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Optimization of Low-Glycemic Composite Snacks from Wheat, African Yam Bean, Cocoyam, and Date Fruit Flours Using D-Optimal Mixture Design

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Abstract: *Type 2 diabetes mellitus is prevalent in Nigeria. Its prevention and management depend largely on imported drugs and specialized foods. Often, the items are costly, scarce, and inaccessible. Besides, the acclaimed effectiveness and long-term safety may be false. The challenges underscore the need for affordable, locally produced dietary alternatives. The study developed and optimized composite snack from locally available crops with desirable nutritional quality and a low glycemic index. Wheat, cocoyam (*Xanthosoma sagittifolium*), African yam bean (*Sphenostylis stenocarpa*), and date fruit (*Phoenix dactylifera*) were processed into flours and combined to produce nineteen composite snack samples using a D-optimal mixture design of the response surface methodology. The samples were evaluated for proximate composition, glycemic index, and sensory attributes using standard analytical methods and a 7-point hedonic scale. The results showed that the proximate composition and glycemic index values of the snacks were within recommended ranges. Most of the samples exhibited low glycemic index values, ≤55, indicating suitability for dietary prevention and management of type 2 diabetes. Sensory evaluation revealed moderate to low acceptability and preference, likely due to limited consumer familiarity with composite formulations. Optimization identified a formulation containing 33.3% wheat flour, 22.0% cocoyam flour, 36.7% African yam bean flour, and 10.0% date fruit flour, which yielded 5.01% moisture content, a glycemic index of 7.33, and 7.38% total nitrogen/protein, with an overall desirability of 85%. These findings demonstrate the potential of locally sourced composite snacks as low-glycemic functional foods. Improved nutritional labeling and consumer education may be required to enhance acceptance and preference.*

Keywords: *D-optimal design, RSM, African yam bean, date palm fruit, sensory evaluation*

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1.0 Introduction

Type 2 diabetes mellitus is a rapidly growing public health concern worldwide, with increasing prevalence in developing countries including Nigeria.(Hossain *et al*., 2024) Dietary management, particularly the consumption of low-glycemic index (GI) foods, plays a critical role in controlling postprandial blood glucose levels and reducing the risk of diabetes-related complications (Zafar *et al*., 2019). However, many commercially available diabetic-friendly foods in Nigeria are imported, expensive, and often inaccessible to low-income populations (Okoduwa *et al*., 2023). This situation highlights the need for affordable, locally sourced functional foods with low glycemic impact. The development of low-glycemic index composite snacks from nutritious, underutilized, locally available, and low-cost crops represents a promising strategy for improving dietary options for individuals with type 2 diabetes. Composite snacks can enhance nutritional quality, promote food security, and provide diverse food choices tailored to specific dietary needs (Abioye *et al*., 2008).

Wheat flour (Triticum aestivum) is widely used in snack production due to its functional properties, but it is predominantly carbohydrate-based and may contribute to high glycemic responses (Doan *et al*., 2025) when used alone. African yam bean (*Sphenostylis stenocarpa*), an underutilized legume, is rich in protein, dietary fibre, and bioactive compounds that may help moderate glucose release and improve nutritional balance (Adegunwa *et al*., 2023). Cocoyam (Colocasia esculenta) provides resistant starch and dietary fibre that can lower starch digestibility and glycemic response (Eddy *et al*., 2012). Date fruit (Phoenix dactylifera), though naturally sweet, contains fibre, antioxidants, and micronutrients that can enhance sensory quality while contributing functional health benefits (Baldwin, 2015). Combining these flours may produce nutritionally improved snacks with moderated glycemic impact.

Response Surface Methodology (RSM), particularly D-optimal mixture design, is widely used in food product development to optimize ingredient proportions while reducing the number of experimental trials required (Meyers *et al*., 2023; Cornell, 2023). The design is widely applied in the development of composite pharmaceuticals and skincare products (Adegunwa *et al*., 2023), and new product development (Meyers *et al.,* 2023; Cornell, 2023).

In vitro estimation of glycemic index is often employed when in vivo testing using human subjects is limited by ethical, financial, or logistical constraints (Eyinla *et al*., 20221). This method measures the rate and extent of starch metabolism *in vitro* (Brouns *et al*., 2005). It mimics the digestive processes in humans, enabling the prediction of glycemic index responses pre- and post- prandial. Values from the method might not be accurate due to the challenge of replication of the complex physiology and metabolism of the human subject; however, it can contribute useful insights into the process, especially since values from *in vivo* methods are often insufficient (National Academies of Sciences, Engineering, and Medicine, 2019).

Sensory evaluation is essential in new food product development, as consumer acceptance ultimately determines market success (Oguntoyibo, 2024). Correlation analysis measures the linear relationship between two variables. In sensory science and consumer research, it shows how attributes like taste, color, and aroma are related and influence perception, acceptance and preference. The analysis identifies patterns in the data to guide product development and marketing (Juyoun & Kyunghee, 2025).

