Physical Properties of Cookies Produced from Cassava – Groundnut-Corn Starch Blend- A Response Surface Analysis

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ABSTRACT

Cookie bars were produced from mixtures of cassava and groundnut flours with cornstarch as binder. Box-Behnken response surface design for k=3 was used to study the effects of experimental variables for cassava flour (25-75%), groundnut flour (25-75%) and corn starch (5-15%). Effects of the experimental variables on physical properties of the cookie bars were assessed. Experimental variables had significant effect on the thickness and spread factor of the cookie bars.

Keywords: *Physical properties, cassava, groundnut, corn, cookies, Response surface*

INTRODUCTION

Biscuits and cookies are usually produced from wheat flour (Ihekoronye, 1999) and they are the same product since the British call them biscuit while the Americans call them cookies (Ishinwu (2005). Anyika and Uwaegbute (2005) identified an increasing tendency among children and adults to move away from traditional eating pattern of three meals a day to eating snacks instead of meal. Cereal foods such as cookies have become very popular in Nigeria especially among children (Ukachukwu *et al.*, 2004).

Kansas (2006) also reported that increase in consumption of bread, cookies and pasta is fastest in the cities where they are now considered convenient foods. Anyika and Uwaegbute (2005) identified cookie (12.5%), coconut cookie (10.00%) and bread (10.00%) as foods that have the highest daily frequency of consumption among adolescent female students. Therefore, cookies could be an excellent means to improve nutritional quality at least to the extent that they incorporate vegetable proteins (in this case-groundnut).

Response surface methodology is made up of a mathematical statistical model of several input (independent, predictor) factors (Cornell, 1990; Iwe, 2000). The most common response surface models are the central composite design (CCD) (Iwe, 1998) and Box-Behnken (BB) designs (Lawson and Madrigal, 1994). The Box-Behnken design is one of the most efficient designs capable of generating a response surface.

This work examines the effect of selected experimental variables (using the Response surface methodology) on the physical properties of cookies produced from mixtures of cassava and groundnut with cornstarch as binder.

MATERIALS AND METHODS

Materials

Cassava (*Manihot utilissima*) tubers of the 99/6012 genotypes were obtained from National Root Crops Research Institute Umudike Umuahia, Abia State, Nigeria. Groundnut, yellow corn and other raw materials were obtained from the Umuahia main market, Abia State, Nigeria.

Preparation of cassava flour

Cassava tubers were washed, cut into slices and boiled in water for 20 minutes. They were then peeled using kitchen knife and afterwards shredded with a locally made

shredder. The thinly sliced shreds were soaked for 24 hours during which time the water was changed twice, after which they were washed and oven dried at 60^{o}C. They were then milled in a milling machine and sieved to separate coarse or fibrous particles from the fine flour.

Preparation of groundnut flour

Mouldy, shrivelled nuts and stones were manually removed from groundnut grains. Dust was removed by winnowing in a basket. The grains were sun-dried to facilitate dehulling and the hulls were manually removed by rubbing between the palms. The groundnut was milled with attrition milling machine and defatted by soaking over-night in hexane. The defatted cake was dried, milled and sieved.

Preparation of cornstarch

Yellow corn was cleaned, steeped in warm water (36^{o}C) containing sulphur dioxide (0.02%) as mild preservative for 10 hours. The swollen and softened kernels were milled thereby loosening the hull and germ. The ground corn was suspended in water and passed over a bolting cloth to remove the hulls. The starch was dried in the oven at 55^{0}C, milled and sieved to obtain fine "flour".

Formulation Of composite blends

Composite blends of processed cassava, groundnut and cornstarch were prepared to fit into the experimental design. The flours were thoroughly mixed, re-milled to reduce particle size and to obtain a homogeneous blend. Samples were stored at ambient temperature (29^{o}C ± 2^{o}C) in sealed polyethylene bags until required.

Formulation and production of cookie bars.

The proportion of ingredients that were used in the production of cookie bars is shown in Table 1 below:-

Table 1: Ingredients for production of Cookie bars.

Ingredients	Composition
Flour	66.3%
Sugar	2%
Fat	3.4%
Corn Starch	5-15%
Baking Powder	1.7%
Salt	1.6%
Liquid Milk	10%
Fresh Egg.	5%

Flour, baking powder, cornstarch and salt were mixed in a container. Fat was rubbed into the dry ingredients. In a separate container, liquid mix was added to the flour based mixture and the mixture kneaded on a lightly floured board until it became soft and smooth. A rectangular (bar) shaped cutter was used to cut out the bars.

