Production and Characterization of Composite Flour Made From Mixture of Cassava Fiber (Seviet), Maize and Plantain, Intended for Cooked-Dough

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ABSTRACT

The study aimed to reduce hunger in Nigeria by turning cassava by-products (seviet), maize, and plantain into nutritious food for cooked doughbb ('swallow') in form of Semovita, garri, pounded yam or cassava 'fufu'. The cassava roots were cleaned, washed, peeled, ground, and then the extracted fiber was dewatered, dried, milled, and sieved. Unripe plantain was washed, peeled, sliced, dried, milled and sieved. The maize grain was cleaned, winnowed, sorted, dried, milled, oven-dried, and sieved. The design keys were cassava fiber X1 (10 – 30 g), maize flour X2 (50 - 60 g), and plantain flour X3 (20 - 30 g), which generated sixteen (16) runs. The samples generated were mixed, packed, stored, and used for laboratory analysis. The composite flour's proximate, sensory, and functional properties were assessed. Moisture content ranged from 10.9 to 12.45 %, while fiber content varied between 3.43 and 5.67 %. The protein content increased from 7.58 to 10.26 % following adjustments to the levels of cassava fiber, maize flour, and plantain flour. Fat content spanned 2.70 to 3.83%, while ash content ranged from 3.27 to 3.87%. Carbohydrate content varied between 66.15 and 69.53%, depending on ingredient ratios. The results were statistically analyzed to determine the means, standard deviations using Statistical Package for Service Solution (SPSS) Software Version 25, while Design Expert Version 12 was used to determine the ANOVA, Mathematical model, Regression equation, Coefficient value and other parameters. Sensory evaluation utilized a 9-point hedonic scale, identifying the best texture in a flour mix containing 17.16 g cassava fiber, 52.84 g maize flour, and 30 g plantain flour, scoring 8.10 for texture. Protein, ash, fat, and carbohydrate were chosen for optimization using Design Expert Version 12, with the objectives of maximizing protein and ash levels while minimizing fat and carbohydrate contents. Optimized mixture ratio was 15.006 g cassava fiber, 60 g maize and 24.9994 g plantain flours with 90.10% desirability.

Keywords used: Production, proximate evaluation, sensory evaluation, and optimization.

INTRODUCTION

Cassava, scientifically referred to as *Manihot esculenta*, is a staple food, particularly in regions like Indonesia and Africa. In Africa, cassava ranks as the third main staple food after rice and corn, highlighting its importance in the local diet (Suharko and Hudayana, 2020). Cassava fiber or Seviet, a byproduct of cassava processing, has gained attention for its potential applications in dough making. Additionally, cassava seviet has a higher crude fiber content providing products made with it greater nutritional value due to its fiber content like whole meal flours. The high fiber content can aid in digestion, help maintain healthy blood sugar levels, and reduce the risk of chronic diseases such as diabetes, heart disease, and obesity. Studies have explored the utilization of cassava in various forms for dough making. For example, the application of dewatered cassava pulp and wheat flour has been suggested for producing spaghetti, demonstrating the possibility of using cassava dough in pasta products (Padi, 2023).

Maize, scientifically known as *Zea mays*, is a significant staple food crop in sub-Saharan Africa, consumed by diverse populations with varying food preferences and socio-economic backgrounds (MOyewale *et al.*, 2020). It is widely cultivated in different agroecological zones and plays a crucial role in ensuring food security (McMillen *et al.*, 2022). Maize serves as both a staple food and a significant cash crop. The highest quality produce is frequently exported, which results in lower quality crops, being retained for local consumption (Misihairabgwi *et al.*, 2017). Maize offers a rich source of carbohydrates and nutrients that can complement the characteristics of cassava seviet in dough formulations. By combining maize with cassava fiber waste, it is possible to create a composite dough that not only utilizes agricultural by-products efficiently but also enhances the overall quality of the end products (Wirunpan *et al.*, 2019). Studies have explored the potential of incorporating maize into cassava-based products to improve their nutritional profiles and sensory attributes. For instance, research has investigated the effect of incorporating high-quality protein maize flour into blends of cassava root flour to produce *Banku* flour (a fermented flour meal of maize or cassava or a combination of both commonly eaten in Ghana), showcasing the impact of maize on the nutrient composition, functional properties, and sensory attributes of the final product (Ogundele *et al.*, 2022). This demonstrates the potential for maize to enhance the nutritional value of cassava-based products, making them more appealing to consumers.

Plantain, a popular dietary staple in Nigeria, is known for its versatility and good nutritional value (Adebayo, 2023). It is rich in nutrients such as minerals, vitamin C, and carbohydrates, particularly resistant starches with prebiotic properties (Leeward, 2023). Additionally, plantain is consumed at different ripening stages, offering varying nutritional benefits (Honfo *et al.*, 2022). The consumption of plantain has been associated with providing essential nutrients like iron, zinc, sodium, calcium, and potassium, which can aid in preventing health issues such as high blood pressure, muscle cramps, and cholesterol increase (Umeh *et al.*, 2022). Plantain flour, known for its nutritional value and traditional culinary uses, can be combined with cassava seviet to create functional dough meals with potential health benefits. Studies have shown that plantain flour can be used in combination with other ingredients like defatted soybean and cassava fiber to develop dough meals that offer antidiabetic properties and improved sensory characteristics (Famakin *et al.*, 2016).

Utilization of cassava seviet, along with maize and plantain flours, will contribute to the valorization of agro-waste materials, promoting sustainability in food production (Lesmana *et al.*, 2021). Furthermore, the industrial applications of cassava seviet residues will provide opportunities for the conversion of the by-products into value-added products (Li *et al.*, 2017). Regarding the physical and textural characteristics of the dough, the addition of maize and plantain can influence the rheological behavior and mechanical properties. Incorporating cassava seviet, plantain, and maize in composite flour production intended for cooked dough offers a novel approach to creating nutritious and functional food products. While there are studies on the utilization of plantain, soybean, and maize in food production (Famakin *et al.*, 2016), there is a gap in research focusing on the potential of cassava seviet in human food production. However, the specific combination of cassava seviet, maize grain, and unripe plantain fruits for composite flour production is an area that requires further investigation. Cassava flour, known for its unique properties such as low retrogradation, high water-binding ability, and high fiber content, could offer distinct advantages when combined with unripe plantain and maize flours (Li, *et al*., 2023). By addressing this gap in knowledge, researchers can provide valuable insights into the feasibility and potential benefits of this composite flour blend for various food applications.

During the processing of cassava, approximately 10 percent of fiber is derived from every 1000 kilograms of cassava roots, which typically have an average starch content of 20 percent. As the starch content decreases, the amount of fiber produced increases. Currently, Nigeria has more than 20 cassava processing plants, each with a minimum capacity to process between one ton and two hundred fifty tons of cassava roots per day.

In Nigeria, the by-products of cassava processing, such as cassava fiber, are utilized as animal feed. This practice overlooks the potential of these by-products to be utilized as a valuable food resource for human consumption. Given the rising global population and the ensuing food scarcity, there is an urgent need to explore alternative food sources. Plantains are cultivated in Nigeria and need to be consumed within a few days of being harvested. They can be used in various food preparations, such as making porridge or frying. The cooked dough from plantain flour has poor mouldability unlike fufu or semovita. The study aims to tackle the issue of global food scarcity and the underutilization of cassava by-products by developing a method to transform cassava fiber, maize grain, and unripe plantain flour into high-quality composite flour, for human consumption. By repurposing these by-products into nutritious food items, the research seeks to contribute to mitigating global food scarcity and reducing the wastage of valuable resources.

MATERIALS AND METHODS

Sources of Raw Material

The cassava roots were procured from Von Farms Nigeria Limited located in Uturu, Abia State while the unripe plantains and maize were purchased from Nkwo Market in Enugwu-Ukwu, Njikoka, Anambra State, Nigeria. Additionally, the production of cassava seviet, unripe plantain flour and maize flour were conducted at Von Food and Farms Limited in Nimo, Anambra State.

Production of cassava fiber (seviet)

Exactly 12 kg of the cassava roots were washed with clean water, peeled, washed again, and 10 kg of the peeled cassava roots were cut into smaller sizes ranged from 1 to 2 cm with cutting blade machine (Kaifeng Sida Agricultural Products Equipment Co. Ltd. made in China, 2017: XD50 – 12) and grounded into pulp using Hammer Grinder machine (Kaifeng Sida Agricultural Products Equipment Co. Ltd. made in China, 2017: FS48 – 24). The starch was extracted using a centrifugal sieve machine (Kaifeng Sida Agricultural Products Equipment Co. Ltd. made in China, 2017: WS -800). The fiber was separated and dewatered to 60 % moisture content using a Fiber filter press machine (Kaifeng Sida Agricultural Products Equipment Co. Ltd. made in China, 2017: XMY/100) according to Von Food and Farms Limited, 2023. The fiber was sun dried at temperature of 29 to 34 °C for a period of two days because the proposed solar dryer was faulty at the time of the experiment. Therefore, sun drying was the alternative measure used to reduce the moisture content to 20 %. The reason was because drying fiber of 60 % moisture content at high temperature could make it to gum in the oven according D.C. Nzenwata (personal communication, June 03, 2025). Then fiber was oven dried (Thermal oven DHG) at 105 °C for 6 h to a moisture content of 10 %, milled into fine fiber of 90 % fineness with the aid of an industrial blender (Combo CM/L-7480681). The fiber was sieved with a sieve size of 180 μm according to NIS 344 (2020) and fine fiber was packed in Ziplock bag.

