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Nutritional Evaluation of Five Indigenous Complementary Food Formulations commonly used in Calabar, Cross River State, Nigeria

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ABSTRACT

Malnutrition among infants and young children remains a significant public health challenge in Nigeria. This study investigated the proximate, mineral and vitamin composition of five indigenous complementary food formulations commonly consumed in Calabar, Cross River State, Nigeria. Five different formulations, composed of locally sourced ingredients were purchased from local markets and processed using standard methods. The various formulations were then analysed for proximate, vitamin and mineral contents. Each formulation offered a unique blend of nutrients, with all the formulations showing appreciable amounts of both fat- and water-soluble vitamins. Formular A stood out from the others, containing the highest concentration of the B-complex vitamins and mineral elements relative to the other formulations, meeting the dietary refence intake for most nutrients. While formulars D and E contained higher vitamin A concentration than the others. Iron and zinc were highest in samples E and C respectively. All formulations contained nutritionally relevant concentrations of essential minerals. Most blends met the recommended daily allowance, while a few may need fortification with some vitamins and/or minerals. The study highlights the options available to fortify these complementary food formulations for better nourishment of infants and young children in Calabar, Nigeria, and beyond. The findings confirm that indigenous food resources, when scientifically optimized, can serve as effective, affordable, and culturally acceptable alternatives to commercial infant formulas. The study further underscores the potential of locally formulated complementary foods to address micronutrient deficiencies, promote dietary diversity, and strengthen food security in low-income communities.

1. INTRODUCTION

Malnutrition among infants and young children continues to present a serious public health burden in Nigeria, with evidence showing high levels of stunting, wasting, and micronutrient deficiencies among children under the age of five [1]. This challenge is particularly severe in rural areas, where poverty, limited access to healthcare services, and inadequate diets prevail, thereby creating an environment where the nutritional needs of children are not met in sufficient quality or quantity. Complementary feeding plays a pivotal role in addressing these concerns, as it refers to the introduction of additional foods and liquids alongside breast milk in order to meet the expanding nutritional requirements of infants. According to the World Health Organisation (WHO), exclusive breastfeeding should be sustained for the first six months of life, after which complementary foods ought to be introduced while continuing breastfeeding until at least two years of age or longer [2]. The essence of this recommendation lies in the fact that while breast milk provides complete nutrition in the first half-year of life, it becomes insufficient on its own beyond this stage to fully support the growing needs of infants. Hence, the transition to complementary foods is not merely cultural but essential for growth, immune protection, and cognitive development. The WHO [3] stresses that the complementary feeding period, typically spanning six months to two years of age, is a sensitive developmental window where nutritional inadequacies may cause irreversible physical stunting and impaired mental capacity. Tables 1, 2 and 3 show nutrient requirements for infants 7-12 months which corresponds to the period of weaning and introduction of complementary diets.

Table 1: Extracted from the dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, and Protein, for infants aged 6 months to 3 years.
(Food and Nutrition Board, Institute of Medicine, National Academies) (2002/2005) [4].

Life Stage Group	Total Water[a] (L/d)	Carbohydrate (g/d)	Total Fiber (g/d)	Fat (g/d)	Linoleic Acid (g/d)	α-Linolenic Acid (g/d)	Protein[b] (g/d)
0–6 mo	0.7*	60*	ND	31*	4.4*	0.5*	9.1*
7–12 mo	0.8*	95*	ND	30*	4.6*	0.5*	**11.0**
1–3 y	1.3*	**130**	19*	ND[c]	7*	0.7*	**13**

ND = Not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts.

The Food and Nutrition Board, Institute of Medicine, National Academies [4] reports that protein requirements increase from 9.1 g per day at 0–6 months to 11g per day by ages 7 months -12months, while carbohydrates rise from 60 g per day to 95 g per day. Similarly, essential vitamins and minerals such as vitamin A, vitamin C, calcium, and iron show significant increases in recommended intakes as children grow, confirming the need for nutrient-dense complementary diets that can fill these nutritional gaps.

Table 2: Extracted from the DietarynReference Intakes (DRIs): Vitamins. (Food and Nutrition Board, Institute of Medicine, National Academies) (2002/2005).

Age in months	**A (µg/d)**	**(B_1) (mg/d)**	**(B_2) (mg/d)**	**(B_3) (mg/d)**	**(B_5) (mg/d)**	**(B_6) (mg/d)**	**(B_9) (µg/d)**	**(B_{12}) (µg/d)**	**C (mg/d)**	**D (IU/d)**	**E (mg/d)**	**K (µg/d)**
0-6	400*	0.2*	0.3*	2.0*	1.7*	0.1*	0.5*	0.4*	40*	400*	4*	2.0*
7-12	500*	0.3*	0.4*	4.0*	1.8*	0.3*	0.5*	**0.5***	**50***	**400***	**5***	**2.5***
12-36	300*	0.5*	**0.5***	6.0*	2.0*	0.5*	0.7*	**0.9***	**15***	**600***	**6***	**30***

ND = Not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts.

Table 3: Extracted from the Dietary Reference Intakes (DRIs): Elements. (Food and Nutrition Board, Institute of Medicine, National Academies) (2002/2005).

Age in months	Calcium (Ca) (mg/d)	Copper (Cu) (µg/d)	Iodine (I) (µg/d)	Iron (Fe) (mg/d)	Magnesium (Mg) (mg/d)	Manganese (Mn) (mg/d)	Phosphorus (P) (mg/d)	Selenium (Se) (µg/d)	Zinc (Zn) (mg/d)	Sodium (Na) (mg/d)	Potassium (K) (mg/d)
0-6	200*	200*	110*	0.27*	30*	0.003*	100*	15*	2.0*	110*	400*
7-12	260*	220*	130*	11*	75*	0.6*	275*	**20***	**3.0***	**370***	**860***
12-36	700*	340*	**90***	7*	80*	1.2*	460*	**20***	**3.0***	**300***	**2000***

ND = Not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts.

