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Original Article

Modeling and optimization of processing parameters of strips produced from blends of cassava and cowpea flour

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ABSTRACT

Most Nigerian traditional foods have a low nutritional value, inconsistent sensory attributes, and short shelf life. Thus, upgrading becomes necessary for the technologies used in the processing, distributing, and storing of indigenous snack foods to improve the products' nutritional, sensory, and storage properties. A Box-Behnken (three-factor) response surface methodology was used to optimize the process. The effect of frying temperature (160 - 180°C), frying time (8 - 12 min) and percent cowpea flour (10 - 30%) on some attributes (moisture, fat, protein contents, texture, and color change) of cassava-cowpea strips fried snack. Data were analyzed by ANOVA and regression analysis. The moisture content ranged between 1.00% and 4.26%, fat content (8.41–11.94%), protein content (30.83–36.42%), texture (5.06–13.14 N) and color change (26.967–40.479). Frying temperature, frying time and % cowpea flour had a significant ($P < 0.05$) effect on moisture, fat, protein contents, texture and color change of cassava-cowpea strips. The processing conditions affected moisture, fat, protein, texture, and color change. Coefficients of determination, R^2 were 0.87, 0.86, 0.79, 0.88 and 0.71, respectively. The best conditions for processing cassava-cowpea strips were 12 min frying time, 166.65 °C frying temperature, and 24.36% cowpea flour content. The desirability of optimization was 0.65. Therefore, composite flour from cassava and cowpea can be adopted or used to produce strips to prevent protein-energy malnutrition in the community.

1. Introduction

For many people, including consumers in developing countries, urbanization is a significant contributor to changing eating habits and food consumption [1]. Because of the hectic pace of city life, people have become too dependent on convenience foods and snacks, mainly made from flour. However, this is rare in most countries of sub-Saharan Africa (including Nigeria), leading to heavy dependence by relying on imported wheat to meet the demand for instant food production [2]. On the other hand, tropical root crops and essential legumes such as cassava and cowpea, abundant in these countries, are mainly used as staple foods with high post-harvest losses [3]. Africa produced more than half of the world's cassava in 2007, with Nigeria alone accounting for 46 million tons of the total 228 million tons produced, making it the leading cassava producer globally [4].

Most sub-Saharan countries, particularly Nigeria, have made several economic reforms to promote the use of local crops as sources of flour for partial or total substitutions of wheat flour in order to maximize the efficient use of tropical root crops (cassava) and essential legumes (cowpea) and to reduce overdependence on wheat importation. In addition, concerns about the massive import of cereal grains as raw materials by manufacturing enterprises have pushed Nigerian scientists to seek local or indigenous alternatives to the imported kind. This strategy is expected to lessen reliance on wheat imports while also increasing livelihoods and generating more money for local

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farmers who grow crops that can be used in flour composites [5].

Cassava (*Manihot esculenta*) is a root crop with significant food and industrial applications. It is a low-cost, high-energy source for humans and animals, with a high energy density of about 610 kg/100 g of fresh weight. The crop comes in various varieties, each with different nutritional content. Cassava is used in flour production, livestock feed, ethanol production, starch for textiles, paints, adhesives, pharmaceuticals, and *gari* production.

In Africa and Southeast Asia, cowpea (*Vigna unguiculata*) is an important legume. It contains approximately 24% protein, 62% carbohydrates, and a trace amount of other nutrients [6]. Cowpea is a fantastic source of many health-promoting components, including soluble and insoluble dietary fiber, phenolic compounds, minerals, dietary protein, carbohydrates, fats, and a variety of other functional compounds, including B-group vitamins [7].

Cassava-cowpea strips are made from a mixture of cassava and cowpea flour seasoned with pepper and onions, extruded, then deep-fried in vegetable oil to make snacks. It is made in certain cities in Nigeria's south-western area, with Oke-Ogun (a region in Oyo State) and Oyo town serving as the primary cottage industries. It is well-liked and enjoyed by both children and adults in the area because of its color and texture. Response surface methodology (RSM) is a statistical-mathematical method that uses quantitative data in an experimental design to determine and simultaneously solve multivariate equations to optimize processes and products [8,9]. Studies have been done on optimizing some other food products [10,11]. However, there has been no published research for optimizing cassava–cowpea strips to improve the nutritional content and quality attributes. Therefore, the study aims to determine the effect of processing parameters such as: (frying temperature, frying duration, and quantity of cowpea flour) on some quality attributes of cassava-cowpea strips.

