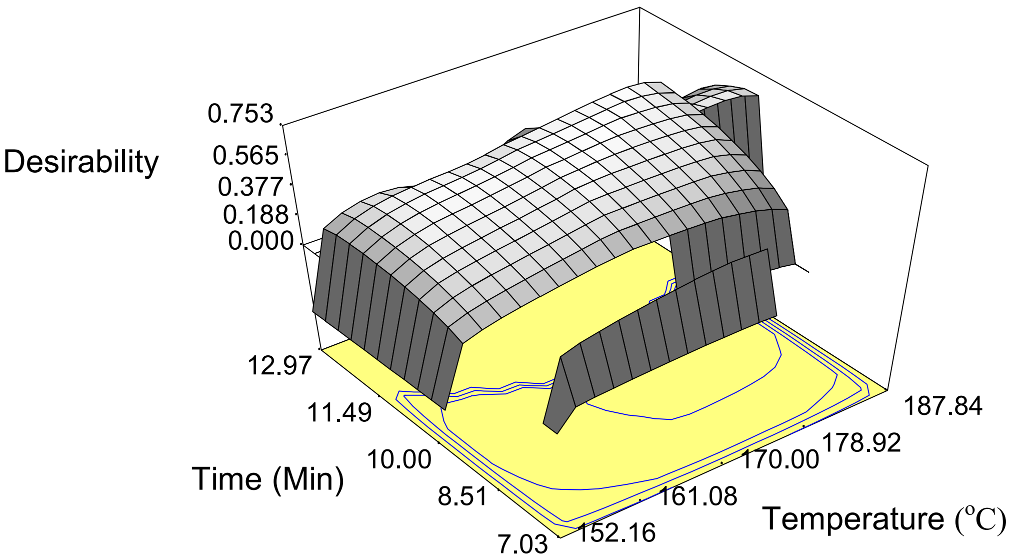


Fig. 6: Optimization plot for the effect of roasting temperature and time on the responses

4. CONCLUSION

Roasting of soya beans at different temperature and time combination affected the general properties of soya beans. Roasting of soya beans reduced moisture content, increased fat content and influenced colour changes. The roasting temperature and time and soaking time of 170°C, 10 min. and 8.99 sec. respectively suggested a product with predicted properties of 10.64% moisture content, 12.28% protein content, 42.5% fat content, 79.38 L* value, 3.34 a* value, 17.66 b* value, 0.18mg/100g trypsin inhibitor and 54.17mg/100g saponin value. There was significant decrease with increase in roasting temperature and time. The impact of roasting temperature and time were significantly evident.

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