**Effect of Optimization on the Composition and Functional properties of Legume-based Stiff Dough Blends**


## Abstract

This study investigated the effect of optimization of process techniques for the production of bambara groundnut flour and optimization of ingredient formulation for legume-based stiff dough, with an aim to improve nutritional composition and functional properties, while retaining its traditional appeal. The legume-based stiff dough comprised of fermented Bambara groundnut flour and three existing stiff dough staples (eba, pounded yam and fufu). The Bambara groundnut, yam and cassava tubers were processed into flour and mixed into different proportions of ratio 90:10, 80:20, 70:30, 60:40 and 100 was used as control. Sensory properties were evaluated to determine most acceptable blend. Most acceptable blend (70% fermented Bambara groundnut flour inclusion) was evaluated for proximate composition (moisture, protein, crude fat, crude fiber, ash and carbohydrate); and functional properties. All data obtained were subjected to appropriate statistical analysis. The functional properties were significantly influenced by the interactions of proteins, carbohydrates, and starch, impacting water and oil absorption, emulsion formation, and gelation. The findings of this study have shown that blending 70% of fermented (48hours) bambara groundnut flour into 30% stiff dough (e.g., Eba) improved nutrient content up to 50% and enhanced functionality, offering valuable insights for food manufacturers and consumers seeking healthier and more sustainable food options.



Keywords: Stiff dough, Bambara groundnut, Proximate composition, Sensory evaluation, Functional properties.


## Introduction

Food optimization refers to the process of improving various aspects of food products to enhance their nutritional value, quality, taste, shelf life, production efficiency, and consumer acceptance. This process often involves adjusting ingredient ratios, processing methods, or formulations to achieve desired characteristics. Optimization of legume-based stiff dough offers a promising strategy to improve the health outcomes associated with staple foods in diverse populations. By addressing the need for functional foods that combine traditional dietary patterns with improved nutritional profiles, this research aligns with global health objectives, through dietary interventions (WHO, 2020).

Stiff dough is made by cooking and pounding starches like yam, cassava, plantain, or maize until they form a smooth, thick, and stretchy dough-like consistency e.g., eba, fufu, pounded yam etc. they are often called swallows. They are usually consumed with soups and ingested by swallowing. Stiff dough food is widely consumed for their energy-dense properties; however, they are often limited in protein and micronutrient density. Enhancing the nutritional quality presents an important opportunity to improve public health outcomes, especially in communities where malnutrition is prevalent (Brand-Miller *et al.*, 2003). One approach to improving nutrition content for stiff dough staples is through ingredient modification particularly by adding legumes (Messina, 2014). Legumes are nutritionally rich, offering high levels of protein, dietary fiber, and bioactive compounds (Messina, 2014). Inclusion of legumes addresses protein-energy malnutrition (which is prevalent in many low- and middle-income countries); improves metabolic markers and contribute to better health outcomes (Michaelsen *et al*., 2009; Gibson *et al*., 2011).

Bambara Groundnut (*Vigna subterranea* L.) is one of the indigenous underutilized legumes which originated from West Africa. It is a sustainable, low-cost source of plant-based protein, unsaturated fatty acids and essential minerals. Bambara groundnut has the potential to play a role in combating food insecurity and malnutrition. It is extremely drought resistant and can be grown under extreme climatic conditions; hence it is a promising crop against global climatic changes (Agbenorhevi *et al.,* 2007). Traditionally Bambara groundnuts are processed by boiling, roasting, crushing into flour to prepare some local dishes like “okpa”, “akara”, “kunu” (Linnemann, 1988).

Modifications in diet can exert both positive and negative effects, making the shift toward nutrient-rich foods with functional health benefits more essential (Aschemann-Witzel *et al*., 2020). This trend is largely driven by heightened health awareness and environmental concerns, leading to increased interest in plant-based diets. Developing reasonable nutrient-dense stiff dough by blending leguminous plants seeds have the potential to play a role in combating food insecurity and malnutrition. In this work, there was individual adjustment of the raw material which used to be only ‘eba’, pounded yam, or ‘fufu’ by blending them with fermented Bambara groundnut flour into various formulations at different ratios.