Indigenous complementary foods, particularly those commonly used in Cross River State, Nigeria, are primarily derived from cereals, legumes, tubers, vegetables, fruits, and seafood, reflecting both the natural resource base and cultural food practices of the region [5]. Their affordability, accessibility, and rootedness in local traditions make them the mainstay for infant and young child feeding in rural communities, yet questions persist about their ability to meet the scientifically recommended nutritional standards. Understanding the proximate, vitamin, and mineral composition of these indigenous formulations is therefore crucial to determining their potential role in sustaining infant health and development. The formulations under study include five locally assembled samples, labelled A through E, each representing unique combinations of staple crops and protein sources. Sample A, for instance, combines yellow maize, soybeans, carrots, and spinach, ingredients that illustrate the synergy between grains, legumes, and vegetables in local diets [6, 7]. Yellow maize provides energy and carotenoids; soybeans contribute high-quality plant protein; carrots supply β-carotene and antioxidants; while spinach enriches the mixture with iron and vitamin A. Sample B, made from local rice, egg yolk, apple, and banana, blends starchy grains with animal protein and fruits, thereby creating a nutrient profile that reflects both indigenous and modern dietary influences [8,9]. The egg yolk introduces crucial vitamins such as A, D, and B-complex, while the fruits contribute dietary fibre and ascorbic acid. Sample C, which incorporates local rice, Titus fish, avocado pear, and apple, emphasizes the role of seafood as a dominant protein source in Cross River State diets due to the geographical proximity to rivers and the Atlantic coastline [9]. The inclusion of avocado pear highlights an adaptation towards nutrient-rich fruits, complementing the high-quality protein of fish with monounsaturated fats and vitamin E. Sample D, composed simply of yellow maize and

soybeans, reflects the widespread reliance on cereal-legume pairings in traditional diets, offering a balance of energy and protein. Finally, Sample E, formulated with unripe plantain, crayfish, and palm oil, presents a highly indigenous combination, where plantain provides carbohydrates and resistant starch, crayfish supplies high-value protein and minerals, while palm oil enriches the mix with vitamin A and essential fatty acids [10]. The socio-economic context of infant feeding further complicates this nutritional landscape. Nigeria, like many other developing nations, is undergoing rapid urbanization and industrialization, leading to profound changes in family structures and dietary practices [11]. Many women, pressed by economic necessity, enter the workforce, leaving limited time for prolonged breastfeeding or the preparation of balanced complementary meals at home. Consequently, infants are often introduced prematurely to monotonous single-ingredient diets or commercial formula foods, both of which may lack the diversity required for optimal growth. Moreover, maternal undernutrition contributes to low breast milk production and inferior nutrient quality, thereby compounding the risks faced by infants [12]. The situation is worsened in households without reliable electricity supply, where perishables such as vegetables, dairy, and fish cannot be adequately stored, limiting dietary diversity [13]. In such settings, caregivers often turn to day-care centres and crèches, where the knowledge of child nutrition is limited, thus increasing the risk of inappropriate feeding practices. Despite these challenges, the reliance on nutrient-dense, locally available ingredients such as maize, soybeans, rice, plantains, leafy vegetables, and seafood demonstrate resilience within indigenous food systems. However, with increasing exposure to globalization, food culture is shifting, as illustrated by the introduction of apples, bananas, and avocado pears into complementary food formulations [9]. These changes symbolize the intersection between traditional practices and modern dietary influences, making it important to evaluate whether the evolving food mixtures continue to meet the nutritional benchmarks established by the Food and Nutrition Board, Institute of Medicine, National Academies [4].

Nutritional adequacy depends not only on cultural acceptance but also on scientific assessment of nutrient content. Proximate analysis serves as the fundamental method for evaluating the nutritional composition of foods, particularly homemade formulations [14]. Studies show that many traditional complementary foods in Nigeria fall short of recommended protein, fat, and micronutrient levels, thus contributing to persistent malnutrition and associated developmental deficits [15]. According to the Food and Nutrition Board, Institute of Medicine, National Academies [4], infants require a progressive increase in micronutrients such as iron, which rises from 0.27 mg per day at 0–6 months to 7 mg per day at 12–36 months, while calcium requirements increase from 200 mg per day in early infancy to 700 mg per day by three years of age. Similarly, vitamin requirements vary, with vitamin A shifting from 400 µg daily in early infancy to 300 µg at 1–3 years, while vitamin C needs decline from 40 mg per day at 0–6 months to 15 mg per day at 1–3 years. These dynamic requirements demonstrate the importance of varied complementary diets rich in both macro- and micronutrients. However, indigenous foods such as maize are limited in essential amino acids like lysine and tryptophan [16], while others, such as unripe plantain, although rich in resistant starch and vitamins A, C, and B6, may still not fully satisfy increasing mineral requirements [17]. To bridge these nutritional gaps, combinations of diverse food sources are

critical. Soybeans, for example, is a source of essential amino acids [18], while crayfish and fish provide high-quality animal protein and essential minerals such as calcium, zinc, and iodine [19]. Palm oil contributes tocopherols and carotenoids [20], while vegetables such as spinach and pumpkin leaves enrich diets with vitamin A, iron, and antioxidants [21]. Thus, by combining these food sources, complementary formulations can approach the recommended nutrient intakes required to support optimal growth and development in young children.

This study, therefore, aims to evaluate the proximate, vitamin, and mineral composition of five indigenous complementary food formulations commonly used in Cross River State, Nigeria, with a view to assessing their nutritional adequacy for infants and young children. The research is timely and relevant, as it contributes to global and national efforts to combat child malnutrition in line with the United Nations Sustainable Development Goals (SDGs), particularly Goal 2, which seeks to end hunger and improve nutrition [22]. Beyond providing valuable data for the Nigerian Food Composition Database, this study also underscores the importance of integrating local food systems into scientific discourse. By grounding its analysis on formulations that are already culturally familiar and widely consumed; Sample A (yellow maize, soybeans, carrots, and spinach), Sample B (local rice, egg yolk, apple, and banana), Sample C (local rice, Titus fish, avocado pear, and apple), Sample D (yellow maize and soybeans), and Sample E (unripe plantain, crayfish, and palm oil)—the research acknowledges both the opportunities and limitations inherent in indigenous dietary practices. Furthermore, it will provide evidence-based insights that could guide nutrition education, policy formulation, and community level interventions in Cross River State. The findings, while specific to this region, may also serve as a reference point for other parts of Nigeria and similar cultural settings, albeit with the caveat that localized variations in food availability and practices necessitate further region-specific research. Ultimately, the study will strengthen the argument that improving child nutrition in Nigeria does not always require reliance on imported or expensive commercial products, but rather a scientific optimization of the foods that communities already consume and trust.

