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ANALYSIS OF OPTIMUM REDUCTION OF ANTI-NUTRITIONAL FACTORS FROM BLEND OF SORGHUM AND GROUNDNUT CAKE FLOUR ENRICHED WITH DATE FRUIT FLOUR AS A RECIPE FOR POST COVID-19 SNACK FOOD

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Abstract

This study aimed at optimization and development of sorghum snack enriched with groundnut cake and date flour using response surface methodology (RSM). Consumer Acceptance and optimum reduction of Antinutritional factors were studied. As the concentration of groundnut in the formulation increased, the product was disliked due to the strong nutty flavour of the groundnut cake, thus affecting the overall acceptability. Date fruit flour (%) was composited to enriched snack. Central composite design was used to develop a polynomial model for the responses. It was observed that higher composition of groundnut in the feed composition and moisture content significantly ($p \leq 0.01$) affected the optimum reduction of AFNs making it less palatable, and thereby reducing the overall acceptability of the snack. Based on the response surface 3D plots, the AFNs

Introduction

One of the ways to overcome the challenges posed by the Covid-19 pandemic is to maintain a well-balanced diet. With advancements in technology for producing nutrient-dense foods, there is an increasing demand in the consumer market for new products that promote the use of indigenous raw materials. Snacks, being quick and easy to eat, provide energy while satisfying short-term hunger. They are typically consumed in a rush and are often made with significant amounts of sweeteners, preservatives, and flavoring agents to cater to the consumer's palate

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content of the samples were optimized at 17.08% (fc), 17.89% (mc) and 6.0ds(mm) with optimal reduction in the predicted responses of 3.758 mg TIA /g, 0.218 mg Tannic acid /g and 112.556mg phytate /g at an optimum desirability of 0.742. The sensory data obtained in this study had revealed that samples produced from appropriate blends of flours from sorghum, date palm fruit and defatted groundnut cake were highly acceptable by the panellists used for this study and it can be used as a post COVID-19 food.

Keywords: Optimum, Anti Nutritional Factors (Afns), Overall Acceptability, Extruded Snack, Sorghum, Groundnuts Cake, Date Palm Flour afnd Covid-19

(Iwe, 2003).

A balanced diet includes adequate amounts of carbohydrates, proteins, fats, as well as fiber, vitamins, and minerals (Deshpande et al., 2008). The importance of a proper diet has become a significant public health concern due to the high levels of table sugar in the production of chocolates, cookies, and beverages. As awareness of diet and nutrition increases, consumers are more inclined to choose organic, fresh foods with lower sugar content. Dates, for instance, serve as a healthier alternative to table sugar and are rich in fiber and various nutrients. Proper processing, blending, and utilization of indigenous food crops can enhance nutrient intake, potentially preventing malnutrition and boosting immunity, making individuals less vulnerable to diseases like Covid-19 (Kumari & Sangeetha, 2017).

Cereals and legumes such as rice, maize, and groundnut are staple foods in Nigeria, known for their richness in vitamins, minerals, carbohydrates, fats, oils, and proteins (Nikmaram et al., 2017). However, some of these crops contain anti-nutritional factors (ANFs) like trypsin inhibitors, phytates, and tannins, which can form complexes with proteins, reducing amino acid bioavailability and affecting protein digestibility. Research by Iwe and Ngoddy (2000) and Juvvi (2012) highlights the numerous health benefits of legumes, including lowering plasma cholesterol, preventing coronary heart disease, cancer, and diabetes, and boosting immune function. Despite these benefits, the presence of ANFs makes legumes less desirable to consumers and limits their use in food production, potentially leading to health complications (Ajibola & Olapade, 2021). ANFs are naturally occurring compounds in edible seeds that affect nutrient absorption by binding to proteins, vitamins, and minerals, forming complexes that reduce their absorption in the gastrointestinal tract (Nikmaram et al., 2017).