The cut out bars were transferred into aluminium baking pans and baked in the oven at 210^{o}C for 15min. They were allowed to cool at ambient temperature, packaged and stored in a cool place.

PHYSICAL ANALYSIS OF COOKIE BARS

Weight of the individual bars was determined using electronic weighing balance. Thickness of each bar was determined using venire callipers while the width of the representative samples was calculated by stacking eight samples of cookies together and calculating the height as the value of their width respectively (Duncan, 2001). The mean value for each parameter was used for calculating the spread factor (width/thickness) of cookie bars (Iwe, 2002, Lorenz, 1983). Fragility of the cookie bars was calculated using the method of Okaka and Isieh (1990).

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

A Box-Behnken rotatable response for k = 3 was employed to study the linear, interactive and quadratic effects of the independent experimental variables. The experimental variables were of three levels as shown in Tables 2 and 3 below.

Table 2: Experimental variables used in the Box-Behnken rotatable design (K = 3).

Independent Variables	**Variable Levels**		
	-1	0	1
Cassava Level (%) X_1	25	50	75
Groundnut level (%) x_2	75	50	25
Corn Starch (%) X_3	5	10	15

Table 3: Experimental Design for RSA (maximum number of experiments = 15)

Run	X_1(% Cassava)	X_2(% Groundnut)	X_3(% corn starch)
1.	-1	-1	0
2.	+1	-1	0
3.	-1	+1	0
4.	+1	+1	0
5.	-1	0	-1
6.	+1	0	-1
7.	-1	0	+1
8.	+1	0	+1
9.	0	-1	-1
10	0	+1	-1
11.	0	-1	+1
12.	0	+1	+1
13.	0	0	0 x 3

Runs 1 – 12 were performed once while run 13 was performed three times. A total of 15 experimental runs were generated. Data on each run was statistically regressed and analysed for variance using the statgraphic computer software (NIST/SEMATECH, 2006). Statistical significance was accepted at 5% probability levels. Plots of the fitted significant responses were made to visualize these effects more clearly.

Statistical package for Social Sciences (SPSS) version 13 was used to obtain mean, standard deviation and analyses of variance (ANOVA) was done and judged for significance at $P \leq 0.05$. Means were separated using Least Significance Difference (LSD) test (NIST/SEMATECH, 2006).

RESULTS AND DISCUSSIONS

Values for the physical properties of the cookie bars are shown in Table 4. The estimated regression coefficients and the ANOVA of the response function for the physical properties of the cookie bars in terms of the studied variables are shown in Tables 5 – 8.

Width

Results of the regression and ANOVA of data on the width of the cookie bars are shown in Table 5. Experimental variables had no significant effect ($P \geq 0.05$) on the width of the cookie bars. Regression Analysis further indicated that the independent variables accounted for 57.1% of the total variation in the width of cookie bars.

Thickness

The regression results of data on thickness of cookie bars and the ANOVA are presented in Tables 6a and b. Results of the effects of the process variables on thickness of cookie bars (Table 6a) showed that linear and quadratic effects of groundnut flour were significant ($P \leq 0.05$). The linear effect of cornstarch and quadratic effect of cassava flour were also significant ($P \leq 0.05$). The interaction between cassava flour and cornstarch, and that between groundnut flour and corn starch equally had significant effect ($P \leq 0.05$) on the thickness of cookie bars. The studied variables accounted for 99.1% of the total variation in the thickness of cookie bars.

Analysis of variance (ANOVA) showed that the variables had significantly linear effect ($P \leq 0.05$) on the thickness of cookie bars. Response surface plots associated with this analysis are shown in Figs. 1a – c.

Addition of cassava flour and cornstarch improved the thickness of the cookie bars (Fig. 1b) and thickness decreased with increase in groundnut flour (Fig. 1a and c). The increase was attributed to the increase in starch granules in the carbohydrate of cassava flour mixtures, which is responsible for the gel, and structure formation of baked goods (Williams, 1974).

Spread factor

Table 7 contains results of the regression and ANOVA of spread factor of cookie bars. Table 7a shows that quadratic effects of cornstarch were significant ($P \leq 0.05$). Experimental variables accounted for 77.5% of the variation in spread factor of cookie bars.