## Materials and Methods

### Materials

The materials: Bambara groundnut white (*Vigna subterranea* L.) seeds, freshly harvested cassava (*Manihot esculenta*) and yam tubers (*Dioscorea esculenta*), were purchased from Mushin market, Lagos, Nigeria.

### Methods

### Processing of Bambara groundnut

Method described by Olapade and Adetuyi (2007) was adopted with some modifications. The seeds were first thoroughly cleaned by picking out the stones, spoilt grains and foreign materials. The cleaned seeds were soaked in water (48 hours) at room temperature (28±3$^{o}$C). The seeds were steamed after fermentation for a period of 60 minutes and dried at 60$^{o}$C for 6 hours in a cabinet drier (Model LEEC F2). The dried seeds were then milled into flour using a hammer mill. The milled grain was sieved through a mesh sieve (60µm) to obtain the legume flour, which was then packaged in polyethylene bags.

**Processing of dried fufu**

Methods described by Oyewole and Sanni (1995) were employed. Cassava roots were peeled, washed, and cut into 4-5cm thick pieces and soaked in water and kept at room temperature (28±3°C) for 72 hours. The fermented cassava was mashed and sieved manually. The troughs were allowed to sediment for 24 hours before the mashes were load pressed in a synthetic sack. Mashes of wet fufu were dried in a cabinet drier (Model LEEC F2) at 65°C for 7 hours. Fufu flour was obtained by milling and sieving through a 60µm mesh and packaged.

**Processing of Garri**

Method described by Odunfa, 1998 was applied. Washed and peeled cassava tubers were grated into a mash, fermented (4 days; ambient temperature), dewatered by pressing (using hydraulic press), then roasted until dry and granular; cooled and packaged.



**Processing of yam tubers**

Instant pounded yam was processed using methods described by Akinwade *et al*., (2008). Wholesome yam tubers were washed properly to remove adhering sand. The washed tubers were peeled and sliced. The sliced yam was parboiled for 10minutes then dried using a cabinet drier. Dried yam chips were ground to flour, sieved to obtain uniform particle sizes and packaged.

**Product Formulation and Preparation**

Processed Bambara groundnut flour produced was blended at different ratios (60:40, 70:30, 80:20, and 90:10) with each of the existing stiff dough flour to obtain a legume-based formula. Preparation of legume-based stiff dough was done by stirring and kneading each legume-base formulation into boiling water.

**Sensory Evaluation**

Sensory evaluation was carried out according to methods described by Iwe, 2010. Twenty-man panel who are usual consumers of stiff dough were semi-trained as panelists. The stiff dough was rated for color, texture, taste, aroma and general acceptability. The scoring was based on a 9-point hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like) and 5 (neither like nor dislike). The values obtained were subjected to statistical analysis using ANOVA.

**Chemical Analysis**

Proximate composition analysis (crude protein, crude fiber, total ash, crude fiber, total carbohydrate, fat and moisture content) was carried out according to methods described by AOAC, 2010.

**Statistical analysis**

Statistical analysis was carried out using SPSS for windows, version 17.0 (SPSS Inc., Chicago, IL). Statistical significance was established using a one-way analysis of variance (ANOVA), and the data was reported as mean values ±standard deviation (SD). Means were separated using Duncan Multiple range test (DMRT). Significant difference was established at $p < 0.05$.

## Results

### Effect of Process optimization

Figure 1 is a combination of clustered column and line chart which presents the effect of processing (fermentation and steaming) on Bambara groundnut seeds. Tannin and protein content were used as benchmark for the quality of the processed legumes. The columns represent processing conditions while the lines represent tannin and protein content. It was observed that as fermentation progressed and with increase in steaming time, tannin decreased while protein increased. Increments in protein content peaked after 48hours fermentation, while the highest percentage loss in tannin content followed the same trend.



