**Evaluation of physicochemical, pasting properties and anti-nutritional properties of Bambara nut, velvet beans and cocoyam flour blends**

 **ABSTRACT**

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| --- |
| The study evaluated the quality attributes of composite flour from Bambara Nut, Velvet Beans, and Cocoyam flours. Sample A of 100% Bambara Nut flour (BNF) served as control, while four variations with a constant 15% Cocoyam flour (CYF) were analyzed using standard methods: A = 100% BNF, B = 80% BNF, 5% VBF, 15% CYF, C = 75% BNF, 10% VBF, 15% CYF, D = 70% BNF, 15% VBF, 15% CYF, E = 65% BNF, 20% VBF, 15% CYF. The functional properties ranged as follows: Bulk density (0.68 g/ml to 0.76 g/ml), Water Absorption Capacity (36.40% to 42.90%), Oil Absorption Capacity (27.30% to 30.50%), and Swelling Index (3.14 g/g to 3.62 g/g). Pasting properties included Peak Viscosity (162.51 RVU to 193.22 RVU), Final Viscosity (207.31 RVU to 253.11 RVU), Setback Viscosity (54.62 RVU to 74.56 RVU), Breakdown Viscosity (9.84 RVU to 14.67 RVU), Pasting Time (6.43 mins to 7.85mins), Pasting Temperature (65.00°C to 68.42°C), and Trough (152.69 RVU to 178.55RVU). The proximate composition ranged as follows: Moisture Content (5.00% to 5.33%), Protein Content (21.96% to 29.63%), Fat Content (3.61% to 4.29%), Ash Content (6.36% to 7.48%), Fibre Content (2.22% to 2.96%), Carbohydrate Content (50.27% to 60.84%), and Energy Value (358.20 kcal/100g to 363.70 kcal/100g). Antinutritional factors of the flour blends ranged thus; Trypsin content (5.32 mg/g to 1.28 mg/g), Oxalates (3.21 mg/g to 1.03 mg/g), L-Dopa (3.73 mg/g to 0.42 mg/g), Hydrogen cyanide (0.03 mg/g to 0.01 mg/g). Sensory evaluation showed that all samples were generally accepted by the panellists. The composite flour demonstrated improved potential for Okpa production due to its rich nutrient profile. |

***Keywords:*** *Okpa; Bambara Nut; Velvet Beans; Cocoyam; functional and pasting properties; proximate; Antinutrients and sensory attribute.*

1. **INTRODUCTION**

Composite flours, derived from cereals, legumes, and tubers, enhance nutritional value and functionality in food products (Makumba *et al.*, 2016). Their scientific study in the mid-20th century has become globally important in addressing food security and promoting sustainable agriculture.

Okpa, a traditional Nigerian steamed pudding, is made from Bambara groundnut (*Vigna subterranea)* flour, palm oil, water, and seasonings. It is widely consumed, particularly in Enugu and Benue states, due to its convenience and high nutritional value (Ezeibe and Asumugha, 2022). Its yellow colour is attributed to palm oil, which enriches its flavor and fatty acid content. As a protein source, Okpa is crucial in communities with limited access to animal protein (Ezeibe and Asumugha, 2022). It is traditionally prepared by steaming the flour mixture in banana or plantain leaves to enhance aroma and moisture retention.

Bambara nuts (*Vigna subterranea)* have been a staple in African diets and it is recognized for their nutritional benefits. They contain approximately 63% carbohydrates, 19% protein, and 18% fat (Murevanhema, Y. Y., and Jideani, V. A 2013). The protein includes all essential amino acids, making it vital for regions with protein deficiencies. Bambara nuts also provide vitamins essential for metabolism and overall health (Murevanhema, Y. Y., and Jideani, V. A 2013). It contains bioactive compounds, including phenolics and flavonoids, and antioxidant benefits that may reduce chronic disease risks (Oyeyinka *et al.,* 2021). They also aid in blood sugar regulation, weight management, and cardiovascular health, contributing to food security and economic growth.

Velvet beans (*Mucuna pruriens*) have gained attention for their high protein content (20–35%) and essential nutrients (Lampariello *et al.,* 2012). They are rich in dietary fibre, iron, zinc, magnesium, folate, and vitamin B6, supporting muscle development, digestive health, and micronutrient balance (Boniface *et al.,* 2024). Notably, velvet beans contain L-DOPA, a dopamine precursor with potential neuroprotective benefits.

Cocoyam (*Xanthosoma spp*.) is a starchy tuber valued for its high carbohydrate (26–30% starch) and fibre content, aiding digestion and blood sugar regulation (FAO, 2021). It provides essential vitamins (C, B6, folate) and minerals (potassium, magnesium, iron) crucial for immune function, cognitive health, and blood pressure regulation (USDA, 2022). Additionally, cocoyam contains antioxidants that reduce chronic disease risks (Ezeocha and Jimelukwe 2012).

Composite flour blends enhance food functionality, improving digestibility, amino acid balance, and consumer acceptability (Igbabul *et al.,* 2015). Incorporating velvet beans and cocoyam into okpa can mitigate common limitations such as poor digestibility, low protein bioavailability, and dryness while supporting food security and crop diversification (Ugwu *et al.,* 2020).

Previous studies have solely focused on the potential benefit of Bambara nut, incorporating VBF and CYF could improve the nutritional, physicochemical, and sensory properties of okpa produced using a composite flour blend of Bambara nut, velvet beans, and cocoyam, providing a more nutritious and sustainable alternative to traditional okpa.

**2.0** **MATERIALS AND METHODS**

**2.1** **Source of Materials**

Samples of Velvet Bean, (*Mucuna pruriens*) were collected from an evergreen forest in Konshisha, Benue State of Nigeria. After thoroughly sun drying for five days, the pods were trashed to remove seeds. Bambara nuts and Cocoyam tubers were obtained from the main market in Gboko, Benue State Nigeria.

2.2 **Sample Preparation**

The Bambara nut flour was produced using the method described by Mazahib *et al.* (2013) with slight modification as presented in Fig. 1, Velvet bean seeds were processed using a modified method of Udensi (2001) as shown in Fig. 2 and the method of Ukonze and Olaitan (2010) was adopted for cocoyam flour production with a little modification as presented in Fig. 3.

Bambara nuts seeds

Sorting

Cleaning

Draining

 Oven Drying (50°C for 6 h)

Cooling

 Milling (attrition mill)

 Sieving (0.05mm mesh sieve)

Bambara nut flour

**Fig. 1:** Flow chart for the production of Bambara nut flour

Source: Mazahib *et al.,* (2013) with modifications.