Analysis of variance showed that quadratic effects of the independent variables had significant ($P \leq 0.05$) effect on the spread factor of cookie bars. Response surface plots associated with the analysis is shown in Fig. 2a –2c. Maximum spread factor was obtained by increasing levels of groundnut flour in the cookie bars (Figs. 2a and c). Increase in spread factors has been correlated with increase in sugar and oil contents (Okaka and Isieh, 1990). Spread factor diminished by the addition of cassava flour and cornstarch (Fig. 2b).

Weight

Data presented in Table 8 show the effect of experimental variables on weight of the cookie bars. Table 8(a) shows that the experimental variables had no significant ($P \geq 0.05$) effect on the weight of the cookie bars. Analysis of variance (ANOVA) also showed that the independent variables had no significant ($P \geq 0.05$) effect on the weight of cookie bars. However, the experimental variables accounted for a total of 66.7% variation in weight of cookie bars.

Fragility

Regression result of data on fragility of cookie bars is shown in Table 9. The experimental variables had no significant effect on the fragility of the cookie bars (Table 9a). Analysis of variance (Table 9b) indicated that the independent variables had no significant ($P \geq 0.05$) effect on the fragility of cookie bars. However, the experimental variables accounted for 81.7% of the variation in fragility of the cookie bars.

Fragility of Cookie bars increased with increase in groundnut flour. This could be as a result of Oil in the groundnut flour. However, fragility reduced when cornstarch and cassava flour were added. This increase in rigidity is due to increase in carbohydrate starch granules, which is responsible for gel and structure formation in baked goods (Williams, 1974).

CONCLUSION

Cookies bars were produced from mixtures of cassava, groundnut and cornstarch. The physical properties of the cookies were optimised using the Response surface methodology. Cookies thickness and spread factor were significantly influenced by the presence of cassava, groundnut and cornstarch, and their interactions. These components did not significantly influence the width and weight of the cookie bars.

Cookie bars produced from cassava-groundnut-corn starch blend had physical properties comparable to that of conventional biscuits.

Table 4: *Physical properties of cookie bars produced from cassava-groundnut-corn starch blends*

% Flour Blend in Bars			Width (Cm)	Spread Factors	Thickness (cm)	Weight (g)	Fragility (g)
Cassava:	**Groundnut**:	**Corn starch**					
25:	75:	10	4.39^{a}	4.33^{fg}	1.02^{b}	22.71^{b}	2540^{m}
75:	75:	10	4.09^{gh}	4.51^{de}	0.91^{cd}	21.08^{c}	4840^{e}
25:	25:	10	4.25^{de}	5.00^{b}	0.85^{d}	20.45^{d}	4418^{j}
75:	25:	10	4.04^{h}	4.19^{g}	0.97^{bc}	20.46^{d}	5320^{b}
25:	50:	5	4.06^{gh}	4.48^{def}	0.91^{cd}	19.54^{i}	2040^{o}
75:	50:	5	4.13^{fg}	4.37^{ef}	0.95^{bc}	18.66^{m}	5020^{d}
25:	50:	15	4.29^{cd}	4.59^{d}	0.94^{bcd}	19.67^{h}	2498^{n}
75:	50:	15	4.13^{fg}	5.24^{a}	0.85^{d}	19.88^{f}	5210^{c}
50:	75:	5	4.37^{ab}	4.32^{fg}	1.01^{b}	20.06^{e}	4122^{l}
50:	25:	5	4.31^{bcd}	4.87^{bc}	0.89^{cd}	22.78^{a}	4328^{k}
50:	75:	15	4.19^{ef}	4.78^{c}	0.88^{cd}	19.77^{g}	4320^{k}
50:	25:	15	4.08^{gh}	4.61^{d}	0.88^{cd}	18.77^{l}	4500^{i}
50:	50:	10	4.34^{abc}	4.85^{bc}	0.90^{cd}	19.79^{g}	4690^{f}
50:	50:	10	4.34^{abc}	4.93^{bc}	0.88^{cd}	19.66^{h}	4640^{g}
50:	50:	10	4.36^{ab}	4.95^{bc}	0.88^{cd}	18.97^{k}	4598^{h}
100% Wheat flour			4.17^{f}	3.40^{h}	1.23^{a}	19.05^{j}	5890^{a}
LSD			0.0627	0.1601	0.0811	0.0687	11.8511

a-k - Means in the same column bearing different superscripts are significantly different ($P \leq 0.05$).

Table 5 (a): Regression Coefficients for width of cookie bars produced from cassava-groundnut-corn starch blends.

