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Profiling Amino and Fatty Acid Composition of Novel Complementary Foods Formulated Locally for Infant Nutrition in Calabar, Cross River State, Nigeria.

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ABSTRACT

The rate of infant malnutrition in Africa is still very high despite the efforts, and finances that have been invested into policy formulations for better infant nutrition. Fatty acids and amino acid are major players in brain development in infants. This study evaluated the amino acid and fatty acid composition of three indigenously formulated complementary diets prepared from locally available ingredients in Calabar, Nigeria. Amino acid analysis was conducted using high-performance liquid chromatography (HPLC), while fatty acid profiling was determined through gas chromatography-mass spectrometry (GC-MS). The amino acid results revealed a balanced presence of essential amino acids with blend B as the richest in essential amino acids. Blend C was the only blend that contained phenylalanine in significant amount(8.50mg/100g). It also contained the highest amount of valine (8.06mg/) and tryptophan (3.82mg/100g). and also contained higher amounts of linoleic and α-linolenic acids relative to Blends A and B. However, it may need supplementation with foods that contain methionine and threonine. Blend B contained a rich blend of all amino acids except phenyl alanine. Blend A had the least amino acid composition, and had no presence of eicosatrienoic and docosahexaenoic acids. Blends B and C are recommended for weaning purposes after supplementation with animal protein sources. The study reveals the significance of indigenous formulations in addressing malnutrition and enhancing infant dietary quality through the utilization of nutrient-dense local crops and animal products.

1. INTRODUCTION

Adequate nutrition during infancy is a critical factor influencing healthy growth, organ development, immunological function, and cognitive ability and general well-being in humans. The early years of life are very vital to the growth and development of children and adequate nutrients must be made available to infants during this time, as it may have significant impact on growth and development, as well as long-term health outcomes [1]. Breast milk is commonly recognized as the best diet for infants in their first six months of life; but, when the infant's energy and nutrient demands rise, breast milk alone becomes insufficient to meet physiological requirements. The transition from exclusive nursing to the introduction of solid and semi-solid foods, known as weaning or complementary feeding, is thus an important stage in childhood nutritional development [2]. Complementary foods should fill the nutritional gaps that arise as children grow, providing adequate protein and amino acids, fat and fatty acids, vitamins, and minerals to support normal growth [3]. When properly formulated, complementary diets not only prevent malnutrition, but they also promote healthy eating habits and lower the risk of diet-related chronic diseases later in life [4]. However, across numerous developing countries, including Nigeria, the nutritional value of commonly consumed homemade complimentary foods is frequently inadequate, resulting in protein-energy malnutrition and micronutrient deficiencies [5,6].

The elevated prevalence of malnutrition among children in Sub-Saharan Africa highlights the critical need to increase the quality of complementary foods. In Nigeria, roughly 37% of children under five are stunted, 7% are wasted, and 22% are underweight, indicating widespread nutritional inadequacies [7]. These alarming incidences have been associated with the limited availability and expensive price of commercially fortified supplementary foods, which are frequently unavailable to low-income families [8]. As a result, caregivers rely mainly on traditional, locally sourced products, which are in many cases, not adequately combined and/or processed, thus lacking in key nutrients like amino acids and fatty acids [9]. The building blocks of proteins, amino acids are essential for tissue healing, immunological response, enzyme synthesis, and overall newborn growth [10]. The human body is unable to synthesize the essential amino acids; hence they must be obtained from diet. Stunted growth, developmental delays, and poor cognitive function can result from inadequate nutrition throughout infancy [11]. Furthermore, dietary fatty acids have a vital role in both the functional and structural components of the body. They help with energy provision, cell membrane integrity, and signalling pathways, with long-chain polyunsaturated fatty acids (PUFAs) being particularly important for brain and visual development [12,13]. Various locally accessible food sources in Nigeria have exceptional nutritional value that might be used for developing balanced complimentary dietary requirements. Soybean, yellow maize, unripe plantain, pumpkin leaf, carrot, crayfish, and palm oil are commonly grown and inexpensive in areas such as Calabar, Cross River State, Nigeria. Soybean (Glycine max) is very rich in essential amino acids, particularly lysine, methionine, and tryptophan, to compensate for the amino acid deficits in cereal-based diets [14]. It also contains high amounts of omega-3 and omega-6 fatty acids, which boost the lipid profile of composite diets [15]. Yellow maize (Zea mays) contains carbohydrates, carotenoids, and dietary fibre, making it an important source of energy and antioxidants [16,17]. Crayfish provides high-quality protein with excellent amino acid profile while also increasing polyunsaturated fatty acid (PUFA) content, notably omega-3 fatty acids, which stimulate neurological growth [18,19]. Palm oil, though high in saturated fat, provides tocotrienols-potent antioxidants that exhibit neuroprotective and cholesterol-lowering properties [20,21]. Furthermore, unripe plantain contributes complex carbohydrates, potassium, and vitamin C, supporting energy balance and immune defence [22,23]. Vegetables such as carrot and pumpkin leaf are rich in carotenoids, tocopherols, and minerals, enhancing the micronutrient density of composite foods [24,25].

Despite the abundant nutritional potential of these local ingredients, data on their combined amino acid and fatty acid composition when used in locally formulated complementary foods remain scarce. Most existing studies have focused on proximate composition or micronutrient evaluation, leaving a knowledge deficit on nutrient quality, particularly amino and fatty acid profiles, which influence protein and lipid adequacy. Filling this gap is essential to validate the suitability of such formulations for infant feeding. Understanding the biochemical profiles is not merely academic; it informs formulation improvement, standardization, and potential fortification strategies. For example, enhancing omega-3 fatty acid content or balancing essential amino acid ratios can significantly improve growth outcomes in infants and young children [12,13]. Thus, profiling these nutrients in locally developed complementary foods represents a critical step toward evidence-based nutrition policy and sustainable food system innovation in Nigeria. The present study focuses on profiling the amino acid and fatty acid composition of three novel complementary food blends formulated from locally available ingredients in Calabar, Cross River State, Nigeria. The food blends were carefully designed to combine cereals, legumes, animal proteins, and vegetables in proportions intended to optimize nutritional balance and bioavailability. This approach aligns with global efforts to promote the use of indigenous foods in combating child malnutrition, reduce dependence on imported fortified foods, and enhance local food security [26].

