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Proximate Composition and Anti-Nutritional Properties of Maize, Pigeon Pea, and Cooking Banana Flours for Composite Food Formulations

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Abstract- This study evaluated the nutritional and anti-nutritional properties of flours produced from maize, pigeon pea, and cooking banana to determine their suitability for use in composite food formulations. The flours were processed using standard methods and analyzed for proximate composition and selected anti-nutritional factors. The proximate composition (moisture, protein, fat, fibre, ash, and carbohydrate) and anti-nutritional factors (phytate, tannin, and haemagglutinin) were determined using standard analytical procedures, and the data obtained were subjected to statistical analysis to determine significant differences among the samples ($p < 0.05$). Significant differences ($p < 0.05$) were observed among the samples. Protein content ranged from 6.45% in maize flour to 7.45% in pigeon pea flour, while maize flour had the highest carbohydrate content (80.82%). Cooking banana flour contained the highest fat (4.12%) and fibre (2.24%) contents, whereas ash and moisture contents ranged from 2.35–2.74% and 5.75–7.23%, respectively. Phytate, tannin, and haemagglutinin contents ranged from 2.23–2.35 mg/100 g, 2.37–2.69 mg/100 g, and 0.74–0.84 Hiu/mg, respectively. Although pigeon pea flour recorded relatively higher anti-nutritional values, the levels observed were low and are expected to be further reduced during conventional food processing. The results demonstrate that each flour possesses unique nutritional attributes that can complement one another when combined. Maize provides a rich source of carbohydrates, pigeon pea contributes higher protein and mineral contents, while cooking banana enhances fibre content. These characteristics make the three flours suitable ingredients for developing nutritionally improved composite food products. The complementary nutritional characteristics of these flours suggest that their incorporation into composite formulations could enhance dietary quality, promote the utilization of locally available agricultural resources, and contribute to the development of affordable and nutritious food products for consumers. The findings provide useful baseline information for selecting appropriate raw materials and support the utilization of locally available crops in the development of value-added foods with improved nutritional quality.

Keywords: Maize flour, Pigeon pea flour, Cooking banana flour, Proximate composition, Anti-nutrients, Raw materials.

I. INTRODUCTION

The use of composite flours has gained increasing attention in food science and nutrition due to their nutritional, economic, and functional advantages. Composite flour refers to a blend of flours derived from different plant sources such as cereals, legumes, roots, tubers, and fruits, aimed at improving the overall nutritional quality and technological performance of food products while promoting the utilization of locally available crops [1]. Maize (Zea mays L.) is one of the most important staple cereals globally and is widely cultivated for both human consumption and animal feed.

It is a major source of carbohydrates and also contributes moderate amounts of protein, dietary fiber, vitamins, and essential minerals. Maize flour is commonly used in the preparation of various cereal-based foods such as breakfast meals, snacks, and baked products [2]. In addition to its macronutrient contribution, maize contains several bioactive compounds including phenolics and carotenoids, especially in pigmented varieties, which enhance its nutritional and functional value [3], [4].

Pigeon pea (Cajanus cajan L.) is an underutilized but nutritionally important legume in many tropical regions, including Nigeria, where it contributes significantly to dietary protein intake. It is known for its relatively high protein content and balanced amino acid profile, making it valuable in addressing protein-energy malnutrition. Pigeon pea also provides essential minerals, vitamins, and diverse phytochemicals with antioxidant potential [5]–[7].

Cooking banana (Musa spp.), particularly in its unripe or green form, is another important crop with considerable nutritional and industrial potential. Green banana flour is rich in starch—especially resistant starch—dietary fiber, and micronutrients, making it suitable for functional food formulations. It is widely processed into flour through drying and milling and is recognized for its energy value, affordability, and versatility in food applications [8]–[11]. Previous studies have reported that green banana flour contains substantial amounts of starch, moderate protein, and ash content, supporting its suitability in composite flour development [12], [13].

Despite the recognized nutritional importance of these crops, their raw flours may also contain anti-nutritional factors such as phytates, tannins, and haemagglutinins, which can reduce nutrient bioavailability and influence product quality. Therefore, evaluating both the nutritional composition and anti-nutritional characteristics of maize, pigeon pea, and cooking banana flours is essential prior to their incorporation into composite food formulations. This study was undertaken to assess the proximate and anti-nutrient properties of selected raw flours in order to provide baseline information for their effective and nutritionally balanced utilization in food product development.

