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Development of biscuits made with wheat, soybean and cassava flour blends using mixture design

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Abstract
Composite flour was made with various blends of wheat, soybean and cassava flours to determine their nutritive potential and sensory acceptability in biscuit manufacture. Numerical optimization of the protein contents of the biscuits was performed using the response optimizer of the Design – Expert software. All the variables' goal were set in range to generate 39 solutions at desirability of 1. The study revealed that most of all the parameters studied were significant in producing high quality biscuits. The results obtained from the contour and 3D – Surface plots for protein show that increasing the quantity of cassava in the flour blends decreases the protein contents of the biscuits. Also increasing both the soyabean and wheat contents of the flour blends increases protein content of the biscuits, with soyabean contributing more to the effect. Proximate composition ranges of the biscuit samples were; protein (2.10 - 28.50 %,) ash (0.16 -4.20 %), fibre (0.09 -0.31 %), fat (22.40 – 34.40%), carbohydrate (27.84-67.44%) and energy (463.60 – 538.70 Kcal/100g). Energy contents increases with addition of soyabean and cassava flours. Biscuit produced with composite blend 66.70 % soyabean: 16.70% wheat: 16.70% cassava contained 515.43 Kcal/100g when compared with 487.08Kcal/100g in 100% wheat. Sensory ratings revealed that biscuits containing 9.73% protein and produced from flour blend; 16.70% soybean: 66.70% wheat: 16.70% cassava were generally accepted as that of wheat biscuit.

Keywords: biscuits, composite flour, cassava, soybean, mixture design

Introduction

Biscuit is a baked good made using flour, shortening, baking powder and other ingredients. Biscuits include such items also known as crackers, hard sweet or semi-sweet biscuits, cookies and wafers. Biscuits can be staple foods, snacks, luxury gifts, dietary products, infant foods and with the addition of chocolate and cream etc. they borderline with confectionery, [1]. Biscuits are known for its good characteristics, including greater convenience, relatively long shelf life, wider consumption base, and good eating quality [2].

Recently, researchers have shifted much interest in the development of food products especially bakery products and pastries using composite flours. Composite flours are a blend of flours from tubers (eg cassava, yam, sweet potatoe) rich in starch and pulses (soy, peanut,banbaranuts) and cereals (maize, rice, millet), rich in protein with or without wheat [3]. Composite flour is economically relevant to developing countries as it reduces foreign exchange/ capital flight, promotes a better supply of protein for human nutrition and a better overall use of domestic agriculture production [4, 5]. The growing market in recent times for confectioneries has increased the Local raw materials substitution for wheat flour [6]. This has prompted several developing countries to initiate programmes that would evaluate the feasibility of alternative locally available flours as a substitute for wheat flour [7]. Following this, the federal government of Nigeria came up with the enactment of High Quality Cassava Flour, (H.Q.C.F) inclusion policy to reduce the amount spent on wheat importation. Implementation of the inclusion policy began in 2002 with 10% H.Q.C.F. inclusion in bread production, 5% inclusion in 2007 -2010 and 40% in 2011-2014 [8]. According to Elemo, [9] H.Q.C.F. inclusion in bread production in Nigeria has the potential of saving the country between N37.75 and N240.0 billion in inclusion of 5 and 40% H.Q.C.F.

Wheat, though a good source of calories and other nutrients is considered nutritionally poor, as cereal proteins are deficient in essential amino acids such as lysine and throenine [10]. Therefore to help improve the nutritional quality of wheat products, supplementation of wheat flour with inexpensive staples such as cereals, tubers, and pulses, become necessary [11]. For example, the protein quality of both cassava–soya and cassava – groundnut breads is higher than that of only wheat bread [12].

Nigeria is the largest producer of cassava in the world, producing about 45.72 million tonnes of cassava tubers from 3.81 million hectares of farmland in 2006 [13]. Also Nigeria is the second largest producer of soybean in Africa. In 2015/1016, Nigeria produced approximately 680,000 tons of soyabean [14]. It follows therefore that the two local crops are abundantly cultivated in Nigeria.