Production of Unripe Plantain Flour

Fresh 12 kg of unripe plantain was washed, peeled, sliced into chips (3 cm) and sun dried at temperature of 29 to 34 °C for 2 days followed by air – oven drying (Thermal oven DHG) at 105 °C for 6 h to a moisture content of 10 %. The dried chips (10 kg) were milled using an industrial blender (Combo CM/L-7480681). The resulted product was sieved into fine flour of 90% fineness with a sieve size of 180 μm according to NIS 344 (2020). The flour was packed in a zip lock bag for analysis.

Production of Maize Flour

Initially, 10 kilograms of maize grains were subjected to cleaning and winnowing processes to remove impurities such as dirt, dust, or foreign particles. The maize grains were air – oven drying (Thermal oven, DHG) at 60 °C for 6h. The dried maize grains were dry milled into fine flour of 90 % fineness using an industrial blender (Combo CM/L-7480681). It was oven dried again (Thermal oven DHG) at 120 °C for 1 h to a moisture content of 12 %, sieved with a sieve size of 180 μm according to NIS 344 (2020) and packed in Ziplock bag and kept for analyses.

Experimental Design for Production of the Composite Flour Intended for Cooked Dough

The experiment was designed in a constraint mixture (D-optimal) using Design Expert Version 12. There were 3 components in each blend that gave total weight of the mixture as 100 g as in Table 3.1. Cassava Seviet (10 - 30 g), Maize Flour (50 - 60 g) and Plantain Flour (20 - 30 g). The design produced 16 runs at varied blends of the various components as shown in Table 3.2 and table 3.1 shows the key for the component mixtures.

Table 3.1: Low and high components mixture with actual values

Mixture Component	**Low**	**High**
Cassava Seviet (g)	10	30

Maize Flour (g)	50	60
Plantain Flour (g)	20	30

Table 3.2 Experimental Design Matrix

Sample	**Cassava Seviet (g)**	**Maize Flour (g)**	**Plantain Flour (g)**
1	19.2213	55.9654	24.8133
2	23.5529	53.6026	22.8445
3	15.4908	60	24.5092
4	24.6527	50	25.3473
5	19.2213	55.9654	24.8133
6	20.8852	50	29.1148
7	14.5429	56.9107	28.5464
8	19.5	60	20.5
9	27.9228	52.0772	20
10	17.1579	52.8421	30
11	17.1579	52.8421	30
12	27.9228	52.0772	20
13	24.6527	50	25.3473
14	19.2213	55.9654	24.8133
15	23.0109	56.9891	20
16	10.6	60	29.4

Formulation of Composite flour

The cassava sievet, maize and plantain flours were mixed using an industrial blender (Combo CM/L-7480681) at various proportions of the experimental design matrix (runs) and packaged in 16 different polyethylene bags for analyses as indicated in table 3.3 below.

Table 3.3 Formulated Composite Flour at different Proportions

Sample	**Cassava Seviet (g)**	**Maize Flour (g)**	**Plantain Flour (g)**	**Composite Flour (g)**
1	19.2213	55.9654	24.8133	100
2	23.5529	53.6026	22.8445	100
3	15.4908	60	24.5092	100

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4	24.6527	50	25.3473	100
5	19.2213	55.9654	24.8133	100
6	20.8852	50	29.1148	100
7	14.5429	56.9107	28.5464	100
8	19.5	60	20.5	100
9	27.9228	52.0772	20	100
10	17.1579	52.8421	30	100
11	17.1579	52.8421	30	100
12	27.9228	52.0772	20	100
13	24.6527	50	25.3473	100
14	19.2213	55.9654	24.8133	100
15	23.0109	56.9891	20	100
16	10.6	60	29.4	100

The optimized sample was reproduced at the ratio of 15.006% cassava fiber, 60% maize flour, and 24.9994% plantain flour and mixed with industrial blender (Combo CM/L-7480681). The mixture was subsequently packaged in 500 g polyethylene bags for the purposes of Microbiological analysis and storage studies.

Laboratory Analysis

Proximate Analysis

The proximate composition such as moisture, fat, fiber, ash, protein, and carbohydrate was determined using AOAC (2010) method for the 16 samples and control (Semolina flour) sample.

Sensory Analysis

This was done based on the method described by Onwuka (2005). Organoleptic evaluation of the cooked dough from the composite flour (blends of cassava seviet, maize flour and plantain flour) was conducted by a 20-member panelist drawn from students and Technologists of Food Science and Technology Department, Nnamdi Azikiwe University Awka. Sixteen different dough samples of the composite flour and control (Semolina flour) sample were evaluated on 9-point Hedonic scale in which the degree to which a product is relished was expressed as like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), dislike extremely (1). Each panelist received individual samples in a well-lit area of the Food Science and Technology Laboratory at Nnamdi Azikiwe University Awka, ensuring accurate colour perception. The panelists observed the sample and scored it based on colour, taste, flavour, texture, and overall acceptability. A neutral palate was maintained before tasting another sample, the panelists were provided with water to rinse their mouths in between sample evaluations.

Statistical Analysis

The results obtained were statistically analyzed to determine the means and standard deviations using Statistical Package for Service Solution (SPSS) Software Version 25. Two way analysis of variance (ANOVA) was performed using Design Expert Software Version 12 which suggested the Mathematical model, Regression equation, Coefficient value and other parameters, where the models with P-value < 0.05 are significant.

Processes used to obtain optimized plots.

The parameters of models with P-value < 0.05 (significant) were selected for optimization using Design Expert Software Version 12. The Numerical optimization was conducted while the limits of the parameters were set based on the research and desirability. Subsequently, graphical optimization was performed, which illustrated the optimized plot and proportions of cassava, maize, and plantain flour blends for composite flour intended for cooked dough.

Preparation of the meal (cooked dough)

Exactly 500 ml of clean water was put in a pot and boiled, then 300 g of the flour was incorporated gradually into the boiling water, stirred continuously to maintain an even consistency between 5 to 7 min until the thickness desired was achieved. The pot was covered and allowed to boil for 5 min. It was stirred thoroughly once more until a firm and consistent mixture (meal) was obtained.

RESULT AND DISCUSSION

Proximate Analysis Results and Discussion

Moisture Content

The results of the moisture content were shown in Table 4.1.

The results of the moisture content from the 16 samples ranged from the lowest value of 10.9 to the highest value of 12.45% while the control (Semovita Flour sample) was 10.13%. Sample 11 had the highest moisture content (12.45%) while sample 1 had the lowest moisture content (10.9%). There were no significant different (P-value > 0.05) among samples 10 and 11. There were no statistically significant differences (P-value > 0.05) between the mean values of samples 1 and 2; samples 3 and 4; samples 7 and 16; samples 6 and 15; and the mean values of samples 8, 12, and 14. The moisture content of the samples obtained in this study (10.9% to 12.45%), adhered to the African Standard CD-ARS 841: 2014 specification for composite flour. which sets the maximum acceptable moisture limit at 13.5%. They also met the 13.5% moisture threshold established by the Nigerian Industrial Standards for wheat flour (NIS 121:2010), which was the primary ingredient in the Semolina used as a control sample in this research. The moisture content results obtained were like 11.05 to 12.16% of proximate composition of Ichipipi (Ghanaian Maize) composite flour formulated at five different ratios as reported by Mpili et al., (2024). The findings were comparable to the moisture content range of 11.45% to 11.91% reported in the proximate analysis of maize, cassava, and soybean composites by (Igbua et al 2018). The moisture contents recorded were slightly higher than those of the control sample and exceeded the 10.0% maximum acceptable moisture content limit set by the Nigerian Industrial Standard (NIS 344: 2020) for high-quality cassava flour. The increased moisture content may be due to the increase in maize and plantain flour. This may be due to the high fiber content of maize that can absorbed moisture from the environment and swell (Igbua et al 2018). The moisture content, also referred to as water content, of a food item represents the aggregate quantity of water in relation to a dry basis (db) or wet basis (Wb). Generally, this metric is expressed as a percentage of weight on a wet basis. Reducing the moisture content of this food product below 10% may be imperative for storability to inhibit microbial proliferation (Roji *et al.,* 2023). Excess water in a food product can cause an increase in the rate of microbial growth, which can not only spoil a product before it reaches the shelves but could also decrease the length of time it can stay fresh for. Moisture content has a lot to do with a food product’s characteristics, including its physical appearance (shape, color, etc.), texture, taste, weight (which can impact the cost) in addition to factors that affect the product’s shelf-life, freshness, quality, and resistance to bacterial contamination (Li *et al.,* 2021). The reduced moisture level reduces the growth of spoilage organisms, particularly mold, thereby enhancing the product's shelf stability (Ezeokeke and Onuoha, 2016). The moisture content of 16 samples was analyzed to develop a mathematical model and statistical data, but the model was not significant.