**Table 1.** **Blend Formation of the flours (%)**

Velvet bean seeds

Sorting

Cleaning

 Soaking (in distilled water for 24h)

Dehulling

 Fermenting (29°C for 72 h)

 Drying (at 50°C for 10 h) Roasting (at 50°C for 8 h)

Cooling

 Milling (attrition mill)

 Sieving (0.05mm mesh sieve)

Velvet beans flour

**Fig 2:** Flow chart for the production of Velvet Beans flour

Source: Udensi. (2001) modified

Cocoyam

Sorting/washing

Peeling/washing

 Size reduction (thin 1-2 mm)

 Blanching (50°C for 10 mins)

 Oven Drying (50°C for 12 h)

 Milling (attrition mill)

 Sieving (0.05mm mesh)

Cocoyam flour

**Fig 3:** Flow chart for the production of Cocoyam flour

Source: The method of Ukonze and Olaitan (2010)

**2.3 Formulation of Bambara nut, velvet beans and cocoyam composite flour**

A flour blend was prepared by mixing Bambara nut flour, velvet bean flour, and cocoyam flour in a constant ratio using a food mixer (blender). The blended samples were then stored in an airtight container at ambient temperature and labelled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SAMPLE** | **BNF** | **VBF**  | **CYF** | **TOTAL** |
| **A** | **100** | **-** | **-** | **100** |
| **B** | **80** | **5** | **15** | **100** |
| **C** | **75** | **10** | **15** | **100** |
| **D** | **70** | **15** | **15** | **100** |
| **E** | **65** | **20** | **15** | **100** |

* 1. **Evaluation of Functional Properties of the Flour**

**Bulk density:** The bulk density of the flour samples is determined using the methods described by Onwuka (2020.) 50 g of the sample is weighed into a 100 mL graduated cylinder. The bottom of the cylinder was gradually tapped until there was no further reduction in the sample level. The final volume is expressed as;Bulk density (g/mL) weight of sample (g) / volume of sample (mL)

**Determination of water absorption capacity:**

The AOAC method of 2015 was used. 1 g of flour was weighed into a graduated conical flask and 10 mL of water was added to the weighed sample and thoroughly mixed. The sample is then allowed to stand at room temperature for 30 mins and then centrifuged at 5000 rpm for 30 mins. The supernatant is then decanted and measured to know the volume of free water. The absorption capacity is expressed as grams of water absorbed per gram of sample in percentage. The water absorption capacity of the sample is further calculated using:

WAC (g/g) = (V1 – V2) x density of water (1g/mL)

Where V1 = initial volume of distilled water added, V2 = volume of supernatant decanted

**Determination of gelatinization temperature:** Using the method described by AOAC 2015, one gram of each sample is suspended in test tubes; with 10 mL of water added to it. The sample is then heated slowly in a water bath while stirring continuously until a gel is formed. 30 sec after gelatinization is visually noticed, the temperature of the sample is taken as the gelatinization temperature.

**Determination of swelling index:** 3 g of each sample is put into a clean graduated 50 mL cylinder and the volume is noted. 30 mL of distilled water is then added to the flour sample; the cylinder is then swirled and allowed to stand for 60 min while volume change (swelling) will be recorded every 15 min. The swelling power of the sample is calculated as a multiple of the original volume, as described by Awuchi *et al.,* 2019.

**2.5 Pasting Properties**

The pasting properties of each flour sample are determined according to AOAC 2015. The flour sample was added into a canister containing 25 mL of distilled water, a paddle was placed into the canister and inserted into the instrument. The measurement cycle was initiated by depressing the motor tower of the instrument. The slurry is then heated from 50 – 95 C, with a holding time of 2 min followed by cooling to 50 C for another 2 min of holding time. The canister is then removed on completion of the test and the results are read from the printout. Peak viscosity, peak time, peak temperature, trough, breakdown viscosity, final viscosity, set back viscosity and pasting temperature values will be taken.

**2.6 Proximate Composition**

**Determination of crude protein**

According to the Kjeldahl AOAC 2015 Method, the sample is weighed and a digestion mixture containing sulfuric acid and a catalyst is added. The digestion process involves heating the mixture to break down the organic material and convert nitrogen to ammonium sulfate. After digestion, the sample is cooled, diluted, and made alkaline by adding sodium hydroxide for distillation. The liberated ammonia is then distilled into a receiving solution containing boric acid, which traps the ammonia. The excess acid in the distillate is titrated with a standardized acid solution (usually hydrochloric acid) using an indicator (such as methyl red) until a colour change indicates the endpoint.

**Determination of moisture content**

Determination of moisture content in each sample is done using the AOAC 2015. About 2 g of each sample is weighed into a dried moisture dish and placed in the moisture extraction oven at 105°C for 5 hours. Thereafter, the dried samples are allowed to cool in a desiccator and weighed after cooling. The process is then repeated thoroughly until constant weight is attained. The percentage of moisture is calculated using:

Moisture Content (%) = $\frac{​(Wi​ - Wf​) }{Wi ​×100}$

Where: Wi​ = Initial weight of the sample before drying, Wf​ = Final weight of the sample after drying.

**Determination of carbohydrate content**

The carbohydrate content of each sample is determined by difference whereby the percentage is obtained by subtracting 100 from the summation of crude protein, crude fat, ash and moisture content

% Total carbohydrate = 100 - % protein + % Fat + % Fibre + % Ash + % Moisture content.

**Determination of crude fat**

Determination of crude fat in each sample is done using the standard procedure of AOAC with petroleum ether as an extracting solvent. The extraction of fat is done by placing 5 g of each sample in the thimble of the Soxhlet apparatus followed by immersing the thimble inside the extraction containing 55 mL of petroleum ether. The extraction thimble with a fat-containing sample is heated to 60°C for 6 hours. The solvent removal is done with a vacuum rotary evaporator at 40°C, while fat drying is done in an oven at 70°C for 30 mins. The amount of crude fat is obtained by subtracting an empty flask from the weight of the flask containing dried fat (AOAC 2019). Percentage crude fat is calculated using the expression:

% Fat = ($\frac{W1 – W2}{W1}$) x 100

Where W1 is the weight of the sample before extraction and W2 is the weight of the sample after extraction

**Determination of crude fibre**

Using standard Association of Official Analytical Chemists procedures as described by Nielsen, 2 g of each sample is added to a mixture of 200 mL of 1.25% H2SO4 and 0.31N NaOH, it is then boiled for 30 minutes and washed with ethanol and petroleum ether twice. The residues obtained are then placed on cool, clean, dry weigh crucibles and dried for at least 8 hours at 110°C in a moisture extraction oven. Thereafter, the crucibles are heated in a muffle furnace at 600°C for 6 hours, cooled, and weighed again (Siyame *et al.,* 2021).

**Determination of energy value**

The energy value is determined using the methods of Farzana and Mohajan (2015). For each blended flour sample, the energy value is obtained as the summation of crude protein, crude fat, and carbohydrate and their respective physiological values (Waters conversion factors) of 4, 9, and 4 calories

**Determination of ash content**

Ash content in each sample is determined using AOAC 2015 standard procedures. The carbolite muffle furnace is used to heat the clean empty crucibles at 600°C for 1 hour. The empty crucibles are then weighed after cooling in a desiccator. The sample of 2 g of each is then placed in the crucibles, and their weight is recorded, followed by burning in the muffle furnace at 550°C for 6 hours. The burnt crucibles containing samples are then cooled in the desiccator and weighed again. The percentage of ash content is determined using the expression;

% Ash = $\frac{(W3 – W1) x 100}{W2}$

where W1 = weight of empty crucible, W2 = weight of sample, W3 = weighted of heated sample and crucible.

**2.7** **Procedure for Preparation of Okpa**

A mixture of 5 g salt and 4 g monosodium glutamate was added to 250 g of flour. Gradually, 500 mL of warm water was incorporated into the flour while gently mixing. Next, 20 g of onion paste and 25 mL of palm oil were added, ensuring thorough mixing to prevent lumps in the batter. Aluminium cups were lightly greased with oil to prevent sticking before pouring in the batter. Each container was filled to about three-quarters of its capacity to allow room for expansion. The Okpa was then steamed in boiling water for 45–60 mins. A sensory evaluation was conducted on the product.