2. Materials and Methods

2.1 Preparation of sample

Cassava (*Manihot esculenta*) roots was procured from Niji Farms (KM 5, Otu Road, Ilero, Oyo State). In addition, cowpea (*Vigna unguiculata*) seeds, vegetable oil, salt, pepper, and onions were all acquired from Waso market in Ogbomoso, Oyo State, Nigeria. The roots were weighed, peeled, rinsed and grated into slurry by a locally constructed motorized cassava grater. The mash was placed in a jute bag and dewatered using a manual screw press before being dried in the dryer at 50 to 60 °C for 12 h. The dried mash was milled and sieved through 0.4-mm aperture sieve before packaging in polyethylene bags and stored in an airtight container. The cowpea seeds were cleaned by hand to remove stones, chaffs, and stalks. The seeds were sun-dried for 72 h after being soaked for 15 min at room temperature. The dried seeds were ground into flour, cooled, sieved, and kept at room temperature in an airtight plastic bag.

2.2 Cassava-cowpea flour blends and cassava strips preparation

Composite flour was made by substituting cowpea flour for cassava flour in 0%, 10%, 20%, and 30%. Each blend was blended independently for 3 min at high speed in a kitchen blender. Before further processing, the individual mixes were wrapped separately in polythene bags and stored in airtight plastic containers. The components (flour, salt, water, onion, and pepper) were thoroughly mixed in a bowl until a smooth consistency was achieved, resulting in sticky dough. The dough was placed in a potato ricer and carefully extruded into an electric fryer with 750 ml of hot vegetable oil at temperatures of 160, 170, and 180 ^{o}C for 8, 10, and 12 min, respectively. Deep-fried strips were drained and chilled. The strips were bagged and stored at room temperature after cooling.

2.3 Design of experiment

The influence of the independent factors on the quality attributes of cassava-cowpea strips was investigated using a Box-Behnken design. The dependent variables were protein, moisture, fat, color, and texture. The independent variables were frying temperature (FT), frying time (Ft), and percent cowpea flour in the flour blend (CF). Each independent variable included three levels: frying temperature of 160, 170, and 180 ^{o}C; frying time of 8, 10, and 12 min; and percent cowpea flour in the flour blend of 10%, 20%, and 30%.

2.4 Determination of quality characteristics

2.4.1 Moisture content Determination

The moisture content was determined using AOAC [12] method. In a cleaned, dried moisture container, two grams of well-mixed material were correctly weighed (W_1). A steady weight was produced by placing the moisture container (containing the sample) in an oven at 103.5 ^{o}C for 4-5 hours. The can was then placed in the desiccator to cool for 30 minutes. It was weighed again after cooling (W_2).

$$\%\text{Moisture} = \frac{W1-W2}{Weight\ of\ sample} * 100 \quad (1)$$

Where;

W_1 denotes the initial weight of can + sample; W_2 denotes the final weight of can + sample.

2.4.2 Fat content Determination

The crude fat in the sample was measured using an intermittent Soxhlet extraction device. The ether extract method was used to determine crude fat using the Soxhlet device. A moisture-free sample of 2 g was wrapped in filter paper, placed in a fat-free thimble, and then inserted into the extraction tube. The flask with the round bottom was dried and weighed before being filled with petroleum ether and placed in the device. The extraction took 6 hours to complete. After then, the ether was left to decompose. With ether cleaning, the extract was placed onto a clean glass dish, and the ether was evaporated on a water bath. Then it went into a 105 °C oven for 30 minutes and cooled in a desiccator [12].

$$Fat\ content = \frac{W_{fo} - W_{ef}}{Weight\ of\ sample} \times 100\% \quad (2)$$

Where;