Protein Content

The results of the protein content were shown in Table 4.1.

The protein content ranged from the lowest value of 7.58 to the highest value of 10.26% while the control (Semovita Flour sample) was 9.57%. Sample 15 (7.58%) had the lowest protein content while sample 5 (10.26%) had the highest protein content. There were no significant difference (P-value > 0.05) among the mean values of samples 12 and 16. There were no significant different (P-value > 0.05) among the mean values of sample 2, 3 and 15; sample 6 and 10; sample 8 and 9; sample 12, 14 and 16.

The result obtained was also similar with protein value of 12.10% of proximate composition of blends of maize, cassava, and soybean composite in the ratio of 70% maize flour, 25% cassava flour and 5% soy flour reported by Igbua et al. (2018). Another similar report but on the blends of 68% of matured unripe plantain, 23% soy cake, and 9% wheat bran yielded protein content of 12.80% according to Adedamola *et al. (*2023). The values were below the Nigerian Industrial Standards (NIS 121:2010) minimum protein content requirement of 11.5% for wheat flour. Whereas African Standard CD-ARS 841: 2014 for composite flour did not specify the minimum and maximum required limits for protein content. The components of the mixture for protein content displayed certain values that were below, within, and above those of the control sample. The World Health Organization/Food and Agriculture Organization recommends that complementary foods contain at least 15% protein daily (WHO/ FAO 2004). The protein content ranged from 7.58% to 10.26%, which is low compared to the 12.80% in a blend of 68% unripe plantain, 23% soy cake, and 9% wheat bran for diabetic meals. The low protein content observed in the study may be an indication of Millard reaction, which results in carbohydrates and protein (Ibukum *et al.*, 2012; Wiriya *et al.*, 2009). It could also be due to drying under elevated temperatures. When exposed to atmospheric oxygen, proteins in tissues undergo reactions that result in intermediates which render the amino group of amino acids non-bio-available (Udo *et al.*, 2021).

Protein-rich ingredients, including flour, concentrates, and isolates, have been incorporated into diverse food systems to improve their nutritional profile and functionality. This enhancement contrasts with products made solely from a single raw material (Jideani, 2011). The increase in protein content may be due to lowering the quantities of cassava fiber, maize flour but increasing that of plantain flour. While decreased in protein content may be due to increasing the quantities of cassava fiber, maize flour and lowering the quantities of plantain flour.

From table 4.3 the ANOVA and coefficient of the terms for parameters that have significant P-values and model. A quartic model was proposed for protein content, demonstrating an insignificant lack of fit with an F-value of 0.28. The model exhibited an Adjusted R^2 of 0.6664 (66.64%) and a coefficient of variation (CV) of 4.67. The probability of the F-value Quartic model was significant (P = 0.0272) which makes protein content fit into the model. The regression equation for prediction was derived from protein content.

$$\text{Protein (Y)} = A + B + C + AB + AC + BC + A^2BC + AB^2C + ABC^2$$

$$\text{Protein} = 11.46A + 23.22B + 10.46 - 34.59AB - 10.51AC - 28.14BC + 208.42A^2BC + 5.49AB^2C - 13.96A$$
Eq. (4.1)

The mathematical model for protein content of the proximate composition of the samples as presented in equation (4.1) showed ‘Y’ is the protein content. The coefficient A, B, C are cassava fiber, maize flour, and plantain flour, respectively. According to equation (4.1), the addition of maize flour into the mixture resulted in the highest mean value, with a coefficient value of 23.22. Conversely, the addition of cassava fiber and plantain flour yielded the lowest mean values, with coefficient values of 11.46 and 10.46, respectively.

As illustrated in Figure 4.1, it was noted that when the values of X1, X2, and X3 shifted from 23.01, 56.99, and 20.00 to 19.22, 55.96, and 24.81 respectively, the protein content exhibited an increase from 7.58% to 10.26%. That showed that lowering the quantities of X1 and X2 but increasing that of X3 increased the protein content of the product.

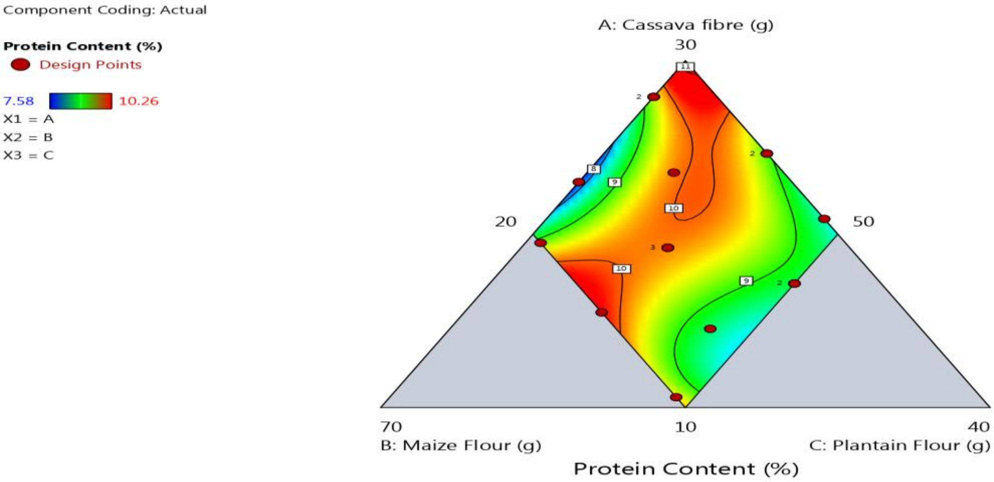

Figure 4.1 shows the contour for % crude protein content of the product.

Fat Content

The results of the fat content were shown in Table 4.1.

The fat content ranged from the lowest value of 2.70 to the highest value of 3.83% while the control (Semovita Flour sample) was 1.05%. Sample 6 (2.70%) had the lowest fat content while sample 15 (3.83%) had the highest fat content. Sample 14 and 16 had the same mean value. There were no significant different (P-value > 0.05) among the mean values of sample 1 and 13; sample 7 and 11; sample 9 and 10; sample 12, 14 and 16. The fat content conform to 3.1% requirement according to standard for whole maize (corn) meal of Food and Agriculture Organization of the United Nations and World Health Organization (FAO and WHO, 2023). The result obtained was similar with fat content value of 4.33% of proximate composition of blends of maize, cassava, and soybean composite in the ratio of 70% maize flour, 25% cassava flour and 5% soy flour reported by (Igbua et al 2018). Another similar report but on the blends of 68% of matured unripe plantain, 23% soy cake, and 9% wheat bran yielded fat content of 4.54% according to (Adedamola *et al.*, 2023).

The values obtained were higher compared to 1.0% maximum acceptable limit according to African Standard CD-ARS 841: 2014 for composite flour. While Nigerian Industrial Standards for wheat flour (NIS 121:2010) did not specify the minimum and maximum required limits for fat content. The mixture component fat contents were slightly higher than the control sample. The increased fat content may be due to the increase in maize or plantain flour.

Furthermore, the fat content results were lower compared to the 10–25% daily recommended fat content in supplemental foods (WHO/FAO 2004). Fat content refers to the amount of fat present in a food or substance, often expressed as a percentage or grams per serving. Fats are recognized for their ability to enhance the sensory qualities of food items; however, a high fat content can make food more susceptible to rancidity, potentially diminishing its shelf life (Omah *et al.,* 2017).

Table 4.3 suggests the ANOVA cubic model. The cubic model for fat content showed insignificant lack of fit F-value of 53.36, with Adjusted R^2 of 0.7953 (79.53%), and coefficient value (CV) of 4.33. The probability of the F-value cubic model was significant (P = 0.0118) which makes fat content fit into the model. The regression equation was derived from the fat content.