Mixture Designs is a statistical technique that can be used to determine the effect that components in a mixture have on the attributes of a finished product [15, 16].

The aim of the present study was to produce biscuits from blends of wheat, soyabean, and cassava flours, and to study the effects of the blends on protein, and some sensory properties of the biscuits and thereby optimize these attributes in the biscuits.

Materials and Methods

Soybean *(Glycine max)* and wheat *(Triticum aestivum)* were purchased from Ogbete market in Enugu. Freshly harvested sweet cultivar of cassava root (*Manihot esculentacrantz)* was purchased from a local farmer in Akugo, Enugu, Nigeria.

Sample preparation
Cassava Flour
High quality cassava flour was produced using the method adapted from [17]. The production process was completed in a day to ensure that the cassava flour produced was near white, odourless and did not ferment. Cassava roots with no bruises were used to produce high quality cassava flour. The roots were peeled, washed thoroughly to remove dirt and then grated. The grated cassava mash was packed in a clean jute bag and pressed using a screw press to remove excess water until the cassava was crumbly. The pressed mash was spread thinly on a clean black plastic sheet on an elevated ground and dried by the sun. Dried cassava mash was milled to produce flour and sifted to remove fibrous materials and lumps. Flour was packaged in an airtight container and stored for biscuit production.

Soybean flour
Soybean flour was prepared according to the method described by [18]. Seeds free from dirt and foreign particles were weighed, cleaned and soaked in tap water for 8 hours. Thereafter, it was drained, de-hulled manually, boiled at 100^0C for 30minutes and dried in an oven at 65^0C for 6 hours. The seeds were stirred at intervals of 30 minutes to ensure uniform drying. The dried seeds were milled and sieved to obtain cooked full-fat soy bean flour. The full-fat soybean flour obtained was finally packaged in an air tight container for biscuit production.

Experimental design
The design was a three-component augmented Simplex centroid design which was carried out using statistical software (Design- Expert version 8.0.3, State – Ease, Inc. Minneapolis, 2010) as shown in Table 2.1. The three mixture components in this study were soyabean flour (x_1), wheat flour (x_2) and high quality cassava flour (x_3). The proportion of each flour was expressed as a fraction of the mixture and for each treatment combination giving the sum of the component proportion as 100.

Where: $\sum X_i = x_1 + x_2 + x_3 = 100$

Table 1: Experimental design used to produce the flour blends

Samples	X_1 (soybean)	X_2 (wheat)	X_3 (cassava flour)
1	0.00	0.00	100.00
2	50.00	0.00	50.00
3	16.70	66.70	16.70
4	50.00	50.00	0.00
5	0.00	100.00	0.00
6	0.00	50.00	50.00
7	33.30	33.30	33.30
8	100.00	0.00	0.00
9	50.00	50.00	0.00
10	66.70	16.70	16.70
11	0.00	0.00	100.00
12	100.00	0.00	0.00
13	0.00	100.00	0.00
14	16.70	16.70	66.70

The total number of runs in design were 14 (Table 1)

Preperation of biscuits
The ingredients used are: Composite flour, 100.0g; hydrogenated vegetable fat, 40.0g; sugar, 20.0 g; egg (whole),25.0 g; baking powder, 2g; salt,1g; vanilla liquid, 5ml; and water, 35ml. Fat and sugar were creamed using an electric mixer. Eggs were added and mixed until both formed a homogenous mixture. Sifted flour, baking powder, salt, and vanilla were added to the mixture and mixing continued for about 30min. Water was gradually added to form a dough. The dough was kneaded and rolled to a uniform thickness of 0.30cm and cut into circular shapes of 5 cm. Baking was carried out at 185^0C for about 15min.The biscuit samples produced were cooled and stored in a polyethylene bags and again in a tight bottle and stored for analysis. Biscuits were made from 100% wheat flour with same processes and quantities of ingredients as above to serve as control.

Proximate composition
The biscuit samples were evaluated to ascertain their nutritional quality. The parameters determined according to standard methods [19] were: protein, fibre, fat, moisture and ash. Carbohydrate contents were determined by difference. Energy was calculated by the Atwater method [20]. The determinations were carried out in triplicates.