W_{fo} = weight of flask with oil,

W_{ef} = weight of the empty flask

2.4.3 Protein content Determination

Protein was determined using Kjeldahl method. A digestion flask placed 0.5-1.0 g of dried materials. Concentrated H_2SO_4 of 10-15 ml and 2 g Na_2SO_4 were added, as well as 0.05 g copper tunings. The flask contents were well mixed before being placed on the heater to begin digesting until the mixture became transparent (blue-green). It took 2 hours to digest. The mixture was cooled and transferred to a 100 ml volumetric flask, which was then filled with distilled water to the desired volume. The digest was distilled using the Markam Still Distillation Apparatus. In the distillation tube, 10 ml of the digested sample and 10 ml of 50% NaOH were gradually added in the same manner. Continuous distillation for 10 minutes yielded 75 ml of NH_3, which was collected as NH_4OH in a conical flask containing 20 ml of 2% boric acid solution and a few drops of methyl red and bromocrysol green indicator. Because of the NH_4OH, a yellowish tint emerges during distillation. The distillate was then titrated against 0.01 N HCL solutions until a pink tint appeared. In addition, a blank was run through all of the preceding stages [12].

2.4.4 Texture Determination

A universal tester (M500: Testometric AX) with a 100 kN load cell was used to determine the texture properties of the samples. Uniformly sized fried cassava strips were placed on metal support approximately 35 mm apart from the jaws and centered with a flat-ended cylindrical plunger (70 mm in diameter) pressed at a rate of 2.5 mm / min (70 mm in diameter) [13].

2.4.5 Color Determination

The color parameters (L *, a *, and b *) are measured with the use of a colorimeter (Color Tec-PCM, Hunterdon, NJ) [14]. The instrument was calibrated and the sample were loaded into the sample holder. Samples were scanned at diverse locations to determine (*L**, *a**, and *b**) parameters. The strips' color difference (ΔE) was calculated with the use of equation (1).

$$\Delta E = [(L - L_{ref})^2 + (a - a_{ref})^2 + (b - b_{ref})^2]^{1/2} \quad (3)$$

Where;

L_{ref}, a_{ref} and b_{ref} are L, a, and b values of strips cut, respectively.

2.5 Statistical analysis and optimization procedure

To analyze the data and perform numerical optimization, Design-Expert Version 6.0.8 (State-ease software) was used. In regression analysis and analysis of variance, the equation was fitted to the experimental data to determine the regression coefficients and statistical significance of model terms (ANOVA). The F-ratio was used to determine the significance of the model terms at a probability of $P < 0.05$. The adequacy of the model was determined using model analysis, the lack of fit test, and the coefficient of determination (R^2). Responses were optimized concurrently using a desirability function, aggregating all responses into a single measurement. The method determines the optimal operating conditions (independent variables) for the desirability function. To determine the value of a variable for the best response, constraints were established (a minimum and maximum level would need to be provided for each variable included). The frying of strips was optimized to find the levels of frying temperature, time, and percent cowpea flour substitution that could minimize moisture, fat content, texture, and color while maximizing protein.

3. Results and Discussion

The effect of processing conditions on quality attributes of cassava and cowpea strips is shown in Table 1. The result of moisture content ranged from 1.00 to 4.26%. The variation in moisture content was due to the processing methods of individual flour. Moisture content measures a product's water content and indicates its storage stability [8]. This is in line with the findings of Dada *et al*. (2017). The moisture content of foods is influenced by type, variety and storage condition [15]. The ANOVA for moisture content is shown in Table 2. The model equation for moisture content is quadratic, and the model terms (Ft, Ft^2, Ft*CF) were significant, while (FT, FT*CF, FT*Ft, CF, FT^2, CF^2) were not significant ($P > 0.05$). The values closer to 1.0 provide the best fit, $R^2 = 0.867$ and adjusted $R^2 = 0.695$ indicate that the model is fit. The significant regression coefficient at $P < 0.05$ was selected for the models that resulted in Equations 2 - 6.