Although several studies have explored composite flours and functional snack development, limited research has simultaneously optimized glycemic index, nutritional composition, and sensory attributes of snacks formulated from wheat, African yam bean, cocoyam, and date fruit. Furthermore, the application of D-optimal mixture design to predict and optimize these combined responses in such underutilized crop blends remains insufficiently reported.

Therefore, this study aimed to optimize the glycemic index, proximate composition, and sensory attributes of composite snacks produced from wheat, African yam bean, cocoyam, and date fruit flours using a D-optimal mixture design of Response Surface Methodology. The study provides a scientific basis for the development of affordable, locally sourced functional snacks that may support dietary management of diabetes, promote the utilization of underexploited crops, and reduce dependence on imported diabetic food products.

2.0 Materials and methods

2.1 Plant materials

Commercial wheat (*Triticum aestivum*), cocoyam (Colocasia tannia), African yam bean (*Sphenostylis stenocarpa*), and date fruit (*Phoenix dactylifera*) were procured from a local bakery and market in Ikot Ekpene, Nigeria, to ensure availability and quality.

2.2 Preparation of the flours

Cocoyam corms, African yam bean seeds, and date fruits were processed into flours following the method of Eddy *et al.* (2012) with slight modifications to optimize drying and grinding conditions. Cocoyam corms, African yam bean, and date fruit flour were prepared according to the method used by Eddy *et al*. (2018) with some modifications. The cocoyam was peeled, sliced, sun-dried, then dried at about 60°C in a hot-air oven (Therma Grosskuchen, Le Chief, Sweden) until brittle and ground into flour. African yam bean seeds were boiled in water until soft, discarding the cooking water, and then sun-dried before further oven drying. The boiled bean was dried in the sun, then in a hot-air oven (Therma Grosskuchen, Le Chief, Sweden) until there was no further loss in weight. , The dried flours were sieved through a 500 µm mesh to ensure uniform particle size before storage. The date fruit was cut to remove the stones, dried in a hot-air oven until brittle, and then ground into flour.

2.4 Experimental design

The D-optimal option of the mixture experimental design of the response surface methodology was used to create nineteen (19) composite flour snack samples. This design allows efficient estimation of component effects on responses while minimizing the number of experimental runs. The characteristics of each composite snack depended on the relative proportions of the component flours rather than their absolute quantities (Adegunwa *et al*., 2024). The response surface plots of the parameters' models illustrate the responses based on the proportions of the component flours. Mathematical models were used to determine the significance and contribution of each flour component to the measured responses, with positive or negative coefficients indicating synergistic or antagonistic effects, respectively.

Table 1 shows the constraints of the component flours in the snacks. Table 2 shows the distribution of the component flours in the samples. The design assumes that the components must add up to 1 or 100%.

Table 1: Experimental layout of the design

Lower level of the component	Constraint			Upper level of the component
0.20	≤	A	≤	0.50
0.20	≤	B	≤	0.50
0.20	≤	C	≤	0.50
0.10	≤	D	≤	0.30
				1.000

**** A = Wheat flour, B = Cocoyam flour, C= African yam bean, D = Date fruit flour Y_n = Any response, A + B + C + D = 1 or 100% and $\sum X_i$ = 100%**

2.5 Preparation of the snacks

2.5.1 Preparation of the composite snacks

Composite snack samples were prepared based on the methods reported by Oladotun (2024), with adjustments to water content and baking time (see Fig. 1). The baking ingredients were mixed thoroughly in measured volumes of water in a blender (KitchenAid, USA), and allowed to rest (Fig. 1). Each run represented an experiment with the component proportions specified in Tables 1 and 2. The dough was shaped, then baked at 190°C for 20 minutes until golden brown and crispy and golden brown. Baked snacks were cooled to room temperature and stored in airtight containers at ambient humidity until analysis.

Fig. 1: Raw materials and composite snack-making flowchart

The distillate was titrated with a standard acid solution. The titer value obtained was used to calculate nitrogen content according to equation 1

$$Total\ nitrogen = \frac{TV\ x\ NA\ x\ 1.4)}{Weight\ of\ sample}\ \text{x}\ 100 \quad \ldots \quad (1)$$

where TV is the titre volume, and NA is the normality of the acid.

2.5.2 Determination of moisture content

Moisture content and total nitrogen of snack samples were determined following the AOAC (2000, 2019) standard methods. determined using the method of AOAC (2000).

2.5.2 Determination of total nitrogen

Total nitrogen content of the samples was determined according to the method of AOAC (2019). Samples were digested in concentrated H_2SO_4, converting nitrogen into ammonium sulfate for subsequent distillation and titration. The ammonia released was trapped in a boric acid solution.

