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GC–MS and HPLC Characterization of Amino and Fatty Acid Composition in Two Locally Produced Complementary Foods for Infants in Calabar, Nigeria

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ABSTRACT

Complementary foods are important foods for ensuring optimal nutrition and growth in infants and young children. They are expected to fill the nutritional gaps that arise when breast milk alone no longer meets the child's dietary needs However, the nutritional adequacy of homemade complementary foods, which are commonly used in many developing countries, is often deficient in important nutrients. This study evaluated the amino acid and fatty acid compositions of two indigenously formulated complementary foods designed for infants in Calabar, Nigeria. The formulations were produced using locally available ingredients: Blend A (rice, egg yolk, apple, and banana) and Blend B (rice, Titus fish, avocado pear, and banana). Amino acid and fatty acid profiles were analyzed using Gas Chromatography–Mass Spectrometry (GC–MS) and High-Performance Liquid Chromatography (HPLC) respectively. Results revealed that Blend A contained higher total fatty acids, dominated by oleic acid (89,700 ppm), linolenic acid (82,500 ppm), and linoleic acid (46,800 ppm), while Blend B exhibited more diverse amino acid composition, with phenylalanine (39.72 mg/100 g) and tryptophan (12.13 mg/100 g) as major essential amino acids. Both blends contained physiologically important fatty acids such as linoleic, α-linolenic, arachidonic, eicosapentaenoic (EPA), and docosahexaenoic (DHA) acids, crucial for infant development. The combined findings indicate that these locally formulated diets provide balanced macronutrient quality comparable to recommended dietary standards. The study establishes the potential of indigenous food resources as sustainable, cost-effective, and nutritionally adequate alternatives for complementary feeding and the prevention of childhood malnutrition in low-income settings.

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Introduction

Malnutrition remains one of the most serious public health problems in sub-Saharan Africa, particularly in Nigeria, where it continues to contribute significantly to child morbidity and mortality. Poor complementary feeding practices and the use of nutrient-deficient weaning foods are among the leading causes of undernutrition in infants and young children (Ogbo et al., 2015). According to the Food and Agriculture Organization (FAO, 2022), approximately two billion people worldwide experience chronic malnutrition, often manifested in conditions such as kwashiorkor and marasmus. Each year, an estimated 10.6 million children die before their fifth birthday, and about 70% of these deaths are associated with diarrheal diseases, pneumonia, measles, malaria, and malnutrition (UNICEF, 2018). Reports from the Nigeria Demographic and Health Survey indicate that four in ten children under five are stunted, one in four are underweight, and nearly 9% suffer from wasting (WHO, 2015). Undernourished children are at a higher risk of infections and face an increased likelihood of death from gastrointestinal and respiratory diseases (Black et al., 2008, Black et al., 2017). With over one-third of Nigerian children under five years old being stunted, the country nutritional indices remain among the worst globally (Adenuga et al., 2017). Complementary feeding, therefore, becomes critical in preventing infant morbidity and mortality. To achieve this, complementary foods must be nutrient-dense and energy-rich, supplying high-quality proteins, vitamins, and minerals (Chukwu et al., 2014). The World Health Organization (2013) recommends that infants begin receiving complementary foods at six months while continuing breastfeeding. Introducing complementary foods at the appropriate age helps bridge the nutritional gap that arises as the child's needs exceed what breast milk alone can provide. International organizations have emphasized the production of affordable, nutrient-dense foods using locally available resources to combat malnutrition and enhance child survival (UNICEF, 2019).