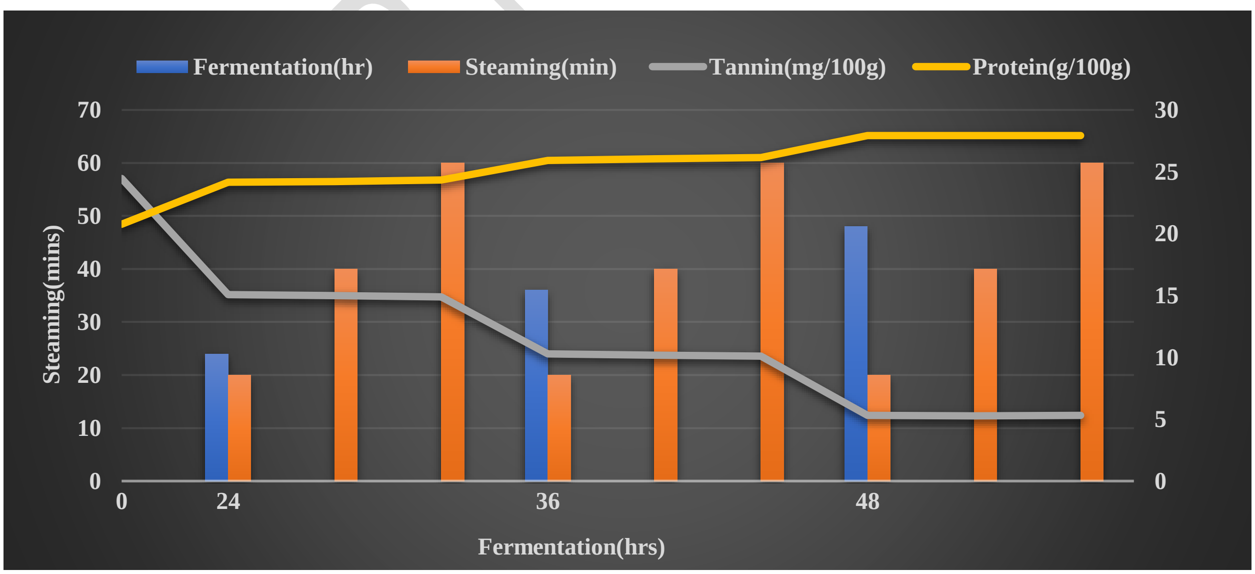



**Figure 1: Effect of Processing on the Tannin and Protein content of Bambara Groundnut**

**Sensory Evaluation of legume-based stiff dough blends**

Table I presents sensory evaluation of blends of Bambara groundnut-Eba (BGEB) stiff dough. The color ranged between 6.10 for BGEB90:10 and 8.70 for EB100. There were significant differences (p<0.05) in the color among samples, however, samples EB100 and BGEB60:40 was not significantly different (p<0.05). Texture was characterized by elasticity and moldability. The texture ranged between 6.10 for BGEB90:10 and 8.60 for EB100. Results indicated significant differences (p<0.05) among the samples. Sample BGEB70:30 was most preferred. The taste ranged between 8.30 for BGEB90:10 and 8.50 for EB100. Samples EB100, BGEB60:40 and BGEB70:30 was not significantly different (p<0.05). Samples BGEB80:20 and BGEB90:10 was also not significantly different (p<0.05) in taste. The aroma ranged between 8.10 for BGEB90:10 and 8.22 for EB100. Samples EB100, BGEB60:40 and BGEB70:30 was not significantly different (p<0.05). Samples BGEB80:20 and BGEB90:10 was also not significantly different (p<0.05). The overall acceptability ranged between 7.15 for BGEB90:10 and 8.57 for BGEB70:30. Results indicated significant differences (p<0.05) among the samples, however, samples EB100 and BGEB60:40 was not significantly different (p<0.05). Sample BGEB70:30 ranked highest in overall acceptability.