2.5.3 Determination of in vitro glycemic index

In vitro glycemic index of the snack samples was determined according to Brouns *et al.* (2005), using glucose as a reference (equation 4), using the method of Bronuns *et al.* (2005), which is illustrated in equation 2

D-glucose + O_2 + H_2O glucose oxidase → D-gluconate + H_2O (2)

An aliquot of 1 mL of each snack sample was incubated with 3 mL of α-amylase solution at 37°C, and glucose release was measured at 0, 30, 50, 70, and 100 minutes. Glucose release was quantified spectrophotometrically (SP-DUVL7) at 515 nm, and plotted to calculate the area under the curve for each sample. Similar treatment was given to the reference glucose. Areas under the curve for the sample (IAUSC) and reference glucose (IAURC) were obtained using Simpson's Rule (equation. 5). The glycemic index of the sample was calculated as in equations 3 and 4

$$\left(\frac{h}{3}\right)\cdot[f(x_0)+4f(x_1)+2f(x_2)+4f(x_3)+\cdots+f(x_n)] \quad (3)$$

where

x_0 = a, x_n = b and h = $\frac{(b-a)}{n}$ while,

$$\text{GI (unit)} = \frac{IAURC\ of\ snack}{IAUSC\ of\ reference\ food}\ \text{x}\ 100 \quad (4)$$

2.7 Sensory evaluation of the samples

Sensory evaluation was performed following Adebayo-Oyetoro *et al.* (2023a,b), using a semi-trained panel of twenty members to assess color, taste, aroma, and overall Panelists evaluated the samples in a traditional eating environment representative of the target consumers using a structured 1–7 hedonic scale Completed copies of the questionnaires were retrieved, responses were organized into a matrix of scores, and analyzed statistically for comparison.

2.8 Statistical analysis

Data on proximate composition, glycemic index, and sensory attributes were fitted to multiple regression models Fitness of the models was evaluated using ANOVA. The significance of the model was determined by p-value <0.05, and the coefficient of determination $R^2 > 0.600$. The mathematical models were refined through the forward elimination method of multiple regression analysis to remove non-significant terms in the model. Response optimization was performed using the desirability function in Design Expert Version 13 to identify optimal component proportions (Cornell, 2023).

Table 2: Experimental layout on 4-component composite snack using the lattice centroid design

Run	A	B	C	D	Y_n
1	0.40	0.24	0.25	0.10	
2	0.27	0.40	0.22	0.11	
3	0.37	0.20	0.21	0.21	
4	0.20	0.20	0.50	0.10	
5	0.27	0.30	0.24	0.20	
6	0.33	0.22	0.34	0.11	
7	0.20	0.40	0.30	0.10	
8	0.35	0.33	0.20	0.12	
9	0.27	0.30	0.24	0.20	
10	0.20	0.20	0.33	0.27	
11	0.33	0.22	0.34	0.11	
12	0.20	0.29	0.33	0.18	
13	0.20	0.29	0.33	0.18	
14	0.20	0.20	0.41	0.19	
15	0.50	0.20	0.20	0.10	
16	0.22	0.28	0.20	0.30	
17	0.28	0.32	0.30	0.10	
18	0.20	0.40	0.20	0.20	
19	0.28	0.20	0.24	0.28	

Source: **Meyers *et al.* (2016), A = Wheat flour , B = Cocoyam flour, C = African yam bean, D = Date fruit flour, Y_n = Any response**

3.0 Results and discussion

3.1 Moisture content

Table 3(a) presents the moisture contents of the composite flour snacks. The table indicates moisture levels ranging from 3.0% to 6.0%. High values of moisture content correspond to high proportions of wheat and cocoyam flours in the samples. *ANOVA indicated that the model for moisture content was not significant ($p > 0.05$) and had low predictability ($R^2 = 0.2861$), suggesting that only 28.6% of the variability in moisture content could be explained by the flour proportions.* However, low R^2 means moisture is mostly influenced by other factors such as environmental drying or flour properties. This means that it is only 26.0% of the moisture content could be explained by the flour proportions. The mean moisture content was 4.85% with a standard deviation of 0.8793, indicating low variability among the samples.

It can be deduced from Table 3 that our values, 3.0% to 6.0%, are lower than but within the range of values of 10.0% reported by Peter-Ikechukwu *et al.* (2019), and Oladotun,, (2024), 4.39-5.80%. The differences in moisture content of the snack samples could be attributed to the variations in the plant materials used in the production of the snacks. Moisture content is a crucial factor in the shelf stability of composite snacks. Low moisture content indicates good shelf stability, resistance to microbial infestation, and growth (Adeyanju *et al.*, 2021).

Table 3: Distribution of components in the composite snacks and the respective GI, proximate composition and organoleptic properties