**2.8 Sensory Attributes**

The five different sample flours were reconstituted and used to prepare okpa. Which was evaluated using a hedonic scale for sensory characteristics and the overall acceptability by a panellist of 20 judges using a 9-point hedonic scale preference test in the year 2024. The hedonic scale was used to check the acceptability of samples based on appearance, aroma, flavour, taste, aftertaste, texture and general acceptability.

9 - like extremely, 8 – like very much, 7 – like moderately, 6 – like slightly, 5 – neither like nor dislike, 4 – dislike moderately, 3 – dislike very much, 2 – dislike very much 1 – dislike extremely (Ezeokeke and Onuoha, 2016).

**2.8 Data Analysis**

The data obtained was analyzed using Statistical Package for Social Science - SPSS, version 26. Mean separation was done using Duncan’s Multiple Range test at a 5% probability level.

**3.0 RESULTS AND DISCUSSIONS**

**3.1** **Functional properties of Bambara nut, velvet beans, and cocoyam flour blends.**

Functional properties of foods refer to the physical, chemical, and biological characteristics that impact how the food behaves during processing and consumption. These properties are crucial in determining the overall quality of food products (Abbasi *et al.,* 2024). In the case of Bambara nut, velvet beans, and cocoyam flours, as presented in Table 2, the flour blends demonstrated significant variations on a one-way ANOVA (p≤0.05) in several functional properties.

**Bulk Density** varied from 0.76 to 0.68 g/ml, with Sample A showing the highest value and Sample E the lowest. Bulk density, which refers to the weight of a given food material (Twinomuhwezi H, *et al.,* 2020), Table 2 shows significant variation (p<0.05) in functional properties of composite flour of Bambara nut, velvet beans, and cocoyam flours. This can be attributed to its high fibre and protein content, different starch-protein interactions, larger particle size, and higher hydration properties, which collectively reduce the compactness of the flour blend (Igbabul *et al.,* 2015).

**Water Absorption Capacity (WAC)** also differed significantly (p≤0.05), ranging from 42.90% in Sample A to 36.40% in Sample E. The observed decrease in WAC is likely due to the lower presence of hydrophilic proteins and fibres from Bambara nuts. Additionally, the increased proportion of velvet beans, known for having lower hydrophilicity and A decrease in flour blend observed in this study may have contributed to this change (Adebowale, K. O. *et al.,* 2005).

**Oil Absorption Capacity (OAC)** The Oil Absorption Capacity (OAC) of the formulated samples varied significantly (p≤0.05), with values ranging from 27.30% in Sample A (100% Bambara Nut Flour) to 30.50% in Sample E (65% BNF, 20% VBF, and 15% CYF). Notably, Sample A exhibited the lowest OAC, while Sample E had the highest.

The observed increase in OAC with increasing levels of Velvet bean flour (VBF) and cocoyam flour (CYF) could be attributed to their higher protein and starch content, which enhances the ability to bind and retain oil. Similar studies on composite flour blends, such as those incorporating legumes and tuber-based flours, have reported comparable trends. A study by Olaoye *et al.* (2018) found that whole wheat flour exhibited a higher oil absorption capacity (OAC) of 3.11 g/g compared to whole Bambara nut flour. This suggests that increasing the proportion of Bambara nut flour in composite blends with cereals may lead to a decrease in OAC, likely due to Bambara nut's lower fat-binding properties relative to other legumes and tuber sources, agreeing with the trend observed in this study.

**Swelling Index** The swelling index (SI) decreased with increasing substitution of Velvet Bean Flour (VBF) and Cocoyam Flour (CYF) for Bambara Nut Flour (BNF). Sample A (100% BNF) exhibited the highest swelling index (3.62), while Sample E (65% BNF, 20% VBF, and 15% CYF) had the lowest value (3.14). The reduction in SI with increasing VBF and a constant CYF substitution could be attributed to the higher fibre and lower starch content in VBF and CYF, which limits water absorption and swelling capacity. However, the lack of significant differences (p≥0.05) between Samples A and B suggests that the addition of 5% VBF and 15% CYF does not substantially affect the swelling ability of the flour blend. Similar trends have been reported in previous studies. Onwuka and Okala (2019) observed a decrease in the swelling index of composite flours with increasing incorporation of legume and tuber flours due to variations in starch granule structure and fibre content. Additionally, Adebowale *et al.* (2005) reported that composite blends containing Bambara nut flour with other high-fibre ingredients tend to exhibit reduced swelling indices due to their reduced ability to gelatinize effectively in the water.

**3.2 Pasting properties of Bambara nut, Velvet Beans, and Cocoyam flour blends**

Pasting properties of foods refer to changes that occur in food as a result of the application of heat in the presence of water. These changes affect the texture, digestibility and end use of the food product. (Palav and Seetharaman, 2023). When heat is applied to starch-based foods in the presence of water, it brings about a series of changes known as Gelatinization and pasting.

Results of the pasting properties (Peak viscosity, final viscosity, set back viscosity, breakdown viscosity, pasting time, pasting temperature and trough) of the Bambara Nut, velvet beans and cocoyam composite flour are represented in Table 3.

The highest peak viscosity (193.22 RVU) was observed in Sample E (65% BNF, 20% VBF, and 15% CYF), while the lowest PV (162.51 RVU) was recorded in Sample A (100% BNF). Peak viscosity represents the maximum swelling of starch granules before breakdown due to shear stress and heat. The increase in peak viscosity with higher VBF and CYF inclusion suggests improved starch-water interaction, leading to higher viscosity. Studies have observed similar trends incorporating legume and tuber flours into composite blends (Adebowale *et al.,* 2012).

Final viscosity represents the ability of starch granules to realign after cooling. Sample E recorded the highest FV (253.11 RVU), while Sample A had the lowest (207.31 RVU). The increase in final viscosity with VBF and CYF suggests enhanced gel stability, making the blend more suitable for food applications requiring high viscosity after cooling (Ikujenlola and Fashakin, 2016).

Setback viscosity, an indicator of retrogradation tendency, ranged from 54.62 RVU (Sample A) to 74.56 RVU (Sample E). The higher setback viscosity in Sample E suggests greater starch reassociation, which could influence texture and shelf stability. Previous studies have shown that legumes and tuber starches exhibit higher setbacks due to increased amylose content and water-binding capacity (Hoover, R. 2001).

Breakdown viscosity, the difference between peak viscosity and trough viscosity, increased with VBF and CYF addition, ranging from 9.84 RVU (Sample A) to 14.67 RVU (Sample E). Higher breakdown viscosity indicates weaker starch granules prone to disintegration under heat and shear stress, which aligns with findings from previous studies (Oladunmoye *et al.,* 2014).

Pasting time increased with more VBF and CYF, ranging from 6.43 min (Sample A) to 7.85 min (Sample E), which agrees with Dhingra *et al.* (2012) the incorporation of legume flours into composite blends increased pasting time due to higher protein interactions with starch, which restricts swelling.

The pasting temperature also decreased from **68.42°C (Sample A) to 65.00°C (Sample E),** implying that adding VBF and CYF reduced the energy required for starch gelatinization.

Trough viscosity, indicating the stability of the starch paste under shear stress, was highest in Sample E (178.55 RVU) and lowest in Sample A (152.69 RVU). The increase in trough viscosity suggests enhanced gel stability in mixed flour samples.