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Fortunately, ANFs are heat-labile, meaning they can be inactivated through heat-based processing (Ajibola & Olapade, 2021). Extrusion cooking, which offers unique advantages over conventional heat processing methods, is particularly effective in preserving nutritional quality while reducing the breakdown of nutrients. This automated technology allows for more efficient energy use and better process control (Rathod & Annapure, 2016). Traditional heat processing methods often involve high temperatures that lead to significant nutrient loss. In contrast, extrusion cooking operates under high temperatures and short durations, subjecting raw materials to strong mechanical shear that breaks down covalent bonds in biopolymers, resulting in structural changes that improve the texture of the finished product (Nikmaram et al., 2017).

MATERIALS AND METHODS

Study Area

The study was conducted at the Federal Polytechnic Mubi, located in Adamawa State, Nigeria. Mubi lies at latitude 10° 16′ 8″ N and longitude 13° 16′ 14″ E (Anonymous, 2015). It is the second-largest city in the state, following Yola, the state capital. The Mubi Local Government Area (LGA) is situated in the northern part of the old Sardauna Province, which now forms part of the Adamawa North Senatorial District (INEC, 2006) (Ajawara, 2006). Mubi is bordered to the north by Borno State, to the west by Hong and Song LGAs, and to the south and east by the Republic of Cameroon. The region covers an area of approximately 4,728.77 km^2, with an estimated population of 151,000 based on the 2006 census projections (Ajawara, 2006).

Processing / Extraction of Sorghum

To remove contaminants and impurities, all raw materials were manually sorted. Sorghum grains were washed in potable water and drained through a perforated basket. After washing, the sorghum was sun-dried for three days (72 hours). In April 2019, fresh date palm fruits were de-pitted, cut into small pieces, and sun-dried for three days before being milled using a grinder (M-20, KA-Werke, GMBH & CO.KG, Staufen, Germany) for five minutes. The powder was sieved through a steel-mesh sifter (0.85mm aperture) and stored in a polyethylene container for future use. Defatted groundnut cake was milled using a hammer mill (Iika Labortec Hnik, Staufen, Germany) and sieved with a 0.85mm mesh before being dried in a hot air oven at 60°C for five hours. The dried material was then cooled and stored in a polyethylene bag for later use. Extrusion cooking was performed using a twin-screw extruder (SGL 65) at 140 rpm in the Department of Food Science and Technology, Federal Polytechnic Mubi, Adamawa State, Nigeria. The processing temperature was set at 110°C for the entire sample.

Determination of Anti-Nutritional Factors

AFN analyses were conducted on both raw blends and extruded snack formulations. Trypsin inhibitor activity was determined using the method of Mukhopadhyay et al. (2007). A plot of trypsin inhibitory units (TIU) per mL versus the volume of extract was made, and the data were extrapolated to zero. One trypsin unit was defined as an increase in absorbance of 0.01 units at 410nm per 10mL of reaction mixture under the given conditions. Trypsin inhibitor activity was expressed as TIU/mg of sample. Tannin content was measured using the Folic-Denis calorimetric method (Iwe, 2003).

The absorbance was measured at 260 nm using a spectrophotometer, with the reagent blank used to calibrate the instrument to zero. The phytate content of the flour was determined using the method outlined by Maga (1989). The concentration of phytic acid was determined by extrapolating from a standard curve created with a standard phytic acid solution. To create the standard curve, various concentrations (0.2–1.0 mL) of sodium phytate solution containing 40–200 µg of phytic acid were prepared and diluted to 1.4 mL with water. A 0.40 optical density (OD) was used, corresponding to 70 µg of phytic acid.

Sensory Evaluation

The sensory attributes of the milled extruded snacks were evaluated following the method described by Rathod & Annapure (2016), with modifications. The snacks were served warm to 30 untrained, regular snack consumers (panelists). The attributes evaluated included appearance, aroma, taste, and overall acceptability, using a 9-point hedonic scale ranging from "like extremely" (9) to "dislike extremely" (1). The panelists were provided with clean potable water to rinse their mouths between tasting different samples. The first, second, third, fourth, and fifth mean scores for each sample were recorded, and the mean score comparison was used to determine the overall rating. For optimization, the mean scores from each sample were used as responses.

Experimental Design

For this analysis, Response Surface Methodology (RSM) with Central Composite Design (CCD) was employed, which typically involves three levels of variables (Nwabueze & Iwe, 2006). The extrusion variables included die scale (2–6 mm), feed moisture content (12–18%), and feed composition (10–30%), with all other parameters kept constant, including 10% date fruit flour across all experimental runs.