Run	A	B	C	D	MC	GI(b)	NC	Col	TA	AR	PR	OA
					a	b	c	d	E	f	g	h
1	0.40	0.25	0.24	0.1	5.00	55.0	4.8	4	5	5	6	6
2	0.27	0.22	0.40	0.1	5.75	48.0	8.6	5	3	3	5	4
3	0.37	0.21	0.20	0.2	5.01	48.0	4.0	3	4	4	3	3
4	0.20	0.50	0.20	0.1	4.11	43.0	3.1	4	2	2	1	2
5	0.27	0.24	0.30	0.2	4.22	41.0	7.0	2	3	3	2	2
6	0.33	0.34	0.22	0.1	5.27	50.2	3.0	3	4	4	5	5
7	0.20	0.30	0.40	0.1	4.11	42.1	9.0	4	2	2	2	2
8	0.35	0.20	0.33	0.1	4.92	45.0	5.0	2	4	5	4	5
9	0.27	0.24	0.30	0.2	6.00	41.0	6.7	4	3	2	3	2
10	0.20	0.33	0.20	0.3	6.11	36.0	3.7	3	3	4	3	2
11	0.33	0.34	0.22	0.1	5.92	47.0	3.9	3	5	5	4	3
12	0.20	0.33	0.29	0.2	5.00	49.0	4.8	5	2	2	2	2
13	0.20	0.33	0.29	0.2	6.17	43.0	4.5	2	2	2	2	2
14	0.20	0.41	0.20	0.2	5.00	37.0	3.0	2	3	3	4	5
15	0.50	0.20	0.20	0.1	4.17	60.0	2.9	3	6	6	6	5
16	0.22	0.20	0.28	0.3	4.19	42.3	4.0	6	3	3	2	2
17	0.28	0.30	0.32	0.1	4.91	48.0	4.9	3	3	3	4	3
18	0.20	0.20	0.40	0.2	3.17	37.0	8.5	3	2	2	3	4
19	0.28	0.24	0.20	0.3	3.21	41.0	3.0	2	3	3	3	4

Source: **From the experiment A = Wheat flour, B = Cocoyam flour, C = African yam bean, D = Date fruit flour and Y_n = Any response**

Water-binding capacity of African yam bean flour, processing methods, experimental design, and their proportions in the samples could influence the moisture content. (Fig. 2 equation 5). Due to the low moisture content in our samples, it could be safe to conclude that the snacks store for a long time without compromising the traditional sensory attributes.

3.2 Total nitrogen

Table 3(b) shows the total nitrogen content of the snacks. Total nitrogen content of the samples ranged from 3.0% to 8.5%, with higher values observed in samples containing greater proportions of African yam bean and cocoyam flours, reflecting the protein-rich nature of these ingredients The model for total nitrogen content was significant ($p<0.05$), with an R^2 of 0.8354. This indicates that 84% of the variation in nitrogen content can be explained by the types of flours used; the remaining variation could be due to other factors, including variety and processing methods.

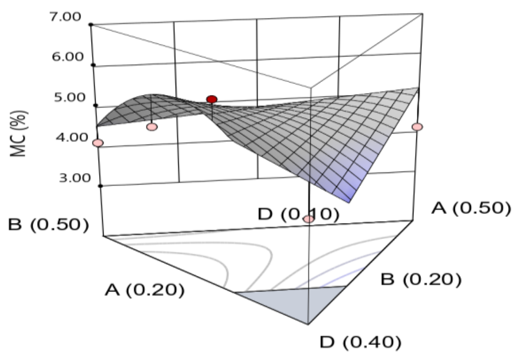
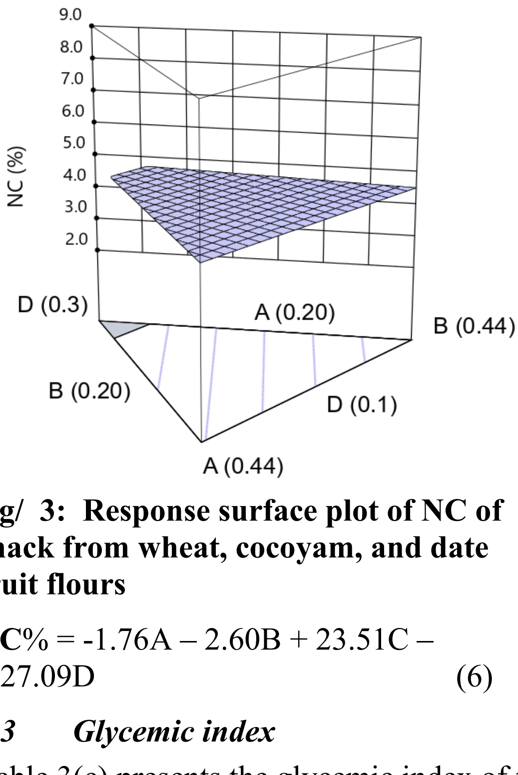


Fig. 2: Response surface plot of MC of snack from wheat, cocoyam, and date fruit flours

$$\text{MC}(\%) = 8.25A - 2.4B + 7.85C - 17.09C + 90.01A \times C \quad (5)$$

For example, African yam bean and cocoyam flours contributed positively to the total nitrogen content, increasing as their proportions in the samples grew (Fig. 3 and equation 4). Total nitrogen content offers an estimate of the protein level in foods. In our study, African yam bean positively influenced the nitrogen content of the snack samples. This observation aligns with the known high protein content of African yam bean, although it remains underutilized in food products due to labor-intensive preparation requirements. Protein plays a key role in regulating the glycemic index of foods, slowing carbohydrate digestion, boosting insulin sensitivity, and providing a feeling of fullness (Juidan *et al*., 2022; Brouns *et al*., 2025). Muscle wasting is a common issue for diabetics, and increased protein intake can help prevent muscle loss, alongside suggested benefits such as improved insulin sensitivity and liver fat management (Judan *et al*., 2022). However, further research is necessary to confirm these claims.