Sensory evaluation
The sensory evaluation of the biscuits were determined. Fifteen (15) semi- trained panellists were randomly selected from Food Science and Technology Students and some staff of Madonna University, Nigeria, Akpugo Campus to evaluate the consumer acceptance of each of the biscuits produced.. Evaluation of all the samples took place in one session. Criteria for selection of the panellists were that panellist were regular consumer of biscuits and were not allergic to any food. Panelists were instructed to evaluate colour, taste, texture and general acceptabilitys of the biscuits. A 9-Point hedonic scale was used with 1= dislike extremely, 5= neither like or dislike, 9=like extremely [18] (Ihekorenye and ngody, 1985). Samples were identified with 3- digit code numbers and presented in a random sequence to the panellists. The panellists were instructed to rinse their mouth with water after every sample and not to make comments during evaluation to avoid influencing other panellists. They were also asked to comment freely on samples on the questionnaire given to them.

Statistical analysis
Analysis of Variance (ANOVA) was carried out on the data generated from proximate composition and sensory evaluation of the biscuit samples using a statistical software (SPSS, Version 16.0 for windows, SPSS Inc. Illinois, USA). Mean separation was carried out using Least Significant difference (LSD). Significance differences between the samples were determined at $p> 0.05$.
The experimental data from proximate composition and sensory evaluation werw also statistically evaluated. The analysis was performed using statistical software (Design-Expert version 8.0.3, State – Ease, Inc. Minneapolis, 2010). Model significance ($p> 0.05$), lack of fit and adjusted regression coefficient ($R_{adj}{}^2$) which indicate the model fitness were considered before fitting response into models.
The model search was started with the special cubic equation as shown in eq. (1) below:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3 \text{ .... } (1)$$

Where y is the predicted response, β is the parameter estimate (coefficient) for each linear and cross product terms for the prediction model. x_1, x_1, x_2, x_3, x_1 x_2, x_1 x_3, and x_1 x_2 x_3 are the linear terms for soybean flour, wheat flour, high quality cassava flour, and their cross product terms.

Numerical Optimization

To perform the numeric optimization of the protein content of the biscuits, the variables were set in range and the response optimizer of the software generated mixture component of the three flours that have desirability of 1 with their respective protein values.

Results and Discussions

Proximate composition of biscuit samples

Proximate composition of biscuit samples is shown in Table 2. The different chemical composition of composite flour affects the nutritional quality of the product. The moisture content of the biscuits ranges from 3.22-4.39%. The low moisture content is within acceptable limit in terms of food storage as recommended by [21] which states 13-15% safe moisture contents as optimal range for storage of food and cereal grain. The higher moisture content in the composite flour products relative to the control may be attributed to the blend composition of the composite flours. Soluble protein contained in soy flour contributes to a greater moisture holding capacity [22].

The crude protein content ranges from 2.01-28.85%. Biscuit samples (1 and 11) produced with 100% cassava flour had 2.01% protein. Sample (5) produced with 100% wheat (control) had 8.49% protein, while samples (8 and 12) produced with 100% soybean flour contained 28.5% protein. Also samples (3,7, and 4) that contain 16.7%, 33.3% and 50% substituted soybean flour had 10.67, 12.10, and 16.18 % protein respectively.. The increase was attributed to the level of substitution of wheat flour with soybean flour. Soybeans were considered in the formulation because of their high protein content and quality amino acid profile and their content of minerals, such as calcium and iron [23]. Nilufer *et al*. [12] observed that the protein quality of both the cassava-soya and the cassava-groundnut breads is higher than that of common wheat bread. Legumes are higher in nutrients, especially in protein (18–24%), than cereal grain [25]. Legume proteins are successfully used in baked products to get a protein-enriched product with improved amino acid balance [26].