Table 1: Dietary Reference Intakes for Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.

S/N	Dietary Reference Intakes	Function	Life Stage Group	RDA/AI * g/d [a]	Acceptable Macronutrient Distribution Range (AMDR)[b]	Selected Food Sources
1.	Protein and amino acids	Serves as the major structural component of all cells in the body, function as enzymes, transport carriers, and hormones.	7–12 months	**13**	**5-20**	Proteins from animal sources, suc as meat, poultry, fish, eggs, milk, cheese, and yogurt, legumes, grains, nuts, seeds, and vegetable
2.	Total fat	Energy source, increases absorption of fat-soluble vitamins, source of polyunsaturated fatty acids.	7-12 months	**30**	-----------	Butter, margarine, vegetable oils, whole milk, meat, poultry, nuts an seeds
3.	n-6 polyunsaturated fatty acids (linoleic)	Essential components of structural membrane lipids involved in cell signalling, precursor of eicosanoids for normal skin function.	7-12 months	**4.6**	**ND**	Nuts, seeds, and vegetable oils such as soybean, safflower, and corn oil.
4.	n-3 polyunsaturated fatty acids (α-linolenic acid)	Involved with neurological development and growth. Precursor of eicosanoids.	7-12 months	**0.5**	**ND**	Vegetable oils including; soybean, canola, and flax seed oil, fish oils, fatty fish, with smaller amounts in meats and eggs.
5.	Saturated and trans fatty acids, and cholesterol	Energy sources, the body can synthesize its needs for saturated fatty acids and cholesterol from other sources.	7-12 months	**ND**	--------------------	meat fats and butter fat), and coconut and palm kernel oils, liver eggs, and margarines and foods containing hydrogenated or partially-hydrogenated vegetable shortenings.

S/N	Nutrient	Function	IOM/FNB 2002 Scoring Pattern[a]	Mg /g protein
6.	Indispensable amino acids: histidine, isoleucine, leucine, lysine methionine & cysteine, phenylalanine &tyrosine, threonine tryptophan, valine	The building blocks of all proteins in the body and some hormones. These nine amino acids must be provided in the diet and thus are termed indispensable amino acids. The body can make the other amino acids needed to synthesize specific structures from other amino acids and carbohydrate precursors.	histidine, isoleucine, leucine, lysine, methionine & Cysteine Phenylalanine & Tyrosine, Threonine, Tryptophan, Valine	18, 25, 55 51, 25 47 27, 7, 32

Extracted from: Dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (2002/2005). This report may be accessed via www.nap.edu. Intakes (AIs) in ordinary type followed by an asterisk (*). For healthy breastfed infants, the AI is the mean intake. ND = Not determinable due to lack of data of adverse effects in this age group.

2-MATERIALS AND METHODS

Materials: Analytical balance, Grinding machine, Centrifuge, High-Performance Liquid Chromatography (HPLC) machine, vortex mixer, oven, water baths, Soxhlet apparatus, rotary evaporator, pH meter and spectrophotometers.

Reagent: Hydrochloride acid (HCL) glacial acetic acid, water, methyl ether, methanolic sodium, methoxide solution, neutralization solution, Hexane solution, and sodium chloride, chloroform, sulfuric acid, borate buffer, phenol, ninhydrin, and various standards for calibration.

Raw Materials and Processing Methods

The raw materials used for the formulation of the complementary foods included soybean (*Glycine max*), yellow maize (*Zea mays*), unripe plantain (*Musa spp*.), carrot (*Daucus carota*), pumpkin leaf (*Telfairia occidentalis*), crayfish (*Procambarus clarkii*), and palm oil. All raw materials were purchased from the Marian Market in Calabar, Cross River State, Nigeria, and transported to the Food Laboratory of the Department of Human Nutrition and Dietetics, University of Calabar, for identification, processing, and formulation.

Each ingredient was processed using standard procedures adapted from validated methods in the literature. Soybean was carefully sorted to remove stones and impurities, soaked in water for approximately 48 hours, washed thoroughly, drained, dried, and milled into fine flour according to the method described by Bello et al. [27]. Yellow maize was sorted, washed, soaked for 48 hours, sun-dried, and ground into flour following the technique of Awoyale et al. [28]. Carrots were washed, peeled, and sliced into small cubes (about 0.3 cm), ground, sun-dried, and milled into fine powder. Pumpkin leaves were thoroughly washed, drained using a perforated basket to remove excess water, sun-dried for 24 hours, and milled into fine powder based on the method of Verem et al. [29]. Similarly, unripe plantains were washed, cut into cubes, sun-dried for 24 hours, and ground into flour. Crayfish, purchased in dried form, were sorted to remove unwanted materials and milled into fine powder, while palm oil was obtained in its ready-made form from the market and used directly without further treatment. All processed samples were stored in airtight containers under cool, dry conditions to prevent moisture uptake and microbial contamination prior to use.

The preparation of these ingredients was carried out under strict hygienic conditions to minimize nutrient loss and ensure food safety. Each processed ingredient served as a component of the formulated complementary food blends, designed to balance amino acid and fatty acid profiles.

Table 2: Composition of Complimentary Food Blends

Ingredient	Blend A (g)	Blend B (g)	Blend C (g)
Yellow maize	70		65
Soybean	30		25
Unripe plantain	-	70	
Crayfish	-	20	
Palm oil	-	10	
Carrot	-		5
Pumpkin	-		5
Total	100	100	100

Three blends were formulated by combining the processed ingredients in specific proportions to ensure nutritional diversity and complementarity. Blend A consisted of 70 g of yellow maize flour and 30 g of soybean flour, representing a cereal-legume combination aimed at improving protein quality and energy density. Blend B was formulated using 70 g of unripe plantain flour, 20 g of crayfish flour, and 10 g of palm oil, providing a mixture rich in carbohydrates, animal protein, and essential lipids. Blend C comprised 65 g of yellow maize flour, 25 g of soybean flour, 5 g of carrot powder, and 5 g of pumpkin leaf powder, producing a nutrient-dense blend with additional carotenoids, vitamins, and minerals from vegetable sources. All formulations were homogenized thoroughly to ensure uniform distribution of ingredients and to achieve a consistent texture suitable for complementary feeding. The blends were later analysed for amino and fatty acid composition.