Fig/ 3: Response surface plot of NC of snack from wheat, cocoyam, and date fruit flours

NC% = -1.76A – 2.60B + 23.51C – 1.27.09D (6)

3.3 Glycemic index

Table 3(c) presents the glycemic index of the snack samples. The table shows that the glycemic index ranged between 36.0% to 55.0%. Higher values correspond to higher proportions of wheat and African yam bean flours in the samples. ANOVA showed the model for glycemic index was significant ($p < 0.05$) with $R^2 = 0.7971$, indicating that 79.7% of the variation in GI could be explained by the flour proportions.

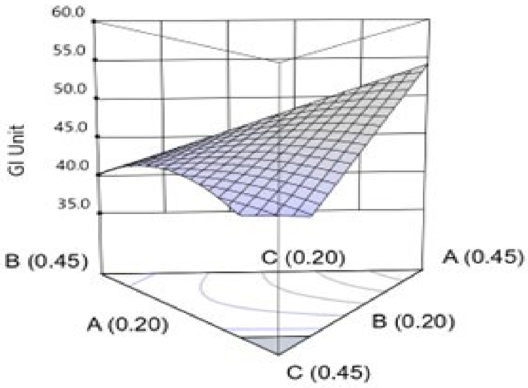


Fig. 4: Response surface plot of glycemic index of composite snack wheat, cocoyam, African yam bean and date fruit flours

The mean GI was 44.93 with a standard deviation of 3.14 (see Table 3c). African yam bean and cocoyam flours GI values decreased with increasing proportions of cocoyam and African yam bean flours, likely due to their higher fiber and protein content, which slow carbohydrate digestion and reduce post-prandial blood glucose spikes (Atkinson *et al*., 2008). Equation 4 shows that date fruit flour is antagonistic to the glycemic index of the snack samples. Glycemic index measures the rate at which blood sugar rises post-prandially. Low glycemic foods, <55%, are suitable for potential and actual diabetic patients (Jenkins *et al.,* 2022). In our study, 17 low-GI composite snack samples were identified (see Table 2). A low glycemic index is beneficial to diabetics because it slows down the digestion and absorption of carbohydrates into the bloodstream, causing a gradual increase in blood sugar and maintaining it at natural, healthy levels. Low GI foods increase insulin sensitivity, aid in weight management, reduce chronic diseases, and improve energy levels (Foster-Powell *et al*., 2002).

$$GI\ (unit) = 102.57A - 15.62B - 24.25C + 26.33D + 307.06BC \quad (11)$$

3.4 Colour

Table 3(d) displays the color ratings of the 19 snack samples which ranged between 2 to 6 on a 1-7 scale. Samples with high wheat and cocoyam flour scored high on colour. ANOVA shows that the model is significant, $p<0.05$, R^2 = 0.7783; all components were significant, $p<0.05$, on color of the samples. The samples with high proportions of wheat and cocoyam flours tended towards 6 on a 1-7 scale. The higher color scores of samples with wheat and cocoyam flours are attributed to Maillard reactions and caramelization of carbohydrates during baking, which produce the familiar brown crust. This observation aligns with the findings reported by Eddy *et al.* (2007). The flours from date fruit and African yam bean, along with their products, are relatively new in the baking industry, which explains the lower ratings for samples containing both flours in increasing proportions.

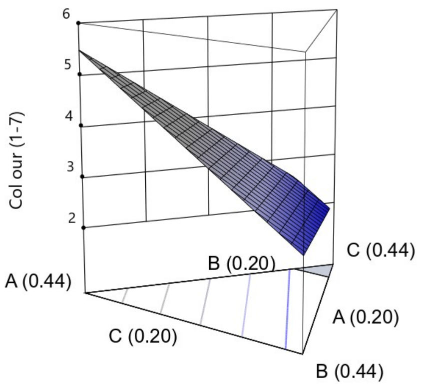


Fig. 5: Response surface plot of wheat, cocoyam, African yam bean, and date fruit flours on the colour of the snack samples

$$Colour = 12.86A + 0.293B + 1.488C + 0.4 - 3D \quad (12)$$

Equation 11 shows the mathematical influence of the flour component to colour, where 12.86 to the parameter more than other components. Colour plays an important role in the choice and acceptability of food before taste and aroma. Colour suggests freshness and has an accompanying effect on taste and aroma. In our study, the observations agreed the values of Katz, (2012) and Spence, (2015). Food producers invest a lot of funds on colour and packaging to increase acceptability and preference.

3.5 Aroma

Table 3(f) shows aroma scores of the snacks. From the table, the parameter scores range from 2 to 6 on a 1-7 scale. Aroma scores increased with higher proportions of wheat and cocoyam flours, but higher African yam bean content reduced aroma intensity, possibly due to its characteristic beany notes. An analysis of variance on the aroma data revealed that the model is significant, $p << 0.05$, R^2 = 0.8478, indicating the model's ability to predict the scores of other blends. The average aroma score of 3.37 suggests a near rejection of the samples on the 1-7 hedonic scale.