Table 1. Experimental levels of the variables

Independent Variables	Coded	-1	0	+1
Feed Composition (%)	X1	10	15	30

Moisture Content (%) X2: 11, 15, 18
Die Size (mm) X3: 2, 4, 6
X1 = Feed Composition, X2 = Moisture Content, X3 = Die Size

The Central Composite Design (CCD) used in this work was produced using the Design Expert statistical software (v.11.1.2.0, Stat-Ease Inc., Minneapolis, MN).
The response was expressed as a second-order polynomial equation according to Equation (1):
Y=b0+b1X1+b2X2+b3X3+b11X12+b22X22+b33X32+b12X1X2+b13X1X3+b23X2X3Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_{11} X_1^2 + b_{22} X_2^2 + b_{33} X_3^2 + b_{12} X_1 X_2 + b_{13} X_1 X_3 + b_{23} X_2 X_3
Where:

- X1=Feed CompositionX_1 = \text{Feed Composition}
- X2=Moisture ContentX_2 = \text{Moisture Content}
- X3=Die SizeX_3 = \text{Die Size}
- b0,b1,b2,b3b_0, b_1, b_2, b_3 are intercepts, linear, quadratic, and interaction regression coefficient terms, respectively.

CCD is suitable for sequential experimentation and provides detailed information for testing lack-of-fit, while minimizing the number of experimental runs. The number of experimental runs in CCD can be estimated by:
N=k2+2k+cpN = k^2 + 2k + c_p
Where:

- kk is the number of independent variables
- cpc_p is the number of replicates of the central point

For this study:
N=32+2×3+5=9+6+5=20N = 3^2 + 2 \times 3 + 5 = 9 + 6 + 5 = 20

Optimization of the Anti nutritional Factors

The Design Expert software version 11.1.2 (Stat-Ease Inc., Minneapolis) was used to analyze the ranges of TIA, Tannins, and Phytate obtained from this study. The software predicted the process conditions that minimize the anti-nutritional factors (AFNs), improving the utilization of the nutritional contents. The coefficients of the polynomial models, the coefficient of determination (R^2), adjusted R^2, and adequate precision values of the chemical properties of the blends were used to evaluate the model's fitness, as indicated in Table 2.

RESULTS AND DISCUSSION

Anti-Nutritional Factors

Extrusion cooking is a high-temperature, short-time process in which raw feed composition is subjected to controlled conditions of high temperature, pressure, and moisture. It has been shown to degrade a variety of anti-nutritional factors (Mukhopadhyay et al., 2007). Table 2 shows some anti-nutritional factors of extruded snacks and raw blends of sorghum, defatted groundnut cake, and date flour. Just like other legumes, groundnut contains anti-nutritional factors such as trypsin inhibitor, tannins, and phytate.

Legumes are known to contain AFNs that limit their nutritional quality, especially digestibility and acceptability (Halilu et al., 2020; Rathod & Annapure, 2016). Trypsin inhibitors, saponins, phytic acid, and tannins are some of the undesirable components in legumes that can reduce the nutritional value of legume seeds by reducing protein digestibility and mineral availability, as well as hindering the utilization and absorption of important minerals like magnesium, calcium, iron, and zinc, which can lead to mineral deficiency. However, they are heat-labile, and as a result, heat-based processing methods can be used to inactivate them (Ajibola & Olapade, 2021). Processing methods such as dehulling, milling, soaking, cooking, germination, fermentation, autoclaving, roasting, and drying were reported to reduce or eliminate these AFNs (Halilu et al., 2020; FAO, 1995). The results of this research are in agreement with this observation.