2-MATERIALS AND METHODS

All apparatus and reagents used were of analytical standards. All equipment used for analysis were calibrated before analysis using standard laboratory quality assurance protocols consistent with the AOAC (2010) [23] method. Quality control was ascertained by running reagent blanks, duplicate and periodic analysis of certified reference materials. All calibrations and verifications were recorded, and those that did not meet the standard criteria were recalibrated before use. The equipment include; sensitive balance (WANT, WT-N), centrifuge (Thermo Scientific, MEGAFUGE 8R), water bath, AAS spectrophotometer (Thermo Scientific, TSGP20), colorimeter (Thermo Scientific, AQ3700), microwave oven (Panasonic, NE-21521), desiccator (Wheaton, Z114375-1EA), filtration setup, ultra violet (UV)- spectrophotometer (Thermo Scientific, 116534139687), heating mantle (Thermo Scientific, EMO500/CE), electric blender (Philips, HR3760/00), crucibles (Thermo Scientific,032963.KF), fume chamber (Thermo Scientific, 51028225), Buchner funnel and kjeldahl flask (Thermo Scientific, 10657711) stirring rod (unbranded).

Reagents/chemicals

All reagents used were of analytical grade and included anhydrous sodium sulphate, concentrated H_2SO_4, boric Acid, methyl red indicator, sodium hydroxide, petroleum ether, anti-foaming agent, and hydrochloric Acid. All reagents were manufactured by BDH Chemicals Limited, Poole, England. Calibrations were done using standard solutions prepared with known molarities and checked with pH meters.

Sample Preparation

Five indigenous complementary food formulations were prepared using locally sourced raw materials obtained from households, local markets, and traditional food producers across various locations in Cross River State, Nigeria. The preparation methods followed traditional household processing techniques commonly used

for infant complementary meals to ensure cultural authenticity and reproducibility of results. Yellow maize grains were cleaned, sorted, and soaked in potable water for 48 hours to facilitate softening and mild fermentation. The soaked grains were wet-milled, and the resulting slurry was sieved through a fine muslin cloth to remove coarse particles. The filtrate was allowed to settle for four hours, after which the supernatant was carefully decanted, and the sedimented pap was collected and oven-dried at 60 °C to a constant weight. The dried pap was subsequently milled into a fine powder suitable for blending.

Soybeans were cleaned, toasted, and lightly crushed using a mortar and pestle to loosen the hulls. The hulls were removed by winnowing, and the dehulled seeds were milled into fine flour using an electric blender. Unripe plantains were peeled, sliced into thin chips, oven-dried at 60 °C to constant weight, and milled into uniform flour. Crayfish were washed, air-dried, and finely ground, while palm oil was incorporated directly in its edible ready-to-use form. Local rice grains were washed thoroughly, boiled until softened, oven-dried, and milled into a fine powder. Fish (Titus) was eviscerated, washed, oven-dried, and pulverized into powder. Egg yolks were separated from the egg whites, boiled, oven-dried, and ground into a homogenous powder. Fruits including apple, banana, and avocado pear, as well as vegetables such as carrot and spinach, were washed, chopped into small pieces, oven-dried at ingredient-specific temperatures until a constant weight was achieved, and then ground to fine powders using a laboratory blender. The formulations were constituted as shown in Table 4.

Table 4: Composition of the various indigenous complementary food formulation samples prepared

Sample	Description (100g total for each blend)
A	Complimentary food made from yellow maize, soybean, carrot, and vegetables. (Yellow maize-65%, soybean-15%, carrot-10%, spinach-10%)
B	Complimentary food made from local rice, egg yolk, and fruits. (Rice-70%, egg yolk-20%, apple-5%, banana-5%)
C	Complimentary food made from local rice, egg yolk, and fruits. (Local rice-60%, Titus's fish-20%, avocado pear-10%, apple-10%)
D	Complimentary food made from yellow maize and soybeans. (Maize-70%, soybeans-30%)
E	Complimentary food made from unripe plantain, crayfish, and palm oil. (unripe plantain-70%, crayfish-20%, palm oil-10%)

The blended samples were packed into sterile, airtight zip-lock bags, properly labelled for identification, and stored under ambient laboratory conditions. All analyses were carried out within one week of preparation to prevent nutrient loss and maintain sample integrity.

Proximate Analysis

The proximate composition of the food samples was determined using standard methods of the Association of Official Analytical Chemists; 978.10(crude fibre), 925.10 (moisture), 923.03 (ash), 2001.11 (crude protein kjedahl), 920.39 (crude fat), 2011.25 (dietary fibre) [23]. The parameters assessed included moisture content (MC), dry matter (DM), ash content, crude protein (CP), crude fat (CF), dietary fibre (DF), and carbohydrate (CHO) content calculated by difference: 100 - (moisture + ash + protein + fat + fiber). Each analysis was done in triplicate and results statistically analysed using ANOVA.

Determination of Moisture Content

Moisture content was determined following the official methods of AOAC 2010 [23] method. Oven dishes were cleansed and dried at 100ºC for 1 hour to a constant weight, cooled in a desiccator, and weighed. Two grams of sample were placed in each dish, weighed, and dried at 105ºC until constant weight was attained. The dishes with samples were cooled in a desiccator and weighed. Calculation: $\%\text{Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$

Determination of Crude Protein Content

Crude protein was determined using the Kjeldahl method AOAC, 2010 [23]. Two grams of sample were mixed with 5g anhydrous sodium sulphate (catalyst) and 25 mL concentrated sulfuric acid (H_2SO_4) with boiling chips, heated until the solution was clear. After cooling, the digest was diluted to 250 mL with distilled water. Five millilitres of 2% boric acid with methyl red indicator were used to collect 5 mL of the distillate after addition of 5 mL of 60% sodium hydroxide and heating until 100 mL distillate was collected. Titration was done with 0.02 N H_2SO_4 to a pink endpoint. A blank was analysed similarly. Calculation: $\%\text{Nitrogen} = \frac{(V_S - V_B) \times N_{\text{acid}} \times 0.01401 \times 100}{W}$

where V_S= volume of acid for sample, V_B= volume of acid for blank, $N_{\text{acid}} = 0.02$, and W= weight of sample in grams.
Crude protein was then calculated as:
$\%\text{Crude protein} = N \times 6.25$

where 6.25 is the conversion factor for nitrogen to protein.