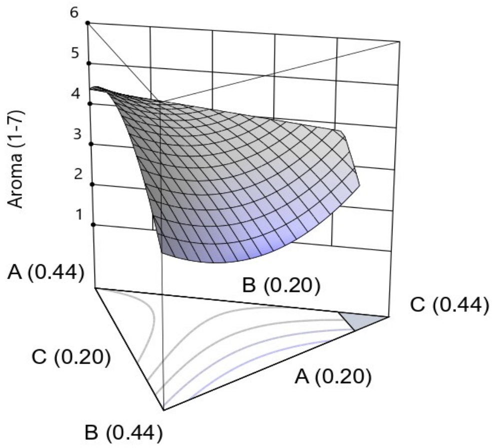


Fig. 6: Response surface plot of wheat, cocoyam, African yam bean, and the aroma of the snack samples

$$Aroma = -1.53A - 13.74B + 27.65C + 76.80AD \quad (13)$$

Fig. 6 shows that the aroma of the samples increases as the proportion of wheat flour increases. In contrast, high levels of cocoyam and African yam bean flours reduced the intensity of the aroma, and consequently the acceptability of the samples. Equation 13 indicates that wheat and cocoyam flours exerted antagonistic effects on aroma, whereas a combination of African yam bean and wheat flours showed synergistic interactions, Aroma plays a role in the overall experience of food acceptability and consumption, indicating quality, comfort, and nostalgia. This observation aligns with submission of Baldwin, (2015). From the table, it can also be seen that products of poor quality were scored highly, the observation could be attributed to individual aroma perception, and psychology of food choice (Baldwin, 2015).

3.6 Preference and acceptability

Table 4 presents the acceptability, hence preference of the snacks. The models for acceptability and preference were significant ($p < 0.05$), but had low predictability (R^2 = 0.3975), reflecting variability in consumer responses to novel composite snacks.

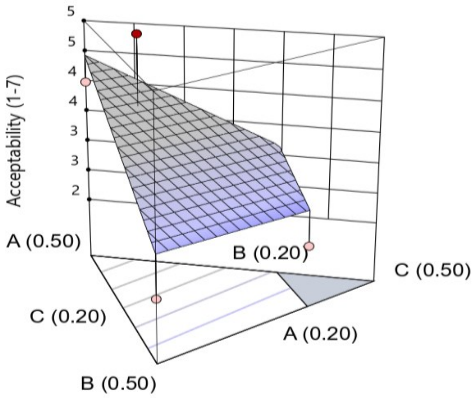


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Fig. 7: Response surface plot of wheat, cocoyam, African yam bean, and acceptability of the snack samples.

$$Accept\ (1-7) = 7.76A + 1.91B + 1.44C - 1.23D \quad (13)$$

This finding was expected because snacks made from composite flours are not traditional. The results and findings of this study, indicated that this finding was expected because snacks made from composite flours are not traditional. fear of new food, disgust, unfamiliarity, sensory attributes, labelling, packaging, including price and lack of information, can hinder acceptability. Low acceptability could result in a decreased preference to purchase the product when other similar options are available in the market.

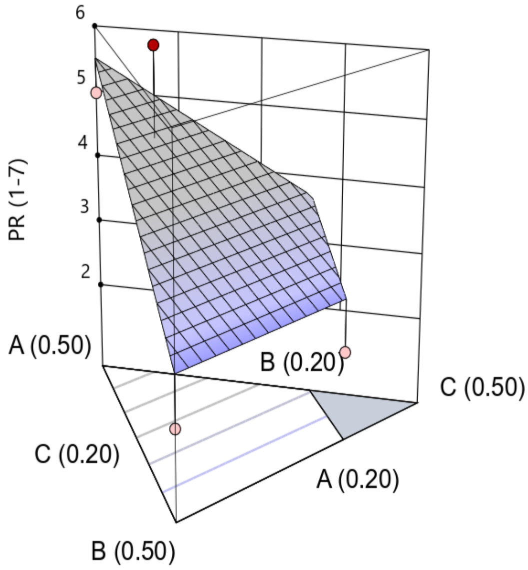

Fig. 7: Response surface plot of wheat, cocoyam, African yam bean and the acceptability and preference of the snack samples

$$PR = 10.34A - 1.17B + 1.33C + 1.53D \quad (14)$$

Table 4: Correlation of the sensory attributes of the composite snacks

	Col	Taste	Aroma	Preferer	Accept.
Col					
Taste	-0.22				
Aroma	-0.29	0.94**			
Pref.	-0.19	0.75**	0.71*		
Accept.	-0.39	0.53*	0.56*	0.81*	

**** =significant at 0.05 level 2-tailed, *= significant at 0.05 level 2-tailed**

The study of the relationship between sensory attributes and acceptability factors of new food products can be challenging especially when relying solely on sensory data. The complexity of human psychology and its interaction with the environment in food choice cannot be replicated in a sensory laboratory (Rahim & Bhuiyan, 2015). Therefore, one sensory attribute may not be enough to estimate acceptability. Table 4 shows that acceptability is highly and positively correlated (0.81) with preference. This indicates that higher acceptability of the composite snacks in terms of taste, colour, and aroma may lead to greater preference (see Table 4). The observations agree with the values reported by Fasuan (20213).