The fat content of the strips ranged from 8.41 to 11.94% (Table 1). The differences in fat content may be due to location and varietal differences [16]. Aiyesanmi and Oguntokun [17] revealed that diets with high fat contribute significantly to humans' energy requirements. High-fat flours are also good for flavour enhancers and useful in improving the palatability of foods in which it is incorporated. This implies that this product would be energy-dense foods suitable for people such as sportsmen that require a lot of energy to work. Since fats make an essential contribution to the shelf life of foods, a relatively high-fat content can be undesirable in baked and fried foods. This is because fat can cause rancidity in foods, forming unpleasant and odorous compounds [18]. The model equation is quadratic, with the model term (CF) being significant ($P < 0.05$) and (FT, Ft, FT*CF, FT*Ft, FT^2 Ft^2, CF^2) not significant ($P > 0.05$) (Table 2). $R^2 = 0.860$ and modified $R^2 = 0.680$ suggest that the model is fit since values closer to 1.0 provide the best fit.

Table 1 shows the protein content of the strips. The values ranged from 30.83% to 36.42%. The protein content differences can be attributed to the geographical location since soils with high nitrogen levels can influence protein levels [19]. The high protein content of the strips may be due to the presence of the cowpea flour ingredient used in the product. Cowpea contains 24% protein [20]. Temple and Bassa [21] reported that adding legumes to cereals improved protein intake. The protein content of the powders in this product suggests that they can be helpful in food formulation systems. Protein is required for tissue replacement, the deposition of lean muscle mass, and growth. Table 2 shows the regression coefficients and ANOVA for protein content. The model equation is linear, and the model terms (CF) were significant ($P < 0.05$), whereas (FT, Ft) were not significant ($P > 0.05$). $R^2 = 0.786$ and adjusted $R^2 = 0.737$ indicate that the model is fit because values closer to 1.0 provide the best fit.

The texture of the cassava-cowpea strips ranged from 5.06 to 13.14 N (Table 1). Hardness is the force required to compress a food substance. It remains the most important parameter among all textural properties, as it decides the consumer's acceptability and commercial value of the fried product [22]. It increased with decreasing frying temperature and reduced with increasing frying time and %cassava-cowpea flour for all conditions, according to the response surface plot (Figure 4). The change caused by starch gelatinization and moisture loss, which leads to crust development on the outside surface of the fried snack, could be attributed to the increase in hardness as the frying temperature rises. This is consistent with Adeyanju *et al.* [10], who found that increasing the frying temperature increases hardness and improves crust development faster. The textural behaviour of food products is directly affected by processing conditions and ingredient formulations [23]. The ANOVA in (Table 2) revealed that the model equation for texture (crispness) is quadratic and that the model terms (CF) were significant ($P < 0.05$). In contrast, the model terms (FT, Ft, FT*CF, FT*Ft, FT^2, Ft^2, CF^2) were not significant ($P > 0.05$). $R^2 = 0.875$ and adjusted $R^2 = 0.715$ indicate that the model is fit because values closer to 1.0 provide the best fit.

The color of cassava-cowpea strips ranged from 26.967 to 40.479 (Table 1). The color change was significantly influenced by increasing the frying temperature and time. The color of cassava-cowpea strips was improved with increasing frying temperature and time but decreased with increasing %cassava-cowpea, according to the response surface plot (Figure 5). The color of any fried product is caused by the Maillard reaction, which is affected by the amount of reducing sugars and amino acids on the surface, as well as the temperature and time of frying [24]. The model equation is 2FI and the model terms (FT, FT*CF) were significant ($P < 0.05$), while (Ft, CF, Ft*CF, FT*Ft) were not significant ($P > 0.05$) (Table 2). $R^2 = 0.705$ and adjusted $R^2 = 0.528$ indicate that the model is fit because values closer to 1.0 provide the best fit.