**Table 2: Functional properties of Bambara nut, Velvet Beans and Cocoyam flour blends.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sample** | **Bulk Density (g/ml)** | **WAC (%)** | **OAC (%)** | **Swelling Index (g/g)** |
| A | 0.76a ±0.02 | 42.90a ±0.14 | 30.50a ±0.70 | 3.62a ±0.03 |
| B | 0.74b ±0.02 | 40.40b ±0.56 | 30.00a ±0.56 | 3.52a ±0.02 |
| C | 0.72c ±0.02 | 39.60c ±0.00 | 29.50b ±0.70 | 3.43b ±0.01 |
| D | 0.70d ±0.02 | 38.50d ±0.70 | 28.50c ±0.70 | 3.30c ±0.02 |
| E | 0.68e ±0.01 | 36.40e ±0.56 | 27.30d ±0.42 | 3.14d ±0.16 |

Values are means ± Standard Deviation. Values with different superscripts within the same column are significantly different (p<$0.05)$.

A = (100% Bambara nut flour)

B = (80% BNF, 5% VBF, and 15% CYF)

C = (75% BNF, 10% VBF, and 15% CYF)

D = (70% BNF, 15% VBF, and 15% CYF)

E = (65% BNF, 20% VBF, and 15% CYF)

BNF = Bambara Nut Flour, VBF = Velvet Beans Flour, CYF = Cocoyam Flour

WAC = Water Absorption Capacity

OAC = Oil Absorption Capacity

**Table 3: Results for Pasting properties of Bambara nut, Velvet Beans, and cocoyam flour blends**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Peak Viscosity (RVU)** | **Final Viscosity (RVU)** | **Setback Viscosity (RVU)** | **Breakdown Viscosity (RVU)** | **Pasting Time (Minutes)**  | **Pasting Temperature (°C)** | **Trough (RVU)** |
| A | 162.51e±0.01 | 207.31e±0.01 | 54.62e±0.01 | 9.84 e ±0.03 | 6.43e±0.02 | 68.42 a ±0.02 | 152.69e±0.02 |
| B | 176.58d±0.01 | 225.70d±0.01 | 60.46d±0.01 | 11.35c±0.01 | 7.13d±0.01 | 67.30 b ±0.01 | 165.28d±0.05 |
| C | 187.31c±0.01 | 243.27c±0.01 | 67.60c±0.02 | 11.68b±0.08 | 7.31c±0.09 | 66.12 c ±0.02 | 175.70c±0.02 |
| D | 189.10b±0.01 | 246.53b±0.01 | 68.29b±0.02 | 10.85d±0.01 | 7.66b±0.02 | 65.43 d ±0.01 | 178.26b±0.02 |
| E | 193.22a±0.01 | 253.11a±0.01 | 74.56a±0.01 | 14.67a±0.01 | 7.85a±0.00 | 65.00 e ±0.00 | 178.55a±0.00 |

Mean values on the same column with the different superscript indicate values are significantly different

A = (100% Bambara nut flour)

B = (80% BNF, 5% VBF, and 15% CYF)

C = (75% BNF, 10% VBF, and 15% CYF)

D = (70% BNF, 15% VBF, and 15% CYF)

E = (65% BNF, 20% VBF, and 15% CYF)

BNF = Bambara Nut Flour, VBF = Velvet Beans Flour, CYF = Cocoyam Flour

**3.3 Proximate properties of Bambara nut, Velvet Beans, and Cocoyam flour blends**

**Moisture Content**: The moisture content of the composite flour samples varied between 5.00% and 5.51%, with Sample B exhibiting the highest moisture content and Sample A the lowest high moisture content as observed in sample B may be due to moisture absorbance from the environment. These values fall significantly below the generally acceptable moisture range for flours given by Codex 2022, which is between 10% and 14%. Maintaining a moisture content within this range is essential for ensuring the flour’s shelf stability, particularly when stored in airtight containers to prevent moisture absorption from the environment.

The relatively low moisture levels observed in these samples offer several advantages. First, they minimise the risk of microbial proliferation, particularly mould and bacterial growth, which are known to thrive in higher moisture environments. This is crucial in extending the flour’s shelf life and maintaining its quality over time. Furthermore, low moisture content contributes to the preservation of the flour’s sensory and functional properties, preventing undesirable changes such as caking or lump formation.

Studies by Alimi *et al.* (2023) and Traynham *et al.* (2007) emphasise that moisture content is a key determinant of flour stability, as higher moisture levels create favourable conditions for spoilage microorganisms, enzymatic activity, and biochemical deterioration. By keeping moisture levels low, the composite flour samples in this study are less prone to microbial contamination and oxidative rancidity, thereby ensuring their safety and usability over extended storage periods.

**Protein Content**: The protein content of the composite flour blends varied significantly (p ≤ 0.05) based on the proportion of velvet bean flour (VBF) incorporated. Sample A, composed entirely of Bambara nut flour (BNF), had the lowest protein content (21.96%), while Sample E, which contained the highest proportion of VBF (20%), exhibited the highest protein content (29.63%). This trend indicates that increasing the amount of VBF in the blend enhances its protein content. This observation is consistent with the known nutritional profile of the velvet bean (Mucuna pruriens), a leguminous crop recognised for its high protein concentration (Adebowale *et al.,* 2017).

The significant increase in protein content with VBF incorporation can be attributed to the inherent protein-rich nature of velvet beans. Leguminous crops are generally rich in essential amino acids, making them an excellent source of plant-based protein for improving the nutritional quality of food products. The observed increase in protein content suggests that velvet bean flour can serve as a functional ingredient in composite flour formulations, particularly in regions where protein malnutrition is a concern.

Ezeocha *et al.* (2012) reported that blending Bambara nut flour with other protein-rich legumes significantly enhanced the protein composition of composite flours. The incorporation of velvet bean flour into cereal-based formulations led to an increase in protein levels, thereby improving the overall nutritional profile. The results of the present study are in agreement with these earlier reports, reaffirming the potential of velvet bean flour as a viable protein supplement in food systems.

**Fat Content**: The fat content of the formulated flour blends ranged from **3.61% (sample A: 100% Bambara nut flour) to 4.29% (sample E: 65% Bambara nut flour, 20% velvet bean flour, and 15% cocoyam flour)**. The observed increase in fat content with higher proportions of **velvet bean flour (VBF)** suggests that VBF has a relatively higher fat composition compared to both **Bambara nut flour (BNF) and cocoyam flour (CYF).** This trend is consistent with findings from previous studies that have reported significant lipid contributions from velvet beans.

**Adebowale *et al.* (2005)** reported that velvet bean (*Mucuna pruriens*) contains a **higher lipid content (5–7%)** compared to Bambara nut, which typically has a lower fat content ranging between **3.2–4.0%** (Olagunju *et al.,* 2018). Similarly, **Oluwole and Karim (2019)** highlighted that the incorporation of high-fat legumes such as velvet beans into composite flour formulations leads to an increase in overall fat content, which can influence product characteristics such as **texture, mouthfeel, and storage stability.**

The increase in fat content in the formulated blends may have implications for **shelf stability and sensory attributes.** Since lipids are prone to oxidation, higher fat content could lead to **rancidity over time,** potentially reducing the shelf life of the flour blends if not properly stored (Chinma *et al.,* 2014). However, the fat content observed in this study remains within acceptable ranges for legume-based composite flours, which typically fall between **3% and 6% fat content** (Eneche, 2009).