Determination of Fat Content

Fat content was measured via Soxhlet extraction [23]. Two grams of sample placed in a thimble were extracted with petroleum ether for six hours. The ether was recovered, and the flask dried at 105ºC for 1 hour, cooled in a desiccator, and weighed. Fat content was calculated as:

$$\%\text{Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

Determination of Crude Fibre Content

Crude fibre was determined using the AOAC [23] method. Three grams of fat-extracted sample were digested sequentially with 1.25% sulfuric acid and sodium hydroxide solutions under heating, filtered, washed, and dried to constant weight at 100ºC. After ignition at 600ºC for 30 minutes, the residue was weighed. Fibre percentage was calculated as:

$$\%\text{Crude fibre} = \frac{\text{Weight after drying} - \text{Weight after incineration}}{\text{Weight of sample}} \times 100$$

Determination of Dietary Fibre Composition

Dietary fibre was measured enzymatically [24]. Five grams of sample were cooked with heat-stable α-amylase, digested with protease and amylo glucosidase, filtered, and separated into insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) by filtration and precipitation with 95% ethanol. IDF and

SDF were corrected for protein and ash content. Total dietary fibre (TDF) was calculated: TDF = IDF + SDF

Determination of Ash Content

Ash content was determined by igniting 2 g of sample in a silica dish first gently, then at 550ºC for 3 hours in a muffle furnace [23]. After cooling in a desiccator, ash was weighed.

Calculation: $\%\text{Ash} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$

where W_1= weight of dish, W_2= weight of dish + sample before ashing, W_3= weight after ashing.

Determination of Carbohydrate Content

Carbohydrate content was calculated by difference [23]:

$$\%\text{Carbohydrate} = 100 - (\%\text{moisture} + \%\text{fat} + \%\text{ash} + \%\text{protein} + \%\text{crude fibre})$$

DETERMINATION OF VITAMIN COMPOSITION

Vitamins were determined by the AOAC, 967.21 (vitamin C),

Vitamin A

Vitamin A was measured colorimetrically using AOAC [23] procedure based on absorbance at 620 nm from the reaction of vitamin A with sodium bisulfite (SbL_3). Sample saponification was performed with alcoholic KOH, followed by extraction with hexane, washing, drying, and absorbance measurement against a blank. Calculation: $\text{Vitamin A} = A_{620nm} \times SL \times \frac{V}{Wt}$

where A_{620nm}= absorbance, SL = slope of standard curve, V= final volume, and Wt= sample weight.

Thiamine (Vitamin B_1) Content

Thiamine was determined using the scalar analyzer method of AOAC [23]. Five grams of each sample was homogenized in 5 mL of normal ethanoic sodium hydroxide solution. The homogenate was filtered and made up to 100 mL with extract solution. A 10 mL aliquot of the extract was treated with 10 mL of potassium dichromate solution. The resultant solution was incubated for 15 minutes at room temperature (25 ± 1ºC). Absorbance was read at 360 nm using a spectrophotometer, with a reagent blank to standardize zero absorbance. Calculation: $\text{Thiamine (mg/100g)} = \frac{100 \times \text{absorbance} \times c \times d}{W}$

where W= weight of sample analyzed, c= concentration of standard solution, d= dilution factor, and absorbance is that of the sample solution.

Riboflavin (Vitamin B_2) Content

Riboflavin content was analyzed following the fluorometric procedure described by AOAC [23]. A 2 g portion of the sample was homogenized with 50 mL of 0.2 N HCl, heated to boiling for 1 h, and subsequently cooled. The pH of the digest was first adjusted to 6.0 with sodium hydroxide and then to 4.5 with 1 N HCl. The mixture was filtered into a 100 mL volumetric flask and diluted to volume with distilled water. From the filtrate, 10 mL aliquots were transferred into two test tubes, with riboflavin standard added to one tube (tube 2). Both tubes were treated with 1 mL glacial acetic acid and 0.5 mL of 3% potassium permanganate solution, allowed to stand for 2 min, and subsequently treated with 0.5 mL of 3% sulfuric acid. Fluorescence measurements were carried out at excitation and emission wavelengths of 470 nm and 525 nm, respectively. Fluorescence of tube 1 was recorded, after which sodium hydrogen sulfate was added to both tubes for blank measurements.

The riboflavin concentration was calculated using the expression:

$$\text{Riboflavin (mg/g)} = \frac{X \times 1}{Y \times W}$$

where W = weight of sample, X = fluorescence of sample minus blank, and Y = fluorescence difference involving the standard.

Niacin (Vitamin B_3) Content

Niacin was measured using AOAC [25] method. A 5 g sample was mixed with 30 mL normal sulfuric acid and shaken for 30 minutes. The extract was filtered and made alkaline with ammonium hydroxide. An aliquot was treated with potassium ferrocyanide and dilute sulfuric acid, allowed to stand for 5 minutes, and absorbance was read at 470 nm. Standard niacin solution was treated similarly and absorbances compared.

$$\text{Calculation: Niacin (mg/100 g)} = \frac{100 \times \text{Abs sample} \times C \times Vf}{W \times As \times Va}$$

where W= sample weight, C= concentration of standard, Vf= volume of filtrate, Va= volume analyzed, As= absorbance of standard.