Fat (Y) = A + B + C + AB + AC + BC + ABC + AB(A-B) + AC(A-C) + BC(B-C)

$$\text{Fat} = 6.84A - 107.62B + 174.18C + 209.30AB - 341.84AC - 111.81BC + 129.81ABC - 154.92AB(A-B) + 201.77AC(A-C) + 369.12BC(B-C) \quad \text{Eq. (4.2)}$$

The mathematical model for fat content of the proximate composition of the samples as presented in equation (4.2) showed 'Y' is the fat content. The coefficient A, B, C are cassava fiber, maize flour, and plantain flour, respectively. A variable with a negative coefficient shows an antagonistic relationship with the response variables. According to Eq. (4.2), maize flour (B) has a negative coefficient (-107.62), which indicates that increase in the amount of maize flour in the mixture component decreases the fat content, whereas an increase in plantain flour and cassava fiber leads to an increase in the product's fat content. Plantain flour significantly increases fat content more than cassava fiber, with a coefficient value of 174.18 compared to 6.84.

Figure 4.2 shows that as X1, X2, and X3 changed from 20.88g, 50.00g, and 29.11g to 23.01g, 56.98g, and 20.00g, the fat content increased from 2.7% to 3.83%. That showed that lowering the quantities of X3 but increasing those of X1 and X2 increased the fat content of the product.

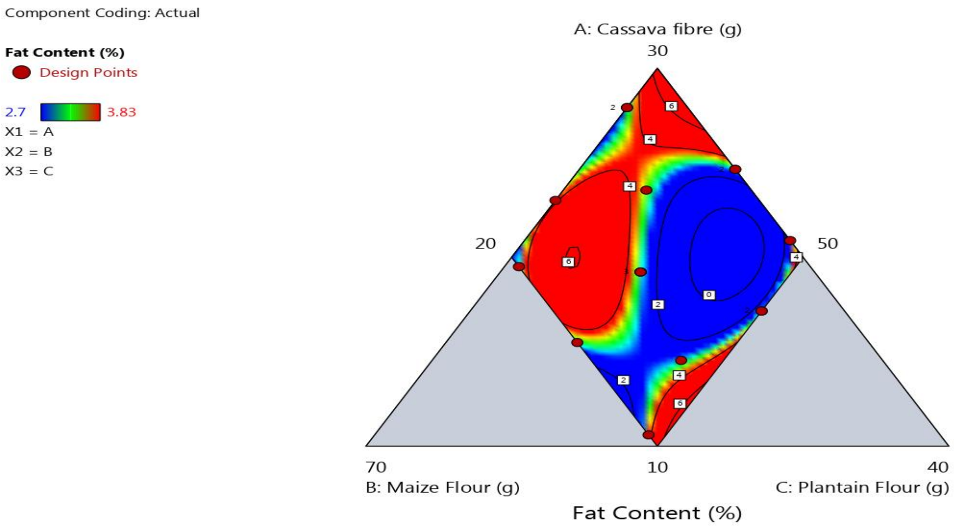

Figure 4.2 shows the contour for % crude fat content of the product.

Crude Fiber Content

The results of the crude fiber content were shown in Table 4.1.

The fiber content ranges from the lowest value of 3.43 to the highest value of 5.67% while the control (Semovita Flour sample) fiber content was 4.09%. Sample 13 (3.43%) had the lowest fiber content while sample 1 (5.67%) had the highest fiber content. Sample 4 and 6 had the same mean value. There were no significant different (P-value > 0.05) among the mean values of sample 1 and 9; sample 2.7 and 11; sample 14 and 16; sample 4, 6. 8. 10 and 15. The following fiber contents results were within African Standard CD-ARS 841: 2014 requirements of 5.0% maximum acceptable limit like 3.43%, 4.75%, 4.85%, 4.87% and 4.9% respectively while the rest where higher than the standard. The results obtained were like report on the blends of 68% of matured unripe plantain, 23% soy cake, and 9% wheat bran yielded fiber content of 3.8% according to (Adedamola *et al.*, 2023). The crude fiber content results obtained were like 4.47 to 5.26% of proximate composition of Ichi pipi composite flour formulated at five different ratios as reported by Mpili et al. (2024). But deviated with report of fiber content value of 1.0% proximate composition of blends of maize, cassava, and soybean composite in the ratio of 70% maize flour, 25% cassava flour and 5% soy flour according to (Igbua et al 2018). While Nigerian Industrial Standards for wheat flour (NIS 121:2010) did not specify the minimum and maximum required limits for fiber content. The same thing applicable to standard for whole maize (corn) meal of Food and Agriculture Organization of the United Nations and World Health Organization (FAO and WHO, 2023). The decrease in fiber content may be due to the reduction of maize flour and cassava fiber of the mixture component. While the increase in fiber content may be due to the increase in maize flour, cassava fiber and plantain flour.

Crude fiber denotes the content of the non-digestible components of food, such as lignin, cellulose, and hemicelluloses (Omokpariola *et al.*, 2021a). Foods high in dietary fiber has been related to lower rates of obesity, hemorrhoids, and high blood pressure (Jaja and Yarhere, 2015). Fiber is needed to assist in digestion and keep gastrointestinal tract health. It adds bulk to the stomach and can also keep blood sugar stable and reduces constipation. Dietary fiber may help reduce high cholesterol and regulate blood sugar levels, thus lowering your risk of heart disease and type-2 diabetes (Synder and Kwon, 2012).

The fiber content could not model because the ANOVA model was not significant. The **Model F-value** of 2.26 implied that the model was not significant.

Ash Content

The results of the ash content were shown in Table 4.1.

The ash content ranges from the lowest value of 3.27 to the highest value of 3.87% while the control (Semovita Flour sample) was 5.09%. Sample 4 (3.27%) had the lowest ash content while sample 5 (3.87%) had the highest ash content. Sample 3 and 5 had the same mean value with the highest ash content of 3.87%. Sample 4, 6, 8, and 10 had the same mean value with the lowest ash content of 3.27%. There were no significant different (P-value > 0.05) among the mean values of sample 1, 12, 14, and 16; sample 2 and 13; sample 9 and 15; sample 7 and 11.

The results obtained were within the range of 4.0% maximum acceptable limit according to African Standard CD-ARS 841: 2014 for composite flour. The results obtained were like the report on the blends of 68% of matured unripe plantain, 23% soy cake, and 9% wheat bran yielded ash content of 4.39% according to (Adedamola *et al.,* 2023). The results obtained in this research complied with the ash content of 4.39% in legume protein concentrate reported by (Yellavila *et al.,* 2015). But the Ash content was slightly higher compared to 3.0% maximum acceptable limit according to standard for whole maize (corn) meal of Food and Agriculture Organization of the United Nations and World Health Organization (FAO and WHO, 2023). Also deviated with report of 1.13% lowest to 2.81% highest ash content values of proximate composition of blends of maize, cassava and soybean composite in the ratio of 70% maize flour, 25% cassava flour and 5% soy flour and 70% maize flour, 10% cassava flour and 20% soy flour according to (Igbua et al 2018).

The results obtained deviated from Nigerian Industrial Standards for wheat flour (NIS 121:2010) with the maximum acceptable limit of 0.67% Ash content. The presence of ashes in food plays a significant role in assessing its nutritional properties, as ash typically has a stable elemental composition and serves as an indicator of the food's mineral content (Omah *et al.,* 2017). Minerals are essential and should be consumed properly.

The ash content of the mixture components was lower than that of the control sample, which measured 5.09%. The decrease in ash content may be because of substitution of cassava fiber to maize and plantain flour. The high ash content in the control sample comes from the minerals in wheat and maize. Ash content in food refers to the inorganic residue left after heating removes water and organic matter (Omokpariola et al., 2021a). The ash content results of this research project were within the acceptable range of 4.0% maximum limit according to African Standard CD-ARS 841: 2014 for composite flour.

Table 4.3 suggests using the ANOVA Quadratic model. The Quadratic model for ash content showed insignificant lack of fit F-value of 1.32, with Adjusted R^2 of 0.4558 (45.58%), and coefficient value (CV) of 4.67. The probability of the F-value Quadratic model was significant (P = 0.0430) which makes ash content fit into the model. The regression equation for prediction was derived based on the ash content.

Ash Content (Y) = A + B + C + AB + AC + BC

Ash Content = 3.57A + 2.67B + 0.5093C + 1.02AB + 4.08AC + 8.01BC Eq. (4.3)

The mathematical model for ash content of the proximate composition of the samples as presented in equation (4.3) showed ‘Y’ is the protein content. The coefficient A, B, C are cassava fiber, maize flour, and plantain flour, respectively. From equation 6 all the responses have positive integer: cassava fiber (A) has coefficient value of 3.57g, maize flour (B) has coefficient value of 2,67g and plantain flour (C) has coefficient value of 0.5093g respectively. This indicates that increase in cassava fiber, maize and plantain flour in the mixture increases the ash content of the product. Cassava fiber had the highest coefficient value followed by maize flour and plantain flour respectively, which showed that addition of cassava fiber contributed to the rise in ash content as well as maize and plantain flours sequentially.