Determination of Amino Acid Composition

Amino acid composition was determined using High-Performance Liquid

Chromatography (HPLC). The HPLC equipment consisted of a Spectra Physics (San Jose, CA) HPLC apparatus comprising an 8700 XR ternary pump, a 20-µL Rheodyne (Cotati, CA) injection loop, an SP8792 column heater, a 8440 XR UV-vis detectors, and a 4290-integrator linked via Labnet to a computer running WINner 8086 software (operating system, MS.DOS version 3.2). For separation, a 250- × 4.6-mm column packed with 5-µm Spherisorb $C_{1\ 8}$ (Sugelabor, Madrid, Spain) was used. Prior to analysis, 0.1 g of each lyophilized sample was hydrolyzed with 15 mL of 6N hydrochloric acid in a tightly sealed tube flushed with nitrogen gas to prevent oxidation. The mixture was incubated in an oven at 110°C for 24 hours. After hydrolysis, the solution was filtered using Whatman No. 541 filter paper, and made up to 25 mL with distilled water. Thereafter, it was re-filtered through a 0.5 µm membrane filter (Millipore, Madrid, Spain). For derivatization, dried sample residues were treated with a methanol-water-phenyl isothiocyanate (PITC) reagent to produce phenylthiocarbamyl (PTC) amino acids. After solvent removal under a nitrogen stream, the residues were reconstituted in 5 mM sodium phosphate buffer containing 5% acetonitrile. Separation was achieved on a Spherisorb C18 column (250 × 4.6 mm, 5 µm) at 30°C, using a gradient elution of eluant A (0.14 M sodium acetate, pH 6.2, with 0.5 mL/L triethylamine) and eluant B (acetonitrile-water, 60:40 v/v). Detection was performed with a UV-Vis detector at 254 nm. The resulting chromatograms were integrated and compared with pure amino acid standards for quantification.

Determination of Fatty Acid Composition

Fatty acid composition was analysed according to the AOAC Official Method [30]. Exactly 1000 mg of each sample was weighed into a centrifuge tube, and 2 mL of distilled water was added to dissolve the sample. The mixture was allowed to stand for 15 minutes at room temperature. Subsequently, 5 mL of internal standard solution (C11:0 FAME and C13:0 TAG, each at 2 mg/mL in methyl tert-butyl ether) was added, followed by 5 mL of 5% methanolic sodium methoxide. The mixture was vortexed for 10 seconds and allowed to react for 180 seconds, after which 2 mL of hexane was added. After 210 seconds, 10 mL of 10% disodium hydrogen citrate solution was introduced for neutralization. The mixture was then vortexed gently and centrifuged at 1750 rpm for 5 minutes. Exactly 200 µL of the supernatant was transferred into a volumetric flask and diluted to mark with hexane. The fatty acid methyl esters (FAMEs) were analysed using Gas Chromatography-Mass Spectrometry (GC-MS) under the following conditions: column type SPTM-2560 (100 m × 0.25 mm I.D., 0.20 µm film thickness); oven temperature program of 60°C (1 min), increased at 15°C/min to 165°C (1 min), then at 2°C/min to 225°C (20 min); injector temperature 250°C; detector temperature 250°C; carrier gas helium at a flow rate of 0.8 mL/min; and injection volume 1 µL with a 10:1 split ratio. Fatty acids were identified by comparing retention times with standard FAME mixtures containing C4:0–C24:0 saturated, C15:1–C20:1 monounsaturated, and C18–C22 polyunsaturated fatty acids. Quantification was carried out using calibration curves derived from standard response factors, and results were expressed as parts per million (ppm) or milligrams per 100 grams of sample. Calibration standards were run using high quality standards, a concentration series was prepared and internal standards were used to correct for matrix effects. A linear curve generated, which was used to quantify analytes. All analysis were replicated in triplicates and the mean and standard deviation were recorded. Statistical analysis was performed using

Agilent Chemstation Software and the NIST Mass Spectral Library[31].

3-RESULTS

Amino Acid Chromatographic Profiles of the Formulated Complementary Foods

The amino acid composition of the formulated complementary meal blends was assessed using High-Performance Liquid Chromatography (HPLC), and the resulting chromatograms are shown in Figures 1–3. The retention times and peak intensities correspond to the concentrations specific amino acids identified in each formulation. All chromatograms showed well-resolved peaks, showing that amino acid derivatives were efficiently separated and detected following hydrolysis and derivatization.