Table 2: Anti-nutritional Factors of Extruded Snacks and Raw Blends

Sample	X1: Feed Composition (%)	X2: Moisture Content (%)	X3: Die Size (mm)	TIA (mg/g)	Tannic Acid (mg/g)	Phytate (mg/g)	TIA (mg/g)	Tannic Acid (mg/g)	Phytate (mg/g)
1	10	12	2	4.65	0.21	115	9.54	0.49	164
2	30	12	2	6.12	0.3	125	12.1	0.62	184
3	10	18	2	4.23	0.11	112	9.44	0.45	160
4	30	18	2	3.67	0.28	122	12.4	0.7	184

5	10	12	6	3.98	0.22	107	8.94	0.52	164
6	30	12	6	5.89	0.28	120	11.8	0.66	180
7	10	18	6	3.42	0.18	110	10.2	0.52	164
8	30	18	6	5.67	0.34	121	12.6	0.68	186
9	3.18	15	4	3.68	0.1	102	7.4	0.42	172
10	36.8	2	15	6.63	0.3	128	12.8	0.82	188
11	20	9.95	4	5.81	0.26	120	10.8	0.5	169
12	20	20.0	5	4	3.02	118	10.4	0.48	168
13	20	15	2	4.23	0.26	118	10.9	0.42	160
14	20	15	6	3.89	0.17	115	10.4	0.44	170
15	20	15	4	3.95	0.21	117	10.5	0.46	172
16	20	15	4	4.01	0.2	119	10.9	0.48	170
17	20	15	4	3.98	0.2	115	10.4	0.48	176
18	20	15	4	4.12	0.18	115	10.6	0.46	172
19	20	15	4	4.01	0.15	118	10.6	0.44	177
20	20	15	4	4.32	0.15	118	10.2	0.48	172

FC=feed composition, MC=moisture content, DS=die size, TIA= Trypsin inhibitor activity

Trypsin Inhibitor Activity (TIA)

Table 2 shows the values of TIA in the raw blend of sorghum, defatted groundnut cake, and date palm flour, which ranged from 7.40 TIU/mg to 12.80 TIU/mg. A closer observation implies that trypsin inhibitor activity (TIA) increased with an increase in the addition of defatted groundnut flour. This observation agrees with that of Iwe (1998) that the addition of soybean to sweet potato considerably increased its trypsin inhibitor level. Dahlin and Lorenz (1993) reported that rice did not exhibit any TIA, whereas the blend of rice and defatted soy flour (70:30) showed high TIA. On a general note, reduction in TIA following extrusion cooking in this work is expected and agrees with earlier reports in the literature (Iwe and Ngoddy, 2000). The nutritional implication of this reduction in the concentration of trypsin inhibitor is that it will lead to an improvement in protein digestibility. Negi et al. (2001) reported higher protein digestibility/quality after heat treatment (autoclaving and roasting), which they attributed to the destruction of heat-labile protease inhibitors and the opening up of protein structures by denaturation, leading to increased accessibility of the protein to enzymatic attack. Moisture content plays an important role in the inactivation of trypsin inhibitors. The result of this study shows that an increase in moisture content causes an increase in the removal of trypsin inhibitor during the extrusion process (Rathod & Annapure, 2016).

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Tannin

Tannins are generally defined as soluble astringent, complex, and phenolic substances of plant origin, which play a significant role in the reduction of dietary protein digestibility by complexing either with dietary proteins or digestive enzymes (Nikmaram et al., 2017). Tannins cause damage to the intestinal tract, increase the risk of carcinogenesis, and also decrease palatability (Anuonye et al., 2012).

The tannin content of the raw blends in Table 4 ranged from 0.42 to 0.82 mg/100g, while the extruded blends ranged from 0.11 to 0.34 mg/100g, which is similar to the result of Rathod & Annapure (2016) who developed a new extruded snack product prepared using fenugreek. The content of ANFs in the extruded product was found to be 0.38 mg/g for tannin, which was lower than in the raw ingredients. The result shows that extrusion had reduced the tannin content. Rathod & Annapure (2016) reported that a high extrusion temperature within the range of 140 to 180°C causes a decrease in anti-nutritional factors by up to 93%. Anuonye et al. (2012) also reported a 61.22% reduction for an extruded pigeon pea-unripe plantain flour blend, which was associated with an increase in moisture content within the range of 14-18%.

Phytate

The result of the phytate content of the extrudate ranged from 102 to 128 mg/100g. The extrusion cooking process decreased the phytate content in the extrudate. The presence of anti-nutritional factors like phytates in plant-based food sources limits the utilization of such minerals in the body (Hallen et al., 2004). Legumes such as cowpeas have...