**Table I: Sensory evaluation of blends of Bambara groundnut-Eba stiff dough**

| **Blending Ratio** | **Sensory Attributes** | | | | |
|---|---|---|---|---|---|
| | **Color** | **Texture** | **Taste** | **Aroma** | **Overall Acceptability** |
| **EB 100** | $8.70^{a}\pm0.01$ | $8.60^{c}\pm0.01$ | $8.50^{a}\pm0.01$ | $8.20^{a}\pm0.01$ | $8.50^{b}\pm0.01$ |
| **BGEB (60:40)** | $8.68^{a}\pm0.01$ | $8.70^{b}\pm0.04$ | $8.48^{a}\pm0.04$ | $8.18^{a}\pm0.02$ | $8.51^{b}\pm0.01$ |
| **BGEB (70:30)** | $8.66^{ab}\pm0.01$ | $8.90^{a}\pm0.02$ | $8.48^{a}\pm0.02$ | $8.22^{a}\pm0.02$ | $8.57^{a}\pm0.06$ |
| **BGEB (80:20)** | $7.60^{c}\pm0.01$ | $7.70^{d}\pm0.02$ | $8.30^{b}\pm0.02$ | $8.10^{b}\pm0.01$ | $7.93^{c}\pm0.02$ |

| | | | | | |
|---|---|---|---|---|---|
| **BGEB (90:10)** | 6.10$^{d}$±0.01 | 6.10$^{e}$±0.02 | 8.30$^{b}$±0.01 | 8.10$^{b}$±0.02 | 7.15$^{d}$±0.02 |

Data=mean ±SD; n=20. Means within a column followed by different letters are significantly different $p<0.05$. Key: EB-Eba; BGEB – Bambara groundnut-Eba

Table II presents sensory evaluation of blends of Bambara groundnut-pounded yam (BGPY) stiff dough. The color ranged between 8.78 for BGPY90:10 and 8.80 for PY100. Samples PY100, BGPY60:40 and BGPY70:30 was not significantly different ($p<0.05$) but at higher concentrations of BGPY80:20 and BGPY90:10 slight significant difference ($p<0.05$) was observed, however, samples BGPY80:20 and BGPY90:10 was not significantly different ($p<0.05$). Texture ranged between 6.10 for BGPY90:10 and 8.90 for BGPY70:30. Results indicated significant differences ($p<0.05$) among the samples. Sample BGPY70:30 was most preferred. The taste ranged between 7.25 for BGPY90:10 and 8.65 for PY100. Results indicated significant differences ($p<0.05$) among samples. Samples PY100, was most accepted. The aroma ranged between 7.12 for BGPY90:10 and 8.40 for PY100. Results indicated significant differences ($p<0.05$) among samples. Sample PY100 was most preferred. The overall acceptability ranged between 7.31 for BGPY90:10 and 8.64 for PY100. Results indicated that samples PY100, BGPY60:40 and BGPY70:30 were not significantly different ($p<0.05$) but differed significantly with samples BGPY90:10 and BGPY80:20, however, samples BGPY90:10 and BGPY80:20 were not significantly different ($p<0.05$).



**Table II: Sensory evaluation of blends of Bambara groundnut-Pounded yam stiff dough**

| **Blending Ratio** | **Sensory Attributes** | | | | |
|---|---|---|---|---|---|
| | **Color** | **Texture** | **Taste** | **Aroma** | **Overall Acceptability** |
| **PY 100** | 8.80$^{a}$±0.01 | 8.70$^{c}$±0.02 | 8.65$^{a}$±0.02 | 8.40$^{a}$±0.01 | 8.64$^{a}$±0.02 |

| | | | | | |
|---|---|---|---|---|---|
| **BGPY (60:40)** | $8.80^{a}\pm0.01$ | $8.75^{b}\pm0.02$ | $8.60^{b}\pm0.01$ | $8.35^{b}\pm0.01$ | $8.63^{a}\pm0.03$ |
| **BGPY (70:30)** | $8.80^{a}\pm0.02$ | $8.90^{a}\pm0.00$ | $8.55^{c}\pm0.02$ | $8.25^{c}\pm0.02$ | $8.63^{a}\pm0.03$ |
| **BGPY (80:20)** | $8.78^{b}\pm0.02$ | $8.00^{d}\pm0.01$ | $7.32^{d}\pm0.01$ | $7.24^{d}\pm0.04$ | $7.84^{b}\pm0.02$ |
| **BGPY (90:10)** | $8.78^{b}\pm0.03$ | $6.10^{e}\pm0.01$ | $7.25^{e}\pm0.02$ | $7.12^{e}\pm0.02$ | $7.31^{c}\pm0.01$ |