Infant mortality in Nigeria remains alarmingly high, estimated at 112 deaths per 1,000 live births, with nearly half attributed to malnutrition (World Bank, 2024). The National Nutrition and Health Survey (NNHS, 2018) reported that acute malnutrition affects about 7% of children aged 6–59 months, while 19.9% are underweight, 32% are stunted, and 1.2% are overweight. Only about two-thirds of Nigerian children grow without signs of stunting or wasting. Addressing this issue requires identifying sustainable, culturally appropriate, and affordable dietary interventions. Locally sourced ingredients such as Titus fish, avocado pear, rice, egg yolk, banana, and apple offer significant nutritional value that could support the development of nutrient-dense complementary foods. Titus fish, commonly known as sardine, is rich in high-quality proteins, omega-3 fatty acids, vitamins, and essential minerals (Swanson et al., 2012). It contains omega-3 fatty acids, docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are essential for infants cognitive development, brain function, and eyesight. Similarly, avocado pear delivers monounsaturated fats that help cardiovascular and cognitive health, as well as vital vitamins E, C, and K

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(Dreher & Davenport, 2013; Fulgoni et al., 2013). Its high fiber content further promotes gut health (Slavin, 2013). Egg yolk also serves as a concentrated source of fat-soluble vitamins (A, D, E, and K), water-soluble vitamins (B6, B12), and vital minerals including calcium, magnesium, iron, and selenium (Huizen, 2017). Additionally, it contains carotenoids that enhance vision and choline that regulates inflammation and cardiovascular function. Proteins such as phosvitins and lipovitellins in egg yolk aid embryo development and mineral storage. Bananas, another important local ingredient, supply fiber, vitamins (A, C, and B-complex), and minerals, contributing to healthy digestion and energy balance (Qamar & Shaikh, 2018). The fruit also contains bioactive compounds such as flavonoids, phenolics, carotenoids, and amines with antioxidant properties that enhance cellular health (Singh et al., 2016). Together, these local ingredients provide a nutrient-rich basis for developing low-cost, balanced complementary foods that can support infant growth and development.

Despite the nutritional potential of these local foods, access to fortified commercial complementary foods remains limited in many Nigerian communities due to high cost and dependence on imported ingredients. As Adu-Afarwuah et al. (2019) noted, imported fortified foods, although effective, are often unaffordable and culturally unsuitable for rural populations. Many Nigerian families cannot consistently afford animal-based protein sources or industrially processed foods. As a result, household-prepared complementary diets often fail to meet essential nutrient standards, perpetuating the cycle of child malnutrition. There is a growing need for locally formulated complementary foods that utilize accessible and affordable ingredients to ensure infants' optimal growth and health. The Food and Agriculture Organization (FAO, 2017) emphasized developing community-based nutrition strategies that leverage indigenous food resources such as rice, avocado, fish, egg yolk, and fruits. Such approaches not only improve nutrient intake but also promote food security and self-sufficiency. Rice, for instance, provides carbohydrates for energy and essential amino acids for growth when combined with other protein sources (FAO, 2018). Locally sourced blends, if properly formulated, can offer balanced macronutrients and essential micronutrients comparable to standard fortified infant foods. The inclusion of animal and plant-based components can ensure that all essential amino acids and fatty acids are represented. According to the World Health Organization (1985), infants aged 3–4 months require specific levels of essential amino acids per kilogram body weight: histidine (28 mg), isoleucine (70 mg), leucine (161 mg), lysine (103 mg), methionine plus cystine (58 mg), phenylalanine plus tyrosine (125 mg), threonine (87 mg), tryptophan (17 mg), and valine (93 mg). For children aged 5–24 months, the requirements are reduced due to slower growth rates, ranging from 27 mg to 73 mg across the same amino acids. Additionally, the National Academy of Sciences (2025) established dietary reference intakes for total fat and fatty acids in infants, noting that infants up to six months require 31 g of fat daily, including 4.4 g of linoleic acid and 0.5 g of α-linolenic acid, while those aged 7–12 months require 30 g total fat, 6 g linoleic acid, and 0.5 g α-linolenic acid. These data provide a

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nutritional benchmark against which locally formulated complementary foods can be assessed.