Pantothenic Acid (Vitamin B_5) Content

Pantothenic acid was determined spectrophotometrically. One gram of sample was mixed with 10 mL distilled water and filtered. Two mL of filtrate was hydrolyzed with 2 mL hydrochloric acid at 60ºC for 1 hour, cooled, then mixed with hydroxylamine reagent and sodium hydroxide. After 5 minutes and pH adjustment to 2.7 with 1M HCl, volume was made up with water. Five mL of this solution was mixed with 1 mL of 1% ferric chloride and absorbance read at 500 nm.

Pyridoxine Hydrochloride (Vitamin B_6) Content

Measured spectrophotometrically. One gram of sample was mixed with 10 mL distilled water and filtered. Two mL of filtrate was combined with ammonium buffer and dye solution (2,6-dichloroquinone chlorimide). Absorbance was measured at 650 nm against blank.

Folic Acid (Vitamin B_9) Content

Folic acid was determined by spectrophotometric method. One gram sample dissolved in 10 mL distilled water and filtered. Five mL filtrate was mixed with potassium permanganate, sodium nitrate, hydrochloric acid, ammonium sulphamate, and dye solution, then kept for 15 minutes at room temperature. Absorbance readings were taken at 535 nm.

Cyanocobalamin (Vitamin B_{12}) Content

Cynanocobalamin was determined by spectrophotometric method. One gram sample dissolved in 10 mL distilled water, filtered. Five mL filtrate mixed with sodium phosphate, citric acid, and sodium metabisulfite. Volume was made to mark, heated at 80ºC for 10 minutes. Absorbance measured at 530 nm against blank.

Vitamin C Content

Vitamin C was measured using the titrimetric method of AOAC [23]. Five grams of sample were homogenized in 50 mL of EDTA/TCA solution, filtered to 50 mL filtrate. A 20 mL aliquot was mixed with 10 mL 30% potassium solution and 1% starch solution, then titrated against 0.01M $CuSO_4$. Vitamin C content calculated based on 1 mL 0.01M $CuSO_4$ equivalent to 0.88 mg vitamin C.

Vitamin D Content

Measured spectrophotometrically. One gram sample dissolved in 15 mL methanol, vortexed, and kept in dark for 2 hours. Vitamin D was extracted twice with 3 mL hexane, centrifuged, and upper organic layer collected, dried under nitrogen, solubilized in methanol, absorbance read at 275 nm. Standard vitamin D solutions from 2 ppm to

10 ppm were used for calibration. Concentration determined by extrapolation from standard curve.

Vitamin E Content

Determined by AOAC [23] method. One gram sample mixed with 10 mL absolute alcohol and 20 mL alcoholic tetraoxosulphate VI acid (H_2SO_4). Ten mL of this solution was heated at 90ºC for 3 minutes, cooled, and absorbance read at 470 nm. Calculation: Vitamin E (mg/100 g) $= \frac{a-b\times c}{w}$

where a= absorbance of test sample, b= absorbance of standard, c= concentration of standard, w= weight of sample.

Vitamin K Content

Measured spectrophotometrically. One gram sample macerated with 20 mL distilled water, filtered. One mL filtrate mixed with 1 mL 0.04% 2,4-dinitrophenylhydrazine in 20% HCl, boiled for 45 minutes, cooled, diluted to 10 mL with 1:30 ammonium hydroxide. Absorbance was measured at 635 nm.

MACRO MINERAL ANALYSIS

Minerals were determined by the AOAC official methods 2010, 968.08 using wet digestion, and atomic absorption spectroscopy.

Sodium Content

Standard solutions were aspirated, and emission intensities recorded to plot a calibration curve for quantification.

Calcium Content

Calcium was determined by titration with EDTA [25] using Eriochrome Black-T indicator.

Calculation: Ca (mg/L) $= \frac{T\times M\times E\times 1000}{\text{Volume of sample used}}$

Phosphorus Content

Phosphorus was measured calorimetrically using the molybdate method with hydroquinone reduction [24]. Absorbance at 660 nm was compared to a standard curve.

Potassium Content

Potassium determination employed flame photometry as described by AOAC [25], calibrated with potassium standards.

Magnesium Content

Magnesium was analysed using Atomic Absorption Spectrophotometry (AAS) standards with calibration against magnesium standards at 202.6 nm.

Microminerals (Zinc, Iron, Copper, Iodine, Selenium, Manganese)

For the analysis of microminerals, samples were subjected to wet digestion using a mixture of nitric acid and perchloric acid. The digest was filtered and analysed by Atomic Absorption Spectrophotometry (Buck Scientific AAS Model 210). Calibration curves were prepared for each element individually. The wavelengths used for measuring each element were as follows: iron at 510 nm, manganese at 329 nm, copper at 324.7 nm, zinc at 214 nm, selenium at 196 nm, and iodine at 550 nm.

Statistical Analysis

All analyses were performed in triplicate. Data are expressed as mean ± standard deviation. Statistical analysis was conducted using SPSS version 25.0. One-way analysis of variance (ANOVA) determined significant differences, with significance set at $p < 0.05$. Tukey's post hoc test was applied where applicable.

3-RESULTS

Table 5: Proximate composition of the different food blends (moisture, dry matter, ash, crude protein, fat, fibre, and carbohydrate content)

Sample	MC (%)	DM (%)	ASH (%)	CP (%)	CF (%)	DF (%)	CHO (%)
A	9.85 ±0.01^{b}	90.15 ±0.01^{d}	3.24 ±0.00^{c}	26.77 ±0.02^{d}	16.77 ±0.02^{d}	9.53 ±0.04^{e}	33.65 ±0.07^{c}
B	10.76 ±0.01^{d}	89.24 ±0.01^{b}	3.46 ±0.01^{d}	32.75 ±0.03^{e}	7.47 ±0.02^{a}	9.89 ±0.04^{f}	35.64 ±0.08^{d}
C	10.47 ±0.01^{c}	89.53 ±0.01^{c}	3.18 ±0.01^{c}	20.46 ±0.00^{c}	13.65 ±0.04^{c}	5.55 ±0.12^{b}	47.30 ±0.47^{e}
D	9.76 ±0.02^{a}	90.24 ±0.02^{e}	2.95 ±0.01^{b}	18.52 ±0.06^{b}	16.84 ±0.02^{e}	8.54 ±0.14^{d}	56.72 ±0.02^{f}
E	19.26 ±0.01^{e}	80.74 ±0.01^{a}	2.47 ±0.01^{a}	9.62 ±0.01^{a}	38.34 ±0.02^{d}	2.50 ±0.01^{a}	27.80 ±0.03^{a}

Values are expressed as mean ±SEM; n=3.
Mean values with similar symbols are homogenous (not significantly different from each other).

