

Proximate, Minerals and Sensory Properties of Protein Fortified Weaning Food Produced from Maize (*Zea Mays*), African Yam Bean (*Sphenostylis Stenocarpa*) And Blood Leaf (*Justicia Secunda*).

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Abstract- *This research evaluated the proximate composition, mineral constituents and sensory properties of protein-fortified weaning food produced from composite blends of maize (*Zea mays*), African yam bean -AYB (*Sphenostylis stenocarpa*), and blood leaf (*Justicia secunda*) flours. Maize grains were soaked, gelatinized, oven-dried (55 °C), milled and sieved (500µm). AYB was soaked, dehulled, boiled (100 °C) for 30min, tray-dried (60 °C) for 12hr, milled and sieved (500µm). Blood leaf leaves were washed, blanched at 80 °C for 3min, tray-dried (60 °C) for 10 hr, milled and sieved (500µm). The maize, African yam bean, and blood leaf flours were blended in ratios 100:0:0, 90:5:5, 80:10:10, 70:15:15, 60:20:20, 50:25:25). Samples were subjected to laboratory analysis using standard methods, data generated were analysed statistically. Results showed moisture range (9.76-10.10%), protein (8.03-16.52%), fat (3.99-4.83%), ash (1.00-5.00%), fibre (2.02-4.75%) and carbohydrates (59.14-75.60%), with energy values of 346.11-370.43 kJ/100g. Mineral contents (mg/100g) ranged: calcium 30.02-88.52, iron 3.02-7.99, magnesium 88.12-169.48, zinc 2.97-6.54 and phosphorus 117.59-194.86. Sensory scores declined slightly with increased substitution, with the control most preferred though all samples remained acceptable. The research concludes that incorporating AYB and Blood leaf flours into maize-based formulations enhances nutritional and sensory acceptability, offering a sustainable approach to combating malnutrition among children*

Key Words: *African Yam Bean, Blood Leaf, Maize and Weaning Food*

I. INTRODUCTION

Weaning foods, also known as complementary foods, represent a critical transition in an infant's diet from exclusive breastfeeding or formula feeding to the inclusion of solid or semi-solid foods, typically beginning around 6 months of age (Abioye et al., 2015). This period is essential for supporting rapid growth, cognitive development, and immune function, as breast milk alone becomes insufficient to meet the increasing nutritional demands of the infant (Adelekan et al., 2020). The World Health Organization (WHO) and the American Academy of Pediatrics recommend introducing complementary foods between 6 and 12 months, alongside continued breastfeeding up to 2 years or beyond, to prevent malnutrition and promote optimal health outcomes (Dewey, 2013). Over the years, research has underscored the long-term importance of nutrient-dense weaning foods. Studies from the 1980s onward, including WHO/UNICEF initiatives, highlighted how inadequate complementary feeding contributes to 45% of child deaths under 5 years globally, emphasizing the need for energy-dense, bioavailable formulations (Ijarotimi et al, 2021). Recent advancements, such as baby-led weaning (BLW) introduced in the early 2000s, promote self-feeding with family foods to foster healthy eating habits and reduce obesity risk, though evidence shows it must be paired with nutritional education to avoid excesses in sodium or fats (Chinma et al.,

2020). In low-income contexts, fortification with legumes and micronutrient-rich plants has proven effective; for instance, legume-enriched porridges improve weight-for-age z-scores by 10-15% in trials across India and Africa. Contemporary challenges include climate change impacting staple availability and rising vegan/vegetarian weaning trends, which require monitoring for deficiencies in B12 and iron. Overall, weaning foods remain pivotal for breaking intergenerational cycles of malnutrition, with recent studies advocating for locally sourced, sustainable formulations to enhance food security and child resilience (Onyango et al., 2017). The development of weaning foods using composite flours from indigenous crops like maize, African yam bean (AYB) (Anosike et al., 2020), and blood leaf offers a sustainable approach to improving nutritional quality while reducing reliance on imported cereals (Ranum et al., 2014; Adegboyega et al., 2020). These raw materials provide complementary nutritional profiles: maize for carbohydrates, African yam bean (AYB) for protein (Ade-Omowaye et al., 2018), and blood leaf for micronutrients and bioactive compounds (Popoola et al., 2021; Swiatek et al., 2023). The incorporation of such blends aligns with global calls for fortification to combat malnutrition, as seen in studies promoting legume-cereal composites for enhanced amino acid profiles and mineral bioavailability (FAO, 2017). Additionally, consumer acceptability remains critical, as sensory attributes like taste, texture, and appearance heavily influence the adoption of fortified weaning foods (Gibson et al., 2010; Ukom et al., 2019). This study explores the chemical composition of weaning foods formulated from maize, African yam bean, and blood leaf highlighting their potential to address nutritional deficiencies and promote sustainable food systems.