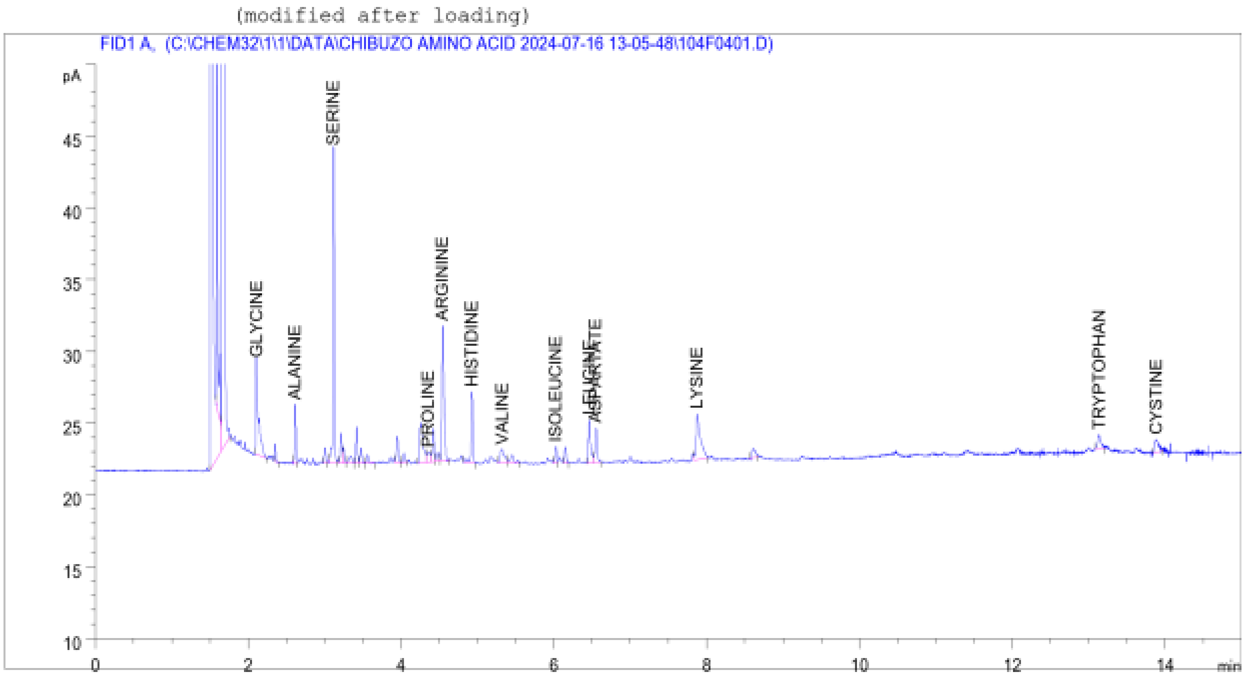

Figure 1. HPLC chromatogram of amino acid composition in Blend A (Maize–Soybean formulation)

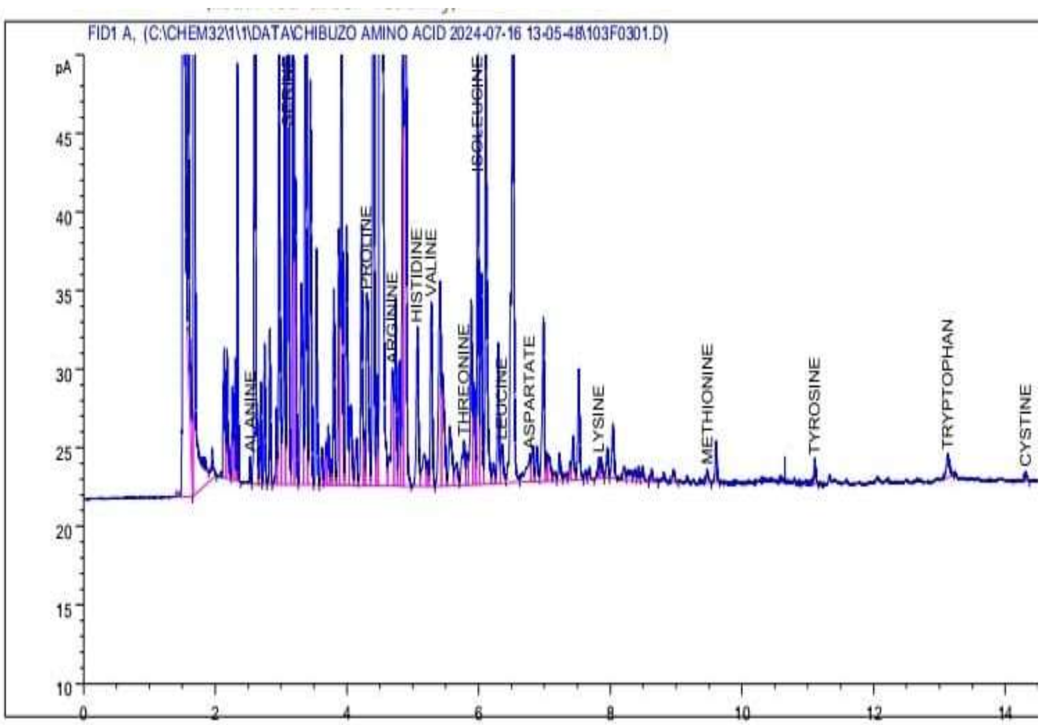

Figure **2. HPLC chromatogram of amino acid composition in Blend B (Plantain–Crayfish–Palm oil formulation)**

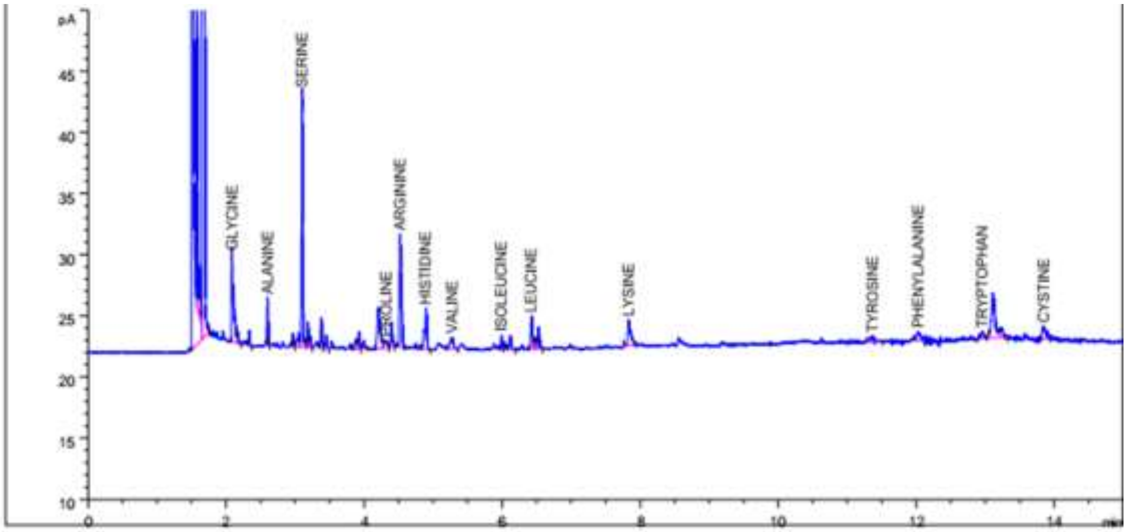

Figure 3. HPLC chromatogram of amino acid composition in Blend C (Maize–Soybean–Vegetable formulation)

The chromatograms revealed different amino acid peaks such as leucine, isoleucine, lysine, valine, methionine, phenylalanine, tryptophan, glutamic acid, and aspartic acid, among others. Blend A showed greater peak intensities for glutamic acid, lysine, and leucine, indicating a more diverse amino acid composition than Blends B and C. The peaks for methionine and tryptophan were smaller yet identifiable, suggesting that they are present in nutritionally significant amounts. The order of amino acid abundance in all blends followed a similar pattern: glutamic acid > aspartic acid > leucine > lysine > valine > isoleucine > alanine > phenylalanine > threonine > glycine > methionine > tryptophan.