Higher phytate content than cereals such as sorghum (Kumar et al., 2010). The enzyme phytase is sensitive to temperature and, hence, susceptible to degradation during extrusion (Juvvi et al., 2012). Due to the degradation of phytate, there was a decrease in phytate content in the extrudate.

Optimal Reduction of Antinutritional Factors

Quadratic models for the desirability of feed composition (FC) and moisture content (MC) formulations were utilized to generate the three-dimensional response surface and contour plots, as shown in **Fig. 1**. The optimal reduction of anti-nutritional factors (ANFs) desirability is presented on the vertical axis in **Fig. 1g** and **1h.** Comparison of these ANFs revealed that the formulations were more affected at higher percentages of groundnut in the feed composition. Since the snacks were prepared by compositing sorghum, groundnut, and date fruit flour, the increase in groundnut level required an increase in other ingredients.

Table 3: Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
X1: FC	Maximize	10	20	1	1	3
X2: MC	Maximize	12	18	1	1	3
X3: DS	Maximize	2	6	1	1	3
TIA	Minimize	3.02	6.63	1	1	3
Tannic acid	Minimize	0.1	0.34	1	1	3
Phytate	Minimize	102	128	1	1	3

FC = Feed composition, MC = Moisture content, DS = Die size, TIA = Trypsin Inhibitor Activity

Optimization was done to achieve the levels of independent variables that led to the optimum formulation of sorghum snacks enriched with groundnut cake and date flour. The goal was to maximize feed composition, moisture content, and die size, while minimizing the responses of TIA, tannic acid, and phytate.

Based on the response surface 3D plots, the AFNs content of the samples were optimized at 17.08% (FC), 17.89% (MC), and 6.0 mm (DS), with the predicted TIA of 3.758 mg/g.

Acid of 0.218 mg/g and phytate of 112.556 mg/g. The desirability of the optimum sample was 0.742.

The TIA, tannin, and phytate contents in the flour blends were lower than the allowable level of 20 mg/g dry mass, 20 mg/g dry mass, and 250-500 mg/100 g dry mass, respectively (Ajibola & Olapade, 2021). Up to 99 percent reduction of phytate, trypsin inhibitors, and tannin is possible. The thermal degradation of these molecules and the forming of insoluble complexes at high cooking temperatures could explain such a significant reduction during the extrusion phase (Nikmaram et al., 2017).

Here is the corrected version of **Table 4** with the necessary formatting adjustments:

Table 4: Coefficients of Polynomial Models & ANOVA of TIA, Tannic Acid, and Phytate Contents of Snack

Source	Coefficients	F-value	p-value	Coefficients	F-value	p-value	Coefficients	F-value	p-value
	TIA			Tannic Acid			Phytate		
Model	Quadratic	81.55	< 0.0001	Quadratic	12.24	0.0002	Quadratic	112.30	< 0.0001
Linear	42.43	< 0.0001	Linear	0.0273	39.69	< 0.0001	3.21	112.30	< 0.0001
Intercept	3.68	0.1568	Intercept	113.57					
X1 - FC	0.2507	57.55	< 0.0001	0.0273	39.69	< 0.0001	3.21	112.30	< 0.0001
X2 - MC	-0.8323	147.9	< 0.0001	-0.0070	0.660	0.4324	-0.3982	0.4312	0.5221
X3 - DS	0.2561	8.65	0.0187	-0.0001	0.0001	0.9919	-1.97	6.46	0.0235
X1X2	0.0451	1.66	0.2331	0.0228					
X1X3	0.0524	2.24	0.1728	0.0358					
X2X3	0.5628	64.68	< 0.0001						
$X1^2$	0.1024	87.34	< 0.0001						
$X2^2$	0.1478	11.41	0.0097	7.79	0.0163				
$X3^2$	-0.2219	6.47	0.0346	5.69	0.0345				
Lack of Fit	Ns	1.90	0.2468	Ns	1.53	0.3296	Ns	1.96	0.2366
R^2	0.9892			0.8361			0.9009		
Adj R^2	0.9771			0.7678			0.8797		
Pred R^2	0.8368			0.6393			0.8066		
Adequate Precision	30.331			12.159			21.541		