The present study, therefore, focuses on the *GC–MS and HPLC characterization of amino and fatty acid composition in two locally produced complementary foods for infants in Calabar, Nigeria*. The investigation aims to evaluate the nutrient profiles of two blended formulations composed of locally sourced ingredients: Blend A (rice, egg yolk, apple, and banana) and Blend B (rice, Titus fish, avocado pear, and banana). By assessing the amino and fatty acid compositions relative to recommended dietary standards, the study seeks to determine the nutritional adequacy of these indigenous complementary foods. The ultimate goal is to demonstrate that locally formulated diets can meet international nutrient standards for infants and young children while remaining affordable and culturally appropriate. This approach aligns with national and global public health goals aimed at reducing childhood malnutrition, improving food security, and promoting the use of indigenous food resources. The findings of this research have the potential to contribute to sustainable nutrition strategies, particularly for low-income households, and to provide scientific evidence supporting the inclusion of locally available ingredients in infant feeding programs across Nigeria and similar developing contexts.

Materials and Methods

Equipment

The equipment used in this study included a refrigerator, an electric blender, an analytical balance, a high-performance liquid chromatography (HPLC) apparatus, a gas chromatography (GC) system, a colorimeter, a grinding machine, a centrifuge, a vortex mixer, an oven, a water bath, a Soxhlet extraction apparatus, a rotary evaporator, a pH meter, and spectrophotometers. These instruments were employed to ensure accurate preparation, processing, and analytical quantification of amino acids and fatty acids in the formulated complementary foods.

Reagents

All reagents used were of analytical grade. The reagents included sodium citrate buffer, hydrochloric acid (HCl), glacial acetic acid, methanol, methyl ether, methanolic sodium methoxide solution, neutralization solution, hexane, sodium chloride, chloroform, sulfuric acid, borate buffer, phenol, and ninhydrin. Standard solutions for calibration were also prepared for both amino acid and fatty acid analyses.

Sample Preparation and Formulation of Complementary Foods

Two complementary food formulations, designated as Blend A and Blend B, were prepared using locally sourced ingredients commonly available in Calabar, Nigeria. Each blend consisted of a combination of carbohydrate, protein, and fat-rich ingredients aimed at producing nutrient-dense foods suitable for infant feeding.

For **Blend A**, rice (45 g), egg yolk (11 g), apple fruit flour (22 g), and banana fruit flour (22 g) were combined to achieve a total weight of 100 g. The egg yolk was obtained by boiling raw eggs in hot water for five minutes to ensure coagulation. The apple and banana fruits were washed thoroughly under running tap water, peeled, sliced into thin pieces, and oven-dried at 60°C for 18 hours to remove moisture while retaining nutrient quality. The dried fruit

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slices were milled into fine flour and sieved through a 250 µm mesh to obtain uniform particle size. The rice grains were also milled, and all ingredients were homogenized in the specified proportions using an electric blender.

For **Blend B**, local rice (60 g), Titus fish (20 g), avocado pear (10 g), and banana fruit (10 g) were combined to produce another 100 g formulation. The Titus fish was cleaned, cooked, and de-boned to eliminate any physical contaminants before blending. The avocado pear was peeled, de-seeded, and mashed into a smooth paste prior to combination with the other ingredients. The mixed samples of both formulations were stored under refrigeration (4°C) in airtight containers until further analysis to prevent oxidative degradation and microbial growth. All formulations were carried out at the Food Preparation Laboratory, Department of Human Nutrition and Dietetics, University of Calabar, Nigeria.

Determination of Amino Acid Composition

The amino acid composition of the samples was determined using High-Performance Liquid Chromatography (HPLC)). The HPLC system used was a Spectra Physics (San Jose, CA) apparatus equipped with an 8700 XR ternary pump, a 20 µL Rheodyne (Cotati, CA) injection loop, an SP8792 column heater, an 8440 XR UV–visible detector, and a 4290-integrator connected to a computer via Labnet running WINner 8086 software under MS-DOS 3.2. Separation was achieved on a 250 × 4.6 mm column packed with 5 µm Spherisorb C18 (Sugelabor, Madrid, Spain) at a constant temperature of 30°C.