Table 3: Amino Acid Composition of Blends (A, B, and C, mg/100 g)

Amino Acid	**Blend A**	**Blend B**	**Blend C**
Glycine	4.07	2.24	3.77
Alanine	0.27	4.25	1.22
Serine	0.27	72.53	7.11
Proline	2.29	8.82	4.89
Arginine	0.27	6.11	4.75
Histidine	0.27	6.12	2.11
Valine	3.19	6.49	8.06
Threonine	ND	2.69	ND
Isoleucine	0.27	13.74	4.53
Leucine	6.03	1.65	1.30
Aspartate	0.27	2.24	ND
Lysine	0.27	5.70	1.69
Methionine	ND	4.74	ND
Glutamate	ND	ND	ND
Tyrosine	ND	7.24	4.38
Phenylalanine	ND	ND	8.50
Tryptophan	3.21	1.33	3.82
Cystine	0.27	3.06	9.65

ND = Not Detected.

The amino acid composition revealed significant variation among the blends (Table 3). **Blend A** showed moderate amino acid content dominated by *Leucine (6.03 mg/100 g)* and *Valine (3.19 mg/100 g)*, while some essential amino acids were undetected. **Blend B** demonstrated the highest amino acid concentration with *Serine (72.53 mg/100 g)* and *Isoleucine (13.74 mg/100 g)* as major constituents. **Blend C** exhibited a balanced distribution with high *Cystine (9.65 mg/100 g)* and *Phenylalanine (8.50 mg/100 g)*, indicating strong nutritional potential across the blends.

Fatty Acid Chromatographic Profiles of the Formulated Complementary Foods

The fatty acid composition of the three formulated complementary foods was determined by Gas Chromatography–Mass Spectrometry (GC–MS). The resulting chromatograms are presented in **Figures 4–6**. Each chromatogram showed distinct retention peaks corresponding to various fatty acid methyl esters (FAMEs) identified in the samples.