Legend:

- FC = Feed Composition
- MC = Moisture Content
- DS = Die Size
- Adj R^2 = Adjusted R^2
- Pred R^2 = Predicted R^2
- p-value = Probability value
- F-value = F-statistic value

Final Equations in Terms of Coded Factors:

TIA (Trypsin Inhibitor Activity):

- TIA=3.68+0.2507X1−0.8323X2+0.2561X3+0.0451X1X2+0.0524X1X3+0.5628X2X3+0.1024X12+0.1478X22−0.2219X32(Eqn. 2)\text{TIA} = 3.68 + 0.2507X_1 - 0.8323X_2 + 0.2561X_3 + 0.0451X_1X_2 + 0.0524X_1X_3 + 0.5628X_2X_3 + 0.1024X_1^2 + 0.1478X_2^2 - 0.2219X_3^2 \quad \text{(Eqn. 2)}

Tannic Acid:

- Tannic Acid=0.1568+0.0273X1−0.0070X2−0.0001X3+0.0228X22+0.0358X32(Eqn. 3)\text{Tannic Acid} = 0.1568 + 0.0273X_1 - 0.0070X_2 - 0.0001X_3 + 0.0228X_2^2 + 0.0358X_3^2 \quad \text{(Eqn. 3)}

Phytate:

- Phytate=113.57+3.21X1−0.3982X2−1.97X3(Eqn. 4)\text{Phytate} = 113.57 + 3.21X_1 - 0.3982X_2 - 1.97X_3 \quad \text{(Eqn. 4)}

Model Significance: Using the response surface method, fitted polynomial equations for TIA, Tannic acid, and Phytate were derived (Eqns. 2, 3, and 4). All equations had a **p-value** < 0.01, indicating statistical significance, and a **non-significant lack of fit**.

For Tannic acid and Phytate (Eqns. 3 and 4), there was a significant lack of fit in the predictive model. This issue was resolved by eliminating certain outliers from the experimental runs. Specifically, **Runs 3 and 13** were removed from the analysis to get a reduced quadratic and linear model for Tannic acid and Phytate.

Model Evaluation: The **R^2** and **Predicted R^2** values were in good agreement, indicating that the fraction of variation of the response predicted by the model closely matched the observed variation. This confirms the reliability of the model. The **signal-to-noise ratio** was used to evaluate the model's adequacy. According to Anuonye et al. (2012), a ratio greater than 4 is considered a strong signal, indicating that the model is capable of successfully navigating the design space and predicting the outcomes.

Sensory Evaluation

The data related to sensory evaluation was shown in Table 4. Experimental run 6 had the highest consumers' acceptance, the consumers disliked the Run 10, which means the overall acceptability, crispness, aroma, and appearance with 8.11, 8.11, 7.78, and 8.00 respectively, the only run that had the highest rating than run 6 is run 4 with a ranking of 8.9 compared to 8.33 for run 6 which had the highest score in terms of overall acceptability, crispness, aroma, and appearance. Consumers described run 10 with lowest scores for all parameters which could be due to higher quantity of groundnut cake content of the run. They disliked Run 10 sample may be due to the strong nutty flavour of the groundnut cake.