II. MATERIALS AND METHODS

Source of Materials

The maize grains used for this study was purchased from Eke-Awka Market, Anambra State while the African yam bean (*Sphenostylis stenocarpa*) was sourced from Eke-Onunwa market in Owerri North Local Government in Imo state and the fresh leaves of Blood leaf (commonly known as Blood leaf) was harvested from the local farms in Nnamdi Azikiwe

University, Anambra State, where the plant grows abundantly in the wild. Other ingredients and materials used for sample preparation and laboratory analysis, including distilled water, packaging materials, and analytical-grade chemical reagents, were obtained from the Department of Food Science and Technology Laboratory, Nnamdi Azikiwe University, Anambra State.

Experimental Design

A completely randomized design (CRD) which involves the combination of raw materials to form unique products was adopted for this study. In this design, the maize, African yam bean and blood leaf flours were blended together at different ratios (100:0:0, 90:5:5, 80:10:10, 70:15:15, 60:20:20, 50:25:25) to produce six different samples of weaning food.

Preparation of Maize Gruel

Dry maize gruel was prepared using a mechanized method adapted from Adelekan (2025). One kilogram (1 kg) of dried white maize grains was sorted, cleaned, soaked in 3 litres of potable water at 30 ± 2 °C for 24 h, with water changed every 8 h. After soaking, the grains were rinsed thoroughly, drained, and dried in a hot-air oven at 55 °C until constant weight was achieved. The dried grains were milled and sieved through a 500-micron mesh sieve. The flour obtained was reconstituted with water (1:3 w/v) and cooked at 90 °C for 10 min with constant stirring until gelatinized. The gelatinized mash was spread thinly on trays and oven-dried at 55 °C to constant weight. The dried flakes were milled again into fine flour, sieved (500 µm), and packaged in airtight, food-grade plastic containers and stored.

Processing of African Yam Bean Flour

The African yam bean flour was prepared following the method described by (Okoye et al., 2024). One kilogram (1 kg) of African yam bean seeds was sorted, soaked in 4 litres of potable water at 30 ± 2 °C for 12 h, dehulled, boiled for 30 min, drained, tray dried at 60°C for 12 h, milled, and sieved through a 500-micron mesh sieve and packaged

Processing of Blood Leaf flour

According to Afolabi et al. (2021), Fresh leaves of blood leaf were sorted, washed in clean water, drained and blanched in hot water at 80°C for 3 min, cooled under running water, dried in a hot air tray dryer at 60°C for 10 h, milled, sieved through a 500-micron mesh and packaged.

Production of Protein Fortified Weaning Food

Protein-fortified weaning food was prepared using flour blends derived from maize, African yam bean and blood leaf. The composite flour blends were formulated according to predetermined proportions, as designed in the mixture experiment. For each formulation, the appropriate quantities of maize flour, African yam bean flour, and blood leaf powder were weighed accurately using a digital balance. Each blend was then thoroughly mixed using a mechanical blender to ensure homogeneity and uniform distribution of nutrients. The homogenized flour blends were used to prepare the weaning food by gradually adding 100 g of the composite flour into 400 mL of clean boiling water under continuous stirring in a stainless-steel pot. This step was essential to avoid lump formation and ensure a smooth texture. The mixture was cooked over low to medium heat for 10 to 15 minutes until a thick, smooth, and gruel-like consistency was obtained. After cooking, the samples were allowed to cool to room temperature.

III. LABORATORY ANALYSIS

Sensory evaluation of the samples was carried out using the method as described by Adelekan et al (2020).

Determination of proximate composition of the weaning food samples

The analysis conducted included moisture content, ash content, crude fat, crude fibre, crude protein, carbohydrate content, and energy value were conducted in triplicates and followed standard procedures described by AOAC (2010).