$$\mathrm{MC} = -72.4177 + 0.908062\mathrm{FT} - 1.20319\mathrm{Ft} + 0.413275\mathrm{CF} - 0.00249\mathrm{FT}^2 + 0.197063\mathrm{Ft}^2 - 0.0043\mathrm{CF}^2 - 0.01028\mathrm{FTFt} + 0.002473\mathrm{FTCF} - 0.06544\mathrm{FtCF} \quad (4)$$

$$\mathrm{Fat} = 132.0858 - 1.66559\mathrm{FT} + 2.675889\mathrm{Ft} + 0.180089\mathrm{CF} + 0.005004\mathrm{FT}^2 - 0.04526\mathrm{Ft}^2 + 0.00393\,\mathrm{CF}^2 - 0.0069\mathrm{FTFt} + 0.001465\mathrm{FTCF} - 0.03878\mathrm{FtCF} \quad (5)$$

$$\mathrm{Protein} = 3.88492 + 0.00334\mathrm{FT} + 0.052529\mathrm{Ft} + 0.262468\mathrm{CF} \quad (6)$$

$$\mathrm{Texture} = 177.4635 - 2.23672\mathrm{FT} + 3.523459\mathrm{Ft} + 0.133596\mathrm{CF} + 0.006671\mathrm{FT}^2 - 0.09726\mathrm{Ft}^2 + 0.005736\mathrm{CF}^2 - 0.00573\mathrm{FTft} + 0.001275\mathrm{FTCF} - 0.03375\mathrm{FtCFa} \quad (7)$$

$$\text{Color change } (\Delta\mathrm{E}) = 380.033 + 2.464842\mathrm{FT} + 24.49283\mathrm{Ft} + 5.69895\mathrm{CF} - 0.14816\mathrm{FTft} - 0.0341\mathrm{FTCF} - 0.00608\mathrm{FtCF} \quad (8)$$

Table 1. Values of moisture, fat, protein content, texture, change color of fried strips

Trial	Independent variables			Dependent variables				
	FT (°C)	Ft (min)	CF (%)	MC (%)	FC (%)	P (%)	Texture (N)	Color (ΔE)
1	180	8	20	4.05	8.41	32.91	104.96	39.31
2	170	8	30	4.26	10.64	32.16	117.64	27.93
3	170	10	20	2.06	11.07	32.78	106.46	26.97
4	180	10	10	1.00	10.29	35.44	150.28	40.48
5	160	10	30	1.10	11.36	35.11	130.19	27.27
6	170	12	10	2.89	11.36	33.42	139.50	27.39
7	170	12	30	1.02	13.07	35.36	106.44	27.46
8	160	10	10	2.05	11.59	30.83	112.62	27.11
9	170	10	20	2.06	11.07	32.78	106.46	27.49
10	160	12	20	1.41	10.46	36.42	129.53	27.51
11	170	10	20	2.06	11.07	32.78	106.46	27.45
12	160	8	20	2.79	11.49	32.70	130.66	27.88
13	170	10	20	2.06	11.07	32.78	106.46	27.49
14	170	8	10	1.06	9.77	32.86	141.33	27.38
15	180	12	20	1.84	11.92	32.94	105.98	27.09
16	170	10	20	2.06	11.07	32.78	106.46	27.49
17	180	10	30	1.07	11.94	32.84	102.73	27.00

Results are the means of three determinations.

FT: Frying temperature (°C); Ft: frying time (min); CF: cowpea substitution in cassava flour (%); MC = Moisture content; FC = Fat content; P = Protein, T = Texture; ΔE = Color difference

Table 2. Regression coefficients and analysis of variance on response surface model of strips

Responses	Sources of Variance	Sum of squares	DF	Mean squares	F-value	*P*-value
MC	Model	14.04949	9	1.561055	5.051552	0.0221
	FT	0.042778	1	0.042778	0.138429	0.7209
	Ft	3.22453	1	3.22453	10.43454	0.0144
	CF	0.039481	1	0.039481	0.127758	0.7313
	FT^2	0.261581	1	0.261581	0.846474	0.3882
	Ft^2	2.61616	1	2.61616	8.46586	0.0227
	CF^2	0.780338	1	0.780338	2.525163	0.1561
	FT*Ft	0.168921	1	0.168921	0.546626	0.4837
	FT*CF	0.24453	1	0.24453	0.791297	0.4032
	Ft*CF	6.851306	1	6.851306	22.17074	0.0022
	Residual	2.163173	7	0.309025		
	Lack of Fit	2.163173	3	0.721058		
	Pure Error	0	4	0		
	Cor Total	16.21266	16			
		R^2 = 0.867; Adj R^2 = 0.695				
FC	Model	36.0434	9	4.004823	4.769279	0.0258
	FT	0.015022	1	0.015022	0.01789	0.8974
	Ft	0.051105	1	0.051105	0.06086	0.8122
	CF	31.55592	1	31.55592	37.57944	0.0005
	FT^2	1.054504	1	1.054504	1.255792	0.2994
	Ft^2	0.137998	1	0.137998	0.164339	0.6973
	CF^2	0.650434	1	0.650434	0.774592	0.4080
	FT*Ft	0.059319	1	0.059319	0.070642	0.7981