SOURCE	Coefficient	Standard error	P-values
Constant	3.65746	0.551948	0.001
Cassava flour	0.02070	0.012944	0.161
Groundnut flour	0.00635	0.012944	0.641
Corn Starch	0.00247	0.030092	0.937
Cassava flour* Cassava flour	-0.00018	0.000106	0.144
Groundnut flour* Groundnut flour	-0.00004	0.000106	0.702
Corn Starch* Corn starch	0.00024	0.000414	0.577
Cassava flour* Groundnut flour	-0.00004	0.000103	0.720
Cassava flour* Corn Starch	-0.00039	0.000510	0.469
Groundnut flour* Corn starch	0.00017	0.000510	0.757
$R^2 = 0.57$			

(b): Analysis of variance for width of cookie bars produced from cassava- groundnut –corn starch blends

Source	df	Sum of squares	F-value	P-value
Regression	9	0.131353	0.89	0.581
Linear	3	0.066149	0.90	0.495
Square	3	0.051400	1.04	0.435
Interaction	3	0.013804	0.28	0.838
Residual	5	0.098641		
Total Error	14	0.229994		

Table 6(a): Regression Coefficients for thickness of cookie bars produced from cassava–groundnut–cornstarch blends**.**

Source	Coefficient	Standard error	P-values
Constant	0.644526	0.059323	0.000
Cassava flour	0.003296	0.001391	0.056
Groundnut flour	0.003746	0.0001391	0.036
Corn Starch	0.013045	0.003234	0.007
Cassava flour* Cassava flour	0.000037	0.000011	0.018
Groundnut flour* Groundnut flour	0.00045	0.000011	0.008
Corn Starch* Corn starch	0.000380	0.000045	0.000
Cassava flour* Groundnut flour	-0.000092	0.000011	0.000
Cassava flour* Corn Starch	-0.000256	0.00055	0.003
Groundnut flour* Corn starch	-0.000256	0.00055	0.003
R^2 =0. 99			

(b): Analysis of variance for thickness of cookie bars produced from cassava –groundnut –corn starch blends

Source	df	Sum of squares	F-value	P-value
Regression	9	0.127136	74.38	0.000
Linear	3	0.089078	7.06	0.022
Square	3	0.016420	34.81	0.000
Interaction	3	0.21638	37.98	0.000
Residual	5	0.001139		
Total Error	14	0.128275		

Table 7(a): Regression Coefficients for spread factor of cookie bars produced from cassava – groundnut-corn starch blends

Source	Coefficient	Standard error	P-values
Constant	5.48043	0.881971	0.001
Cassava flour	-0.00540	0.020684	0.803
Groundnut flour	-0.00380	0.020684	0.860
Corn Starch	-0.07736	0.048084	0.159
Cassava flour* Cassava flour	-0.00030	0.000170	0.127
Groundnut flour* Groundnut flour	-0.00034	0.000170	0.091
Corn Starch* Corn starch	-0.00206	0.000662	0.021
Cassava flour* Groundnut flour	0.00040	0.000164	0.051
Cassava flour* Corn Starch	0.00152	0.000815	0.111
Groundnut flour* Corn starch	0.00144	0.000815	0.128
$R^2 = 0.91$			

(b): Analysis of variance for spread factor of cookie bars produced from cassava –groundnut –corn starch blends.

Source	df	Sum of squares	F-value	P-value
Regression	9	2.54942	6.75	0.015
Linear	3	1.42368	0.88	0.504
Square	3	0.59744	5.94	0.031
Interaction	3	0.52830	4.20	0.064
Residual	5	0.25187		
Total Error	14	2.80129		

Table 8(a): Regression Coefficients for weight of cookie bars produced from cassava–groundnut–corn starch blends

Source	Coefficient	Standard error	P-values
Constant	30.1768	4.80307	0.001
Cassava flour	-0.0707	0.11264	0.553
Groundnut flour	-0.2512	0.11264	0.067
Corn Starch	-0.4680	0.26186	0.124
Cassava flour* Cassava flour	0.0007	0.00093	0.491
Groundnut flour* Groundnut flour	0.0021	0.00093	0.061
Corn Starch* Corn starch	-0.0055	0.00360	0.180
Cassava flour* Groundnut flour	-0.0007	0.00089	0.490
Cassava flour* Corn Starch	0.0024	0.00444	0.605
Groundnut flour* Corn starch	0.0077	0.00444	0.134
$R^2 = 0.67$			

(b): Analysis of variance for weight of cookie bars produced from cassava –groundnut-corn starch blends

Source	df	Sum of squares	F-value	F-value
Regression	9	14.9287	1.33	0.375
Linear	3	2.2589	2.24	0.184
Square	3	7.8770	2.49	0.158
Interaction	3	4.7928	1.28	0.362
Residual	5	7.4696		
Total Error	14	22.3983		

Table 9(a): Regression Coefficients for fragility of cookie bars produced from cassava–groundnut–corn starch blends.