IV. RESULTS AND DISCUSSION

Proximate Composition of Weaning Food Samples

The proximate composition of the formulated weaning food samples is presented in Table 1.

The moisture content of the samples ranged from 9.76% to 10.10%. The 100% maize sample (MAJ-A) recorded the highest value (10.10%) while the sample containing 25% African yam bean and 25% Blood leaf (MAJ-F) had the least value (9.76%). There were significant ($p \leq 0.05$) differences among the samples. The progressive reduction in moisture with increasing substitution levels of African yam bean and Blood leaf suggests that these ingredients contributed to lower moisture retention in the blends, possibly due to their higher dry matter content and reduced water-binding capacity compared to maize. This trend aligns with the findings of Olayiwola et al. (2024), who reported that the inclusion of leguminous and leafy plant flours tends to reduce the moisture content of cereal-based blends due to their dense protein and fibre structure. Low moisture levels are desirable in complementary food production because they minimize microbial proliferation and extend shelf life. According to Adewale et al. (2023), the lower the moisture content, the better the product's stability during storage, since moisture is directly associated with susceptibility to spoilage.

Table 1 Proximate composition (%) of weaning food Samples

| Ample | Moisture | Protein | Fat | Ash | Fibre | Carbohydrate | Energy (Kcal/100g) |
|-------|--------------------------|--------------------------|-------------------------|-------------------------|-------------------------|--------------------------|---------------------------|
| MAJ-A | 10.10 ^a ±0.14 | 8.03 ^c ±0.01 | 3.99 ^e ±0.01 | 1.00 ^c ±0.00 | 2.02 ^c ±0.01 | 75.60 ^a ±0.01 | 370.43 ^a ±0.01 |
| MAJ-B | 9.95 ^b ±0.01 | 10.55 ^d ±0.07 | 4.35 ^d ±0.01 | 1.03 ^c ±0.04 | 2.65 ^d ±0.07 | 71.25 ^b ±0.01 | 366.35 ^b ±0.01 |
| MAJ-C | 9.90 ^{bc} ±0.01 | 12.10 ^c ±0.14 | 4.45 ^c ±0.01 | 2.00 ^d ±0.00 | 3.15 ^c ±0.07 | 68.44 ^c ±0.01 | 361.85 ^c ±0.01 |
| MAJ-D | 9.85 ^{bc} ±0.01 | 12.93 ^c ±0.10 | 4.51 ^c ±0.01 | 3.01 ^c ±0.01 | 3.75 ^b ±0.07 | 65.95 ^d ±0.01 | 356.11 ^d ±0.01 |
| MAJ-E | 9.80 ^{bc} ±0.01 | 14.57 ^b ±0.68 | 4.67 ^b ±0.01 | 4.45 ^b ±0.07 | 4.01 ^b ±0.01 | 62.50 ^e ±0.01 | 350.31 ^e ±0.01 |

| Sample | Moisture | Protein | Fat | Ash | Fibre | Carbohydrate | Energy (Kcal/100g) |
|--------|-------------------------|--------------------------|-------------------------|-------------------------|-------------------------|--------------------------|---------------------------|
| MAJ-F | 9.76 ^c ±0.01 | 16.52 ^a ±0.70 | 4.83 ^a ±0.07 | 5.00 ^a ±0.00 | 4.75 ^a ±0.36 | 59.14 ^f ±0.01 | 346.11 ^f ±0.01 |

Values are mean ± standard deviation and any value that is not followed with same superscription each column is significantly different ($p \leq 0.05$)

Key Words

MAJ-A (Maize 100%), MAJ-B (Maize 90%, African yam bean 5%, Blood leaf 5%), MAJ-C (Maize 80%, African yam bean 10%, Blood leaf 10%), MAJ-D (Maize 70%, African yam bean 15%, Blood leaf 15%), MAJ-E (Maize 60%, African yam bean 20%, Blood leaf 20%), MAJ-F (Maize 50%, African yam bean 25%, Blood leaf 25%)

The increase in ash content with higher substitution levels reflects the higher mineral density of African yam bean and Blood leaf compared to maize. This result agreed with the findings of Chinedu and Okoye (2023) and Many et al. (2023) who reported that inclusion of legume and leafy vegetable flours in cereal-based blends significantly enhances their ash content, an indicator of improved mineral presence. The ash values obtained in this study (1.00–5.00%) are comparable to those reported by Adebayo et al. (2023) for maize–soybean blends (1.5–4.8%) and Adewale et al. (2023) for maize–Bambara groundnut complementary foods (2.2–5.1%). According to FAO/WHO (2021), the acceptable ash range for complementary foods lies between 1–5%, meaning all samples fall within acceptable limits. The increase in ash content indicates an improvement in the mineral composition of the formulated weaning food, which is essential for bone formation, blood production, and enzyme activation in infants (Adejuyitan et al., 2023).