	FT*CF	0.085871	1	0.085871	0.102262	0.7585
	Ft*CF	2.405946	1	2.405946	2.865202	0.1343
	Residual	5.877987	7	0.839712		
	Lack of Fit	5.877987	3	1.959329		
	Pure Error	0	4	0		
	Cor Total	41.92139	16			
			R^2=0.860; Adj R^2= 0.680			
P	Model	55.20887	3	18.40296	15.95357	0.0001
	FT	0.008926	1	0.008926	0.007738	0.9312
	Ft	0.088296	1	0.088296	0.076544	0.7864
	CF	55.11165	1	55.11165	47.77644	0.0001
	Residual	14.99592	13	1.153532		
	Lack of Fit	14.99592	9	1.666213		
	Pure Error	0	4	0		
	Cor Total	70.20479	16			
			R^2= 0.786; Adj R^2= 0.737			
T	Model	52.78591	9	5.865101	5.46156	0.0179
	FT	0.01138	1	0.01138	0.010597	0.9209
	Ft	0.000163	1	0.000163	0.000151	0.9905
	CF	46.96993	1	46.96993	43.73822	0.0003
	FT^2	1.873517	1	1.873517	1.744612	0.2281
	Ft^2	0.637307	1	0.637307	0.593458	0.4663
	CF^2	1.385186	1	1.385186	1.28988	0.2935
	FT*Ft	0.044937	1	0.044937	0.041845	0.8437
	FT*CF	0.065051	1	0.065051	0.060575	0.8127
	Ft*CF	1.822611	1	1.822611	1.697209	0.2339
	Residual	7.517212	7	1.073887		
	Lack of Fit	7.517212	3	2.505737		
	Pure Error	0	4	0		
	Cor Total	60.30313	16			
			R^2= 0.875; Adj R^2= 0.715			
ΔE	Model	195.805	6	32.63416	3.988719	0.0266
	FT	72.58672	1	72.58672	8.871931	0.0138
	Ft	21.33506	1	21.33506	2.607683	0.1374
	CF	20.1887	1	20.1887	2.467569	0.1473
	FT*Ft	35.12351	1	35.12351	4.292981	0.0651
	FT*CF	46.51173	1	46.51173	5.68491	0.0383
	Ft*CF	0.059243	1	0.059243	0.007241	0.9339
	Residual	81.81614	10	8.181614		
	Lack of Fit	81.60409	6	13.60068	256.5596	< 0.0001
	Pure Error	0.212047	4	0.053012		
	Cor Total	277.6211	16			
				R^2= 0.705; Adj R^2=0.528		