Preparation of Samples and Standards

For hydrolysis, 0.1 g of lyophilized sample was weighed into a 16 × 125 mm screw-cap Pyrex tube. Fifteen milliliters of 6 N hydrochloric acid were added, and the tube was flushed with nitrogen gas to prevent oxidation, sealed tightly, and incubated in an oven at 110°C for 24 hours. After hydrolysis, the mixture was vacuum-filtered through Whatman No. 541 filter paper, and the filtrate was made up to 25 mL with distilled water. A portion of this hydrolysate was further filtered through a 0.50 µm membrane filter (Millipore, Madrid, Spain). Standard solutions were prepared by dissolving 1.25 µmol/mL of each amino acid in 0.1 N hydrochloric acid for calibration.

Derivatization Procedure

After drying the sample under vacuum at 65°C, 30 µL of a methanol–water–phenylisothiocyanate (2:2:1 v/v) solution was added, followed by another drying step under vacuum. Next, 30 µL of a derivatizing reagent composed of methanol–water–phenylisothiocyanate (7:1:1:1 v/v) was added to the residue, mixed thoroughly, and allowed to react at room temperature for 20 minutes. The reaction mixture was evaporated under nitrogen, and the residues were stored at 4°C until analysis. Before HPLC injection, 150 µL of diluent (5 mM sodium phosphate containing 5% acetonitrile) was added to each sample.

Chromatographic Conditions

Chromatographic separation was conducted using a gradient elution with two eluants. Eluant A consisted of an aqueous buffer prepared by adding 0.5 mL/L triethylamine to 0.14 M sodium acetate, adjusted to pH 6.2 with glacial acetic acid. Eluant B was a mixture of acetonitrile and water in a 60:40 (v/v) ratio. The flow rate was maintained at 1.0 mL/min, and the gradient program gradually reduced Eluant A from 90% to 0% over 22 minutes, followed by re-equilibration to the initial conditions. The amino acids were detected at a wavelength specific for the derivatized phenylthiocarbamyl derivatives. Quantification was based on peak areas

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obtained from the standard calibration curves.

Determination of Fatty Acid Composition

The fatty acid composition of the complementary foods was analyzed using Gas Chromatography (GC) following the Association of Official Analytical Chemists (AOAC) Official Method (2012). One thousand milligrams of each powdered sample were weighed into a 25 mL centrifuge tube. Two milliliters of distilled water were added and mixed thoroughly. The mixture was allowed to stand for 15 minutes at room temperature to ensure hydration. 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% (w/v) methanolic sodium methoxide solution. The tube was covered and vortexed for 10 seconds. After exactly 180 seconds, 2 mL of hexane was added, and after another 30 seconds, 10 mL of neutralization solution (10% disodium hydrogen citrate in water) was introduced to halt the reaction. The mixture was gently shaken and centrifuged at 1,750 rpm for 5 minutes. Approximately 200 µL of the supernatant was transferred into a 10 mL volumetric flask and diluted to the mark with hexane prior to GC analysis.

Gas Chromatographic Conditions

The analysis was conducted on an SP™-2560 capillary column (100 m × 0.25 mm i.d., 0.20 µm film thickness). The oven temperature was programmed to begin at 60°C (held for 1 minute), then increased at 15°C/min to 165°C (held for 1 minute), followed by a 2°C/min ramp to 225°C, which was maintained for 20 minutes. The injector and detector temperatures were set at 250°C. Helium was used as the carrier gas at a flow rate of 0.8 mL/min. One microliter of each sample was injected with a 10:1 split ratio using a wool-packed split/splitless liner. Detection was achieved using a flame ionization detector (FID). The fatty acid methyl esters (FAMEs) were identified by comparing their retention times with those of known standards containing saturated fatty acids (C4:0–C24:0), monounsaturated fatty acids (C15:1–C20:1), and polyunsaturated fatty acids (C18–C22). Quantification was based on response factors derived from calibration curves of FAME standards, and the concentrations were expressed as milligrams of fatty acid per 100 grams of sample.