3.7 Optimization of the product

Optimization using the desirability function indicated that a blend of 33.3% wheat flour, 22% cocoyam flour, 36.7% African yam bean flour, and 10% date fruit flour yielded snacks with optimal characteristics: 5.01% moisture, 47.33 GI, 7.38% total nitrogen, 3.84 color score, 5.18 aroma, and 4.02 acceptability/preference on the 1–7 hedonic scale.

4.0 Conclusion

The composite snacks developed from locally available carbohydrate crops demonstrated acceptable sensory quality and improved nutritional composition. Most of the formulated samples exhibited low glycemic index values (≤55), indicating their potential suitability for dietary management and prevention of type 2 diabetes. Despite these health benefits, initial consumer acceptability and preference were relatively low, likely due to unfamiliarity with the composite formulations. To enhance market acceptance, clear nutritional labeling and consumer education highlighting the functional and health benefits of the products are recommended. Such strategies may improve consumer perception, acceptance, and overall preference for these functional snacks.

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5.0 References

Abioye, V. F., Ade-Omowaye, B. I. O., & Babarinde, G. O. (2023b). Quality attributes of cookies produced from composite flours of wheat, germinated finger millet flour, and African yam bean. Journal of Food Science and Technology, 60, 1, pp. 538-546. doi: 10.1080/10942912.2022.2123519

Adebayo-Oyetoro, A. O., Adeyeye, S. A. O., & Ogundipe, O. O. (2023a). Development and quality evaluation of composite flour crackers from wheat, cocoyam, and plantain. Journal of Food Science and Technology, 60(2), 1050-1058. DOI: 10.1080/10942912.2022.2154141

Adegunwa, M. O., Adebowale, A. A., & Bakare, H. A. (2023). Effect of baking temperature on the quality of cookies made from composite flour of wheat, cassava, and yam. Journal of Food Science and Technology, 60, 6, pp. 1860-1868. doi: 10.1080/10942912.2022.2155555

Adegunwa, M. O., Ogungbesan, B. O., Adekoya, O. A., Akinloye, E. E., Idowu, O. D., & Alamu, O. E. (2024). Production and characterization of snacks utilizing composite flour from unripe plantain (*Musa paradisiaca*), breadfruit (*Artocarpus altilis*), and cinnamon (*Cinnamomum venum*). *Foods*, *13*(6), 852. https://doi.org/10.3390/foods13060852

Adeyanju, J. A., Babarinde, G. O., Olanipekun, B. F., Bolarinwa, I. F., & Oladokun, S. O. (2021). Quality assessment of flour and cookies from wheat, African yam bean and acha flours. Food Research, 5, 1, pp. 371-379.

Akinbisoye, A. F., Grace, O. B., Olatunde, Lawrence, O., and Beatrice, I. Olayemi, A. (2024). antioxidant, anti-diabetic and sensory properties of bread produced from flour blends of wheat and pretreated African yam bean and Bambara groundnut seed coat. *European journal of Nutrition & Food Safety* 16, 7, pp. 65-78. https://doi.org/10.9734/ejnfs/2024/v16i71457

AOAC International (2019). Official Methods of Analysis of AOAC International. Rockville, MD. (Method 984.13 for the Kjeldahl method).

Atkinson, F. S., Foster-Powell, K., & Brand-Miller, J. C. (2008). International tables of glycemic index and glycemic load values: 2008. Diabetes Care, 31, 12, pp. 2281-2283. doi: 10.2337/dc08-1239

Baldwin, E. A. (2015). *Flavour and aroma of fruits and fruit products*. In M. A. Rao & S. S. H. Rizvi (Eds.), Engineering aspects of food quality (pp. 281-304)

Brouns, F., Bjorck, I., Frayn, K. N., Gibbs, A. L., Lang, V., Slama, G., & Wolever, T. M. S. (2005). Glycaemic index methodology. Nutrition Research Reviews, 18, 1, pp. 145-171. doi: 10.1079/NRR2005100

Cornell, J. A. (2023). *Experiments with mixture: Designs, models, and the analysis of mixture data*. John Wiley and Sons.

Doan, H. T. T., Kim, T., Cha, M., & Kim, S.-J. (2025). Synthesis and potential application of slowly digestible starch. *Journal of Functional Foods*, *131*, 106955. https://doi.org/10.1016/j.jff.2025.1069555

Eddy, N. O., Essien, E., Ukpe, R. A. & Ebenso, E. E. (2012). Industrial potentials of two varieties of cocoyam in bread making. *E. Journal of Chemistry* 9, 1, pp. 451-464.