The crude fibre content of the samples ranged from 2.02% to 4.75%. The lowest value was observed in MAJ-A (100% maize, 0% African yam bean and 0% Blood leaf) while MAJ-F had the highest. The increase in crude fibre with higher substitution levels could be attributed to the naturally high fibre content of African yam bean and Blood leaf both of which contribute insoluble fibres that aid digestion and enhance bowel movement. Similar results were obtained by Adewale et al. (2023) in maize–bambara

groundnut weaning foods where fibre increased proportionally with legume addition. Dietary fibre plays an important physiological role, promoting satiety and preventing constipation, which are crucial for infant digestive health (FAO/WHO, 2021). The fibre content in this study falls within the 1–5% acceptable range for complementary foods (FAO/WHO, 2021).

The crude fat content of the samples ranged from 3.99% to 4.83%. MAJ-A had the lowest value while MAJ-F recorded the highest. There were significant ($p \leq 0.05$) differences among samples. The observed increase in fat content with substitution can be linked to the lipid contribution of African yam bean and Blood leaf both of which contain oil fractions rich in unsaturated fatty acids (Many et al., 2023). The fat content observed in this study falls within the range (3–10%) recommended by FAO/WHO (2021) for complementary foods. Similar fat levels (4.2–5.0%) were reported by Dabels et al. (2023) for maize–mung bean blends and by Adewale et al. (2023) for maize–bambara formulations. The slight increase in fat as substitution increases suggests a positive contribution to energy density and improved nutrient bioavailability.

The protein content of the samples ranged from 8.03% to 16.52%. MAJ-A had the least value (8.03%) while MAJ-F had the highest (16.52%). The progressive increase in protein content with substitution clearly demonstrates the protein enrichment effect of African yam bean and Blood leaf. African yam bean is a legume that contains about 21–25% protein while Blood leaf contributes additional amino acids and phytonutrients that enhance protein quality (Olayiwola et al., 2024). The significant increase in protein across the samples ($p \leq 0.05$) is consistent with the findings of Adejuyitan et al. (2023) who reported similar improvements in protein content when legume flours were incorporated into cereal-based weaning formulations. Adequate protein intake during infancy is essential for rapid growth and tissue development. According to FAO/WHO (2021), the recommended minimum

protein content for complementary foods is 13% indicating that all blends containing African yam bean and Blood leaf (MAJ-B to MAJ-F) meet and exceed this standard. The enhancement in protein composition observed in this study suggests that the formulated products can help combat protein–energy malnutrition (PEM), which remains prevalent among infants in developing countries (Adebayo et al., 2023; Many et al., 2023). The carbohydrate content of the samples ranged from 59.14% to 75.60%. The control MAJ-A had the highest carbohydrate value (75.60%) while MAJ-F had the lowest (59.14%). There were significant ($p \leq 0.05$) differences among the samples. The reduction in carbohydrate with increasing substitution is typical in cereal–legume formulations since legume and leafy vegetable flours contribute more protein and fibre, thereby reducing the relative carbohydrate proportion. This trend is in line with the reports of Olayiwola et al. (2024) and Adebayo et al. (2023) who observed a similar pattern in maize–soybean blends. The carbohydrate contents of the samples fall within the recommended range (50–75%) for complementary foods (FAO/WHO, 2021). Carbohydrates serve as the primary energy source for infants and the observed levels are nutritionally adequate to meet daily energy demands while maintaining balanced macronutrient distribution. The energy value of the samples ranged from 346.11 to 370.43 kcal/100 g. The control sample MAJ-A (100% maize, 0% African yam bean and 0% Blood leaf) had the highest energy value (370.43 kcal/100 g) while MAJ-F recorded the least (346.11 kcal/100

g). The gradual decrease in energy with higher substitution could be attributed to the increase in fibre and ash fractions and the corresponding decrease in carbohydrates. Similar observations were reported by Adewale et al. (2023) and Dabels et al. (2023).