Quality Control and Statistical Analysis

All analyses were conducted in triplicate to ensure reproducibility. The accuracy of amino acid and fatty acid quantification was validated by comparing sample chromatograms with certified standards. Instrument calibration and procedural blanks were routinely performed to prevent analytical errors. Data interpretation focused on the presence, proportion, and nutritional relevance of the identified amino acids and fatty acids in both food blends.

Results and Discussion

Fatty Acid Composition

The gas chromatography–mass spectrometry (GC–MS) analysis of the two complementary food formulations (Blend A and Blend B) revealed the presence of several essential and non-essential fatty acids with varying concentrations (Table 1 and Figure 1). In Blend A, ten major fatty acids were identified. Oleic acid (C18:1) was the most abundant, with a concentration of approximately 89,700 ppm, followed by linolenic acid (C18:3) at 82,500 ppm, arachidic acid (C20:0) at 53,000 ppm, and (Z,Z)-9,12-octadecadienoic (linoleic) acid (C18:2) at 46,800 ppm. Linolelaidic acid (C18:2) appeared at 39,600 ppm, timnodonic acid or eicosapentaenoic acid (C20:5) at 50,000 ppm, mead (eicosatrienoic) acid (C20:3) at 36,100 ppm, and cervonic or

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docosahexaenoic acid (C22:6) at 39,500 ppm. Minor fatty acids included arachidonic acid (C20:4) and behenic acid (C22:0), detected at 24,100 ppm and 24,200 ppm, respectively. The presence of these long-chain polyunsaturated fatty acids, particularly DHA and EPA, indicates a potentially high nutritional quality for infant brain and visual development.

In Blend B, sixteen fatty acids were identified, with varying concentrations. Lauric acid (C12:0) was the most abundant at 81.11 ppm, followed by myristic acid (C14:0) at 49.78 ppm, linoleic acid (C18:2c) at 4.13 ppm, and linolelaidic acid (C18:2t) at 3.53 ppm. Other notable fatty acids included stearic acid (C18:0) at 2.79 ppm, palmitic acid (C16:0) at 2.23 ppm, arachidonic acid (C20:4) at 2.08 ppm, and α-linolenic acid (C18:3) at 1.41 ppm. Docosahexaenoic acid (C22:6) and oleic acid (C18:1c) appeared at 1.62 ppm each, while docosanoic acid (C22:0) had the lowest concentration of 0.038 ppm. The overall composition revealed the coexistence of saturated, monounsaturated, and polyunsaturated fatty acids, suggesting a balanced lipid profile beneficial for infant nutrition.

Table 1. Fatty Acid Composition of Locally Formulated Complementary Foods (Blend A and Blend B)

Fatty Acid Name	Lipid Number / Formula	Blend A (ppm)	Blend B (ppm)
Lauric acid	C12:0	–	81.11
Myristic acid	C14:0	–	49.78
Palmitic acid	C16:0	–	2.23
Stearic acid	C18:0	–	2.79
Oleic acid	C18:1	89,700	1.62
(Z,Z)-9,12-Octadecadienoic (Linoleic) acid	C18:2	46,800	4.13
(E,E)-9,12-Octadecadienoic (Linolelaidic) acid	C18:2	39,600	3.53
Linolenic acid (α-Linolenic)	C18:3	82,500	1.41
Mead (Eicosatrienoic) acid	C20:3	36,100	0.26
Arachidonic acid	C20:4	24,100	2.08
Timnodonic (Eicosapentaenoic) acid (EPA)	C20:5	50,000	0.17
Arachidic acid	C20:0	53,000	0.85
Behenic acid	C22:0	24,200	0.04
Cervonic (Docosahexaenoic) acid (DHA)	C22:6	39,500	1.62
Dihomo-γ-linolenic acid	C20:3	–	0.26
Docosanoic acid	C22:0	–	0.04

Note: (–) indicates the fatty acid was not detected in the respective sample.