Ash content of the biscuit samples ranges from 0.16 – 4.2%. Ash content in 100% (cassava, wheat, and soyabean) biscuit samples were; 0.16, 1.69, and 4.20%. Also ash content in sample 10 (66.7% soybean: 16.7 wheat: 16.7% cassava) and sample 14 (16.7% soybean: 16.7% wheat: 66.7% cassava) were 2.89 and 2.20 %. The ash content of control (100% wheat biscuit) differed significantly ($p<0.05$) with the samples. The results indicated higher levels of ash with incremental substitution of soyabean flour. Ash content of the composite blend increased due to the significantly higher mineral content of all the non-wheat flours. These results are in agreement with those obtained by [27]. High ash content has been attributed to high minerals which invariably could increase the mineral content of the consumers and are good for the bones as reported by [28].

Fat content of the biscuits varies from 22.24 to 34.50% and increased as the proportion of soybean flour in the blends increases. Fat content in 100% (wheat, cassava and soybean) biscuit samples were; 26.11, 22.24 and 34.50 % respectively. Fat content in sample 10 (66.7 % soybean: 16.7 % wheat: 16.7 % cassava) and sample 14 (16.7% soybean: 16.7% wheat: 66.7% cassava). Were 29.11 and 25.60 % respectively. Control (100% wheat biscuit) differed significantly ($p<0.05$) with the samples. High values of crude fat content agree with the findings of [28].

Fibre content of the biscuits varies from 0.09 to 0.31%. The fibre content in 100% (cassava, wheat, and soyabean) biscuit samples were 0.09, 0.16 and 0.31% respectively. Fibre content in sample 10 (66.7% soybean, 16.7% wheat and 16.7% cassava) and sample 14 (16.7% soybean, 16.7 % wheat and 16.7 % cassava) were 0.27 and 0.22 % respectively. The fibre content of control (wheat biscuit) differed significantly ($p<0.05$) from the samples. Result showed that while cassava addition decreases fibre level, soybean increases it. Dietary fibre forms a significant fraction of the bran of whole grains and their health promoting benefits have been researched extensively [29] (Malunga *et al*., 2017). High value of fibre contents could also improve the digestion and aid waste elimination in the body and guide against anthracites [30].

The carbohydrate contents of composite biscuits were influenced by the level of cassava flour supplementation and the highest (67.94 %) content was found in 100 % cassava flour sample compared to 100% wheat biscuit (63.24%). The carbohydrate content decreased significantly ($p < 0.05$) with increase in soybean flour substitution as recorded in sample 4 (50 % soybean: 50 % wheat) 45.17%, sample 10 (66.7 % soybean: 16.7 % wheat: 16.7% cassava) 42.85% and sample 8 (100 % soybean) 27.84% having the least carbohydrate value. The relatively low carbohydrate values in the composite flour products may be attributed to the lower levels of wheat flour used relative to the control [31]. Using composite flour made from grain cereals and root and tubers in bread and biscuit preparation increases the fibre content which lowers the carbohydrate value of the product. This finding was reported by *Serrem et al.*[32] who obtained similar results. However all samples were found to be significantly ($p<0.05$) different from the control (63.24%)

The energy content of the biscuit samples varies from 463.6 to 538.7 Kcal/g. Energy content increases with addition of soybean and cassava flours to wheat biscuit. Highest energy content (538.7 Kcal/g) was observed in biscuit sample 2 (50 % soybean: 50% cassava) and is higher than in 100% wheat sample (487.08Kcal/g) and sample 10 (66.7 % soybean: 16.7 % wheat: 16.7 % cassava) (515.43 Kcal/g). The energy content of the formulated mixtures for children is in accordance with the recommended energy values of 360-400 kcal/100g 0f food [33].