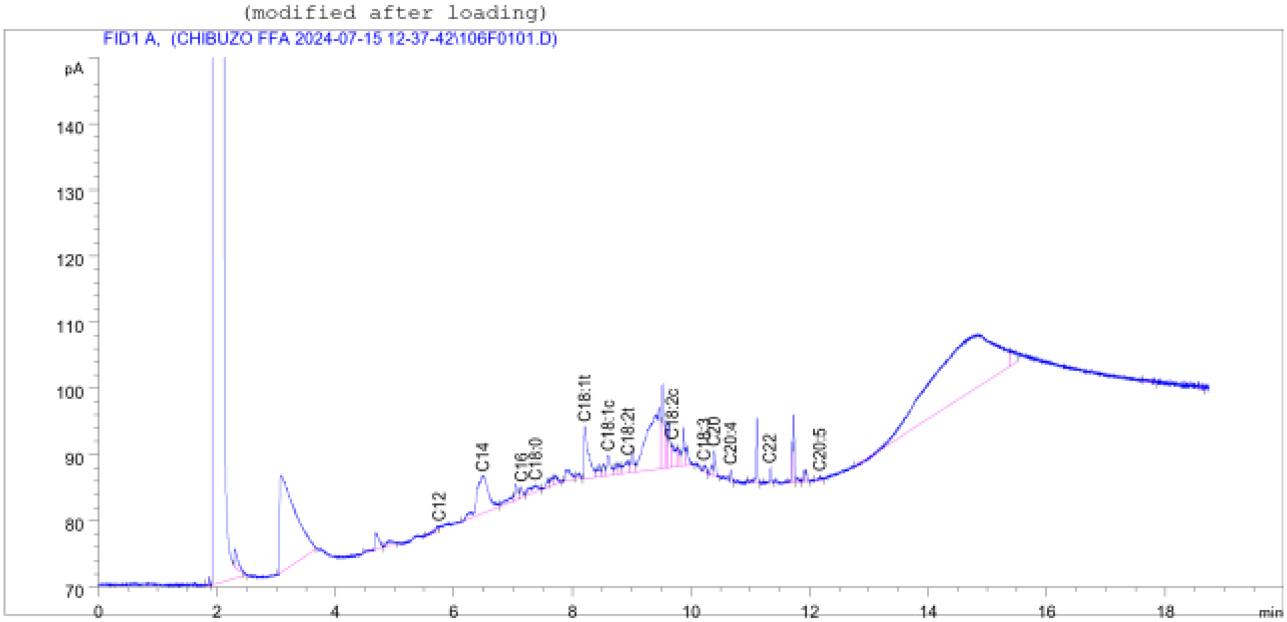

Figure 4. GC–MS chromatogram of fatty acid composition in Blend A

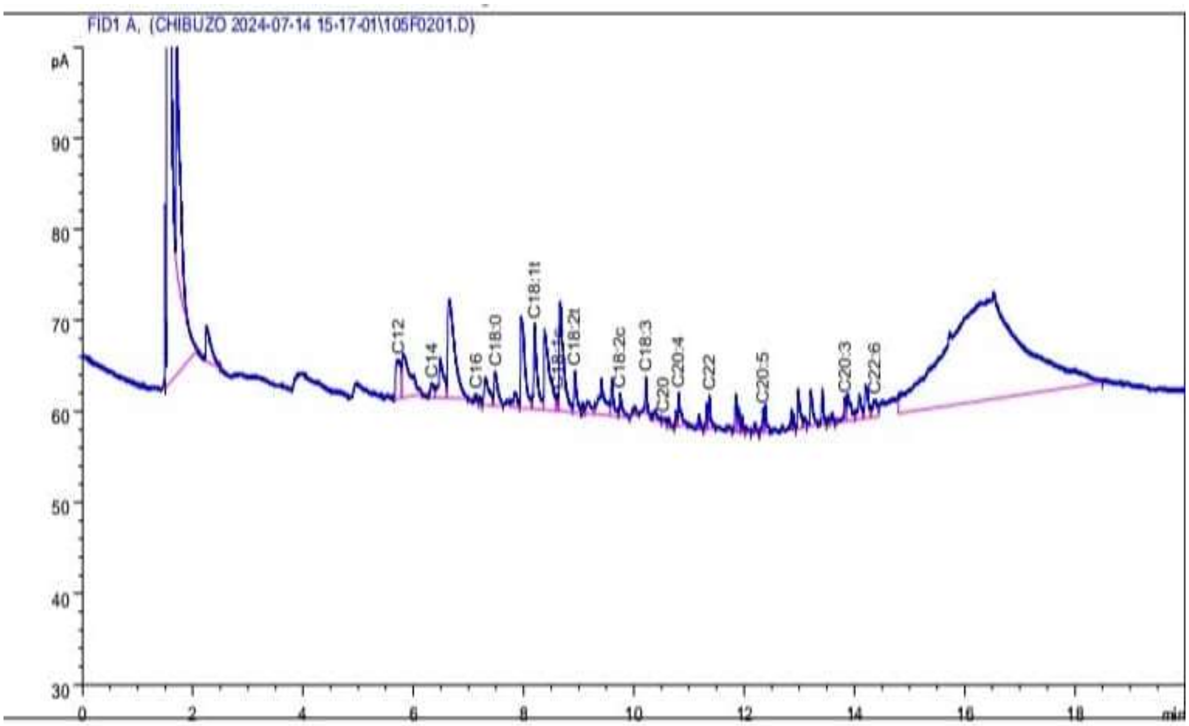

Figure 5. GC–MS chromatogram of fatty acid composition in Blend B

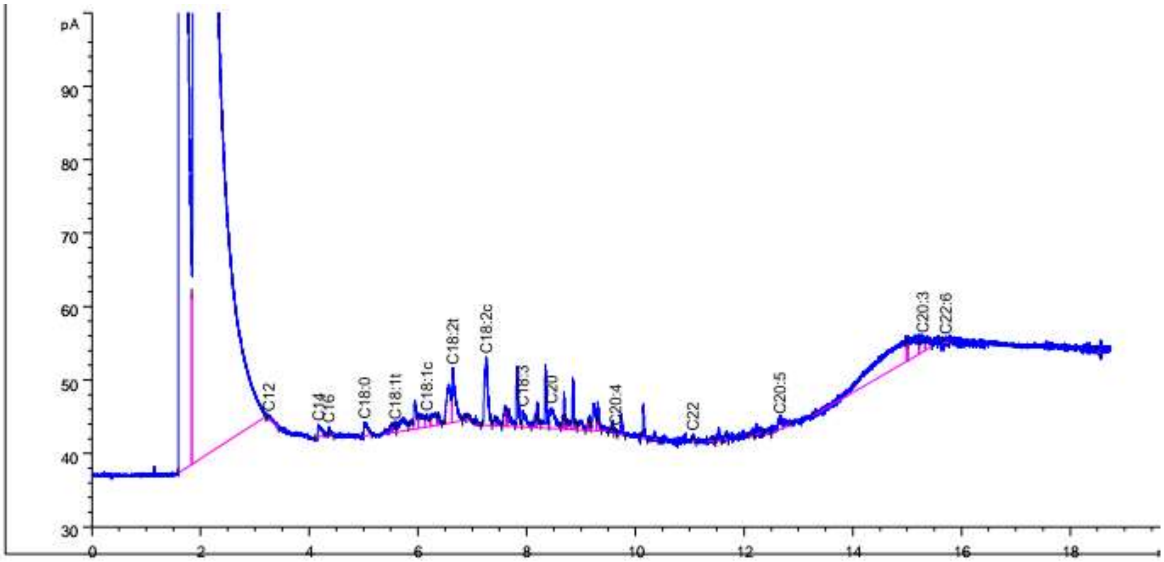

Figure 6. GC–MS chromatogram of fatty acid composition in Blend C

The chromatograms indicated the presence of saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids across all blends. The dominant saturated fatty acids were palmitic acid (C16:0) and stearic acid (C18:0), while oleic acid (C18:1) represented the major monounsaturated fatty acid. Linoleic acid (C18:2) and α-linolenic acid (C18:3) were identified as the key polyunsaturated fatty acids.

Table 4: Fatty Acid Composition of Blends (A, B, and C mg/100 g)

Fatty Acid	Blend A	Blend B	Blend C
C12:0 (Lauric acid)	0.47	0.96	0.10
C14:0 (Myristic acid)	0.58	0.27	0.22
C16:0 (Palmitic acid)	1.14	1.79	0.77
C18:0 (Stearic acid)	4.14	0.70	0.31
C18:1t (Elaidic acid)	0.17	1.56	0.16
C18:1c (Oleic acid)	0.53	1.00	ND
C18:2t (Linoleic trans)	0.30	0.62	0.26
C18:2c (Linoleic cis)	0.63	0.32	1.18
C18:3 (α-Linolenic acid)	0.18	0.32	1.55
C20:0 (Arachidic acid)	0.10	0.69	0.39
C20:3 (Eicosatrienoic acid)	ND	0.09	0.16
C20:4 (Arachidonic acid)	0.10	0.07	0.73
C20:5 (Eicosapentaenoic acid – EPA)	0.31	0.03	0.42
C22:0 (Behenic acid)	0.12	0.34	0.27
C22:6 (Docosahexaenoic acid – DHA)	ND	0.16	0.10

ND = Not Detected.

Fatty acid analysis indicated diverse lipid profiles among the blends (Table 4). **Blend A** contained 13 fatty acids, largely saturated, with *Stearic acid (4.14 mg/100 g)* and *Palmitic acid (1.14 mg/100 g)* as dominant. **Blend B** exhibited 15 fatty acids with prominent *Palmitic (1.79 mg/100 g)* and *Elaidic (1.56 mg/100 g)* acids, suggesting a moderate balance of saturated and trans unsaturated lipids. **Blend C** comprised 14 fatty acids, rich in polyunsaturated components such as *α-Linolenic acid (1.55 mg/100 g)* and *Linoleic acid (1.18 mg/100 g)*, indicating enhanced nutritional quality and potential cardiovascular benefits.