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From figure 4.3, it was observed that changing the values of X1, X2, and X3 from 20.88, 50.00, and 29.11 to 15.49, 60, and 24.81 respectively, resulted in an increase of ash content from 3.27% to 3.83%. That showed that lowering the quantities of X1 and X3 but increasing that of X2 increased the ash content of the product.

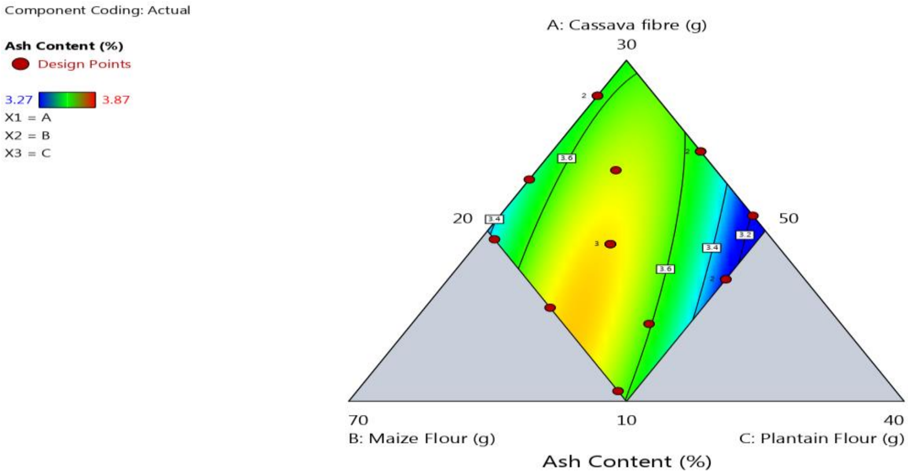

Figure 4.3 shows the contour for % Ash content of the product.

Carbohydrate Content

The results of the carbohydrate content were shown in Table 4.1.

The carbohydrate content ranged from the lowest value of 66.15 to the highest value of 69.53% while the control (Semovita Flour sample) was 73.08%. Sample 3 (66.15%) had the lowest carbohydrate content while sample 6 (69.53%) had the highest carbohydrate content. Sample 3 and 5 had the same mean value with the lowest carbohydrate content. There were no significant differences between (P-value > 0.05) among the sample 3, 5, 9, 12, and 14; sample 1 and 2; sample 11 and 13; sample 7, 8, and 10; sample 4, 6, and 15.

The results obtained were similar to report on the blends of 70% of matured unripe plantain, 25% soy cake, and 5% wheat bran yielded carbohydrate content of 71.76%, where 68% of matured unripe plantain, 23% soy cake, and 9% wheat bran yielded carbohydrate content of 67.97%, and 69% of matured unripe plantain, 24% soy cake, 7% wheat bran yielded carbohydrate content of 66.55% according to (Adedamola *et al.,* 2023). The results were also similar with report on the blends of maize, cassava and soybean composite in the ratio of 70% maize flour, 15% cassava flour and 15% soy flour yielded 63.40% carbohydrate. While 70% maize flour, 20% cassava flour and 10% soy flour yielded 66.24% carbohydrate and 70% maize flour, 25% cassava flour and 5% soy flour yielded 69.79% carbohydrate respectively according to (Igbua et al 2018). The results obtained were slightly lower compared to the higher carbohydrate values as reported in maize-soy flour blends of 67.11% - 84.31% (Ikya *et al.,* 2013). The results obtained were slightly lower in comparison to both the control sample and the findings reported by Ikya et al. (2013).

The standard for whole maize (corn) meal of Food and Agriculture Organization of the United Nations and World Health Organization (FAO and WHO, 2023) did not specify the standard requirements for carbohydrate content. The African Standard CD-ARS (841: 2014) for composite flour did not specify the standard requirements for carbohydrate content. The Nigerian Industrial Standards for wheat flour (NIS 121:2010) also did not specify the standard requirements for carbohydrate content.

Carbohydrates are one of the three main macronutrients found in the human diet, alongside protein and fat. These compounds consist of carbon, hydrogen, and oxygen atoms. Carbohydrates have a vital function in the human body. They serve as a source of energy, help regulate blood glucose and insulin levels, participate in the metabolism of cholesterol and triglycerides, and assist in fermentation processes. When consumed, the digestive system begins to convert carbohydrates into glucose, which serves as energy. Excess glucose in the blood is stored in the liver and muscle tissues for future energy use. Carbohydrates cover a range of substances, including sugars, fruits, vegetables, fibers, and legumes. Although there are various classifications of carbohydrates, a

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specific subset is particularly beneficial for human health (Bolla *et al.*, 2019). Excessive consumption of simple and refined carbohydrates can lead to health issues. These include cardiovascular issues, weight gain, and an elevated risk of type 2 diabetes. Carbohydrates are an essential source of energy, but too much of them can interfere with metabolism and have detrimental effects on health (Mikstas, 2024).

From table 4.3 the ANOVA Special Quartic model was suggested. The Special Quartic model for Carbohydrate content showed insignificant lack of fit F-value of 0.3794, with Adjusted R^2 of 0.7157 (71.57%), and coefficient value (CV) of 0.8876. The probability of the F-value Special Quartic model was significant (P = 0.0165) which makes carbohydrate content fit into the model. The regression equation for prediction was derived from the ash content.

Carbohydrate Content (Y) = $A + B + C + AB + AC + BC + A^2BC - AB^2C + ABC^2$

Carbohydrate Content = $63.99A + 55.12B + 62.19C + 36.13AB + 25.30AC + 30.95BC - 276.06A^2BC - 19.46AB^2C + 0.1284ABC^2$ Eq. (4.4)

The mathematical model for carbohydrate content of the proximate composition of the samples as presented in equation (4.4) showed 'Y' is the protein content. The coefficient A, B, C are cassava fiber, maize flour, and plantain flour, respectively. From the equation (4.4) cassava fiber (A) had the coefficient value of 63.99g, followed by plantain flour (C) with coefficient value of 62.19g and maize flour (B) with coefficient value of 55.12g respectively. This indicates that the increase in cassava fiber, plantain and maize flour in the mixture increases the carbohydrate content of the product. Cassava fiber had the highest coefficient value followed by plantain flour and maize flour respectively, which showed that addition of cassava fiber contributed to the rise in carbohydrate content as well as plantain and maize flour sequentially.

From figure 4.4 below, it was observed that when X1, X2, and X3 changed value from 19.22, 55.96 and 24.81 to 20.88, 50.00 and 29.11 respectively, the carbohydrate content increased from 66.30% to 69.53%. That showed that lowering the quantities of X2 but increasing that of X1 and X3 increased the carbohydrate content of the product.

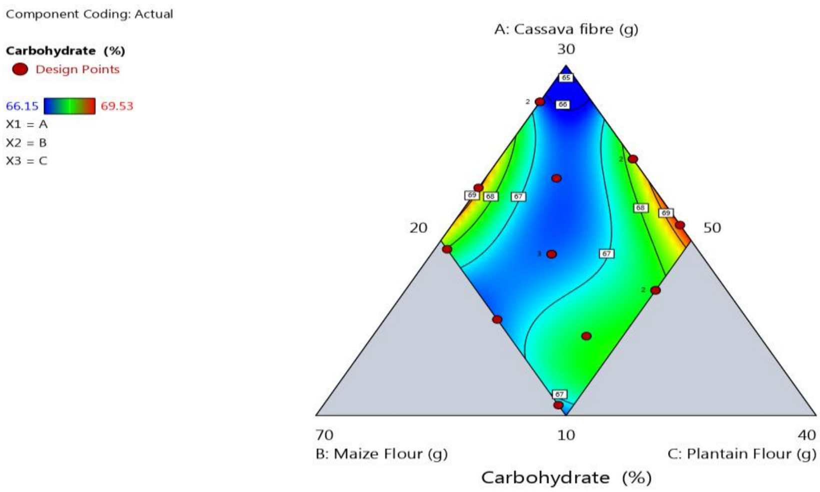

Figure 4.4 shows the contour for % Carbohydrate content of the product.