**Ash Content**: Ash content is a key determinant of the mineral composition of food products. It represents the total inorganic matter present, which includes essential minerals like calcium, phosphorus, magnesium, iron, and zinc. In this study, the ash content of the flour blends increased progressively with higher incorporation of velvet bean flour (VBF), ranging from 6.36% in sample A (100% Bambara nut flour) to 7.48% in the blend containing 65% BNF, 20% VBF, and 15% cocoyam flour (sample E).

The observed trend suggests that velvet bean flour has a higher mineral content than Bambara nut flour, which is consistent with findings from previous studies. **Adeyeye *et al.* (2019)** reported that velvet bean seeds contain significant levels of calcium, phosphorus, and iron, contributing to an increased ash content when incorporated into composite flour blends. Similarly, **Oluwajuyitan and Ijarotimi (2020)** report that the addition of leguminous flours such as velvet bean and pigeon pea to composite blends resulted in a notable increase in ash content due to their high mineral density. The results align with the findings of Dhingra ***et al.* (2012)**, who reported that increasing legume substitution in composite flours leads to a rise in ash content, signifying improved mineral availability. The increase in ash content in this study may be attributed to the naturally high mineral composition of velvet bean flour compared to Bambara nut flour**.**

Cocoyam flour (CYF), which remained constant at 15% across all blends, likely had minimal influence on the ash content variation, indicating that the primary contributor to the increase was the velvet bean flour.

**Fibre Content**: The fibre content of the samples analyzed varied from 2.22% (Sample A: 100% Bambara nut flour) to 2.96% (Sample E: 65% Bambara nut flour, 20% velvet bean flour, and 15% cocoyam flour). The observed trend indicates that increasing the proportion of velvet bean flour (VBF) in the blend leads to an increase in fibre content. This suggests that VBF is a significant contributor to dietary fibre in composite flour.

Bambara nut flour (BNF) is known to contain moderate amounts of dietary fibre. According to Murevanhema and Jideani (2015), Bambara nut contains approximately 2.0 – 4.5% crude fibre, depending on the processing method. However, velvet bean (*Mucuna pruriens*) is recognised as a legume with a relatively high fibre content. Kakati *et al.* (2010) reported that velvet beans contain about 5–7% crude fibre, which explains its contribution to the increased fibre levels in the composite blends.

Cocoyam flour (CYF) also contributes to the fibre content, though its effect seems to be less pronounced in this study. As reported by Onwuka and Nwosu (2021), cocoyam contains approximately 2.3–3.5% crude fibre, which aligns with the observed fibre values in the composite flours.

The findings of this study are consistent with previous literature on the dietary fibre contributions of these ingredients. Adegunwa *et al.* (2012) observed a similar increase in fibre content when legume flours were incorporated into composite blends.

**Carbohydrate Content**: The carbohydrate content of the flour blends analyzed in this study ranged from **50.27% in sample E (65% BNF, 20% VBF, and 15% CYF) to 60.84% in sample A (100% BNF).** This trend indicates that as **velvet bean flour (VBF) was incorporated into the blends,** the carbohydrate content of the composite flour decreased.

The reduction in carbohydrate content with increasing velvet bean substitution can be attributed to the **inherent composition of velvet bean flour, which has a relatively lower carbohydrate content compared to Bambara nut flour and cocoyam flour**. Velvet beans (*Mucuna pruriens*) are known to be **higher in protein and fibre while containing lower levels of carbohydrates** (Siddhuraju *et al.,* 2000). Studies have reported that **the carbohydrate content of raw velvet bean seeds is approximately 45-50%, significantly lower than that of Bambara nut flour, which can have carbohydrate levels of 55-65%** (Adebowale *et al.,* 2005).

Bambara nut flour (BNF) primarily consists of **complex carbohydrates, including starch and non-starch polysaccharides, contributing to its relatively high carbohydrate levels**. The high carbohydrate content observed in **sample A (60.84%)** aligns with reports by Amarteifio *et al.* (2006), which found that **Bambara nut flour typically contains 58-65% carbohydrates,** depending on processing methods and variety.

Cocoyam flour (CYF), which was maintained at **15% across all blends,** is also known for its high carbohydrate content (Ezeocha and Jimelukwe, 2012). Despite its presence in all the samples, its effect on the total carbohydrate content was relatively stable, implying that the primary factor influencing the reduction in carbohydrate content was the proportion of VBF in the blend.

The findings of this study are consistent with Adegunwa *et al.* 2012 studies, which suggest that increasing legume-based flour in composite blends **often results in a reduction in carbohydrate content due to their higher protein and fibre composition**. The observed trend also agrees with **past studies on legume-cereal and legume-tuber blends**, where the addition of protein-rich legumes resulted in a dilution of total carbohydrate content.

The reduction in carbohydrate content with increasing velvet bean substitution may have **implications for the energy profile of the flour blend**. While **higher carbohydrate levels are desirable for energy-dense food formulations**, the inclusion of velvet bean flour **may enhance the protein and fibre content, improving the nutritional quality of the flour**. This could be beneficial for food product development aimed at improving **protein intake, satiety, and glycemic response** in formulated diets.

**Energy Value**: The energy value of the flour blends ranged from **358.20 kcal/100g (sample E) to 363.70 kcal/100g (sample A),** with a noticeable decrease as the proportion of **Velvet Beans Flour (VBF)** increased. This trend aligns with the **nutritional composition of velvet beans,** which contain lower carbohydrate levels compared to **Bambara Nut Flour (BNF)** and **Cocoyam Flour (CYF)**.Since carbohydrates are a primary energy source in food formulations (FAO, 2003), the substitution of **BNF with VBF** resulted in a corresponding decrease in the energy value of the composite flour.

Findings in previous studies support the reduction in energy value with increasing VBF substitution. According to **Arogba (2019),** velvet beans have a relatively higher protein and fibre content but a lower carbohydrate concentration than **Bambara nuts and cocoyam**. This could explain the lower caloric contribution of the flour blends with higher VBF inclusion. Similarly, **Adebowale *et al.* (2021)** reported that composite flours with **increased legume content** (such as velvet beans) often exhibit a decline in energy value due to their lower carbohydrate and higher fibre composition.

**Onyeka *et al.* (2018)** observed that the energy value of legume-enriched composite flours was significantly influenced by the carbohydrate-to-protein ratio, where flour blends with higher protein levels but reduced carbohydrate content tend to yield lower caloric values. This agrees with the findings in the current study, where **sample A (100% BNF)** had the highest energy value, while **sample E (with the highest VBF content at 20%)** exhibited the lowest energy value.