Data=mean ±SD; n=20. Means within a column followed by different letters are significantly different p<0.05. Key: PY – Pounded yam; BGPY – Bambara-Pounded yam

Table III presents sensory evaluation of Bambara groundnut-fufu (BGFF) stiff dough blends. The color ranged between 6.25 for BGFF90:10 and 8.80 for FF100. Results indicated significant differences (p<0.05) among the samples. Texture ranged between 7.25 for BGFF90:10 and 8.36 for BGPY70:30. Results indicated significant differences (p<0.05) among the samples. Sample BGPY70:30 was most preferred. The taste ranged between 7.94 for BGPY90:10 and 8.20 for PY100. Results indicated significant differences (p<0.05) among samples, however, samples BGPY70:30 and PY100 were not significantly different. The aroma ranged between 7.92 for BGPY90:10 and 8.20 for PY100. Results indicated significant differences (p<0.05) among samples, however, samples BGPY70:30 and PY100 were not significantly different (p<0.05). Overall acceptability ranged between 7.34 for BGFF90:10 and 8.33 for FF100. Results indicated significant differences (p<0.05) among samples, however, samples BGFF70:30 and BGPY60:40 were not significantly different (p<0.05).

**Table III: Sensory evaluation of blends of Bambara-fufu stiff dough**

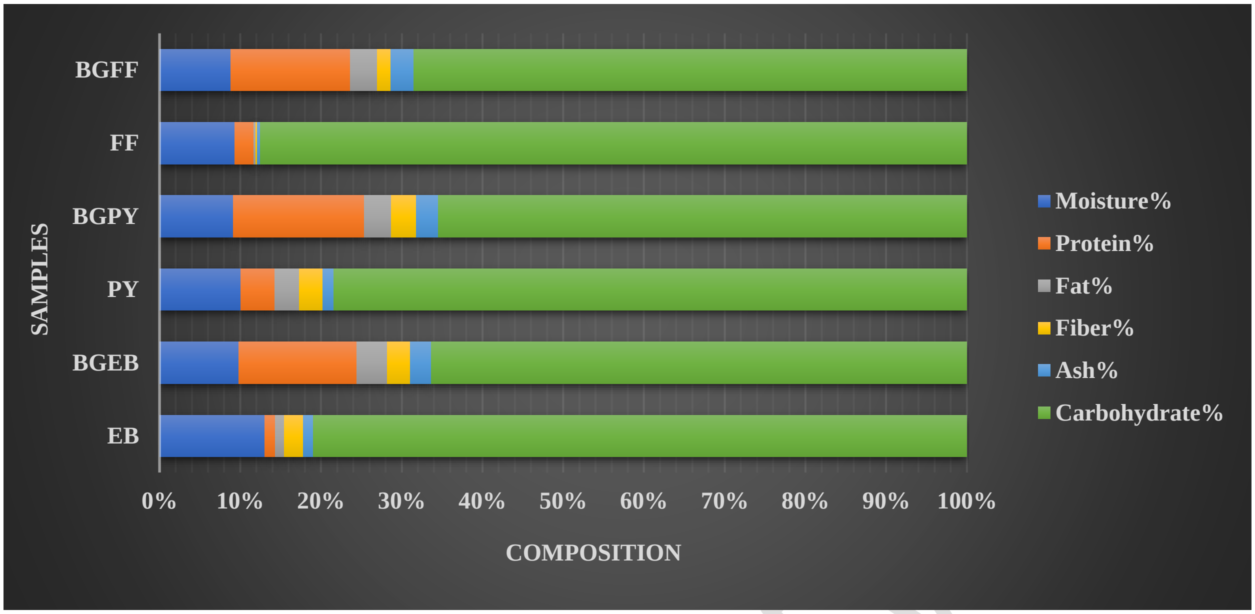
| **Blending Ratio** | **Sensory Attributes** | | | | |
|---|---|---|---|---|---|
| | **Color** | **Texture** | **Taste** | **Aroma** | **Overall acceptability** |
| **FF 100** | $8.80^{a}\pm0.02$ | $8.10^{c}\pm0.01$ | $8.20^{a}\pm0.03$ | $8.20^{a}\pm0.01$ | $8.33^{a}\pm0.02$ |
| **BGFF (60:40)** | $7.70^{b}\pm0.01$ | $8.22^{b}\pm0.01$ | $8.15^{b}\pm0.03$ | $8.14^{b}\pm0.11$ | $8.05^{b}\pm0.01$ |