Table 4.1: Proximate Composition of the Samples

SAMPLE	Parameters of components CASSAVA MAIZE PLANTAIN FIBER (g) FLOUR (g) FLOUR (g)			MOISTURE (%)	PROTEIN (%)	FAT (%)	FIBER (%)	ASH (%)	CARBOHYDRATE (%)
1	19.2213	55.9654	24.8133	10.9 [g]±0.04	9.80 [b]±0.00	3.17 [cd]±0.01	5.6 [a] ±0.03	3.79 [bc]±0.03	66.74 [de]±0.13

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2	23.5529	53.6026	22.8445	10.92 ^{g}±0.11	10.09 ^{a}±0.10	3.23 ^{b}±0.03	5.23 ^{d}±0.01	3.68 ^{cd}±0.00	66.83 ^{de}±0.02
3	15.4908	60	24.5092	11.09 ^{f}±0.03	10.21^{a}±0.10	3.13 ^{de}±0.11	5.59 ^{ab}±0.19	3.87 ^{b}±0.02	66.15 ^{e}±0.11
4	24.6527	50	25.3473	11.15 ^{f}±0.01	8.46 ^{f}±0.10	2.91 ^{g}±0.03	4.85 ^{e}±0.03	3.27 ^{f}±0.02	69.37 ^{b}±0.09
5	19.2213	55.9654	24.8133	11.06 ^{fg}±0.07	10.26^{a}±0.00	3.20 ^{bc}±0.00	5.45 ^{bc}±0.05	3.87 ^{b}±0.04	66.15 ^{e}±0.18
6	20.8852	50	29.1148	11.39 ^{e}±0.02	8.46^{f}±0.10	2.70 ^{I}±0.02	4.85 ^{e}±0.01	3.27 ^{f}±0.39	69.53 ^{b}±0.11
7	14.5429	56.9107	28.5464	11.83 ^{d}±0.27	8.86^{e}±0.10	2.82 ^{h} ±0.01	5.17 ^{d}±0.04	3.32 ^{ef} ±0.00	67.99 ^{c}±0.16
8	19.5	60	20.5	12.19 ^{bc}±0.05	9.34^{d}±0.10	3.00 ^{f} ±0.05	4.75 ^{e}±0.01	3.31 ^{f}±0.01	68.08 ^{c}±1.25
9	27.9228	52.0772	20	12.20 ^{b}±0.02	9.34^{d}±0.10	2.96 ^{fg}±0.02	5.64 ^{a}±0.30	3.50 ^{de}±0.04	66.52 ^{e}±0.16
10	17.1579	52.8421	30	12.39 ^{a}±0.03	8.52^{f}±0.10	2.95 ^{fg}±0.04	4.87 ^{e}±0.04	3.27 ^{f}±0.03	68.00 ^{c}±0.21
11	17.1579	52.8421	30	12.45 ^{a}±0.01	8.81^{e}±0.10	2.83 ^{h}±0.01	5.19 ^{d} ±0.01	3.33 ^{ef}±0.01	67.47 ^{cd}±0.04
12	27.9228	52.0772	20	12.08 ^{bc}±0.19	9.57^{c}±0.10	3.08 ^{e}±0.04	5.31 ^{cd}±0.04	3.70 ^{bc}±0.04	66.30 ^{e}±0.11
13	24.6527	50	25.3473	12.01 ^{c}±0.11	9.74^{b}±0.10	3.15 ^{cd}±0.01	3.43 ^{f}±0.02	3.67 ^{cd}±0.02	67.46 ^{cd}±0.91
14	19.2213	55.9654	24.8133	12.12 ^{bc}±0.04	9.51^{c}±0.10	3.07 ^{e}±0.01	5.31 ^{cd}±0.01	3.69 ^{bc}±0.02	66.30 ^{e}±0.15
15	23.0109	56.9891	20	11.43 ^{e}±0.06	7.58^{g} ±0.10	3.83 ^{a}±0.01	4.91 ^{e}±0.02	3.50 ^{de}±0.02	68.95 ^{b}±0.26
16	10.6	60	29.4	11.69 ^{d}±0.02	9.57^{c}±0.10	3.07 ^{e}±0.01	5.29 ^{cd}±0.02	3.69 ^{bc}±0.03	66.70 ^{e}±0.05
17	Control (Semolina Flour Sample)			10.13 ^{h}±0.26	9.57^{c}±0.10	1.05 ^{k}±0.07	4.09 ^{ef}±0.20	5.09 ^{a}±0.10	73.08 ^{a}±0.3

The data are means ± standard deviations values of triplicate determinations. Means in the columns bearing different superscript differed significantly ($p < 0.05$).

Sensory Evaluation Results and Discussion

Colour

The sensory scores for the colour of the samples were shown in Table 4.3

The sensory scores for colour for the 16 samples ranged from 5.30 to 6.80 while the control (Semovita Flour sample) was 6.60. There was no significant difference in the colour of the 16 samples ($p > 0.05$). That means the colour of the sample ranged neither like nor dislike to like moderately.

The results obtained were similar with the report of Ezegbe et al (2024) on sensory evaluation of pasta produced with wheat semolina flour and African yam bean flour blends in different ratios where the score for colour ranged from 6.60 to 8.30. The results obtained were also similar with the report of Udofia et al (2014) on Sensory evaluation of wheat -cassava soybean composite flour (WCS) bread by the mixture experiment design in different ratios where the score for colour ranged from 2.07 to 9.16. The result was lower than Igbua et al. (2018), where the colour score of maize, cassava, and soybean blends ranged from 7.00 to 7.80. The colour of the product plays a significant role as a sensory characteristic that can improve its acceptability. The colour of the prepared dough was light brown. The brown colour is attributed to the presence of nutrients, especially iron, within the product. Plantains are believed to possess significant iron content. The browning of dough could be because of Maillard browning reactions that occurred during cooking, influenced by the presence of amino acids, reducing sugars, temperature, cooking duration, and moisture levels in the prepared dough (Deny, 2013). This finding may be linked to the elevated levels of amino acids in maize flour and the high iron content in plantain flour.

Texture

The sensory scores for texture of the samples are shown in Table 4.3

The sensory scores for texture for the 16 samples ranged from 4.90 to 8.10 while the control sample was 6.80. There was no significant difference in the texture of the 16 samples ($p > 0.05$). Which implies that the sample ranged dislike slightly to like very much.

The results obtained were similar with the report of Ezegbe et al (2024) on sensory evaluation of pasta produced with wheat semolina flour and African yam bean flour blends in different ratios where the score for texture ranged from 6.83 to 8.37. The results were also similar with the report of Udofia et al (2014) on Sensory evaluation of wheat -cassava soybean composite flour (WCS) bread by the mixture experiment design in different ratios where the score for texture ranged from 2.00 to 8.90. Again, the result obtained was similar with the work of Igbua et al (2018) on sensory evaluation of composition of blends of maize, cassava, and soybean composite in different ratios where the score for texture ranged from 5.60 to 8.00. Food texture can occasionally encompass its visual aspects (Eduordo et al. 2013). High supplementation reduces elastic property of the composite flour dough rendering the dough incapable of retaining the gas emanating from fermentations (Giami *et al.*, 2004).

Taste

The sensory scores for taste of the samples are shown in Table 4.3

The sensory scores for taste for the 16 samples ranged from 4.20 to 5.60 while the control sample was 6.40. There was no significant difference in the texture of the 16 samples ($p > 0.05$). That means that the sample ranged dislike slightly to neither like nor dislike.

The results obtained deviated with the report of Ezegbe et al (2024) on sensory evaluation of pasta produced with wheat semolina flour and African yam bean flour blends in different ratios where the score for taste ranged from 6.40 to 8.20. The results obtained were similar with the report of Udofia et al (2014) on Sensory evaluation of wheat -cassava soybean composite flour (WCS) bread by the mixture experiment design in different ratios where the score for taste ranged from 2.56 to 8.79. While the result obtained was compared with the report of Igbua et al (2018) on sensory evaluation of composition of blends of maize, cassava, and soybean composite in different ratios where the score for taste ranged from 6.40 to 7.60. Taste is an important sensory attribute of any food. Intake of food is often enhanced by taste (Sim and Tam, 2001).

One of the sensory characteristics of cassava flour according to Nigerian Industrial Standards (NIS 344: 2020) is that the product must be tasteless. According to Dendy (2013) Soybean flour has beany flavour and poor aroma, addition of high proportions of the flour in the composite flour may introduce objectionable characteristics which overwhelmed the traditional taste attribute of the pure wheat flour blend samples and affected the choice of their taste.

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The observation attributed to the taste of cassava fiber which may have overwhelmed the taste of the stiff dough, it may be attributed to the strangeness of the new novel product. Consumers' attitudes may tune to accepting the new novel product since it is food for the elderly and diabetes.

Flavour

The sensory scores for the flavour of the samples are shown in Table 4.3

The sensory scores for flavour for the 16 samples ranged from 4.65 to 6.05 while the control sample was 6.50. There was no significant difference in the flavour of the 16 samples ($p > 0.05$). Which implies that the sample ranged dislike slightly to like slightly.