**Table 4: Proximate properties of Bambara nut, velvet beans and cocoyam flour blends**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample**  | **Moisture (%)** | **Protein (%)** | **Fat (%)** | **Ash (%)** | **Fibre (%)** | **Carbohydrate (%)** | **Energy Value (Kcal/g)** |
| A | 5.00d±0.00 | 21.96e±0.02 | 3.61e±0.01 | 6.36e±0.02 | 2.22e±0.02 | 60.84a ±0.08 | 363.70a±0.14 |
| B | 5.51a±0.14 | 23.21d±0.02 | 3.81c±0.02 | 6.71d±0.02 | 2.31d±0.02 | 58.43b ±0.09 | 360.90c±0.14 |
| C | 5.01d±0.21 | 25.41c±0.02 | 3.81c±0.01 | 6.81c±0.01 | 2.61c±0.02 | 56.33c±0.09 | 361.30b±0.14 |
| D | 5.21c±0.14 | 27.96b±0.02 | 3.95b±0.02 | 6.96b±0.02 | 2.76b±0.01 | 53.14d±0.09 | 360.00d±0.14 |
| E | 5.33b±0.21 | 29.63a±0.01 | 4.29a±0.02 | 7.48a±0.02 | 2.96a±0.02 | 50.27e±0.14 | 358.20e±0.18 |

Values presented as means ± Standard Deviation. Values with different superscripts within the same column are significantly different ((p<$0.05)$.

A = (100% Bambara nut flour)

B = (80% BNF, 5% VBF, and 15% CYF)

C = (75% BNF, 10% VBF, and 15% CYF)

D = (70% BNF, 15% VBF, and 15% CYF)

E = (65% BNF, 20% VBF, and 15% CYF)

BNF = Bambara Nut Flour, VBF = Velvet Beans Flour, CYF = Cocoyam Flour

**3.4 Antinutritional factors of Bambara nut, Velvet Beans, and Cocoyam flour blends**

**Trypsin Inhibitors:** Trypsin inhibitors are naturally occurring antinutritional factors present in legumes and cereals. These compounds interfere with protein digestion by inhibiting trypsin, a key enzyme involved in breaking down dietary proteins. Excessive intake of trypsin inhibitors can lead to reduced protein absorption and pancreatic hypertrophy (Islamiyat *et al.,* 2019).

The results from this study indicate trypsin inhibitor content in the formulated samples ranged from **1.28 mg/g (Sample A: 100% Bambara Nut Flour) to 5.32 mg/g (Sample E: 65% BNF, 20% VBF, and 15% CYF).** These values are **within the acceptable limit of 4–10 mg/g** trypsin inhibitor activity per gram of protein for safe human consumption (Islamiyat *et al.,* 2019).

The variation in trypsin inhibitor activity across the samples can be attributed to the lowest trypsin inhibitor level observed in Sample A, which contained **100% BNF**, suggesting that Bambara nut flour inherently has a lower concentration of these inhibitors compared to other legumes. Conversely, the highest trypsin inhibitor content was recorded in Sample E, which contained **20% VBF**, indicating that including Velvet Bean Flour contributed to the increased levels. This aligns with findings from previous studies, such as anti-nutritional factors in the composite flour. **Velvet beans contain higher levels of trypsin inhibitors compared to other legumes, though processing methods such as soaking and roasting can reduce their activity**.

**Oluwatosin and Fasoyiro (2018)** observed similar trypsin inhibitor levels (ranging from 1.50–6.20 mg/g) in Bambara nut and composite blends with legume flours. Additionally, **Akinjayeju *et al.* (2011)** also reported that the incorporation of legume flours into composite blends increased the trypsin inhibitor content due to the naturally high antinutritional factors in legumes.

**Oxalates:** Oxalates are naturally occurring compounds found in many plant-based foods, and their presence in food products is of significant nutritional and health concern. High oxalate consumption has been linked to an increased risk of kidney stone formation due to its ability to bind with calcium, forming insoluble calcium oxalate crystals (Holmes and Assimos, 2004). The World Health Organization (WHO) suggests that a daily intake of 50–60 mg is generally safe for most individuals, while those prone to kidney stones should consume foods with oxalate levels within the acceptable limit of 2–10 mg per 100 g of food (Holmes & Assimos, 2004).

The oxalate content of the formulated blends ranged from **3.21 mg/g (321 mg/100 g) to 1.03 mg/g (103 mg/100 g)**. Sample **E (65% BNF, 20% VBF, and 15% CYF) had the highest oxalate content (3.21 mg/g), while Sample A (100% BNF) had the lowest value (1.03 mg/g)**. These values indicate that the inclusion of **Velvet Bean Flour (VBF) and Cocoyam Flour (CYF) contributed to the increased oxalate content** in the composite samples, as sample A, which contained only **Bambara Nut Flour (BNF), recorded the lowest oxalate level**.

Bambara nut has been reported to contain moderate oxalate levels. According to Nwosu *et al.* (2014), the oxalate content of Bambara nut flour ranges from **0.5 to 1.5 mg/g,** depending on processing methods. The value recorded for Sample A (1.03 mg/g) aligns with these findings, confirming that Bambara nut is a relatively low-oxalate legume.

Velvet bean (Mucuna pruriens), on the other hand, is known for its **high anti-nutrient content, including oxalates,** which explains why an increase in VBF inclusion resulted in higher oxalate levels. Studies by Adebowale *et al.* (2018) show that raw velvet beans contain **oxalate levels between 2.8 and 4.5 mg/g**, which is relatively high. This supports the findings that Sample E, with 20% VBF, had the highest oxalate content among the blends.

Cocoyam also contributes to oxalate content, as reported by Akomolafe and Aborisade (2007), who found that **the oxalate levels in cocoyam tubers range from 2.1 to 4.0 mg/g,** depending on the variety and processing methods. This further validates the increase in oxalate levels as more CYF was added to the blends.

Although the highest oxalate content recorded in this study (3.21 mg/g or **321 mg/100 g**) exceeds the **2–10 mg/100 g range recommended for low-oxalate diets**, it is important to consider **processing methods** that can help reduce oxalate levels. Techniques such as soaking, fermentation, and heat treatment have been shown to significantly reduce oxalate levels in legumes and tubers (Akinmutimi, 2006; Ezeocha and Onwuka, 2010).

**L-Dopa:** The study assessed the L-Dopa content in various formulations containing Bambara nut flour (BNF), Velvet beans flour (VBF), and Cocoyam flour (CYF). The results revealed a range of L-Dopa concentrations from 0.42 mg/g (sample A, 100% BNF) to 3.73 mg/g (sample E, 65% BNF, 20% VBF, and 15% CYF). This indicates a direct relationship between the proportion of Velvet bean flour and L-Dopa content, as VBF is known to be a rich natural source of L-Dopa.

The presence of L-Dopa in the samples aligns with existing studies, particularly those highlighting Velvet bean (*Mucuna pruriens*) as a significant natural source of this compound. Velvet bean has been reported to contain between 3.1 mg/g and 5.3 mg/g of L-Dopa in raw seeds (Pugalenthi *et al.,* 2005; Siddhuraju *et al.,* 2000). The highest L-Dopa content recorded in this study (3.73 mg/g in Sample E) is within this range, confirming that the L-Dopa levels observed in the formulated samples are consistent with previous research.

Further, Siddhuraju *et al.* (2000) noted that processing methods such as roasting, boiling, or fermentation can significantly reduce L-Dopa levels, often by more than 50%. The relatively lower values in the blended samples compared to pure Velvet bean flour suggest that the dilution effect of BNF and CYF, as well as possible processing steps, contributed to the final L-Dopa concentrations.

L-Dopa is widely recognised for its pharmacological importance, particularly in the treatment of Parkinson’s disease. However, dietary intake from natural sources must be carefully monitored due to potential side effects such as nausea, hypotension, and gastrointestinal disturbances (Maldonado, 2018). The acceptable medicinal limit is up to 100 mg/day, but dietary intake should generally remain below 5 mg/day to avoid adverse effects.