| | | | | | |
|---|---|---|---|---|---|
| **BGFF (70:30)** | $7.64^{c}$±0.01 | $8.36^{a}$±0.01 | $8.20^{a}$±0.01 | $8.20^{a}$±0.01 | $8.10^{b}$±0.01 |
| **BGFF (80:20)** | $6.40^{d}$±0.02 | $7.80^{d}$±0.02 | $8.02^{c}$±0.01 | $8.00^{c}$±0.01 | $7.56^{c}$±0.02 |
| **BFF (90:10)** | $6.25^{e}$±0.03 | $7.25^{e}$±0.01 | $7.94^{d}$±0.02 | $7.92^{d}$±0.01 | $7.34^{d}$±0.05 |

Data=mean ±SD; n=20. Means within a column followed by different letters are significantly different p<0.05. Key: FF – Fufu; BGFF – Bambara-Fufu

**Proximate Composition**

Figure 2 presents a stacked column chart highlighting proportional difference in the proximate composition of stiff dough flours without Bambara groundnut flour inclusion and stiff dough flours with 70% fermented Bambara groundnut flour inclusion. Moisture content ranged from 9.31% to 13.01% and 8.83% to 9.82%; protein content ranged from 1.31% to 4.24% and 14.63% to 16.26%; fat content ranged from 0.26% to 3.02% and 3.31% to 3.77%; fiber content ranged from 0.17% to 2.90% and 1.64% to 3.12%; ash content ranged from 0.37% to 1.38% and 2.63% to 2.84%; carbohydrate ranged from 78.43% to 87.53% and 65.47% to 68.54% for stiff dough with 0% and 70% fermented Bambara groundnut flour inclusion respectively. Results varied significantly different (P<0.05) among samples.




EB: Eba; BGEB: Bambara-Eba; PY: Pounded yam; BGPY: Bambara-Pounded yam; FF: Fufu; BGFF: Bambara-Fufu.

**Figure 2: Proximate composition of stiff dough with 0% and 70% fermented Bambara groundnut flour**

**Functional properties of Bambara based stiff dough blends**

Table IV shows the functional properties of the Bambara-based stiff dough. The moisture content ranged between 8.83% for BGFF and 9.82% for BGEB. Results indicate significant difference ($p<0.05$) among samples. The bulk density ranged between 1.54g/cm$^3$ for BGEB and 2.00g/cm$^3$ for BGPY and were not significantly different ($p<0.05$). Swelling capacity ranged between 3ml for BGFF and 11.5ml for BGEB. Results indicated significant difference among samples. Foaming capacity ranged between 4% for BGEB and 8% for BGPY. Results indicated significant difference among samples ($P<0.05$). Foam ability for all samples was not stable. Water absorption capacity ranged between 12% for BGFF and 20% for BGEB and varied significantly different ($p<0.05$) among samples. Oil absorption capacity ranged between 7.4% for BGPY and 8.1% for BGFF. Results indicated significant difference among samples. Emulsion activity ranged between 1.39 for BGEB and 1.47 for BGPY. Results indicate significant difference ($p<0.05$) among samples. Emulsion capacity ranged between 1.47 seconds for BGEB and 4.41 seconds for BGPY. Results indicate significant difference ($p<0.05$) among samples. The least gelation concentration ranged between 8% for BGFF and 22% for BGPY. Results indicated significant difference ($p<0.05$) among samples.