Table 2: Mean results of proximate analysis of biscuit sample (%)

Sample	Moisture	Protein	Ash	Fat	Crude fiber	Carbohydrate	Energy content (Kcal/ 100g)
1	$3.22^a±0.10$	$2.01^a±0.08$	$0.61^a±0.03$	$26.11^a±0.07$	$0.09^a±0.00$	$67.94^a±0.12$	514.79
2	$3.38^a±0.17$	$18.82^b±0.43$	$0.36^a±0.32$	$30.70^b±0.50$	$0.12^a±0.01$	$46.08^b±0.76$	538.70

3	4.03^{b}±0.30	10.67^{c}±0.17	2.26^{b}±0.15	26.07^{a}±1.03	0.26^{b}±0.01	56.69^{c}±1.06	504.07
4	3.49^{a}±0.60	16.18^{d}±0.16	2.56^{b}±0.15	32.08^{c}±0.26	0.25^{b}±0.01	45.17^{b}±0.08	534.12
control	4.15^{b}±0.10	8.49^{e}±0.09	1.69^{c}±0.10	22.24^{d}±0.53	0.16^{ae}±0.01	63.24^{d}±0.75	487.08
6	3.84^{ab}±0.09	5.22^{f}±0.18	2.20^{b}±0.00	22.40^{d}±0.46	0.19^{e}±0.01	66.18^{e}±0.10	487.20
7	4.39^{b}±0.11	12.10^{g}±0.28	2.33^{b}±0.22	25.29^{e}±0.27	0.21^{bce}±0.01	55.56^{h}±0.57	498.25
8	4.29^{b}±0.26	28.85^{h}±0.51	4.20^{d}±0.17	34.50^{f}±0.45	0.31^{d}±0.00	27.84^{f}±0.92	537.26
9	3.74^{ab}±0.12	16.18^{d}±0.16	2.56^{b}±0.15	32.08^{c}±0.26	0.25^{b}±0.01	45.44^{b}±0.39	535.20
10	4.35^{b}±0.17	20.53^{y}±0.32	2.89^{e}±0.17	29.11^{y}±0.13	0.27^{bd}±0.01	42.83^{k}±0.67	515.43
11	3.22^{a}±0.10	2.01^{a}±0.08	0.16^{a}±0.36	26.11^{a}±0.07	0.09^{a}±0.00	67.94^{a}±0.12	514.79
12	4.29^{b}±0.26	28.85^{h}±0.05	4.20^{d}±0.17	34.50^{f}±0.45	0.31^{d}±0.00	27.84^{f}±0.92	537.26
13	4.14^{b}±0.12	8.49^{e}±0.90	1.66^{c}±0.11	22.25^{d}±0.4	0.16^{ae}±0.09	63.24^{d}±0.75	487.08
14	3.66^{a}±0.05	6.72^{z}±0.94	2.20^{b}±0.20	25.60^{z}±0.22	0.22^{be}±0.00	51.58^{l}±0.30	463.60

Data are means of triplicate determinations + SD, Data in the same row with different superscript differed significantly ($p<0.05$)

Sensory analysis

Table 3 shows the results of sensory scores for the biscuits produced at different levels of composite flours and compared to the control.

Taste is the key sensory attribute which affects the perception of food to be consumed. For taste, sample 3 was closest to control and was rated "like slightly" and control rated "like moderately". However there was significant difference ($p<0.05$) between the control and other samples for taste. The low score ratings observed in samples 4, 5, and 7 may be due to addition of more soybean and cassava flours to wheat flour. Also according to some of the panellists, there was a limiting sensory attribute of a beany taste and "root crop" after taste in these samples. Several studies have reported that higher substitution of wheat flour with soyabean and cassava flours in biscuits was associated with a beany flavour "root" aroma and after taste [22, 34].

Appearance plays a major role in determining consumer acceptance of foods products. The score rated for the control is significantly ($p<0.05$) higher than other samples excepting sample 3. The low rating of appearance in other samples could be attributed to darker colour and brownish of the biscuits as substitution of wheat flour with soyabean and cassava flour increases. Browning in bread could be as a result of maillard reaction and caramelization as the protein contributed by soyabean flour must have reacted with added sugar and sugar released by amylases from cassava starch during biscuit processing [10]. Sharma and Chanhan, [35] had reported a decrease in appearance score of composite flour baked products as substitution increased.