Eddy, N. O. & Udofia, P. G., Udoudoh, P. J. and Eyo, D. (2007). Sensory evaluation of composite bread produced by cassava and wheat flour. *African Journal of Biotechnology* 16:3-6

Eyinla, T. E., Sanusi, R. A., & Maziya-Dixon, B. (2022). Evaluation of *in vitro* and *in vivo* glycemic index of common staples made from varieties of white yam (*Dioscorea rotundata*). *Frontiers in Nutrition*, *9*, 983212. https://doi.org/10.3389/fnut.2022.983212

Fasuan, T. O. (2021). Ready-to-eat flakes from acha, partially defatted sesame meal and modified corn starch: Modeling, optimization and characterization. *Food Science & Nutrition Technology*, 6, 1, Article 16000249. https://doi.org/10.23880/fsnt-16000249

Flores-Hernández, M. N., *et al*. (2024). Efficacy of a High-Protein Diet to Lower Glycemic Levels in Type 2 Diabetes Mellitus: A Systematic Review. International Journal of Molecular Sciences, 25(20), 10959. DOI: 10.3390/ijms252010959

Hossain, M. J., Al-Mamun, M., & Islam, M. R. (2024). Diabetes mellitus, the fastest growing global public health concern: Early detection should be focused. *Health Science Reports*, 7, 3, e2004. https://doi.org/10.1002/hsr2.20044

Jenkins, D. J., Kendall, C. W. & Augustin, L. S. (2002). Glycemic index: Overview of implications in health and disease. American Journal of Clinical Nutrition, 76, 1, pp. 266S-273S., doi: 10.1093/ajcn/76/1.266S.

Jiudan, Z., Olga, P., Stefan, K., Mariya, M., Silke, H., Stephanie, S., Sascha, R., Jürgen, M. and Andreas F. H. P. (2022). High protein diets improve liver fat and insulin sensitivity by prandial but not fasting glucagon secretion in type 2 diabetes. Front Nutr, 9, 808346. DOI: 10.3389/fnut.2022.808346

Juyoun, L. & Kyunghee, K. (2025) Consumer acceptance and perceived sensory characteristics of commercial vegan mayonnaise. Foods, 14, 9, 1542; https://doi.org/10.3390/foods14091542

Katz, D. L. (2012). Colour and flavour. A neuroscientific perspective. Food Quality and preference, 25(1): 12-21.

Meyers, R. H., Montgomery, D. C., & Anderson-Cook, C. M. (2016). *Response surface methodology. Process and product optimization using designed experiments.* John Wiley & Sons.

National Academies of Sciences, Engineering, and Medicine. (2019). Replicability. In *Reproducibility and replicability in science*. National Academies Press. https://doi.org/10.17226/25303

Okoduwa, S. I. R., & Abdulwaliyu, I. (2023). Dietary approach for management of Type-2 diabetes: An overview of glycemic indices of commonly consumed foods in Nigeria. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *17*(1), 102698. https://doi.org/10.1016/j.dsx.2022.102698

Oladotun, O. O. (2024). Chemical composition and sensory characteristics of cookies produced from wheat flour and African yam bean flours. Agriculture, Food, and Natural Resources Journal, 3, 2, pp. 275-281, doi.org/10.2581/zenodu.-14179858.

Peter-Ikechukwu, A. I., Ogbuagu, J. C., Osuji, C. M., Ihediohamma, N. C., Okafor, D. C. and Chukwu, M. N. (2019). Proximate composition and organoleptic characteristics of sausage rolls made from cocoyam and wheat flour enriched with soybean flour. *Research Journal of Food Science and Nutrition*, 4, 1, pp. 1-11, doi.org/10.312481rjfsn2018.057.

Rahim, T., & Bhuiyan, F. R. (2015). Consumer's sensory perception of food attributes: A survey on flavor. *Journal of Food and Nutrition Sciences*, *3*(1), 157. https://doi.org/10.11648/j.jfns.s.2015030102.40

Spence, C. (2015). On the Psychological impact of food colour. Food quality and preference, 4, 69-77.

Zafar, M. I., Mills, K. E., Zheng, J., Regmi, A., Hu, S. Q., Gou, L., & Chen, L. L. (2019). Low-glycemic index diets as an intervention for diabetes: A systematic review and meta-analysis. *The American Journal of Clinical Nutrition*, 110, 4, pp. 891–902. https://doi.org/10.1093/ajcn/nqz149

Declaration

Conflict of interest

No conflict of interest declared by the authors.

Availability of Data

Data shall be made available upon request.

Ethical Consideration

The sensory evaluation involved voluntary adult panellists who provided informed consent. The study posed no health risk, and all food samples were prepared following standard food safety and hygiene practices. No clinical procedures or personal data collection were involved.

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Availability of Data

Data shall be made available upon request

Author Contributions

Patrick Gregory Udofia conceived and designed the study, conducted experiments, performed data analysis, and drafted the manuscript. Anthony Christopher Iwok supervised the research, validated analytical procedures, and critically revised the manuscript. Idongesit James Edet coordinated sensory evaluation, assisted in data interpretation, and contributed to manuscript editing and final approval.