**Discussion**

Consumption of stiff dough staples is a deeply rooted cultural dietary practice for Nigerians. Stiff dough is prepared from carbohydrate rich staples. They are rich in calorie but poor in certain key nutrients such as protein. Protein energy malnutrition (PEM) is one of the major burdens of malnutrition worldwide. Diversification into utilization of legumes will improve nutrient composition. Leguminous plants have the potential to play a role in combating food insecurity and malnutrition. However, the possibility of processing it into a stiff dough staple remains a challenge because of its low gelatinization tendencies and activities of its anti-nutrient compounds. Optimizing process techniques (Fig1) was designed to improve nutrient quality of the legume prior to product formulation. Fermentation is a desirable process of biochemical modification used to enhance the bio accessibility of nutrients from primary food matrix, as well as improve organoleptic properties and extend shelf life (Kahajdova and Karovicova, 2007; Hotz and Gibson, 2007; Chaves-Lopez *et al*., 2014). Imperatively reduction of tannin (Fig 1) brought about increases in protein content because tannin has the ability to form complexes with protein which affects digestibility, leading to mal-absorption of proteins. These observations are similar to earlier reports on the effect of processing conditions on anti-nutritional compounds (Udensi and Okoronkwo, 2006; Diouf *et al.*, 2019). Fermentation followed by cooking (boiling) has been reported to be effective in increasing protein digestibility, bringing it nearly to the same level as meat (Osman, 2011), however, in this case steaming($100^{o}C$) was applied. Steaming will not only prevent leaching of nutrients into the boiling water which will be discarded but will also inactivate fermentative organisms and heat sensitive antinutritive compounds. Diouf *et al.,* 2019 reported that a combination of steaming with other techniques could be a good track for reducing anti-nutritional compounds while retaining nutritional and organoleptic qualities of the final product.

The best formulation ratio was determined by results obtained from sensory evaluation. This is the highest ratio that will not compromise traditional quality patterns. These are patterns which have been strongly linked to a territory; have historical depth and have been passed from generation to generation. Results revealed that 70% fermented legume flour inclusion was most accepted. The blend in taste, aroma and color for some of the samples could be attributed to the fact that most of the flour were fermented during processing; and the fermented Bambara groundnut flour which was cream colored was close to the color of the existing stiff dough.

Proximate composition of the developed legume-based stiff dough (70% fermented Bambara groundnut flour inclusion) showed significantly improved nutrient content with protein content rising above 50%. It is evident that the fermented Bambara groundnut flour is the major source of protein in the composite flour blends. This confirms earlier report by Fashakin *et al*., (1986) on the beneficial effects of vegetable protein supplementation. Increased protein could also be attributed to microbial degradation of anti-nutrients; activities of hydrolytic enzymes; the degradation of complex proteins to amino acids through proteolysis as well as increased biomass (Akubor and Chukwu 1999; Difo *et al.,* 2014). Increase in fat content could be attributed to breakdown of lipids by lipase (Adebowale and Maliki 2011). Increased ash content could be due to the metabolic activities of the fermenting organism which hydrolyze the metal-phytate complexes improving its availability. Increase in fiber may be due to the degrading activity of cellulase on cellulose/hemicellulose from the fermentative micro biome (Onoja and Obizoba, 2009; Granito et al., 2002).