Based on the recorded values, assuming an average consumption of 100 g of the flour blends per day:

* Sample A (100% BNF, 0.42 mg/g): 42 mg L-Dopa per 100 g
* Sample E (65% BNF, 20% VBF, 15% CYF, 3.73 mg/g): 373 mg L-Dopa per 100 g

This indicates that sample E may exceed the safe dietary threshold for regular consumption if eaten in large quantities. Blends with lower VBF content (e.g., samples B and C) provide more moderate L-Dopa levels, which may be safer for general consumption.

**Hydrogen Cyanide (HCN):** The study analyzed hydrogen cyanide (HCN) content in composite flour blends containing varying proportions of **Bambara Nut Flour (BNF), Velvet Bean Flour (VBF), and Cocoyam Flour (CYF).** Results indicated that hydrogen cyanide levels ranged between **0.01 mg/g (10 ppm) in Sample A (100% BNF) and 0.03 mg/g (30 ppm) in Sample E (65% BNF, 20% VBF, 15% CYF).** The increase in cyanide levels corresponded to the increasing proportion of **velvet bean flour** in the blends.

The observed trend aligns with existing literature, as velvet beans contain significant amounts of **cyanogenic glycosides,** which can release hydrogen cyanide upon enzymatic hydrolysis. According to **Siddhuraju *et al.* (2002)**, raw velvet beans contain between **36 to 45 mg HCN/kg,** but proper processing can effectively reduce these levels.

The **Codex Alimentarius Commission (2013)** recommends a hydrogen cyanide limit of **≤10 ppm (0.01 mg/g)** in processed cassava flour and related products. In this study, Sample A (100% BNF) falls within this acceptable range. However, blends incorporating **higher levels of velvet bean flour (Samples C, D, and E)** exceed this limit, with Sample E reaching **30 ppm (0.03 mg/g),** which is higher than the recommended threshold.

Although these values are below the acute toxicity range (0.5–3.5 mg HCN/kg body weight) established by EFSA, **chronic exposure to even moderate cyanide levels can lead to health risks** such as goitre and neurological disorders (**Nwokoro *et al.,* 2005**). Therefore, proper processing methods—such as **soaking, fermentation, or prolonged cooking**—are essential to mitigate potential toxicity and improve the safety of these flour blends (**Udedibie *et al.,* 1996**).

The study further revealed an **increase in antinutrient levels** with higher velvet bean incorporation. This finding is consistent with previous studies indicating that ***Mucuna pruriens*** contains **antinutritional compounds** such as **phytates, tannins, and oxalates** in addition to cyanogenic glycosides (**Vadivel & Pugalenthi, 2010**). These compounds **reduce nutrient bioavailability** and may hinder protein digestion, necessitating effective processing techniques (**Afolabi *et al.,* 2014**).

**Table 5: Antinutritional factors of Bambara nut, velvet beans and cocoyam flour blends**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sample** | **Trypsin (mg/g)** | **Oxalates (mg/g)** | **L-Dopa (mg/g)** | **Hydrogen cyanide (mg/g)** |
| A | 1.28e±0.01 | 1.03e±0.02 | 0.42e±0.02 | 0.01c±0.00 |
| B | 2.32d±0.01 | 1.46d±0.02 | 1.22d±0.02 | 0.02b±0.00 |
| C | 3.69c±0.01 | 2.28c±0.02 | 2.28c±0.02 | 0.02b±0.00 |
| D | 4.55b±0.02 | 2.37b±0.02 | 2.91b±0.02 | 0.02b±0.00 |
| E | 5.32a±0.02 | 3.21a±0.02 | 3.73a±0.02 | 0.03a±0.00 |

Values are presented as means of ± Standard Deviation. Values with different superscripts within the same column are significantly different ($<0.05)$ while those with the same superscript are not significantly different.

A = (100% Bambara nut flour)

B = (80% BNF, 5% VBF, and 15% CYF)

C = (75% BNF, 10% VBF, and 15% CYF)

D = (70% BNF, 15% VBF, and 15% CYF)

E = (65% BNF, 20% VBF, and 15% CYF)

BNF = Bambara Nut Flour, VBF = Velvet Beans Flour, CYF = Cocoyam Flour

**3.5** **Sensory attributes of Okpa produced from flour blends of Bambara Nuts, Velvet Beans and Cocoyam**

The sensory attributes of Okpa prepared from composite flour blends of Bambara Nuts, Velvet Beans, and Cocoyam are presented in Table 4.7. The sensory attributes analyzed include appearance, taste, texture, flavour, and general acceptability.

**Appearance:**
The sensory evaluation results indicate that the appearance scores of the Okpa samples formulated with varying proportions of Bambara nut flour (BNF), Velvet beans flour (VBF), and Cocoyam flour (CYF) ranged from **6.85 (sample B) to 6.05 (sample E)**. The statistical analysis revealed **no significant difference (p≥0.05)** among the samples, suggesting that panellists perceived the visual appeal of the Okpa as relatively uniform across all formulations. This implies that incorporating VBF and CYF into Bambara nut flour-based Okpa did not adversely impact its appearance.

The absence of a significant difference in appearance aligns with findings from previous studies. **Ikpeme *et al.* (2019)** reported that blending Bambara nut flour with other legumes and tuber-based flours does not significantly alter the colour or general appearance of traditional dishes due to the dominant pigmentation of Bambara nut flour. **Oladejo *et al.* (2021)** found that Okpa made from composite flour blends maintained a comparable visual appeal, as the primary colour components of Bambara nut remain unchanged even when mixed with other flour types in moderate proportions.

**Akinwande *et al.* (2020)** suggest that **composite flour-based products tend to exhibit minor variations in appearance**, particularly when the substituted flour does not introduce a dominant colour change. The results from this study corroborate these findings, indicating that **VBF and CYF, when incorporated at 5–20% levels, did not significantly affect the panellists' perception of Okpa’s appearance.**

Thus, the findings confirm that while variations in composite flour formulations can influence other sensory attributes such as texture, taste, and overall acceptability, **the appearance of Bambara nut-based Okpa remains relatively stable** across different flour compositions. This insight is valuable for food product development, especially in optimizing nutrient-dense composite flour formulations without compromising consumer acceptability.

**Taste:**
The mean taste scores for the composite flour samples ranged from **7.0 (Sample A)** to **6.70 (Sample E)**. Sample A, which consisted of 100% Bambara Nut Flour (BNF), had the highest taste rating, while Sample E (65% BNF, 20% Velvet Bean Flour (VBF), and 15% Cocoyam Flour (CYF)) had the lowest. However, the statistical analysis indicated **no significant difference (p≥0.05)** among the samples, suggesting that the inclusion of Velvet Bean Flour and Cocoyam Flour did not cause a substantial decline in taste acceptability.

The slight reduction in mean taste scores with increasing levels of VBF and CYF could be attributed to **panellists’ familiarity with Sample A**, which may have influenced their preference. This aligns with findings by **Adebo *et al.* (2017)**, who reported that **consumer preference for traditional food formulations tends to be higher due to familiarity**, even when composite blends show no statistical difference in sensory attributes.

Additionally, studies on composite flours incorporating legumes and tubers, by **Adeleke & Odedeji (2010)** have demonstrated similar trends. These studies noted that while fortification with alternative flour sources slightly affects taste scores, the changes often remain **statistically insignificant (p≥0.05)**, especially when well-balanced formulations are used.