$P < 0.05$ indicates statistical significance

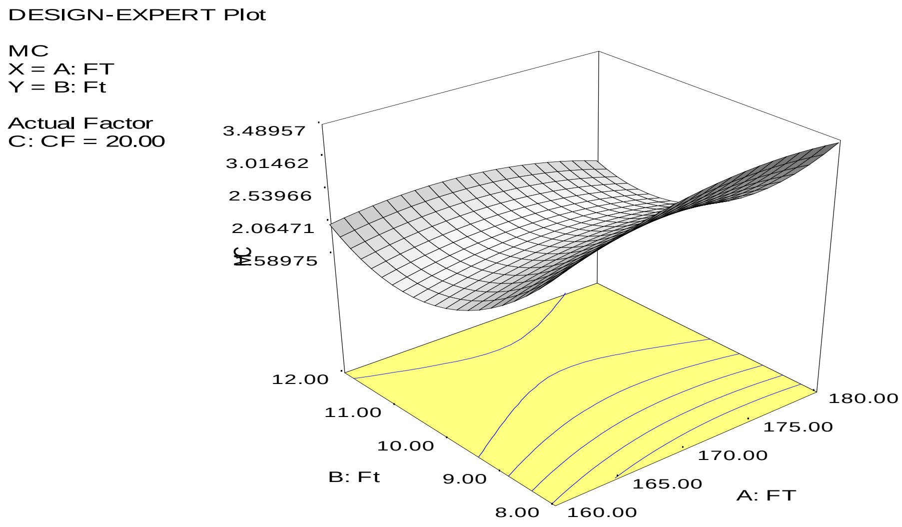

Fig 1. Response surface plot depicts the influence of process parameters on strip moisture content

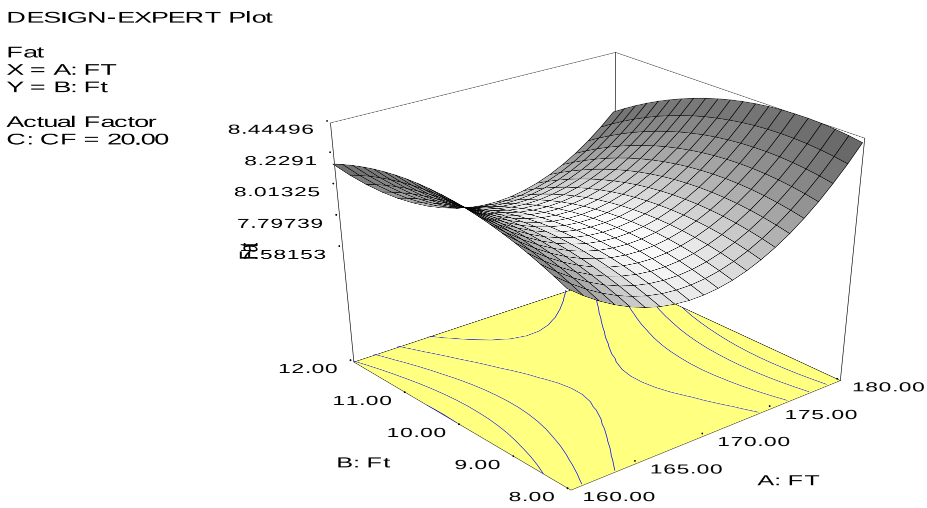

Fig 2. The response surface plot depicts the influence of process parameters on strip fat content

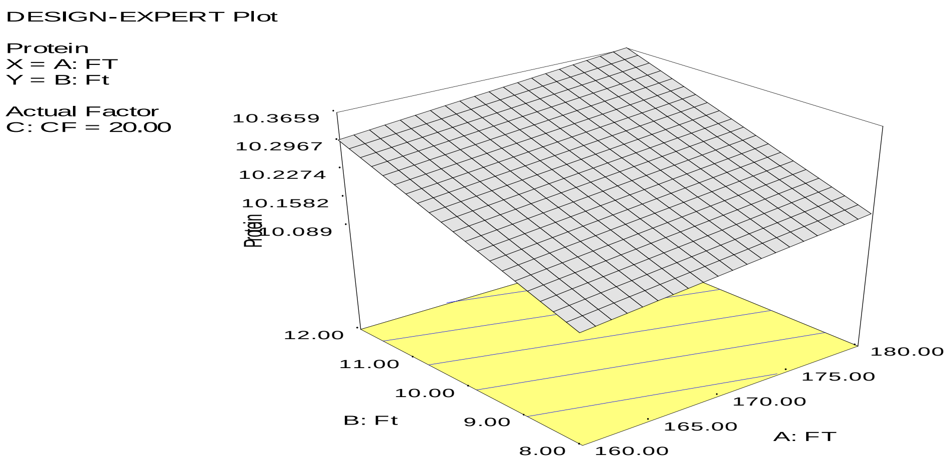

Fig 3. The response surface plot depicts the influence of process parameters on strip protein