II. MATERIALS AND METHODS

Materials

The maize grain, pigeon pea and cooking banana used in this study were purchased from Anyigba main market. All reagents used were of analytical grade and were purchased from a government-licensed store.

Production of maize flour

Maize grains were processed into flour using the method described by [14] with slight modification. Maize grains were sorted, cleaned, and tempered by spraying water on the maize grain for 30 mins to soften the cotyledon of the maize. It was then dehulled and winnowed. The winnowed maize grains were pulverized with an attrition mill, the obtained flour was sieved using a 500 μm mesh and stored in an airtight container before analysis.

Production of pigeon pea flour

The pigeon-pea was processed into flour using the method described by [15] with a slight modification. Pigeon-pea seeds were sorted, cleaned and steamed in a retort at 120 °C for 5 min. The steamed pigeon-pea seeds were manually dehulled, dried in a cabinet dryer at 65 °C for 48 h. The steam-dried pigeon-pea was pulverized using an attrition mill, sieved using a 500-μm mesh, and the flour was packed in an airtight container before analysis.

Preparation of cooking banana

The cooking banana was processed into flour using the method described by [16] with a slight modification. The cooking banana was washed with clean water and manually peeled to separate the pulp from the peel. The pulp was sliced and blanched for fifteen (15) min. The blanched cooking banana was dried in a hot air oven at 55 °C for 18 h. The dried cooking banana was pulverized using an attrition mill, sieved using a 500 μm mesh and the flour was packed in an airtight container before analysis.

Methods of Analyses

Determination of the proximate composition of raw material (flour)

The proximate composition (moisture, crude protein, crude fat, crude fibers and crude ash) of the raw material was determined according to the method described by [17]. The total carbohydrate was determined by difference.

Phytochemical determination

Phytate determination

Phytate content was determined using the indirect colorimetric method of Wheeler and Ferrel [18]. Approximately 4 g of the sample was extracted with 100 mL of 2% hydrochloric acid (HCl) for 3 h at room temperature and filtered through Whatman No. 1 filter paper. An aliquot (25 mL) of the filtrate was transferred into a conical flask, followed by the addition of 5 mL of 0.3% ammonium thiocyanate solution as an indicator. Thereafter, 53.5 mL of distilled water was added to acidify the solution. The mixture was titrated with a standard iron (III) chloride solution (0.00566 g/mL, containing 0.00195 g Fe/mL) until a persistent brownish coloration was observed for 5 min. The phytate content was calculated and expressed as mg/100 g of sample.

Determination of Haemagglutinin

Haemagglutinin was determined according to the method described by [19]. Two grammes (2 g) of the sample was weighed into 40 ml normal saline solution buffered at pH 6.4 with 0.01 m phosphate buffer solution. It was allowed to stand at room temperature for 30 mins and centrifuged to obtain the extract. Half of a milliliter (0.05 ml) of the extract was diluted in a test tube. 1 ml of heparinized rabbit blood was poured. The blank was prepared by adding 1 ml of blood into a test tube and allowed to stand for 4 h at room temperature. 1 ml of normal saline was added to all the test tubes and it was allowed to stand for 10 min, after which the absorbance was read at 620 nm.

Haemagglutinin unit/g = (b − a) × F
where b = absorbance of the blank

$$F = \frac{1}{w} \times \frac{f}{Va} \qquad \text{Eqn. 2}$$

Where; W = Weight of sample; VF = Total volume of extract; VA = Volume of extract used in the assay; D = dilution factor.

Determination of Tannin content

Tannin content was determined using the ferric chloride–potassium ferrocyanide colorimetric method described by [20]. The absorbance was measured at 720 nm after colour development, and tannin content was determined from a tannic acid standard curve. Results were expressed as mg tannic acid equivalent (TAE)/100 g sample.

Statistical analysis

Data were generated in triplicate; one-way analysis of variance (ANOVA) was used to analyze the results obtained using Statistical Package for Social Sciences (SPSS) version 21. Means were separated using Duncan's new multiple range test (DNMRT). Statistical significance was accepted at $p \leq 0.05$.