Source	Coefficient	Standard error	P-values
Constant	292.469	645.713	0.667
Cassava flour	14.854	15.143	0.365
Groundnut flour	3.409	15.143	0.829
Corn Starch	49.586	35.204	0.209
Cassava flour* Cassava flour	0.063	0.124	0.633
Groundnut flour* Groundnut flour	0.121	0.124	0.367
Corn Starch* Corn starch	0.409	0.485	0.431
Cassava flour* Groundnut flour	-0.272	0.120	0.064
Cassava flour* Corn Starch	-0.136	0.597	0.827
Groundnut flour* Corn starch	-0.798	0.597	0.230
$R^2 = 0.82$			

(b): Analysis of variance for fragility of cookie bars produced from cassava –groundnut –corn starch blends.

Source	df	Sum of squares	F-value	P-value
Regression	9	603256	2.98	0.099
Linear	3	389462	0.83	0.524
Square	3	56761	0.67	0.601
Interaction	3	157034	2.33	0.174
Residual	6	135002		
Total Error	15	738258		

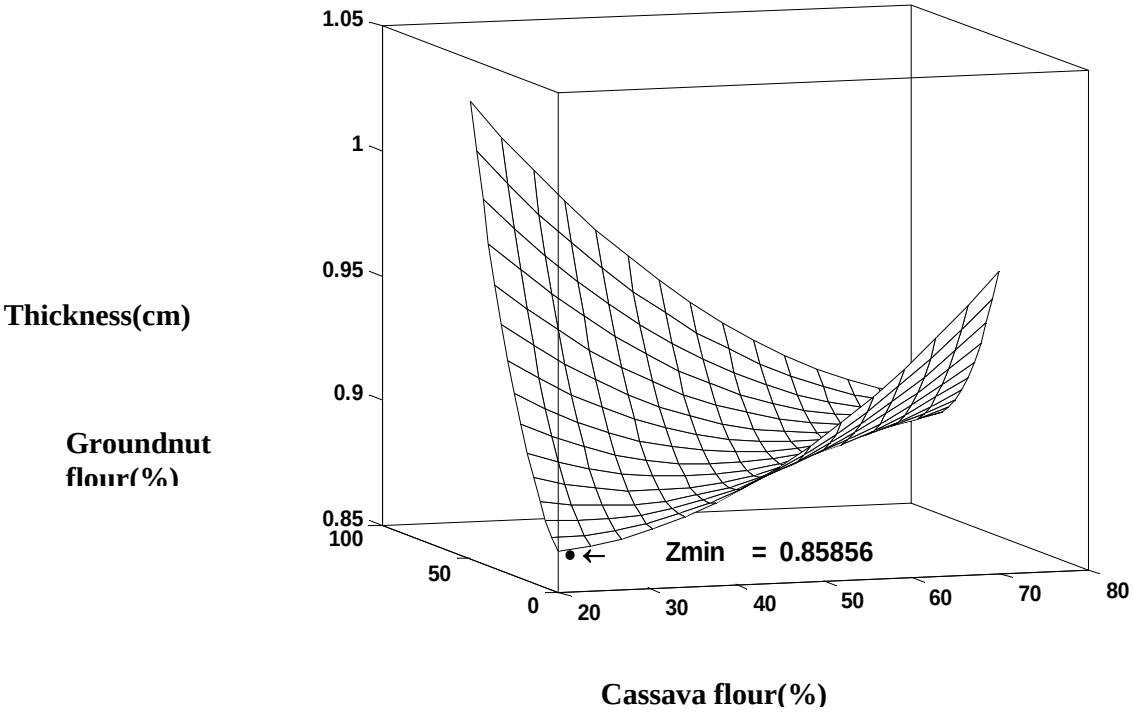

Fig.1a. Effect of groundnut flour and cassava flour on Thickness of Cookie bars.
Analysis of the response surface showed that the critical values of the independent variables were at