**Oluwajuyitan & Ijarotimi (2019)** studied the sensory evaluation of legume-tuber composite flours and found that **taste acceptability remains relatively high if the legume content does not introduce excessive bitterness or off-flavours**. Since Velvet Bean Flour has a slightly bitter taste due to its **L-dopa content**, its inclusion in increasing proportions could have subtly influenced taste scores, though not significantly.

**Texture:**
The texture of food products plays a significant role in consumer acceptability, particularly in traditional foods such as Okpa, a steamed pudding-like product commonly prepared from Bambara nut flour (BNF). In the present study, the mean texture scores ranged from **6.90 (sample C: 75% BNF, 10% VBF, and 15% CYF) to 6.60 (sample A)**. The lack of a significant difference (**p≥0.05**) in texture among the samples suggests that incorporating Velvet Bean Flour (VBF) and Cocoyam Flour (CYF) into Bambara Nut Flour (BNF) did not adversely affect the mouthfeel and consistency of the Okpa samples.

These findings indicate that the composite flour blends maintained similar textural properties to the control sample, which was composed entirely of Bambara nut flour. This could be attributed to the functional properties of BNF, which is known for its good gelling and water-holding capacity, contributing to a stable and cohesive product structure (Adebowale *et al.,* 2017). Additionally, previous studies have demonstrated that legume-based flours, including Bambara nut, contribute to desirable textural attributes due to their high protein and starch content, which influence the viscosity and firmness of food products (Akinwande *et al.,* 2015).

The inclusion of Velvet bean flour and cocoyam flour did not significantly alter the texture, possibly due to the balance between the water absorption properties of CYF and the protein content of VBF, which may have complemented the structural matrix of the Okpa.

The results suggest that Okpa formulated with composite flours containing up to **20% Velvet Bean Flour and 15% Cocoyam Flour** can maintain an acceptable texture comparable to the traditional 100% Bambara nut flour Okpa. This aligns with previous literature, which has shown that appropriate flour blends can improve nutritional composition while maintaining desirable sensory qualities (Onimawo and Asugo, 2004).

**Flavor:**
The flavour scores for the formulated samples ranged from 7.00 (sample B) to 6.80 (sample E), indicating a generally acceptable sensory perception among the panellists. The absence of significant differences (p≥0.05) suggests that substituting Bambara Nut Flour (BNF) with varying proportions of Velvet Beans Flour (VBF) and Cocoyam Flour (CYF) did not have a notable impact on flavour perception. This result implies that the inclusion of VBF and CYF, up to 20% and 15% respectively, does not negatively influence the sensory acceptability of the product in terms of flavour.

These findings align with previous studies on composite flour blends. According to Adebowale *et al.* (2012), the incorporation of underutilized legumes and tuber flours into composite blends does not significantly alter sensory attributes such as flavour, as long as the proportion is within acceptable limits. Similarly, Ayo *et al.* (2018) observed that the addition of legumes and tubers to traditional flour formulations could maintain or even enhance sensory properties, particularly when well-balanced in formulation.

Furthermore, Nwosu *et al.* (2020) reported that legume and tuber-based composite flour products could achieve comparable sensory scores to 100% legume-based products, provided that the proportion of substitution does not introduce off-flavours or undesirable textural changes. The slight variations in flavour scores observed in this study may be attributed to individual panellists’ preferences rather than any significant formulation effect.

Overall, the results suggest that BNF-based composite blends incorporating VBF and CYF can be used without compromising flavour quality, supporting their potential use in food formulations aimed at improving nutritional and functional properties.

**General Acceptability:**

The sensory evaluation results indicate that all the Okpa samples formulated with varying proportions of Bambara nut flour (BNF), Velvet bean flour (VBF), and Cocoyam flour (CYF) were generally well-accepted by the panellists. The general acceptability scores ranged from **7.40 (sample B) to 7.15 (sample E)**, with no significant difference (**p ≥ 0.05**) among the samples. This implies that despite the differences in composite flour formulations, the sensory characteristics such as taste, texture, aroma, and overall palatability were not significantly affected. The high scores (above 7.0 on a 9-point hedonic scale) suggest that the substitution of BNF with VBF and CYF did not negatively impact consumer preference.

These findings align with previous studies that have explored the acceptability of composite flour-based Okpa and other legume-based products. **Akanbi *et al.* (2019)** reported that the inclusion of alternative legumes and tuber flours in traditional Bambara nut-based foods did not significantly reduce sensory acceptability, as long as the substitutions were within acceptable proportions. Similarly, **Olapade and Ogunade (2021)** found that the use of legume and tuber blends in snack formulations maintained consumer acceptability due to their ability to improve nutritional quality while preserving the desired texture and flavour.

The high acceptability scores obtained in this study may be attributed to the synergistic effects of the different flour components. Velvet bean flour (VBF) and Cocoyam flour (CYF) may have contributed to textural smoothness and enhanced flavour, complementing the natural richness of Bambara nut flour. Previous research by **Ene-Obong *et al.* (2018)** has also shown that blending underutilized legumes and tubers can enhance the sensory appeal of traditional foods while improving their protein and dietary fibre content.

Overall, these findings suggest that composite flour formulations incorporating Bambara nut, Velvet bean, and Cocoyam can be successfully used in Okpa production without compromising consumer acceptance. This supports the potential for promoting these underutilized crops in food product development, enhancing food security, and offering diverse nutrient-rich alternatives.

**Table 6**. **Sensory attributes of Okpa produced from flour blends of Bambara Nuts, Velvet Beans and Cocoyam**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sample** | **Appearance**  | **Taste**  | **Texture**  | **Flavor**  | **General Acceptability** |
| A | 6.75 ±1.01 | 7.00 ±0.97 | 6.60 ±1.03 | 6.95 ±0.99 | 7.30 ±1.01 |
| B | 6.85 ±1.08 | 6.95 ±0.94 | 6.75 ±0.99 | 7.00 ±0.00 | 7.40 ±1.09 |
| C | 6.65 ±1.09 | 6.85 ±0.81 | 6.90 ±0.96 | 6.90 ±1.00 | 7.25 ±1.08 |
| D | 6.70 ±1.07 | 6.75 ±0.08 | 6.70 ±1.02 | 6.90 ±1.06 | 7.25 ±1.06 |
| E | 6.05 ±1.07 | 6.70 ±0.80 | 6.65 ±1.08 | 6.80 ±1.09 | 7.15 ±1.06 |

Values presented as means ± Standard Deviation. Values with the same superscript are not significantly different.

A = (100% Bambara nut flour)

B = (80% BNF, 5% VBF, and 15% CYF)

C = (75% BNF, 10% VBF, and 15% CYF)

D = (70% BNF, 15% VBF, and 15% CYF)

E = (65% BNF, 20% VBF, and 15% CYF)

BNF = Bambara Nut Flour, VBF = Velvet Beans Flour, CYF = Cocoyam Flour

**4.0 CONCLUSION**

This study concludes that composite flours made from Bambara nuts, velvet beans, and cocoyam offer an effective alternative for producing Okpa with enhanced nutritional value while preserving its physicochemical functionality and sensory attributes. This approach will provide industrial benefits by facilitating the production of innovative food products. With the potential to improve food security and nutrition in Nigeria. However, proper processing is key to mitigating antinutritional risks to ensure sustainable and nutrient-dense food products.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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