The proximate composition of the five indigenous complementary food formulations (Samples A–E) showed significant variation in their macronutrient content (Table 5). Moisture content ranged from 9.76% in Sample D to 19.26% in Sample E, indicating varying degrees of dryness that influence product stability and storage quality. Dry matter content was highest in Sample D (90.24%) and lowest in Sample E (80.74%). Crude protein values were highest in Sample B (32.75%) and lowest in Sample E (9.62%), reflecting the contribution of egg yolk and soybean to protein enrichment. Fat content ranged between 7.47% in Sample B and 38.34% in Sample E, the latter attributed to the inclusion of palm oil and crayfish. Carbohydrate concentration varied widely, with Sample D showing the highest value (56.72%) and Sample E the lowest (27.80%). Ash content, indicative of total mineral matter, was highest in Sample B (3.46%) and lowest in Sample E (2.47%). Dietary fibre ranged from 2.50% to 9.89%, with Sample B exhibiting the highest value. These results indicate that each formulation offers different nutrient advantages based on ingredient composition and processing methods.

Table 6a: Vitamin composition of the different food blends (A, B_1, B_2, B_3, B_5, B_6)

	Beta-Carotene (ug/g)	Vitamin A (µg/g)	B1 mg/100g	B2 mg/100g	B3 mg/100g	B5 mg/100g	B6 mg/100g
A	15.86 ±0.01^{d}	41.57 ±0.03^{c}	0.67 ±0.01^{d}	0.80 ±0.00^{c}	1.91 ±0.01^{e}	0.84 ±0.01^{e}	0.94 ±0.00^{e}

B	9.64 ±0.03[a]	37.43 ±0.02[a]	0.72 ±0.00[e]	0.94 ±0.00[d]	1.74 ±0.01[d]	0.78 ±0.00[d]	0.75 ±0.00[a]
C	11.31 ±0.01[b]	38.93 ±0.04[b]	0.63 ±0.01[c]	0.78 ±0.00[b]	1.31 ±0.01[b]	0.71 ±0.01[c]	0.84 ±0.00[c]
D	36.76 ±0.01[e]	111.83 ±0.02[c]	0.58 ±0.01[b]	0.76 ±0.00[a]	1.43 ±0.01[c]	0.64 ±0.00[b]	0.80 ±0.00[b]
E	48.30 ±0.01[f]	115.20 0.81[d]	0.56 ±0.00[a]	0.79 ±0.00[c]	1.19 ±0.01[a]	0.60 ±0.00[a]	0.91 ±0.01[d]

Table 6b: Vitamin composition of the different food blends (B_9, B_{12}, C, D, E, and K)

	B9 (µg/g)	B12 (µg/100g)	C (mg/100g)	Vitamin D (IU/g)	E (mg/100g)	Vitamin K (µg/g)
A	316.76 ±0.02[f]	1340 ±0.00[a]	6.87 ±0.02[e]	3.2 ±0.00[f]	1.83 ±0.01[d]	39.50 ±0.04[d]
B	228.61 ±0.11[e]	900 ±0.00[e]	5.60 ±0.01[d]	1.2 ±0.00[c]	1.94 ±0.00[e]	35.68 ±0.04[c]
C	216.58 ±0.14[d]	930 ±0.01[b]	4.90 ±0.01[c]	2.0 ±0.00[d]	±0.85 ±0.00[a]	29.12 ±0.36[b]
D	192.61 ±0.01[b]	890 ±0.01[a]	3.83 ±0.01[a]	1.2 ±0.00[b]	1.26 ±0.00[b]	24.67 ±0.04[a]
E	184.79 ±0.01[a]	1070 ±0.01[c]	4.33 ±0.01[b]	1.2 ±0.00[a]	8.45 ±0.00[f]	68.01 ±0.15[f]

Values are expressed as mean ±SEM, n=3.
Mean values with similar symbols are homogenous
(i.e. not significantly different from each other)

The vitamin composition of all five formulations is presented in Tables 6a and 6b. The results revealed that all formulations contained appreciable amounts of both fat and water-soluble vitamins, with notable differences among samples. Sample A demonstrated the highest concentrations of several B-complex vitamins, including B3 (1.91 mg/100 g), B5 (0.84 mg/100 g), B6 (0.94 mg/100 g), and folate (B9: 316.76 µg/g), as well as vitamin C (6.87 mg/100 g). Samples D and E contained the highest vitamin A levels (111.83 µg/g and 115.20 µg/g, respectively), primarily due to the presence of carotenoid-rich ingredients such as maize, unripe plantain, and palm oil. Vitamin E content was highest in Sample E

(8.45 mg/100 g), while vitamin K was also more abundant in the same sample (68.01 µg/g). Although all blends met or exceeded the dietary reference intakes for most vitamins, the concentration of vitamin C across all samples remained comparatively low relative to the DRI (Table 2). The overall results indicate that the formulated blends provide substantial amounts of essential vitamins necessary for optimal growth and metabolic activity in infants.