The results obtained deviated with the report of Ezegbe et al (2024) on sensory evaluation of pasta produced with wheat semolina flour and African yam bean flour blends in different ratios where the score for flavour ranged from 6.50 to 8.00. The results obtained were similar with the report of Udofia et al (2014) on Sensory evaluation of wheat -cassava soybean composite flour (WCS) bread by the mixture experiment design in different ratios where the score for flavour ranged from 2.95 to 5.61. Also, the result obtained was similar with the work of Igbua et al (2018) on sensory evaluation of composition of blends of maize, cassava, and soybean composite in different ratios where the score for flavour ranged from 5.70 to 8.10.

Flavour is an essential parameter of food. In fact, good aroma from food attracts the taste buds, getting the system ready to accept the food product. Whereas poor flavour may cause outright rejection of food before tasted (Iwe, 2002).

General Acceptability

The sensory scores for general acceptability of the samples are shown in Table 4.3

The sensory scores for general acceptability for the 16 samples ranged from 5.00 to 6.06 while the control sample was 6.58. There was no significant difference in the general acceptability of the 16 samples ($p > 0.05$). Which implies that the sample ranged neither like nor dislike to like slightly.

The results obtained agreed with similar report of Ezegbe et al (2024) on sensory evaluation of pasta produced with wheat semolina flour and African yam bean flour blends in different ratios where the score for general acceptability ranged from 5.93 to 8.30. And with similar report of Udofia et al (2014) on Sensory evaluation of wheat -cassava soybean composite flour (WCS) bread by the mixture experiment design in different ratios where the score for general acceptability ranged from 2.29 to 9.19. But deviated with the report of Igbua et al (2018) on sensory evaluation of composition of blends of maize, cassava, and soybean composite in different ratios where the score for general acceptability ranged from 6.50 to 8.30.

Both acceptance and preference are fundamentally economic concepts. The acceptance of food differs based on living standards and cultural backgrounds, while preference relates to the choices made when options are available (Elemuo, 2022). Preferences are shaped by biases, religious beliefs, social conformity, perceived status, and snobbery, in addition to the food's quality. Individuals have preferences, even if they seem irrational. As a result, these factors are challenging to assess during new product development (Sim and Tam, 2001). However, all samples were acceptable by the panelists.

Table 4.2: Sensory Scores of the Prepared Stiff Dough Samples

SAMPLE	Parameters of components CASSAVA MAIZE PLANTAIN FIBER (g) FLOUR (g) FLOUR (g)			COLOUR	TEXTURE	TASTE	FLAVOUR	GENERAL ACCEPTABILITY
1	19.2213	55.9654	24.8133	$6.80^{a}\pm1.36$	$6.30^{ab}\pm2.18$	$5.50^{bc}\pm1.54$	$5.65^{bc}\pm1.76$	$6.06^{b}\pm0.28$

2	23.5529	53.6026	22.8445	6.15 ^{abc}±1.53	5.55 ^{ab}±1.73	5.10 ^{bc}±1.59	5.45 ^{bc}±1.39	5.56 ^{fg}±0.14
3	15.4908	60	24.5092	5.70 ^{abc}±1.78	5.25 ^{ab}±1.16	4.75 ^{bc}±1.83	5.45 ^{bc}±1.61	5.28 ^{j}±0.14
4	24.6527	50	25.3473	6.10 ^{abc}±1.74	6.15 ^{ab}±2.08	4.65 ^{bc}±2.37	5.55 ^{bc}±1.70	5.61 ^{ef}±0.14
5	19.2213	55.9654	24.8133	5.60 ^{abc}±1.43	4.95 ^{b}±1.70	4.35 ^{bc}±1.81	4.80 ^{bc}±1.88	5.00 ^{k}±0.07
6	20.8852	50	29.1148	6.15 ^{abc}±1.50	4.90 ^{b}±1.68	5.30 ^{bc}±1.84	5.30 ^{bc}±1.69	5.42 ^{h}±0.14
7	14.5429	56.9107	28.5464	5.50 ^{bc}±1.70	5.05 ^{b}±1.96	4.35 ^{bc}±1.80	5.10^{bc} ±1.92	5.15 ^{j}±0.71
8	19.5	60	20.5	6.20 ^{abc}±1.73	6.10 ^{ab}±2.17	4.95 ^{bc}±1.76	5.50 ^{bc}±2.04	5.68 ^{e}±0.28
9	27.9228	52.0772	20	6.00 ^{abc}±1.69	6.65 ^{ab}±1.18	5.60 ^{b}±1.64	5.55 ^{bc}±1.47	5.93 ^{c}±0.07
10	17.1579	52.8421	30	5.75 ^{abc}±1.25	8.10 ^{a}±1.40	4.20 ^{c}±1.91	5.25 ^{bc}±1.92	5.81 ^{d}±0.07
11	17.1579	52.8421	30	6.20 ^{abc}±1.64	6.10 ^{ab}±1.83	5.10 ^{bc}±1.65	5.20 ^{bc}±1.85	5.63 ^{ef}±0.21
12	27.9228	52.0772	20	5.80 ^{abc}±1.61	6.00 ^{ab}±1.34	5.00^{bc} ±1.75	5.25 ^{bc}±1.29	5.56 ^{fg}±0.92
13	24.6527	50	25.3473	5.75 ^{abc}±1.80	6.45 ^{ab}±1.67	5.2^{bc}±1.74	5.80 ^{bc}±1.40	5.83 ^{cd}±0.07
14	19.2213	55.9654	24.8133	5.45 ^{bc}±1.70	5.15 ^{b}±1.69	4.70 ^{bc}±1.46	4.65 ^{c}±1.65	5.10 ^{j}±1.48
15	23.0109	56.9891	20	6.60 ^{ab}±1.96	5.95 ^{ab}±1.85	5.45 ^{bc}±1.82	6.05 ^{b}±2.09	5.83 ^{cd}±0.07
16	10.6	60	29.4	5.30 ^{c}±2.13	5.90 ^{ab}±2.27	5.45 ^{bc}±1.47	5.39 ^{bc}±1.73	5.50 ^{gh}±0.07
17	Control (Semolina Flour Sample)			6.60 ^{ab}±1.70	6.80 ^{ab}±1.50	6.40 ^{a}±1.71	6.50 ^{a}±1.20	6.58 ^{a}±0.28

The data are means ± standard deviations values of triplicate determinations. Means in the columns bearing different superscript differed significantly ($p < 0.05$)

Table 4.3 Summary of ANOVA and Coefficient of the terms for Parameters that have significant P – values and model in Table 4.1

Model	**Parameters Protein content**	**Fat content**	**Ash content**	**Carbohydrate content**
ANOVA Model	Quartic	Cubic	Quadratic	Special Quartic
Model F-value	4.74	7.48	3.51	5.72

P-value < 0.05 (Significant)	0.0272	0.0118	0.0430	0.0165
A – Cassava fiber (g)	11.46	6.84	3.57	63.99
B – Maize flour (g)	23.22	-107.62	2.67	55.12
C – Plantain flour (g)	10.46	174.18	0.5093	62.19
AB	-34.59AB	209.30AB	1.02AB	36.13AB
AC	-10.51AC	-341.84AC	4.08AC	25.30AC
BC	-28.14BC	-111.81BC	8.01BC	30.95BC
ABC		129.81ABC		
A^2BC	$208.42A^2BC$			$-276.06A^2BC$
AB^2C	$5.49AB^2C$			$-19.46AB^2C$
ABC^2	$-13.96ABC^2$			$0.1284ABC^2$
AB(A-B)		-154.92AB(A-B)		
AC(A-C)		201.77AC(A-C)		
BC(B-C)		369.12BC(B-C)		
Lack of fit F-value (not significant)	0.28	53.36	1.32	0.3794
Adjusted R^2	0.6664	0.7953	0.4558	0.7157
% Coefficient value (CV)	4.67	4.33	4.67	0.8876

Model is adequate when $p < 0.05$, Adjusted R^2 ($\geq 60\%$), Lack of fit F-value (not significant) and % Coefficient value (CV) low

Optimization

Optimization of Protein, Fat, Ash, and Carbohydrate Content

The optimized values of protein, fat, ash, and carbohydrates are shown in Table 4.4. The optimization was based on significant regression models ($P < 0.05$), high Adj-R^2 values and non-significant lack of fits. A non-significant lack of fit is a good indicator of response and should be used for prediction but reported that if a model has a significant lack of fit ($P<0.05$), it is not a good indicator of the response and should not be used for prediction (Anand *et al.,* 2017).

Note: during optimization of protein content, fat content, ash content and carbohydrate content; Ash content was maximized because it indicated the presence of mineral elements which may be needed for the elderly and diabetic patients (Omah *et al.,* 2017). The protein content was also maximized due to protein is needed to enhance new novel product nutritional value and functionality (Jideani, 2011). The importance of minerals and proteins cannot be overemphasized and thus should be consumed appropriately. While the fat content was minimized due to high fat content which can make food more susceptible to rancidity, potentially diminished its shelf life (Omah *et al.,* 2017). Whereas carbohydrate content was minimized due to the new novel product does not need high carbohydrate content considering the elderly and diabetic patients. All other parameters like moisture, fiber and sensory were not used for optimization because the ANOVA model were not significant. Consuming too many carbohydrates, especially from simple and refined sources, can cause a number of health problems. These include cardiovascular issues, weight gain, and an elevated risk of type 2 diabetes. Carbohydrates are an essential source of energy, but too much of them can interfere with metabolism and have detrimental effects on health (Mikstas, 2024).