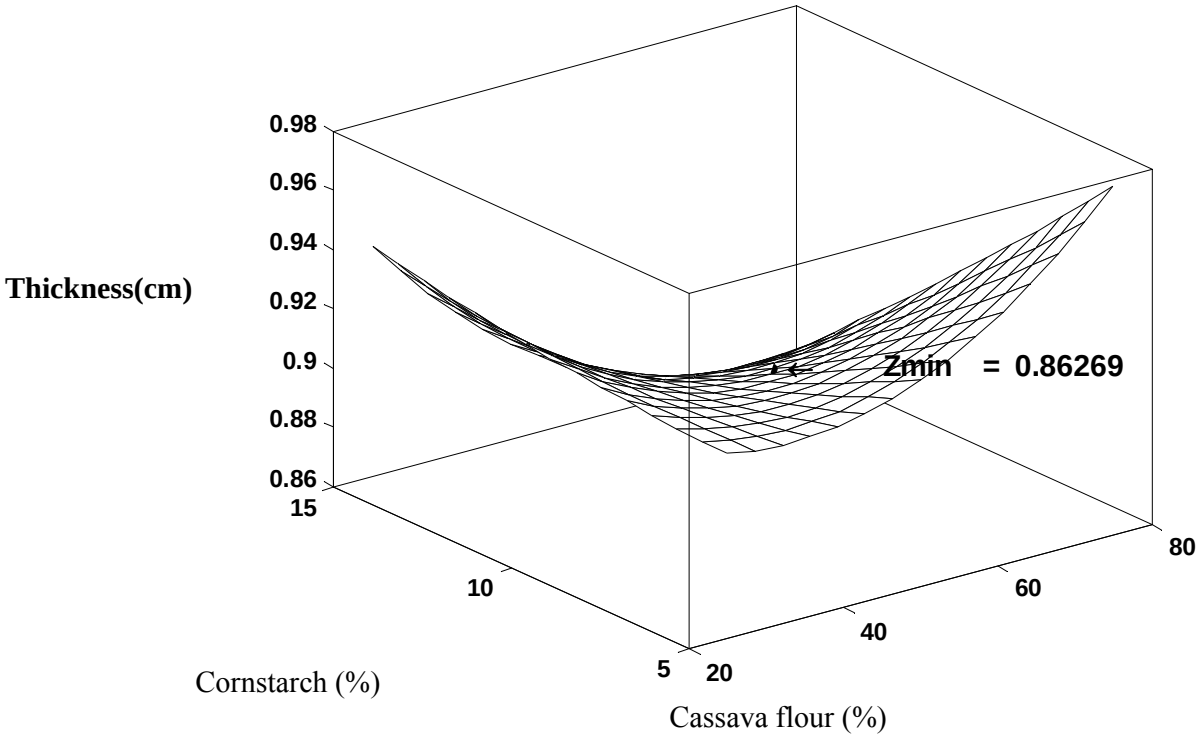

Fig.1b: Effect of Corn starch and cassava flour on Thickness of Cookie bars.

Analysis of the response surface showed that the critical values of the independent variables were at Cassava flour of 25.5% and Corn starch of 10%