Table 7a: Macronutrient composition of the different food blends (Mg, Na, K, P and Ca)

	Mg (mg/100g)	Na (mg/100g)	K (mg/100g)	P (mg/100g)	Ca (mg/100g)
A	316.94 ±0.73^{d}	85.11 ±0.32^{e}	476.82 ±0.96^{a}	483.05 ±0.21^{f}	246.25 ±0.15^{e}
B	241.50 ±3.14^{a}	73.32 ±0.04^{c}	584.32 ±0.63^{e}	416.76 ±0.04^{e}	231.13 ±0.74^{d}
C	248.35 ±0.03^{b}	73.47 ±0.04^{c}	518.36 ±0.02^{c}	382.76 ±0.04^{c}	197.79 ±0.50^{b}
D	260.62 ±2.62^{c}	78.37 ±0.04^{d}	494.40 ±0.03^{b}	284.71 ±0.02^{a}	216.31 ±0.05^{c}
E	247.29 ±0.69^{b}	45.84 ±0.04^{b}	564.78 ±0.00^{d}	292.77 ±0.02^{b}	185.60 ±0.12^{a}

Table 7b: Micro nutrient composition of the different food blends (Fe, Zn, I, Cu, Se and Mn)

	Fe (mg/100g)	Zn (mg/100g)	Iodine (µg/100g)	Cu (µg/100g)	Se (ug/100g)	Mn (mg/100g)
A	7.62 ±0.01^{c}	2.62 ±0.01^{d}	125.83 ±0.01^{d}	2840 ±0.01^{f}	11.74 ±0.06^{f}	1.93 ±0.01^{d}
B	4.83 ±0.01^{a}	1.97 ±0.01^{c}	126.39 ±0.02^{e}	1930 ±0.01^{d}	5.77 ±0.01^{b}	1.36 ±0.01^{c}
C	5.66 ±0.01^{b}	4.47 ±0.01$_{e}$	122.77 ±0.02^{b}	2350 ±0.01^{e}	7.41 ±0.01^{d}	1.25 ±0.01^{b}
D	5.70 ±0.01^{b}	1.65 ±0.00^{a}	132.68 ±0.05^{f}	1700 ±0.01^{b}	8.61 ±0.01^{e}	1.22 ±0.01^{a}
E	9.33	1.82	108.32	1240	2.66	1.33

	±0.01[e]	±0.01[b]	±0.06[a]	±0.01[a]	±0.01[a]	±0.02[c]

Values are expressed as mean ±SEM, n=3.
Mean values with similar symbols are homogenous
(i.e. not significantly different from each other)

The macro- and micromineral contents of the food blends are presented in Tables 7a and 7b. Among macro minerals, Sample A exhibited the highest concentrations of magnesium (316.94 mg/100 g), sodium (85.11 mg/100 g), phosphorus (483.05 mg/100 g), and calcium (246.25 mg/100 g), while potassium was most abundant in Sample B (584.32 mg/100 g). In terms of microminerals, Sample A also recorded superior levels of copper (2840 µg/100 g), selenium (11.74 µg/100 g), and manganese (1.93 mg/100 g). Iron content ranged from 4.83 mg/100 g in Sample B to 9.33 mg/100 g in Sample E, while zinc concentration was highest in Sample C (4.47 mg/100 g). Iodine levels were highest in Sample D (132.68 µg/100 g), indicating variation according to ingredient type and proportion. The mineral data confirm that all the blends contain nutritionally relevant concentrations of essential minerals, although their distribution varied based on the source components in each formulation.

DISCUSSION

The proximate composition of the five indigenous complementary food formulations (Samples A–E) revealed marked differences that reflect ingredient selection and traditional processing methods, with direct implications for meeting the dietary requirements of infants aged 7–12 months [4]. Sample A exhibited a notably high crude protein concentration (26.77%), which translates to 10.7 grams of protein per 100 grams of food, significantly meeting the dietary reference intake (DRI) according to the Food and Nutrition Board, Institute of Medicine (Table 5) which recommends 11.0g. Its fat content of 16.77% falls short of the recommended intake of 30 g/day (Table 5). However, depending on the number of servings consumed per day, the recommended daily amount could be met as infants feed between 3 to 5 meals daily. Its carbohydrate (33.65%) and dietary fibre (9.53%), producing a balanced macronutrient profile consistent with requirements for growth and tissue accretion in infancy [4]. Sample B recorded the highest protein (32.75%) but the lowest fat (7.47%), indicating that while protein RDA targets per 100 g are satisfied by this blend, its energy density may be insufficient unless feeding frequency or lipid content is increased, an observation in keeping with previous considerations regarding the need for adequate fat in complementary diets [26]. Sample C composition (protein 20.46%, carbohydrate 47.30%) suggests an energy-focused blend suitable where immediate caloric provision is needed, while Sample D (protein 18.52%, carbohydrate 56.72%) typified cereal-legume formulations that prioritize carbohydrates for energy, but may fall short on protein quality and specific amino acids unless paired with complementary protein sources. An excessive intake of carbohydrates can lead to energy imbalances, potentially causing unhealthy weight gain and other metabolic issues, this sample may need to be balanced with other nutrient-rich foods to ensure that the energy intake remains appropriate for the infant's needs without promoting overconsumption. [27]. Sample E profile was distinctive: a high lipid concentration (38.34%) but low protein (9.62%) and high moisture (19.26%). High fat content can contribute to energy density and palatability as it exceeds the recommended fat intake for

infants (30 g/day) (Table 5). While fat is necessary for providing energy and supporting the absorption of fat-soluble vitamins, excessive fat intake can lead to unhealthy weight gain and cardiovascular health issues. Fortification with more protein-rich foods such as; meat and fish is recommended for balance in blend E as protein is essential for growth, development, and maintenance of overall health in infants. Fibre deficiency is another concern in this blend as dietary fibre is essential for maintaining healthy digestion and preventing constipation, especially in young children whose digestive systems are still developing. Across blends, moisture values (9.76–19.26%) and ash levels (2.47–3.46%) indicate practical storage considerations and mineral presence, respectively, framing each formulations' suitability for complementary feeding and shelf stability under local conditions [14,25].