The scores for texture shows non-significant difference between sample 3 (16.7 % soybean: 66.7% wheat: 16.7% cassava) and control (100% wheat). Biscuits containing 50% and 66.7% soybean, each representing samples 2 and 10 had low sensory score rating relative to sample 3 and control. Texture depicts softness and chewiness of composite biscuits. The contribution of additional fibre ostensibly from cassava and soybean in the composite blends might have resulted in the hard texture of the cake biscuits relative to the control [22]. Substitution of wheat flour with non-wheat flour in bakery products results in the retention of less gas hence producing a dense texture that is undesirable to the consumers [31].

General acceptability scores reveal that samples 3 and 9 that contain 50 and 66.7% wheat were rated "like slightly" and "like moderately" respectively. In totality, sample 3 produced biscuit samples were rated highest among all attributes and was not significantly ($p<0.05$ different from the control wheat sample.

Table 3: Mean results of sensory analysis

Samples	Taste	Appearance	Texture	General acceptability
1	6.06^{a}±2.08	5.93^{a}±1.66	6.13^{a}±1.80	6.26^{a}± 1.53
2	5.40^{a}±1.88	6.46^{ab}±1.45	5.80^{a}±1.69	6.13^{a}±1.50
3	6.66^{c}±2.28	7.46^{b}±1.06	6.86^{ab}±1.68	7.06^{bc}±1.83
4	5.13^{b}±1.95	5.93^{ac}±1.94	5.66^{ab}±2.02	5.33^{ac}±1.59
5	7.26^{d}±1.57	7.66^{b} ±1.24	7.66^{ab}±1.29	7.46^{bc} ±1.27
6	6.40^{a}±1.59	6.06^{a}±1.57	6.33^{a}±1.75	6.33^{a}±1.51
7	5.66^{a}±1.54	6.33^{a}±1.17	5.86^{a}±1.80	5.80^{ac}±1.52
8	4.00^{b}±1.77	4.80^{c}±2.04	4.33^{b}±1.54	4.13^{b}±1.64
9	6.06^{a}±1.48	6.00^{a}±0.92	5.73^{a}±1.09	6.53^{a}±1.06
10	5.46^{a}±1.68	6.26^{a}±1.66	5.13^{ab}±1.99	5.60^{ad}±1.76
11	6.26^{a}±1.57	4.73^{c}±2.01	6.33^{a}±1.34	6.20^{a}±1.32
12	3.60^{b}±1.76	4.60^{c}±1.72	4.46^{b}±1.94	3.80^{bd}±1.65
13	7.00^{d}±1.92	7.06^{a}±1.38	7.53^{b}±1.12	7.20^{acd}±1.74
14	6.00^{a}±0.92	6.33^{a}±1.34	6.60^{ab}±1.05	6.40^{a}±0.82

Data are means of triplicate determinations ± SD., Data in the same row with different superscript differed significantly ($p<0.05$)

Fitting of the model

Table 4 shows the analysis of the variance (ANOVA) of the protein content of the biscuit made from the composite flours of wheat, soyabean and cassava. It shows that the model, linear (A, B), interactions (AB & AC) terms were significant at $p<0.05$. The coefficient estimate of protein for the components are: A (+ 28.87), B (+ 8.72), C (+ 1.87), AB (- 10.7), and AC (+ 10.87), While the Model for protein is presented as:

Protein = 28.87A + 8.72 B +1.87C- 10.87AB------------Eq. 1

The correlation coefficient (R^2) 0.9954 and R^2 adj (0.9925) for protein were high. R- squared value is an indication of the level of response that could be explained by the model. The result shows that 99.54% of the response could be explained by the model at 0.0001 significant level.

Table 4: Analysis of variance (ANOVA) for mixture quadratic model

Source	Sum of squares	Df	Mean square	F value	P value prob> F	
Model	996.43	5	199.29	349.09	0.0001	Sig.
Linear Mixture	978.92	2	489.46	857.40	0.0001	Sig.
AB	10.93	1	10.93	19.15	0.0024	Sig.
AC	6.48	1	6.48	11.36	0.0098	Sig.