III. RESULTS AND DISCUSSION

Proximate Composition of Raw Materials (Flour)

The proximate composition of pigeon pea, maize, and cooking banana flours (Table 1) showed clear variations in nutrient content, reflecting their different botanical origins and compositional characteristics. Protein content ranged from 6.45% in maize flour to 7.45% in pigeon pea flour, with cooking banana flour recording an intermediate value of 7.05%. The differences among the samples were statistically significant ($P < 0.05$), indicating true variation in protein levels. The higher protein content observed in pigeon pea flour is consistent with its classification as a legume, which is generally richer in protein than cereals and starchy fruits. Previous studies by [21] have reported protein contents of 20.70% in pigeon pea flour.

This protein content shows that pigeon pea protein is of exceptional quality, particularly rich in lysine, making it a crucial complement to cereals, fruits, and root-based diets. [22] reported 4.49 to 4.79% protein in two varieties of cooking banana flour, indicating that although banana is not a high-protein source, it contributes meaningfully when incorporated into composite formulations.

Ash content, which represents the total mineral residue, ranged from 2.35% in cooking banana flour to 2.74% in pigeon pea flour, with statistically significant differences among samples ($P < 0.05$). The trend observed (pigeon pea > maize > banana) suggests a higher mineral concentration in legume flour compared to cereal and fruit flours. Ash content serves as a measure of the total mineral content in food and is indicative of its overall mineral quality

[23]; pigeon pea flour exhibited relatively high ash values due to its richer micronutrient composition, particularly iron, calcium, and phosphorus. Similarly, [24] reported ash values of 3.96% for pigeon pea flour. The comparatively lower ash value in cooking banana flour may be associated with mineral losses during slicing and drying processes.

Crude fibre content varied slightly among the flours, ranging from 2.04% in pigeon pea flour to 2.24% in cooking banana flour, with significant differences observed ($P < 0.05$). The relatively higher fibre level in cooking banana flour may be attributed to the presence of resistant starch and non-starch polysaccharides, which are known to contribute to improved digestive health and glycaemic control. The lower fibre content in pigeon pea flour could be linked to partial dehulling during processing, which often reduces the fibre fraction in legume flours.

Fat content showed marked variation among the samples, with cooking banana flour recording the highest value (4.12%), followed by maize flour (2.26%) and pigeon pea flour (1.82%). These differences were statistically significant ($P < 0.05$). The elevated fat level in cooking banana flour may be related to naturally occurring lipid components and starch–lipid complexes within the pulp. In contrast, the relatively low fat contents of maize and pigeon pea flours are advantageous for storage stability, as lower lipid levels reduce the risk of oxidative rancidity and extend shelf life.

Moisture content ranged from 5.75% in maize flour to 7.23% in pigeon pea flour, with all values falling below 10%. Such low moisture levels are desirable for flour storage, as they limit microbial growth and enhance product stability. The observed values are consistent with recommended standards for dry flours and suggest that the samples possess good keeping quality under appropriate storage conditions.

Carbohydrate content, determined by difference, was highest in maize flour (80.82%), followed by pigeon pea flour (78.72%) and cooking banana flour (77.57%), with significant variation among samples ($P < 0.05$). The higher carbohydrate level in maize flour reflects its well-known starch richness and energy-dense nature. The slightly lower carbohydrate contents in pigeon pea and cooking banana flours may be attributed to their comparatively higher proportions of protein, fibre, and fat. Overall, the complementary distribution of nutrients among the three flours highlights their potential suitability for balanced composite flour formulations.

Table 1: Proximate composition of raw materials (flour)

Samples	Protein (%)	Ash (%)	Fibre (%)	Fat (%)	Moisture (%)	Carbohydrates (%)
Pigeon pea flour	$7.45^a \pm 0.01$	$2.74^a \pm 0.05$	$2.04^c \pm 0.00$	$1.82^c \pm 0.00$	$7.23^a \pm 0.00$	$78.72^b \pm 0.06$
Maize flour	$6.45^c \pm 0.00$	$2.62^b \pm 0.00$	$2.11^b \pm 0.00$	$2.26^b \pm 0.06$	$5.75^c \pm 0.00$	$80.82^a \pm 0.06$
Cooking banana flour	$7.05^b \pm 0.03$	$2.35^c \pm 0.00$	$2.24^a \pm 0.00$	$4.12^a \pm 0.00$	$6.68^b \pm 0.01$	$77.57^c \pm 0.04$

Values are mean ± standard deviation (n = 3). Means with same superscripts along the same column are not significantly different ($p < 0.05$).