Despite the reduction, all samples fall within the recommended energy density (340–400 kcal/100 g) for complementary foods (FAO/WHO, 2021). Energy density is critical for infant feeding because it determines how much nutrient is available per serving. Therefore, the formulated blends can meet the daily caloric requirements for infants and young children, as they are comparable to values reported for commercial complementary foods (Many et al., 2023; Chinedu and Okoye, 2023). Overall, the results of this study demonstrate that the substitution of maize with African yam bean and Blood leaf significantly improved the nutritional profile of the weaning food samples. The increase in protein, fat, ash, and fibre content enhances the overall nutrient density, while the moisture content remains within acceptable limits for stability. All samples meet the proximate composition standards recommended by both Codex Alimentarius (FAO/WHO, 2021) and SON (2018). The formulated weaning foods therefore have the potential to improve nutritional adequacy, dietary diversity, and health outcomes among infants and young children, particularly in regions vulnerable to protein–energy malnutrition.

Table 2: Sensory Properties of Weaning Food Samples

| Sample | Appearance | Flavour | Aroma | Texture | Taste | Mouth-feel | Overall acceptability |
|--------|--------------------------|-------------------------|--------------------------|-------------------------|--------------------------|--------------------------|--------------------------|
| MAJ-A | 6.92 ^a ±1.85 | 6.96 ^a ±2.01 | 7.00 ^a ±1.47 | 7.00 ^a ±1.89 | 6.88 ^a ±1.76 | 7.00 ^a ±1.61 | 7.12 ^a ±1.56 |
| MAJ-B | 6.56 ^{ab} ±1.61 | 6.92 ^a ±1.44 | 6.97 ^a ±1.47 | 6.68 ^a ±1.80 | 6.84 ^a ±1.91 | 6.88 ^{ab} ±1.62 | 6.68 ^a ±1.60 |
| MAJ-C | 6.48 ^{ab} ±1.92 | 6.53 ^a ±1.93 | 6.80 ^{ab} ±1.91 | 6.56 ^a ±1.56 | 6.77 ^{ab} ±1.76 | 6.65 ^{ab} ±1.76 | 6.33 ^{ab} ±1.52 |
| MAJ-D | 6.44 ^{ab} ±1.69 | 6.44 ^a ±1.45 | 6.76 ^{ab} ±1.51 | 6.37 ^a ±1.67 | 6.25 ^{ab} ±1.74 | 6.57 ^{ab} ±1.57 | 6.12 ^{ab} ±1.88 |
| MAJ-E | 6.31 ^{ab} ±1.52 | 7.02 ^a ±1.33 | 6.45 ^{ab} ±1.33 | 6.15 ^a ±1.88 | 6.10 ^{ab} ±1.79 | 6.32 ^{ab} ±1.32 | 6.08 ^{ab} ±1.23 |
| MAJ-F | 6.25 ^{ab} ±1.83 | 6.04 ^a ±1.20 | 5.85 ^b ±1.53 | 6.04 ^a ±1.88 | 5.72 ^b ±1.49 | 5.88 ^b ±1.78 | 5.75 ^b ±1.86 |

Data are mean ± standard deviation of twenty (20) semi – trained judges. Means in the same column bearing different superscripts differed significantly ($p < 0.05$) from each other.

MAJ-A (Maize 100%), MAJ-B (Maize 90%, African yam bean 5%, Blood leaf 5%), MAJ-C (Maize 80%, African yam bean 10%, Blood leaf 10%), MAJ-D (Maize 70%, African yam bean 15%, Blood leaf

Keys:

15%), MAJ-E (Maize 60%, African yam bean 20%, Blood leaf 20%), MAJ-F (Maize 50%, African yam bean 25%, Blood leaf 25%)

The slight reduction in flavor intensity with increasing substitution could be attributed to the natural beany flavor of African yam bean and the herbaceous undertones of Blood leaf (Adebayo et al., 2023). This trend aligns with the report of Adejuyitan et al. (2023), who found that legumes and leafy vegetables sometimes impart mild earthy flavors that reduce flavor ratings slightly. Nonetheless, all samples were rated between “liked moderately” and “liked slightly,” suggesting that the flavor was acceptable and appealing to most panelists.