BC	0.37	1	0.37	0.66	0.4415	not sig.
Residual	4.57	8	0.57			
Lack of Fit	4.57	4	1.14			
Pure Error	0.000	4	0.000			
Cor total	1000.99	13				

Numerical Optimization

The protein content of the biscuit was optimized based on the range of protein values (2.01 – 28.85 %) from the experimental samples. The lowest and highest values for protein were selected and the response optimizer of the software generated mixture component of the three flours that have desirability of 1 with their respective protein values as shown in table 5

To perform the numerical optimization, the response optimizer of the software was used and all the variables goal were set in range to generate 39 solutions as shown in table 5.

Table 5: Numerical optimization of the protein content of the biscuits

Solutions	Flours				
Number	Soybean	Wheat	Cassava	Protein	Desirability
1	10.000	10.000	80.000	5.7586	1.000
2	50.000	50.000	0.000	16.082	1.000
3	80.909	9.091	10.000	24.3383	1.000
4	33.333	33.333	33.333	12.8002	1.000
5	16.667	16.667	66.667	8.06182	1.000
6	5.000	0.000	50.000	17.8976	1.000
7	16.667	66.667	16.667	9.74268	1.000
8	0.000	100.000	0.000	8.72496	1.000
9	66.667	16.667	16.667	20.8627	1.000
10	0.000	50.000	50.000	4.6876	1.000
11	95.268	0.386	4.346	28.0015	1.000
12	20.751	2.364	76.885	9.1483	1.000
13	65.40	12.445	22.152	20.8968	1.000
14	2.308	66.024	31.668	6.4177	1.000
15	51.045	24.971	23.984	17.0716	1.000
16	43.963	31.745	24.292	15.296	1.000
17	17.428	79.300	3.272	10.5042	1.000
18	4.170	11.184	84.646	3.83567	1.000
19	47.263	27.707	25.030	16.135	1.000
20	4.731	80.689	14.580	8.0468	1.000
21	34.023	16.349	49.628	13.0814	1.000
22	80.562	2.898	16.539	24.9052	1.000
23	91.550	5.698	2.752	26.6672	1.000
24	12.108	28.394	59.498	7.02761	1.000
25	65.566	8.225	26.209	21.237	1.000
26	12.649	47.807	39.543	7.94995	1.000
27	40.280	10.835	48.884	14.8756	1.000
28	63.632	14.165	22.203	20.3955	1.000
29	0.434	97.528	2.039	8.57907	1.000
30	64.618	29.611	5.771	19.6048	1.000
31	66.026	31.682	2.296	19.733	1.000
32	10.058	67.416	22.527	8.32898	1.000
33	0.330	11.801	87.869	2.53817	1.000
34	26.525	32.045	41.430	11.092	1.000
35	53.042	37.610	9.348	17.0186	1.000
36	7.908	53.928	38.164	7.04171	1.000
37	31.778	31.246	36.976	12.4193	1.000
38	41.227	38.696	20.077	14.5684	1.000
39	37.964	43.918	18.118	13.821	1.000

The contour and 3D – surface plots of the protein content of the biscuits are shown in figures 1 and 2 respectively. Both graphs show that increasing the quantity of cassava flour in the blend decreases the protein content. Also increase in both soybean and wheat flours in the blend increased the protein content of the biscuit. However, soybean flour contributed more to the increase than wheat flour.