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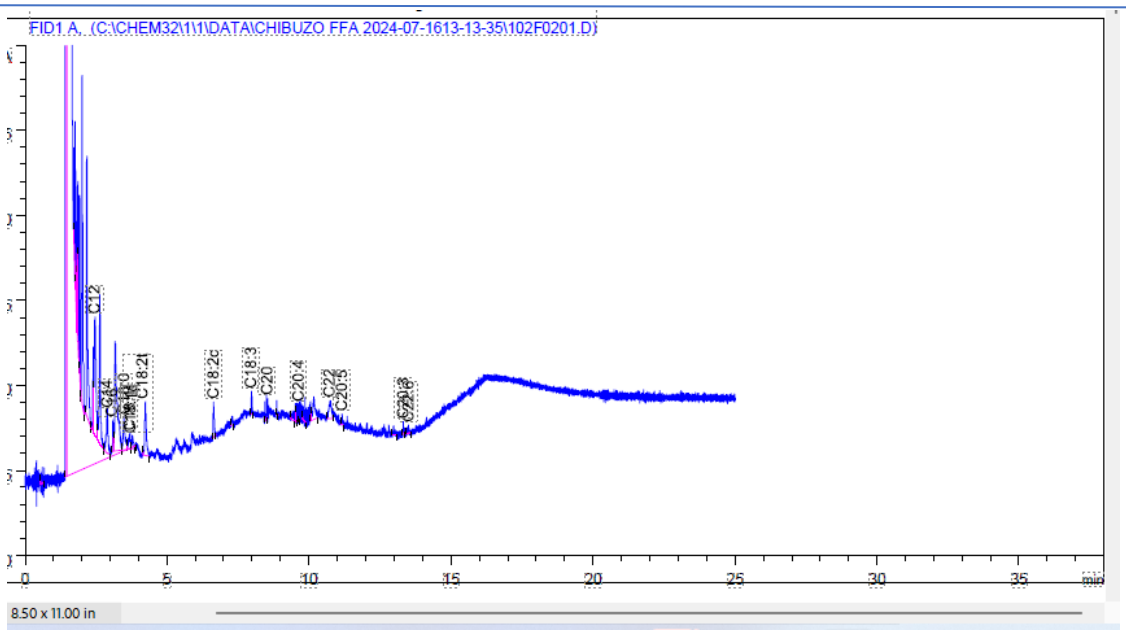