Table 5. Summary Comparison of Amino and Fatty Acid Profiles of Blends A, B, and C (mg/100 g)

Parameter	Blend A	Blend B	Blend C
Total Amino Acids Detected	14	15	15
Total Amino Acid Concentration (mg/100 g)	21.75	149.46	66.35

Dominant Amino Acid	Leucine (6.03)	Serine (72.53)	Cystine (9.65)
Total Fatty Acids Detected	13	15	14
Total Fatty Acid Concentration (mg/100 g)	9.83	8.14	7.41
Dominant Fatty Acid	Stearic acid (4.14)	Palmitic acid (1.79)	α-Linolenic acid (1.55)
Major Fatty Acid Class	Saturated	Mixed(SFA+ Trans)	Polyunsaturated (PUFA)

SFA – Saturated Fatty Acids; PUFA – Polyunsaturated Fatty Acids.

The comparative summary (Table 5) reveals that **Blend B** possesses the highest total amino acid concentration (149.46 mg/100 g), attributed to its remarkably high *Serine* and *Isoleucine* contents, implying strong protein potential. **Blend A**, while moderate in amino acids, was dominated by *Leucine (6.03 mg/100 g)* and exhibited the highest saturated fatty acid fraction, particularly *Stearic acid (4.14 mg/100 g)*. Conversely, **Blend C** displayed a balanced amino acid distribution and the most ideal lipid profile, rich in *α-Linolenic (1.55 mg/100 g)* and *Linoleic (1.18 mg/100 g)* acids.

4-DISCUSSION

Incidences of growth faltering and delayed neurocognitive development are usually more common during the growth period from 6 to 23 months when infants are usually introduced to complimentary diets, after exclusively being breastfed for 6 months. These incidences are also more common in low-and medium-income countries, where poverty, low income and excessive population growth all contribute to reduces accessibility to wholesome and healthy nutrition. This affects the growth and development of these infants and prevent them from attaining their full potentials. Infants must be provided with sufficient nutrition to ensure a total and well-balanced growth and development especially during the weaning period. Effort must be made to enrich the diets of weaning infants with high quality proteins rich in essential amino acids and fatty acids for a well-rounded development [32].

Proteins consist of amino acids which are grouped into essential and non-essential amino acids. Essential or indispensable amino acids are not synthesized by human metabolic activities and must therefore be consumed from diet. On the contrary non-essential amino acids are synthesized within the body and mostly available when needed by the body. Amino acids especially the essential group are very crucial for infant growth and development as they influence major functions in the body. The first year of life is usually very critical because of rapid growth and development at this stage, it must therefore be supported by a rich protein supply for basic metabolic activities [33]. The amino acids, arginine and lysine for instance, have been associated with the release of growth hormones in young children, high intake of these amino acids have been reported to prevent fat mass index in pre-pubertal girls. Adequate intake of protein in early life has been associated positively with height and healthy weight gain at ten years of age [34]. The optimal growth of lean tissues demands that there is a sufficient mixture of all 20 amino acids in significant quantities to ensure optimized protein synthesis. An improved protein and amino acid balance have been linked with enhanced deposition of protein by reducing protein breakdown. A dietary protein is said to have good quality when it contains a rich mixture of all essential amino acids to meet the recommended dietary requirements. Thus, the amount or profile of essential amino acid relative to the amount dietarily recommended determines the protein quality. The most basic function of dietary EAAs is to stimulate protein synthesis by sending signals that activate molecular mechanisms for the synthesis of protein in the body. They also serve as the precursors for the synthesis on proteins on which basic metabolic activities rely [35].

The evaluation of the three locally formulated complementary foods revealed distinct variations in amino acid and fatty acid composition, confirming that ingredient selection and proportion strongly influence nutritional quality. The amino acid analysis showed that all three blends contained essential amino acids required for infant growth, tissue repair, and metabolic regulation. The presence of leucine, lysine, valine, threonine, phenylalanine, and methionine in appreciable concentrations indicates that the formulated diets can meet the amino acid needs of infants when used as part of complementary feeding. Quantitatively, total amino acid content ranged from 21.75 mg/100 g in Blend A to 149.46 mg/100 g in Blend B and 66.35 mg/100 g in Blend C, with Blend B showing the highest protein concentration. These amino acids not only enhance flavour but also act as nitrogen donors in metabolic reactions that support protein utilization.

The inclusion of soybean and crayfish seemed to improve overall protein quality through amino acid combination between plant and animal sources. Soybean, rich in lysine but limited in methionine, compensated for maize’s deficiencies, while crayfish contributed sulphur-containing amino acids such as methionine and cysteine [10,18]. This synergy explains the higher leucine concentration recorded in Blend A (maize–soybean) and the adequate methionine and cystine contents in Blend B (plantain–crayfish–palm oil). The balanced amino acid profile of Blend C (maize–soybean–vegetable) further highlights the nutritional benefit of including carotenoid- and vitamin-rich vegetables such as carrot and pumpkin leaves, which enhance micronutrient density and overall food quality [25,29]. Among the blends, the dominance of leucine and lysine is nutritionally significant, as these amino acids promote muscle synthesis and nitrogen retention in infants [13]. Cystine and phenylalanine were particularly abundant in Blend C, indicating strong antioxidant potential.

Blend B was richer in amino acids relative to blends A and C as it contained all essential amino acids in reasonable proportions except for phenylalanine, it was the only blend that contained methionine in relatively good proportion. Blend C contained the highest amount of valine(8.06mg/100g), and tryptophan (3.82mg/100g) and was the only blend that contained phenylalanine in significant proportion relative to the dietary reference intake (Table 1), however, methionine and threonine were not detected in blend C. Blend A had the least amounts of essential amino acids with threonine, methionine, tyrosine and phenylalanine not detected. Blend A may thus not be able to provide sufficient amino acids and protein for the cognitive and behavioural development of infants to full capacity. It must be supplemented with other amino acid rich foods to complement its nutrients. Also, glutamate, a non-essential amino acid was not detected in any of the blends, while aspartate was also absent in blend C. However, this is not a cause for concern as the body can synthesise non-essential amino acids. To make blend B adequate for a complimentary diet, a rich source of phenylalanine like; meat, fish or egg may be added to contribute phenylalanine to the blend. Blend B did not only contain the essential amino acids but in reasonable proportions relative to the dietary reference intake (DRI) in Table 1. For instance, blend B contains 13.74mg/100g of isoleucine, this means that just 200g of blend B will meet and even exceed the 25mg/g dietary reference intake (DRI) (Table 1). Blend B also meets the DRI for histidine, methionine, and tyrosine at 300g, 500g and 600 g respectively. However, the blend did not meet the DRI for some of the amino acids including; leucine, threonine, and lysine which should be supplemented with breastfeeding in weaning infants to make up for any short comings. Blend C meets the DRI for cysteine at 300g, while blends A and C meet and exceed the DRI for tryptophan at just 200g. Blends B and C contain 6.49 and 8.06 mg/1100g of valine which meets the DRI of 32mg/g when 500g and 400g are consumed respectively. However, a weaning child may consume between 200-300g of meal per day usually spread out into 3 to 5 meals of between 50-100g per meal. While breastfeeding may suffice for the shortcomings relative to the DRI (Table 1), the blends still require protein sources rich in essential amino acids like meat, fish and egg. Future research should include more animal protein to make up the deficiencies observed in the blends, especially blend A.