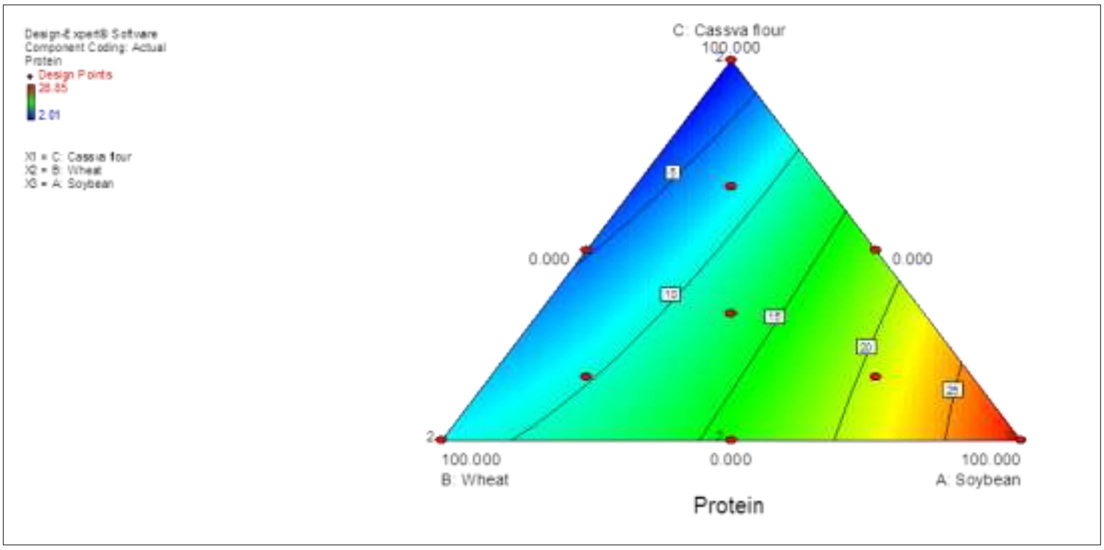

Fig 1: Contour plot for protein

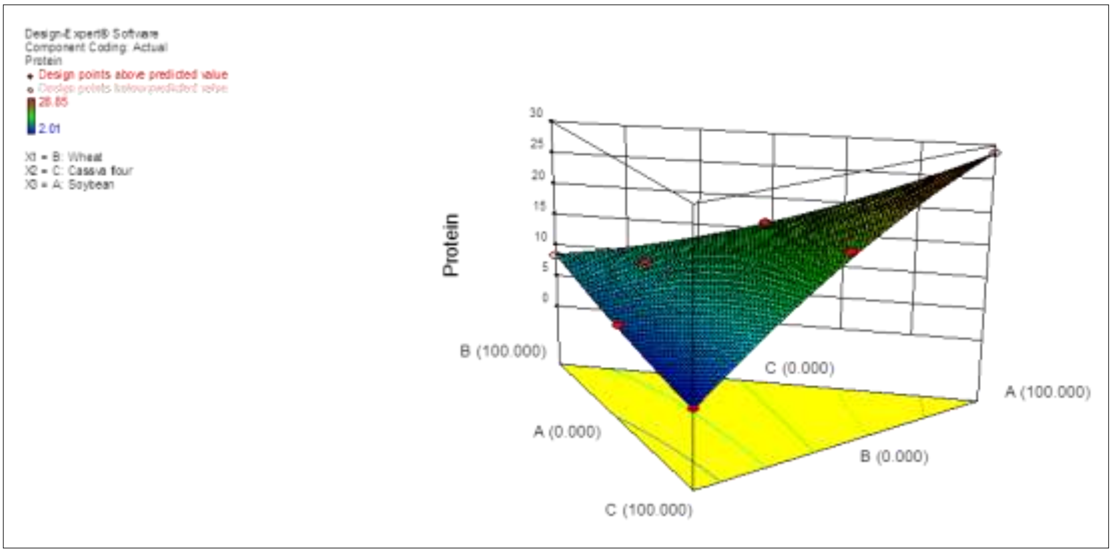

Fig 2: 3D-Surface plot for protein

Conclusion

Numerical optimization of the protein content of the biscuits were performed using the response optimizer of the Design - Expert software that generated 39 mixture components of soybean, wheat and cassava flours that would have desirability of 1 and their corresponding protein values. This invariably provides varied options of flour blends and corresponding protein values to choose from by biscuit manufacturers that would satisfy targeted consumers. Biscuits produced from 16.67% soyabean: 66.67 % wheat: 16.67 % cassava blends that contained 9.743 % protein indicated highest general acceptance on sensory scores. However, relatively cheap biscuits with moderate sensory score that contains 16.135% protein could be produced from blend of 47.263% soyabean: 27.707% wheat: 25.030% cassava flours.

The use of composite flours made from locally grown crops will reduce foreign exchange for wheat importation and impact positively on local agriculture.

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