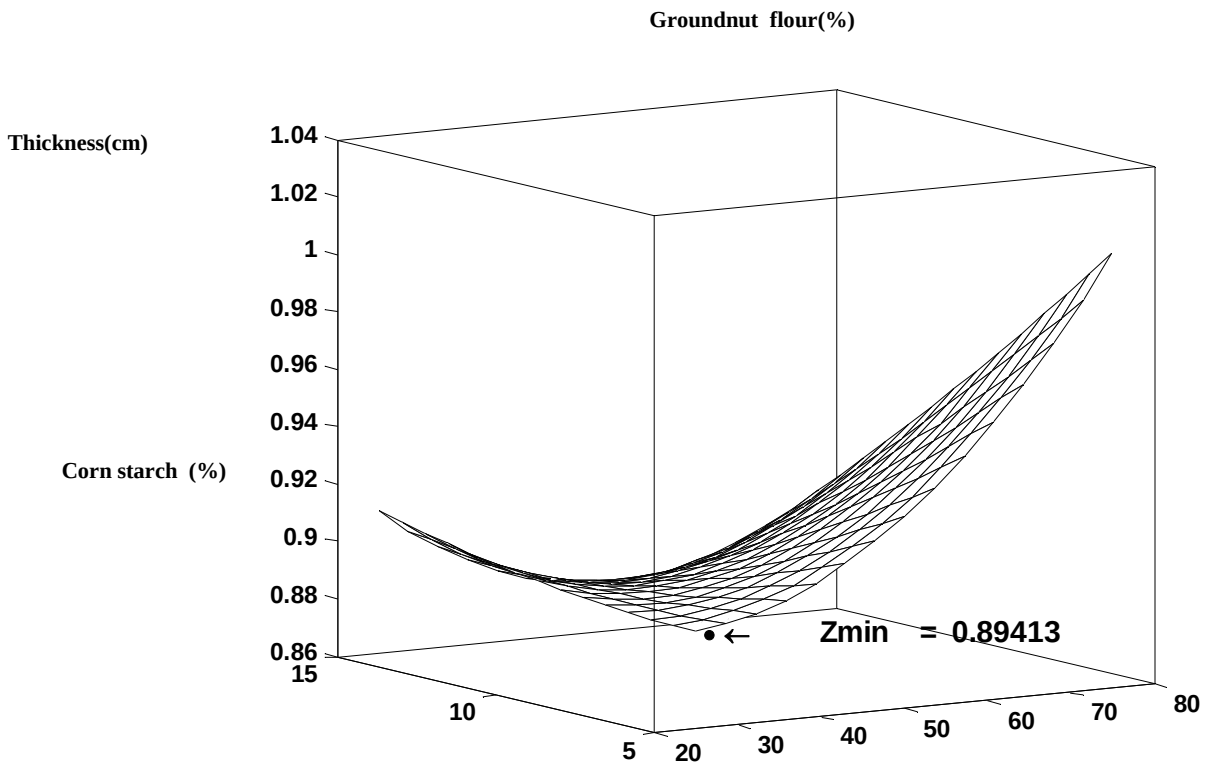

Fig 1c: Effect of groundnut flour snd corn starch on thickness of cookie bars

Analysis of response surface showed that the critical values of the independent variables were at cornstarch of 7% and groundnut flour of 30%

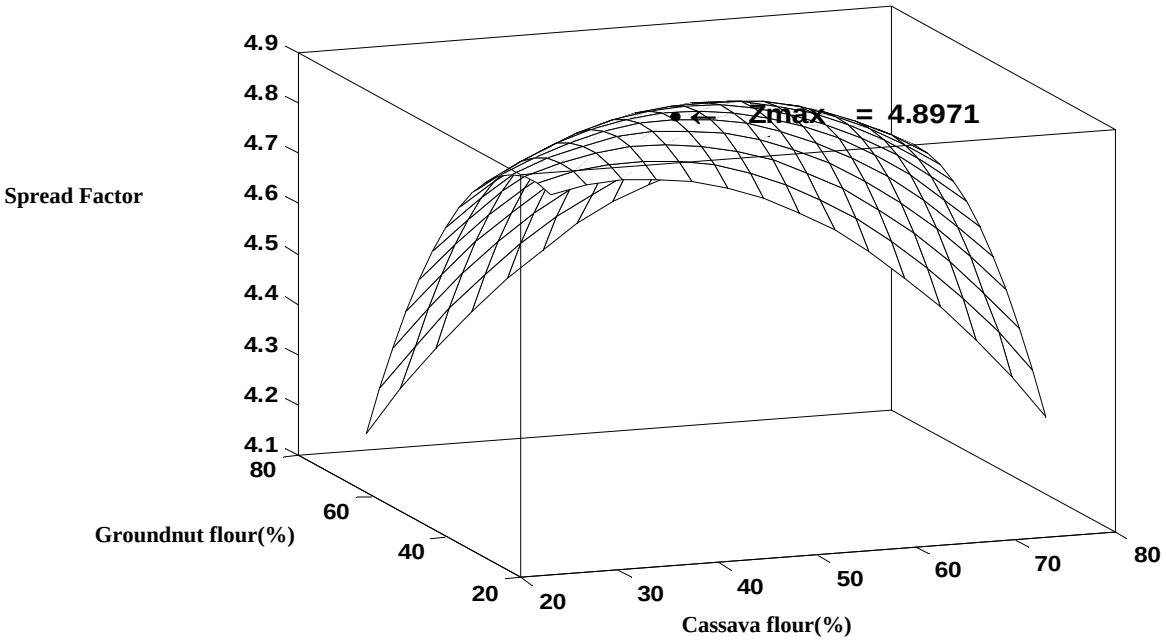

Fig.2a: Effect of groundnut flour and cassava flour on Spread factor of Cookie bars.