A look at the vitamin profile of the 5 blends shows that they all met the RDA for vitamins A, B1, B2, B6, B9, B12 and K (Table 6a and b). Blend E also met the RDA for vitamin E at 100g (Table 2).This is indeed very interesting, even the vitamins whose RDAs were not met at 100g such as vitamins; B3,B5, C, and D will likely have their RDAs met at 2 to 3 servings given that infants of that age eat between 3 to 5 meals corresponding to between 50g to 100g per serving. Sample A consistently exhibited elevated levels of multiple B-complex vitamins notably B3 1.91 mg/100 g, B5 0.84 mg/100 g, B6 0.94 mg/100 g, folate B9 316.76 µg/g and B12 1.34 µg/100 g) and had the highest amount of vitamin C (6.87 mg/100 g), reflecting the nutritive contributions of soy, carrot and leafy vegetables incorporated into this blend. These concentrations indicate that Sample A is capable of supplying substantial proportions of infant B-vitamin requirements per 100-g portion (Table 6a and 6b). Samples D and E showed the greatest provitamin A and vitamin A equivalents (111.83 µg/g and 115.20 µg/g, respectively), consistent with ingredients such as yellow maize, unripe plantain and palm oil known to be carotenoid-rich; vitamin E and K were also higher in Sample E (E = 8.45 mg/100 g; K = 68.01 µg/g) owing to palm oil content, which enhances fat-soluble vitamin density and bio accessibility [20].

Despite these strengths, all blends demonstrated relatively low vitamin C concentrations compared with other vitamins. Vitamin C is required for the biosynthesis of collagen, L-carnitine, and certain neurotransmitters. It is also involved in protein metabolism and antioxidant activities, and has been shown to regenerate antioxidants like alpha-tocopherol (vitamin E). It also plays an important role in immune function. Insufficient vitamin C intake could cause scurvy in infants. The processing methods may have affected ascorbic acid content, and it is recommended to pair formulations with fresh or minimally heated fruit sources to meet vitamin C needs since humans are not able to synthesize vitamin C endogenously like other animals, it is must always come from food [28,29]. Overall, vitamin data shows that, with the exception of vitamin C, single 100-g servings of several blends (particularly A and B) provide a significant proportion of infant RDIs for multiple vitamins, and that combined or multiple daily servings would likely meet adequacy for the majority of measured vitamins (Table 6a and b).

Mineral profiling demonstrated that ingredient selection directly determined macro and micronutrient density, with Sample A again showing the broadest mineral richness and sample-specific strengths evident across the set. Sample A recorded the highest magnesium (316.94 mg/100 g), phosphorus (483.05 mg/100 g), calcium

(246.25 mg/100 g) and sodium (85.11 mg/100 g), consistent with the inclusion of soybean and leafy vegetables and aligning with observations that legume-vegetable blends concentrate mineral content [30]. Potassium was most abundant in Sample B (584.32 mg/100 g), likely contributed by fruit components such as banana and apple, while iron ranged from 4.83 mg/100 g in Sample B to 9.33 mg/100 g in Sample E, the latter reflecting crayfish contribution. Zinc was highest in Sample C (4.47 mg/100 g) and iodine peaked in Sample D (132.68 µg/100 g), demonstrating that different formulations can be targeted to address specific mineral shortfalls. The higher copper content observed in Blend A likely reflects the contribution of leafy vegetables such as spinach, which are known to contain appreciable amounts of copper [31]. These results align with the findings of Adebayo et al. [32], who reported copper levels between 1500 and 3000 µg/100 g in complementary blends containing legumes and leafy vegetables, closely matching the values observed in this study. Similarly, Ekpo et al. [33] also emphasized that the inclusion of vegetables and soybeans enhanced copper density in infant foods compared to cereal-only diets. To avoid copper toxicity in infants taking blend A, the amount of soybean and spinach which are very high calcium foods, may be adjusted to correspond with the dietary recommendation for infants. Results from these blends contrast with traditional cereal porridges, which are often copper-deficient [34].

Notably, calcium and iron levels in some blends did not meet recommended levels per 100-g serving, implying that multiple servings, dietary pairing (e.g., with milk or iron-enhancing foods), or modest fortification may be required to ensure full adequacy.

Taken together, the proximate, vitamin and mineral results support the central conclusion that locally available ingredients, when formulated appropriately, can yield complementary foods with substantial capacity to meet many of the nutritional needs of infants aged 7–12 months corresponding to the weaning age. Samples A and Sample B repeatedly emerged as the most balanced in terms of protein, micronutrient density and reasonable fat content (Tables 5 and 6a), whereas Sample C and D can serve as energy-dense options and Sample E as a high-energy, fat-rich supplement. The data justify the study's recommendations for targeted optimization by improving vitamin C retention through reduced heat exposure or fruit inclusion, increasing protein or amino-acid quality in cereal-dominant blends (D and E), and considering low-level fortification or paired feeding to correct specific mineral shortfalls such as calcium and iron [14,15].

4-CONCLUSION

The comprehensive evaluation of five indigenous complementary food formulations commonly used in Calabar, Cross River State, Nigeria, revealed significant variations in their nutritional profiles, highlighting both the strengths and areas requiring improvement for optimal infant feeding. Among the five blends, Sample A (yellow maize, soybean, carrot, and spinach) emerged as the most nutritionally balanced formulation, possessing high protein, fibre, and mineral content, while maintaining moderate fat and carbohydrate levels suitable for infant growth and development (Tables 5 and 6). Sample B also demonstrated high protein quality and nutrient density, making it a valuable complement to Sample A in community-based nutrition programs. Conversely, Samples D and E exhibited deficiencies in key nutrients, particularly protein, vitamin C, and certain minerals, emphasizing the need

for fortification or the inclusion of additional nutrient-dense ingredients such as legumes, fish, fruits, and leafy vegetables. The findings confirm that indigenous food resources, when scientifically optimized, can serve as effective, affordable, and culturally acceptable alternatives to commercial infant formulas. The study further underscores the potential of locally formulated complementary foods to address micronutrient deficiencies, promote dietary diversity, and strengthen food security in low-income communities. It also aligns with the United Nations Sustainable Development Goal 2, which targets the eradication of hunger and malnutrition through sustainable and locally driven food systems. Therefore, promoting nutrition education, community-level awareness, and local food fortification initiatives remains crucial to improving child health outcomes. Future interventions should focus on standardizing preparation techniques, extending shelf life, and conducting clinical validation of nutrient bioavailability. Ultimately, the integration of these improved indigenous complementary formulations into public health nutrition programs would contribute substantially to reducing childhood malnutrition and improving the overall well-being of infants and young children in Nigeria and other developing regions.

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The authors declare no conflict of interest.

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