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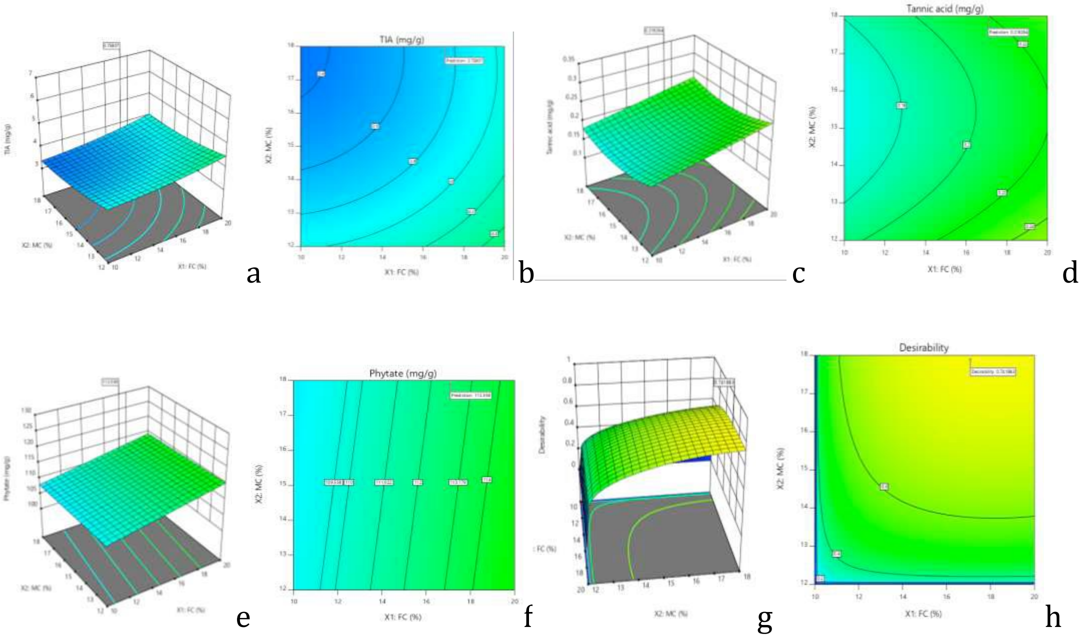

Figure 1. The response surfaces and estimated contours of (a and b) Trypsin inhibitor activity (TIA), (c and d) Tannic acid, (e and f) Phytate (g and h) desirability

Here is the corrected table for the sensory scores of the extruded snack from the Sorghum-Groundnut-Date Flour blend:

Table 4: Sensory Scores of Extruded Snack from Sorghum-Groundnut-Date Flour Blend

S/N	FC (%)	FCM (%)	DS (mm)	Appearance	Aroma	Taste	Crispness	Overall Acceptability (OA)
1	10	12	2	7.56 ± 0.03b	7.11 ± 0.00b	6.67 ± 0.01h	8.00 ± 0.00b	8.11 ± 0.00a
2	30	12	2	5.33 ± 0.01k	6.33 ± 0.01f	6.44 ± 0.01j	5.78 ± 0.01m	6.78 ± 0.01g
3	10	18	2	6.78 ± 0.01e	7.00 ± 0.01b	6.67 ± 0.03h	7.33 ± 0.01e	7.33 ± 0.01d
4	30	18	2	7.11 ± 0.00c	7.00 ± 0.01b	8.90 ± 0.00b	7.44 ± 0.06d	7.44 ± 0.06c
5	10	12	6	6.67 ± 0.01f	6.44 ± 0.03e	7.11 ± 0.00e	7.00 ± 0.00g	7.00 ± 0.00f

6	30	12	6	8.00 ± 0.00a	7.78 ± 0.00a	8.33 ± 0.04a	8.11 ± 0.00a	8.11 ± 0.00a
7	10	18	6	5.67 ± 0.01j	6.44 ± 0.03e	7.00 ± 0.01f	6.67 ± 0.01h	6.67 ± 0.01h
8	30	18	6	6.78 ± 0.00e	6.22 ± 0.02g	7.00 ± 0.01f	7.00 ± 0.00g	7.00 ± 0.00f
9	3.18	15	4	7.00 ± 0.00d	6.67 ± 0.00e	7.22 ± 0.03d	7.56 ± 0.01c	7.56 ± 0.01b
10	36.8	15	4	6.11 ± 0.00i	6.33 ± 0.01h	6.67 ± 0.01h	6.14 ± 0.03l	6.14 ± 0.03k
11	20	9.95	4	6.37 ± 0.02h	6.33 ± 0.06f	7.11 ± 0.00e	6.78 ± 0.01h	6.78 ± 0.01g
12	20	20.0	5	6.56 ± 0.01g	6.44 ± 0.06e	6.89 ± 0.01i	6.44 ± 0.57h	6.44 ± 0.06i
13	20	15	2	6.67 ± 0.01f	6.56 ± 0.01d	6.89 ± 0.00g	7.11 ± 0.00f	7.11 ± 0.00e
14	20	15	6	8.00 ± 0.00a	7.11 ± 0.01b	7.67 ± 0.01c	7.56 ± 0.01c	7.56 ± 0.01b
15	20	15	4	8.00 ± 0.01a	7.11 ± 0.01c	6.22 ± 0.03k	6.33 ± 0.04k	6.33 ± 0.00all

Note: All means ± SD bearing the same superscripts are not significantly different ($p > 0.05$).