Aroma scores ranged from 5.85 in MAJ-F (50% maize, 25% African yam bean and 25% Blood leaf) to 7.00 in MAJ-A (100% maize, 0% African yam bean and 0% Blood leaf), showing significant ($p \leq 0.05$) differences among samples. The aroma of the control sample was most preferred, while the sample with the highest proportion of Blood leaf and African yam bean had the least score. The slight decrease in aroma rating can be attributed to volatile compounds in Blood leaf and the inherent leguminous odor of African yam bean, which may have masked the natural aroma of maize (Chinedu and Okoye, 2023). Texture ratings ranged from 6.04 to 7.00, with MAJ-A having the highest value and MAJ-F (50% maize, 25% African yam bean and 25% Blood leaf) the lowest. Although the scores slightly declined with higher substitution, no significant differences ($p > 0.05$) were observed among the samples. The result suggests that partial substitution with African yam bean and Blood leaf did not adversely affect the textural smoothness or consistency of the product.

The mean taste scores ranged from 5.72 in MAJ-F to 6.88 in MAJ-A. The slight decline with increasing substitution could be due to the characteristic earthy taste of Blood leaf and the mild bitterness from its phytochemical constituents such as saponins and alkaloids (Adebayo et al., 2023). Nevertheless, all samples were within the acceptable sensory threshold. According to FAO/WHO (2021), weaning foods should possess a neutral or mildly sweet taste to ensure palatability and infant acceptance. The

current study’s findings align with those of Adejuyitan et al. (2023) who noted that legume–vegetable enrichment often leads to lower taste scores but does not render the product unacceptable if sweetness or mild flavoring is incorporated. Mouthfeel scores ranged from 5.88 to 7.00, with MAJ-A recording the highest and MAJ-F the lowest. The decrease across substitution levels may be associated with the increased fibre content of African yam bean and Blood leaf which could impart a slightly gritty sensation (Adewale et al., 2023). However, since all scores remained above 5.0, the texture and smoothness of the product were still perceived as acceptable. Overall acceptability ranged from 5.75 to 7.12, with the control MAJ-A being most preferred and MAJ-F least. There were significant ($p \leq 0.05$) differences among samples. The gradual decline in acceptability corresponds with the incremental inclusion of African yam bean and Blood leaf. Nonetheless, all samples were generally liked (scores ≥ 5.0), indicating that the products were organoleptically acceptable to the panelists. This observation agrees with the reports of Many et al. (2023) and Olayiwola et al. (2024), who found that cereal–legume–vegetable blends, though sometimes slightly less preferred than pure cereals, are still acceptable due to their enhanced nutritional and functional benefits.

V. CONCLUSION

The results showed that blending maize with African yam bean and Blood leaf significantly improved the nutritional and functional properties of the weaning food samples. The protein, ash, crude fibre, and fat contents of the blends increased with higher substitution levels, while moisture and carbohydrate contents decreased. These results indicate that African yam bean and Blood leaf contributed valuable nutrients to the formulations, making them richer in protein and minerals and more suitable for infant growth and development. The protein contents (8.03–16.52%) obtained in this study are within the FAO/WHO recommended range for complementary foods, thereby meeting the basic protein needs of weaning infants. The reduction in moisture content across the blends suggests better shelf stability and less susceptibility to microbial spoilage, enhancing

the product's storage potential. The control sample (100% maize) had slightly higher ratings in appearance and overall acceptability; however, the formulated blends-maintained scores within the "liked moderately" to "liked very much" range. This indicates that the inclusion of African yam bean and Blood leaf did not negatively affect the sensory quality of the products. The mild variations observed at higher substitution levels may be attributed to the natural beany flavor of African yam bean and the characteristic greenish hue of Blood leaf. The product meets recommended nutrient standards for complementary foods and offers a sustainable and affordable alternative for infant feeding, especially in regions facing food insecurity and high dependency on imported baby foods. The formulation can serve as a practical intervention for reducing malnutrition and improving the nutritional status of infants and young children in developing countries.

VI. ACKNOWLEDGEMENTS

The authors acknowledge the Department of Food Science and Technology, Nnamdi Azikiwe University Awka, Anambra State, Nigeria.

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