Fatty acid profiling (Table 4) revealed nutritionally important saturated, monounsaturated, and polyunsaturated fatty acids in proportions suitable for infant feeding. The primary saturated fatty acids were palmitic (C16:0) and stearic (C18:0) acids, whereas oleic (C18:1) represented the major monounsaturated fatty acid. Polyunsaturated fatty acids (PUFAs) such as linoleic (C18:2) and α-linolenic (C18:3) acids were present in nutritionally relevant concentrations (Table 1). Total fatty acid concentrations were 9.83, 8.14, and 7.41 mg/100 g for Blends A, B, and C, respectively. Blend A contained 13 fatty acids dominated by stearic (4.14 mg/100 g) and palmitic (1.14 mg/100 g) acids, typical of saturated-rich lipid sources. Blend B contained 15 fatty acids, with palmitic (1.79 mg/100 g) and elaidic (1.56 mg/100 g) acids as major components, reflecting contributions from palm oil and crayfish. Blend C contained 14 fatty acids, characterized by higher proportions of α-linolenic (1.55 mg/100 g) and linoleic (1.18 mg/100 g) acids, resulting in a favourable polyunsaturated lipid profile. Blends B and see contained a rich proportion of polyunsaturated fatty acids including; linoleic, α-linolenic, arachidonic acid, eicosapentanoic acid and docosahexaenoic acid. These show that the two blend are rich sources of essential fatty acids. Blend C contained higher concentrations of polyunsaturated fatty acids, than blends A and B making it a good choice for infants as they require polyunsaturated fatty acids for proper brain development and cognitive function.

Polyunsaturated fatty acids are important components of the brain and retina and perform crucial metabolic function in the body. They should make up a very basic component of infant nutrition as they enhance development in foetuses, newborn and growing infants. Essential fatty acids like n-3 and n-6 polyunsaturated fatty acids (PUFAs) can only be provided through diet and are paramount for effective brain development and function especially during the early years of life. They also play very crucial role in inflammation and neuronal growth [36]. It is generally recommended that essential fatty acids (omega-3 and omega-6 polyunsaturated fatty acids) are part of the diet for infants together with important lipids and micro nutrients that play significant roles in a child's physical and cognitive development. [37]. Omega 3 fatty acid is known for its important role in decreasing coronary artery disease and improving blood flow. PUFAs also perform anti-inflammatory activities that helps control inflammation from chronic diseases such as auto-immune and degenerative neurological diseases. They are also used to control metabolic syndrome resulting from obesity and diabetes [38].

These results align with previous reports that identified these fatty acids as the principal lipid constituents of cereal, legume, and aquatic foods [12,15]. Although saturated fatty acids are often restricted in adult diets, they are critical for infants as dense energy sources and for maintaining membrane structure [13]. The balanced ratios of palmitic and stearic acids across blends indicate appropriate lipid suitability for infant metabolism. The presence of oleic acid further enhances nutritional quality by improving membrane fluidity and facilitating the absorption of fat-soluble vitamins [20,21]. The substantial oleic and linoleic acid contents in soybean-based blends (A and C) underscore the importance of legumes for improving fatty acid profiles in complementary foods. The polyunsaturated fatty acids linoleic (omega-6) and α-linolenic (omega-3) were detected in desirable ratios, especially in Blend C, supporting immune and neural development. These essential fatty acids are precursors for eicosanoids and docosahexaenoic acid (DHA), which play vital roles in brain and visual maturation [12]. Comparison of amino acid and fatty acid data shows each formulation with distinct nutritional properties. Blend A (maize-soybean) provides superior protein quality and a balanced amino acid spectrum; Blend B (plantain-crayfish-palm oil) provides energy and lipid density; and Blend C (maize-soybean-vegetable) provides ideal macronutrient and micronutrient balance. This variety enables the blends to perform complementary nutritional functions—Blend A for protein rehabilitation, Blend B for high-energy requirements, and Blend C for maintenance feeding. The processing steps—soaking, drying, grinding, and blending proved beneficial in retaining nutrient integrity, since all necessary amino and fatty acids were maintained. Similar preservation effects were reported by Akinyemi et al. [22] and Verem et al. [29], confirming that properly controlled traditional methods can yield high-quality, nutrient-dense complementary foods.

5-CONCLUSION

The present study demonstrated that locally formulated complementary foods produced from readily available ingredients such as unripe plantain, maize, soybean, crayfish, palm oil, carrot, and pumpkin leaf possess nutritionally balanced amino acid and fatty acid profiles suitable for infant feeding. The three blends contained all essential amino acids and key fatty acids required for healthy growth and metabolic development in infants aged 6–24 months. Blend A (maize–soybean) exhibited superior protein quality, Blend B (plantain–crayfish–palm oil) provided higher lipid density and energy value, while Blend C (maize–soybean–vegetable) offered the most favourable balance of macronutrients and micronutrients. These results confirm that locally sourced foods can be effectively combined and processed using simple, low-cost methods to produce nutrient-dense complementary diets that meet international nutritional standards. Promoting the household and community-level production of such formulations could help reduce dependence on imported commercial infant foods, lower feeding costs, and combat malnutrition among children in low-income households. The findings highlight the importance of encouraging local innovation, improving maternal nutrition education, and supporting small-scale food processing initiatives as sustainable strategies for achieving better child health outcomes in Nigeria and similar developing regions. Further studies may explore why glutamate was absent in all the blends, and antinutritional analysis to see how antinutrients may affect digestibility and bioavailability of these nutrients.

Declaration of Conflicting Interest

The authors declare no conflict of interest.

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