Key:

- **FC** = Feed Composition
- **FCM** = Feed Moisture Content
- **DS** = Die Size
- **OA** = Overall Acceptability
- **Appearance**: Appearance of the snack
- **Aroma**: Aroma of the snack
- **Taste**: Taste of the snack
- **Crispness**: Crispness of the snack

Appearance

Panellists' scores for appearance of the extrudates are shown in Table 4. Appearance is a major response variable governing food acceptance (Maga and Kim, 1989). Panellists' responses ranged from 5.33 to 8.00. Since appearance relies on the sense of sight, extrudates colour and shape were most outstanding in the decision of panellists. The effect of extrusion processing on product colour has been variously described in the literature (Hsich et al., 1990, Iwe et al., 2001; Iwe, 2003). Similar reports on the effect of protein source on starch-based blends were reported (Badire and Mellowes, 1992). Thermal processing of food can result in an increase in the potential for interaction between lipids, protein, and carbohydrates and their breakdown products.

Aroma

Table 4 shows the results of aroma. The value ranged from the minimum score of 6.33 to a maximum score of 7.78 on the nine-point Hedonic scale. Aroma values ranging from 5.0 to 6.0 on the nine-point Hedonic scale for extruded mixtures of soy and sweet potato flour were reported by Iwe et al. (2001). Protein – starch (Dahlin and Lorenz 1993) and protein – lipid (Badire and Mellowes, 1992) interaction during extrusion processing could affect flavour development of extrudates. Protein and starch can interact due to the attraction of their opposite charges to form “ionic” bonds, thus preventing the loss of extrudates from granules, resulting in a decrease in viscosity (Dahlin and Lorenz 1993).

Taste

The results for taste ranged from 6.44 to 8.33 on the nine-point Hedonic scale. A nutty flavour was experienced in terms of taste. This nutty flavour development can be attributed to dry heating that took place during extrusion, Maillard reaction, and caramelization interaction (Rathod & Annapure, 2016).

Crispness

Panellists’ mean scores for crispness of the extruded snacks from the blends of sorghum, defatted groundnut cake, and date palm (Table 4.) ranged from 5.78 to 8.11. In general, a slight increase in defatted groundnut cake in the blends led to an increase in the mean score for likeness. The observation confirms the reports by some researchers (Singh et al., 2007 and Nwabueze, 2006) that slight addition of protein enhanced the crispness of extruded products.

Overall acceptability

The mean scores for overall acceptability (Table 4.) ranged from 6.14 to 8.11. The overall acceptability is influenced by all the other sensory attributes (appearance, aroma, crispness, and taste). A similar report on the sensory properties of extruded snacks as influenced by feed composition has been documented by Gupta & Premavalli (2012) on extrudates. Feed composition and moisture content have been found to significantly determine the overall quality attributes of expanded food products, especially in terms of the expansion ratio, texture, sensory properties, and shelf life (Nikmaram et al., 2017). Results of this study agreed with the earlier observations, and hence it can be anticipated that at higher groundnut levels, together with higher concentrations of other ingredients, process variables and sensory properties of the snack formulations and overall acceptability would be adversely affected. Similarly, at higher levels of groundnut, interactions might have been affecting the properties of the formulations, thus changing the AFNs and the overall acceptability (Deshpande et al., 2008).

Conclusion and Recommendations

The overall acceptability sensory data obtained in this study had revealed that samples produced from appropriate blends of flours from sorghum, date palm fruit, and defatted groundnut cake were highly acceptable by the panellists used for this study. The overall acceptability and the AFNs data obtained are reliable to predict the behaviour of the system under different factor combinations, which could be used to produce good quality extrudates, with optimal reduction of anti-nutritional factors that could be used for the development of post-COVID-19 snack food.

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