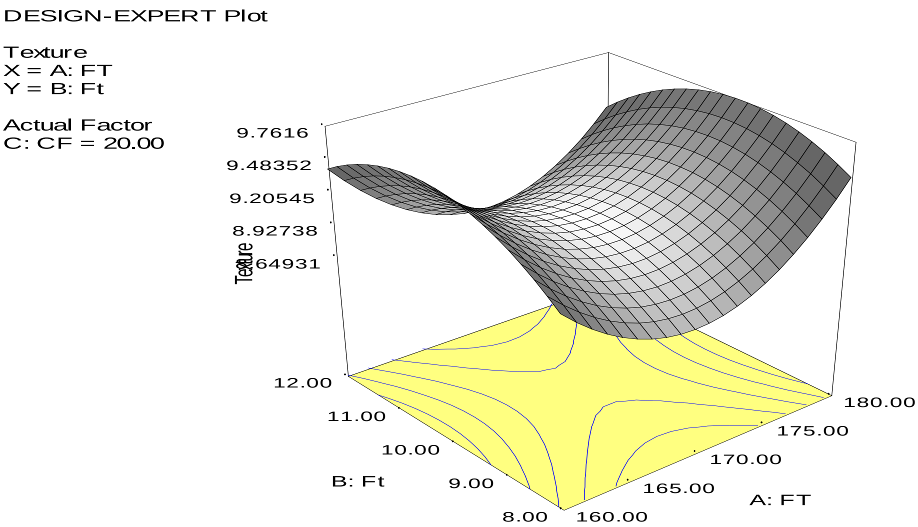

Fig 4. The response surface plot depicts the influence of process parameters on strip texture

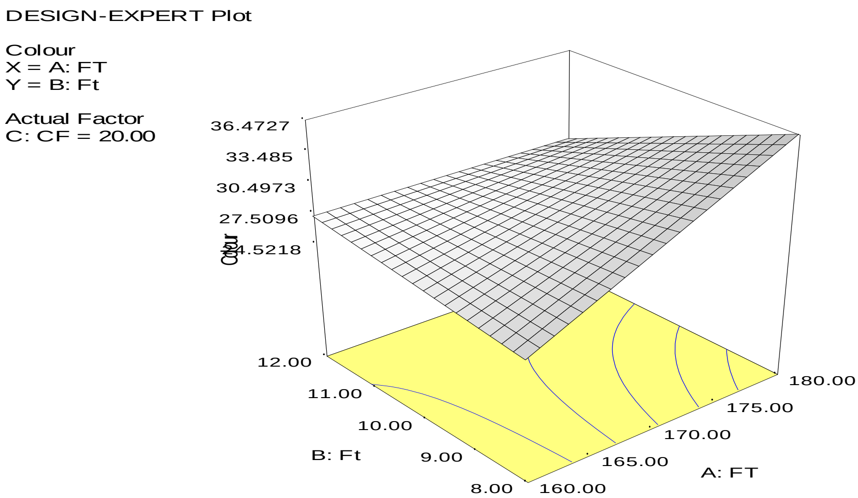

Fig 5. The response surface plot depicts the influence of process parameters on strip color

3.1 Optimization process

Three suitable solutions were identified in the optimization process using the software package. To maximize protein, minimize fat and moisture content, and maintain a moderate color and texture (crispness), three frying temperatures, frying time, and percentage cowpea inclusion could be adjusted. The solution had desirability of 0.65. The optimum conditions for the variables investigated for producing cassava–cowpea strips with suitable quality characteristics were cowpea inclusion of 24.36%, the frying temperature of 166.65 °C and frying time of 12 minutes.

4. Conclusion

This study examined the optimum conditions for deep-fat frying of cassava-cowpea strips quality attributes. The relationship between the independent variables (% cowpea substitution, frying temperature, and frying time) and the dependent variables (moisture, fat, protein content, texture, and color change) was investigated. The desirability function technique examined the optimum conditions that maximize the frying conditions of cassava-cowpea strips quality attributes. Therefore, the optimum process parameters are 24.36% cowpea flour inclusion, 166.65 °C frying temperature, and 12 min frying time with a 0.65% desirability. This information is necessary for producing cassava-cowpea strips with improved nutrient composition and exploitation on a large scale.

Conflict of interest

The authors declare that they have no conflicts of interest.

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