Analysis of the response surface showed that the critical values of the independent variables were at Cassava flour of 46.09% and Groundnut flour of 43.62%

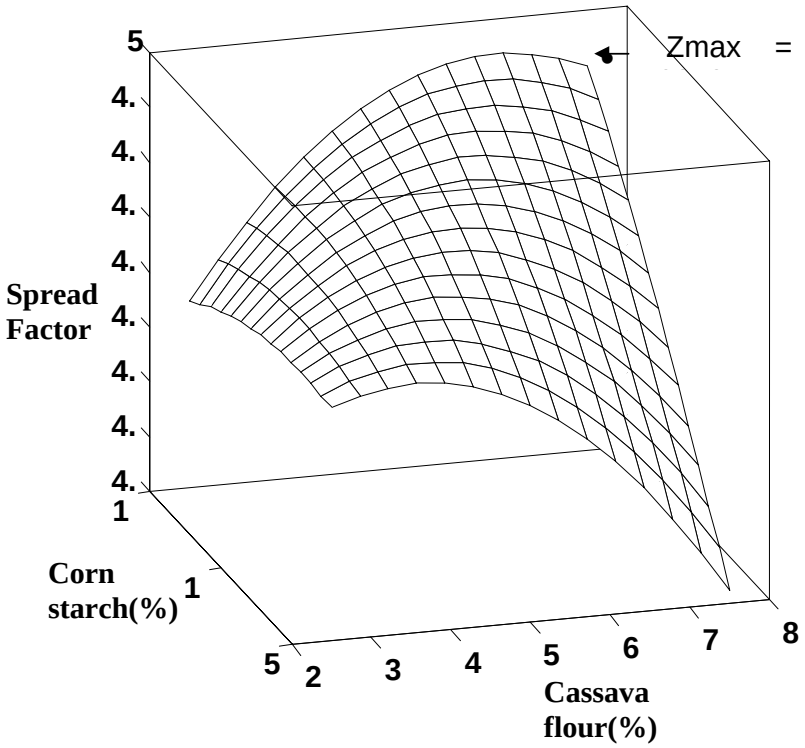

Fig.2b: Effect of corn starch and cassava flour on Spread Factor of Cookie bars. *Analysis of the response surface showed that the critical values of the independent variables were at Cassava flour of*

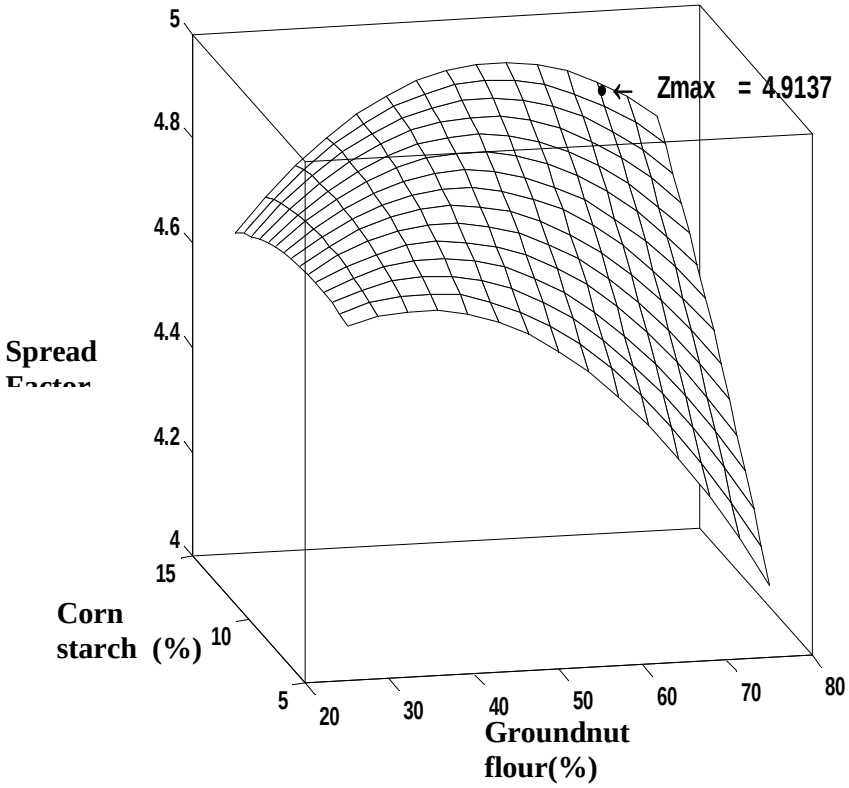

Fig.2c: Effect of groundnut flour and cornstarch on Spread Factor of Cookie bars. *Analysis of the response surface showed that the critical values of the independent variables were at Cornstarch of 13% and Groundnut flour of 60%*

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