From table 4.4 below the numerical optimization of the mixture component showed that 15.006% cassava fiber, 60% maize and 24.9994% plantain flours gave the best novel product with 10.19% protein content, 2.69% fat content, 3.73% ash content, and 66.61% carbohydrate with overall desirability function of 0.901 (90.10%). Therefore, the optimized composite four obtained from this finding will be used to manufacture nutrient-rich flour products intended for preparation of meal. A similar desirability value (0.91) was reported by Elsabet and Ramesh (2022) for overall optimization of complementary food made with oat (40 g), chickpea (25.81 g), yellow maize (13.78 g), avocado powder (10.4 g), and Jaggery (10 g). The desirability obtained was higher compared to that of Ibrahim et al. (2024) with optimum desirable blending ratios for nutritional and functional properties of 47.46% finger millets, 34.54% of OFSP, and 17.99% of soybean four with a desirability of 0.58.

Table 4.3 showed that the model fitted for the optimized parameters. Figure 4.5 illustrated the numerical optimization plots, while the overlay plot resulted from the optimization was displayed in figure 4.6, while figure 4.7 showed the desirability plot of the component mixture.

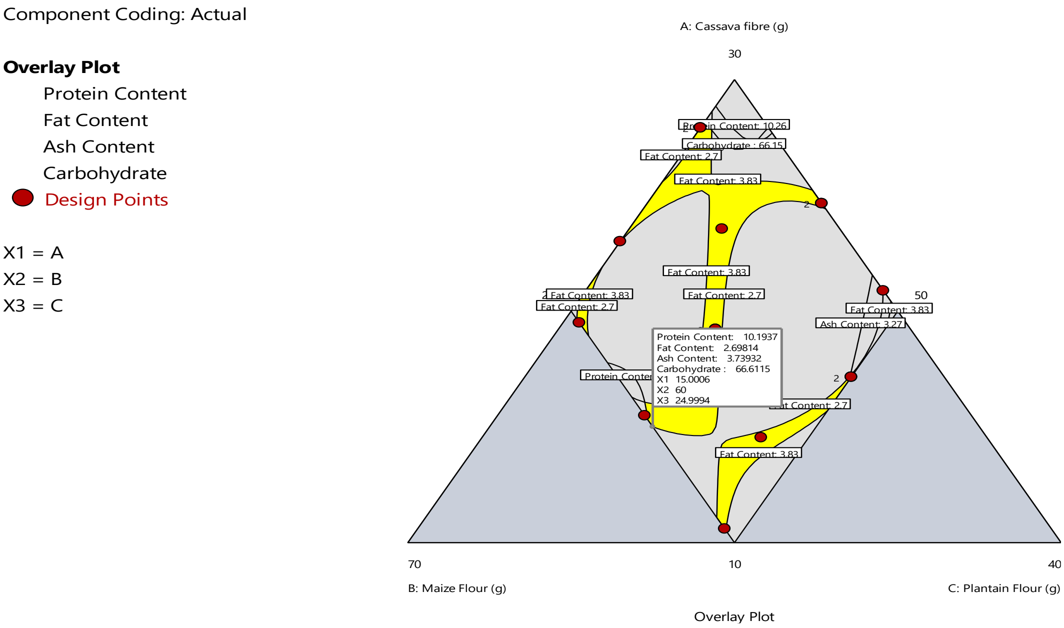

Figure 4.6 showed the overlay plot of the component mixture.

Graphical optimization of the response and the optimum levels of the variables X1, X2, and X3 represent cassava seviet, maize and plantain flour, respectively.

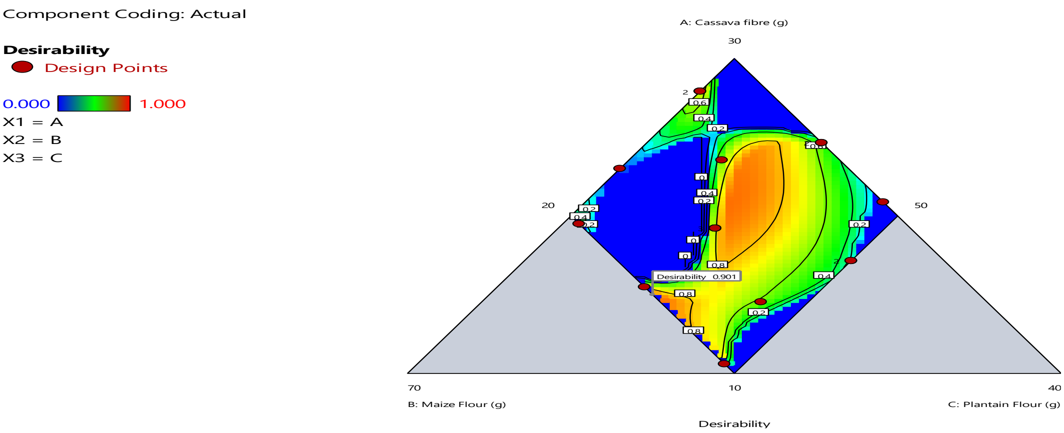

Figure 4.7 showed the Optimization graph of the component mixture.

Graphical optimization of the response and the optimum levels of the variables X1, X2, and X3 represent cassava seviet, maize and plantain flour, respectively.

Table 4.4: Optimized Values of the mixture components

Components	**Optimized Mixture Component (G)**	**Protein Content (%)**	**Fat Content (%)**	**Ash Content (%)**	**Carbohydrate Content (%)**	**Desirability (%)**
Cassava Fiber	15.006	10.1928	2.69999	3.73936	66.6121	0.901
Maize Flour	60					
Plantain Flour	24.9994					90.1

CONCLUSION

This study demonstrated the economic and industrial usefulness of cassava fiber (Seviet) mixed with maize and plantain flour in the production of high-quality novel nutritional food products for elderly and diabetics. This study addressed the limited use of plantain in the preparation of cooked dough by adding cassava fiber and maize flour to improve its mouldability, such as fufu and semovita. The texture has the highest score of 8.10 at the ratio of 17.1579g cassava fiber, 52.8421g maize flour and 30g plantain flour respectively which improved the mouldability of the novel product. The result obtained was similar with the work of Igbua et al (2018) on sensory evaluation of composition of blends of maize, cassava, and soybean composite in different ratios where the score for texture ranged from 5.60 to 8.00.

Protein, fat, ash, and carbohydrate were selected for optimization.

Optimized mixture ratio was 15.006 g cassava fiber, 60 g maize flour and 24.9994 g plantain flour where protein and ash contents were maximized whereas fat and carbohydrate contents were minimized and possessed the best nutrients of interest for the elderly and diabetic persons with 90.1% desirability, 10.1928% protein, 3.73936 ash, 66.6121% carbohydrate and 2.69999% fat content respectively. Ash content increased because it indicated the presence of mineral elements which might be needed for the elderly and diabetic patients (Omah *et al.*, 2017). The protein content was also maximized due to protein is needed to enhance new novel product nutritional value and functionality (Jideani, 2011). While the fat content was minimized due to high fat content which can make food more susceptible to rancidity, potentially diminished its shelf life (Omah *et al.*, 2017). Carbohydrate was reduced because they are an essential source of energy, but too much of them can interfere with metabolism and have detrimental effects on health (Mikstas, 2024). A similar desirability value (0.91) was reported by Elsabet and Ramesh (2022) for overall optimization of complementary food made with oat (40 g), chickpea (25.81 g), yellow maize (13.78 g), avocado powder (10.4 g), and Jaggery (10 g).

RECOMMENDATION

Global Food Safety Initiatives (GFSI) which Food Safety System Certification 22000 (FSSC: 22000) version 6 Part 2 additional requirements for control of food loss and waste in all food chain categories is recommended to cassava starch, flour, glucose and sorbitol factories in Nigeria to minimize food wastage.

The area of improvement should be on further reduction of the moisture content of the composite flour to (< 10%) as recommendation by FAO and WHO (2004) for complementary food products meant for dough meal. Also get a significant P – value less than 0.05 for fiber content and obtain the optimize ratio for fiber content of this composite flour.

Future researchers should try to employ solar drying technics for drying fiber, and sliced plantain to reduce drying time as well minimize contamination.

The operating procedures used in the research work may serve as a guide to food regulatory bodies in developing applicable standards for this very product or related food products without any negative impact on food safety.

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