The variations observed in the functional properties can be attributed to several factors, including differences in water absorption rates and swelling behavior of starch granules during heating (Ragaee and Abdel-Aal, 2006). These factors are influenced by the specific legume varieties used in the blends and their processing methods. Bulk density is an important consideration for packaging and handling of products. While a higher bulk density might intuitively suggest less packaging space required, Agunbiade and Ojezele (2010) reported that lower bulk density actually necessitates more packaging volume. This is relevant when considering the efficient transportation and storage of the legume-based stiff dough blends. Water absorption capacity (WAC) is a crucial functional property influencing the reconstitution and texture of stiff dough products. High WAC indicates a better ability of the flour blend to absorb water, leading to improved dough formation and final product quality (Uwaegbute *et al.,* 2000). This is particularly important in stiff doughs, where proper hydration is essential for achieving the desired consistency. Proteins and carbohydrates, abundant in legumes, are the primary components responsible for WAC due to their hydrophilic nature, possessing polar or charged side chains that attract water molecules (Chandra *et al.,* 2015). The developed legume-based blend is rich in both protein and carbohydrates, suggesting a favorable WAC. Oil absorption capacity (OAC) plays a role in the ability of the flour components, primarily starch, to physically bind fat through capillary attraction. However, as observed in this study, increased fat content within the flour blends may have led to a reduced capacity to absorb or retain additional oil (Kinsella, 1976). This could be attributed to the saturation of binding sites within the flour matrix. Emulsion properties are also significant in food systems. Emulsion activity and capacity, which describe the ability of proteins to interact with and emulsify oil, respectively, are influenced by both oil and protein concentrations (Sikorski, 2002). The observed emulsion activity in the legume-based blend suggests the nature of protein-fat interactions within the system. Gelation, the process of forming a three-dimensional network that traps water, is a key functional property for stiff doughs. The least gelation concentration (LGC) serves as an indicator of gelation capacity; a lower LGC signifies a stronger gelling ability (Akintayo *et al.,* 1999) and is a desirable protein functionality advantage in legume-based stiff dough applications, contributing to texture and structure (Oshadi *et al.*, 1997). The Bambara-fufu blend therefore demonstrates potential as a gel-forming additive in food products.

**Table IV: Functional Properties of Bambara groundnut-based flour blends**

| Sample | Moisture (%) | Bulk density (g/cm³) | Swelling capacity (ml) | Foam capacity (%) | Foam stability (%) | Water absorption capacity (%) | Oil absorption capacity(%) | Emulsion activity | Emulsion stability (secs) | Gelation temperature(°C) | Least Gelation concentration (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BGEB | 9.82[b] ±0.02 | 1.54[a] ±0.01 | 11.50[a] ±0.01 | 4.00[c] ±0.01 | 0 | 20.00[a] ±0.01 | 7.80[b] ±0.01 | 1.39[c] ±0.01 | 1.47[bc] ±0.01 | 103°C[ab] ±0.01 | 18.00[b] ±0.01 |
| BGPY | 9.10[a] ±0.01 | 2.00[a] ±0.01 | 8.50[b] ±0.01 | 8.00[a] ±0.01 | 0 | 14.00[b] ±0.01 | 7.40[c] ±0.01 | 1.47[a] ±0.01 | 4.41[a] ±0.01 | 101°C[a] ±0.00 | 22.00[a] ±0.01 |
| BGFF | 8.83[b] ±0.01 | 1.91[a] ±0.01 | 3.00[c] ±0.01 | 6.00[b] ±0.01 | 0 | 12.00[c] ±0.01 | 8.10[a] ±0.01 | 1.43[b] ±0.01 | 1.53[b] ±0.00 | 100°C[a] ±0.01 | 8.00[c] ±0.01 |

Data=mean ±SD; n=3; Means within a row followed by different letters are significantly different p<0.05. BEB-Bambara-Eba; BPY-Bambara-Pounded yam; BCM-Bambara-Corn meal; BFF-Bambara-Fufu; BUP-Bambara-Unripe plantain.

## Conclusion

Blending 70% fermented Bambara groundnut flour into selected stiff dough staples offers a pathway to nutrient-dense, health-promoting diets, as demonstrated by this study. This innovative approach to traditional food systems promotes dietary diversification, offers a potential fortification strategy against malnutrition, optimizes local agricultural resources, and encourages consumption of improved local staples, reducing reliance on imported processed foods. This contributes to sustainable food systems and aligns with Sustainable Development Goals 2 (Zero Hunger), 9 (Industry, Innovation, and Infrastructure), and 12 (Responsible Consumption and Production).

## Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.



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