Anti-nutrient Properties of Raw Materials (Flour)

The anti-nutritional properties of maize, pigeon pea, and cooking banana flours are presented in Table 2. Phytate content ranged from 2.23 to 2.35 mg/100 g, with maize flour recording the lowest value (2.23 mg/100 g) and cooking banana flour the highest (2.35 mg/100 g). Phytates are naturally occurring compounds known to chelate essential minerals such as calcium, iron, and zinc, thereby reducing their bioavailability in the human body. The relatively low phytate levels observed across all samples suggest minimal interference with mineral absorption when these flours are used in food formulations, as the phytate concentrations fall within the typical range for plant-derived foods. Furthermore, such levels can be effectively reduced through conventional processing methods including soaking, fermentation, germination, and thermal treatment.

Tannin content varied from 2.37 mg/100 g in maize flour to 2.69 mg/100 g in pigeon pea flour, while cooking banana flour recorded 2.59 mg/100 g. Tannins are polyphenolic compounds that possess antioxidant properties but may reduce protein digestibility by forming insoluble complexes with proteins and digestive enzymes when present in high concentrations. Tannins are important physicochemical compounds that contribute to several physiological effects; they help speed up blood clotting, help lower blood pressure, reduce serum lipid levels, and influence liver damage (necrosis) and immune system activity [25]. The slightly higher tannin concentration in pigeon pea flour may be attributed to its inherent polyphenolic composition, which is characteristic of many legumes. Although elevated tannin levels can negatively influence palatability and nutrient utilization, the concentrations recorded here remain within acceptable dietary limits and may contribute beneficial antioxidant effects at low levels.

Haemagglutinin content ranged from 0.74 to 0.84 Hiu/mg, with pigeon pea flour exhibiting the highest value and cooking banana flour the lowest. Haemagglutinins have been known to agglutinate red blood cells and impair various physiological and biochemical processes in mammals upon ingestion [26]. However, these compounds are heat-labile and are substantially inactivated during common food processing operations such as boiling, roasting, and extrusion. [27] reported that dehulling in combination with heat treatment such as boiling, blanching, autoclaving, and roasting resulted in a greater reduction of the anti-nutrient contents of African yam bean flours. The higher value observed in pigeon pea flour is consistent with the natural tendency of legumes to contain greater lectin concentrations than cereals and fruits. Overall, the low levels recorded across the samples indicate limited toxicological concern, particularly when the flours are subjected to adequate thermal processing prior to consumption.

Table 2: Anti-nutrient properties of raw materials (flour)

Sample	Phytate (mg/100g)	Tannin (mg/100g)	Haemagglutinin (Hiu/mg)
Maize flour	2.23±0.01	2.37±0.01	0.78±0.00
Pigeon pea flour	2.34±0.16	2.69±0.00	0.84±0.00
Cooking banana flour	2.35±0.00	2.59±0.00	0.74±0.00

IV. CONCLUSION

This study demonstrated that maize, pigeon pea, and cooking banana flours possess distinct but complementary nutritional and anti-nutritional characteristics that support their suitability for composite food formulation. Pigeon pea flour exhibited relatively higher protein and ash contents, confirming its value as a protein-enriching ingredient in cereal-based products. Maize flour showed the highest carbohydrate content, highlighting its role as a primary energy source, while cooking banana flour contributed comparatively higher fat and fibre levels, which may enhance dietary fibre intake and functional properties in formulated foods. Although anti-nutritional factors such as phytates, tannins, and haemagglutinins were present in all samples, their concentrations were within acceptable limits and can be further reduced through conventional processing methods such as soaking, fermentation, or thermal treatment. The overall findings indicate that strategic blending of these flours can improve nutritional balance while maintaining acceptable safety and quality attributes. Consequently, maize, pigeon pea, and cooking banana flours present promising potential for the development of nutritionally enhanced composite food products and value-added formulations.

Conflict of Interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author Contributions
AGADA Thankgod: Conceived and designed the study, collected the data, performed the experiments, wrote the first draft of the manuscript and interpreted the results. OLONIYO Rebecca Olajumoke: Analyzed the data, and contributed to revising and improving the manuscript. UGWUONA Fabian Uchenna: Supervised the research, provided methodological guidance, reviewed the manuscript critically, and approved the final version. All of the authors have read and approved the final manuscript. This manuscript has not been submitted to, nor is under review at another journal or other publishing venue.

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