Figure 1a: GCMS of fatty acids composition of Blend A

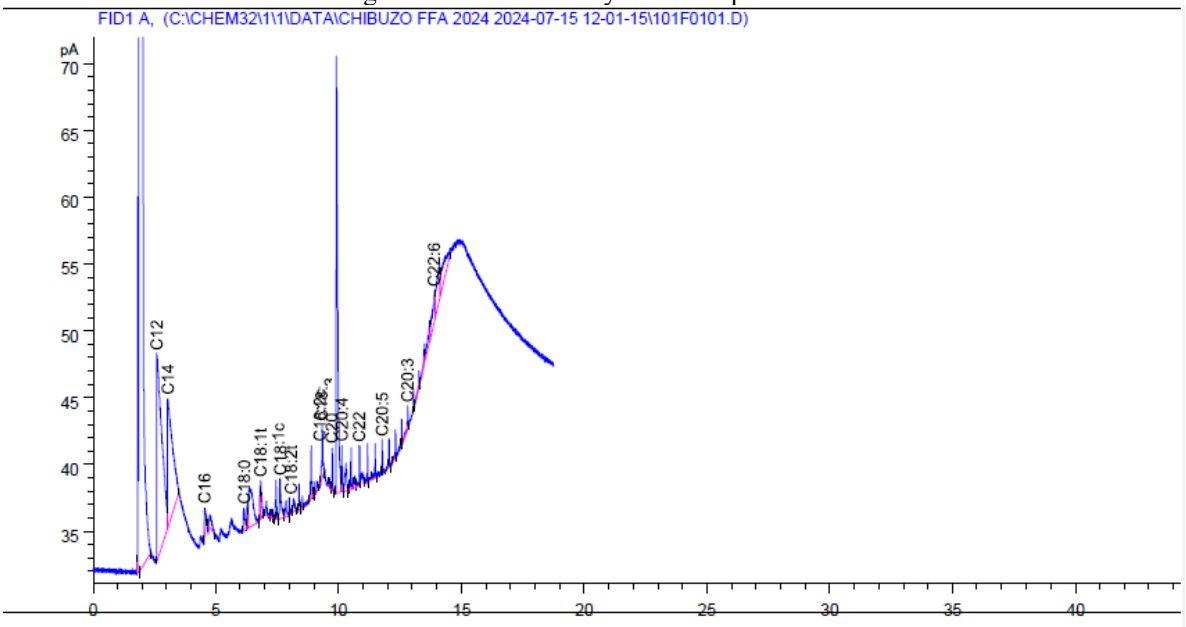

Figure 1b: GCMS of fatty acids composition of Blend B

Amino Acid Composition

The high-performance liquid chromatography (HPLC) analysis identified essential and non-essential amino acids in both formulations, indicating the protein quality of the locally produced complementary foods (Table2 and Figure 2). In Blend A, five essential amino acids were quantified. Isoleucine was present at 10.36 mg/100 g protein, phenylalanine at 3.11 mg/100 g, methionine at 2.60 mg/100 g, and tryptophan at 1.15 mg/100 g, giving a total essential amino acid content of 17.22 mg/100 g protein. Among the non-essential amino acids, proline and arginine were the most concentrated at 10.68 mg/100 g and 10.07 mg/100 g, respectively. Alanine, glutamic acid, serine, cystine, and tyrosine were also detected, ranging between 1.11 and 6.05 mg/100 g. The predominance of proline and arginine suggests a favorable amino acid balance supporting tissue growth and repair in infants.

In Blend B, a broader range of amino acids was identified, indicating a more complex protein composition.

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Phenylalanine was the most abundant essential amino acid at 39.72 mg/100 g, followed by tryptophan (12.13 mg/100 g), valine (5.25 mg/100 g), threonine (3.91 mg/100 g), and histidine (1.72 mg/100 g). Leucine and methionine were present at trace levels (0.26–0.33 mg/100 g). The total essential amino acid content in Blend B was notably higher than that of Blend A, primarily due to the inclusion of Titus fish as a protein source. Non-essential amino acids such as proline (2.96 mg/100 g), arginine (8.44 mg/100 g), glutamate (3.50 mg/100 g), tyrosine (3.61 mg/100 g), and cystine (1.25 mg/100 g) were also recorded. Glycine, alanine, and serine appeared in smaller quantities, ranging between 0.27 and 2.16 mg/100 g. These findings confirm that Blend B provides a richer amino acid spectrum, contributing to improved dietary protein quality.

The amino acid chromatograms presented distinct peaks corresponding to individual amino acids, confirming precise separation and quantification. Figure 2 shows the HPLC chromatographic profiles for both blends, with clear resolution of essential amino acids including isoleucine, phenylalanine, methionine, and tryptophan in Blend A, and a broader amino acid distribution in Blend B.

Table 2. Comparative Amino Acid Composition of Locally Formulated Complementary Foods (Blend A and Blend B)

Amino Acid	Blend A (mg/100 g)	Blend B (mg/100 g)
Isoleucine	10.36	1.27
Leucine	–	0.26
Lysine	–	0.33
Methionine	2.60	0.26
Phenylalanine	3.11	39.72
Threonine	–	3.91
Tryptophan	1.15	12.13
Valine	–	5.25
Histidine	–	1.72
Proline	10.68	2.96
Arginine	10.07	8.44
Tyrosine	1.11	3.62
Cystine	2.11	1.25
Alanine	6.05	0.27
Glutamic acid / Glutamate	3.22	3.50
Serine	4.20	0.58
Aspartic acid / Aspartate	–	0.92
Glycine	–	2.16

Note: (–) indicates the amino acid was not detected in the respective sample.

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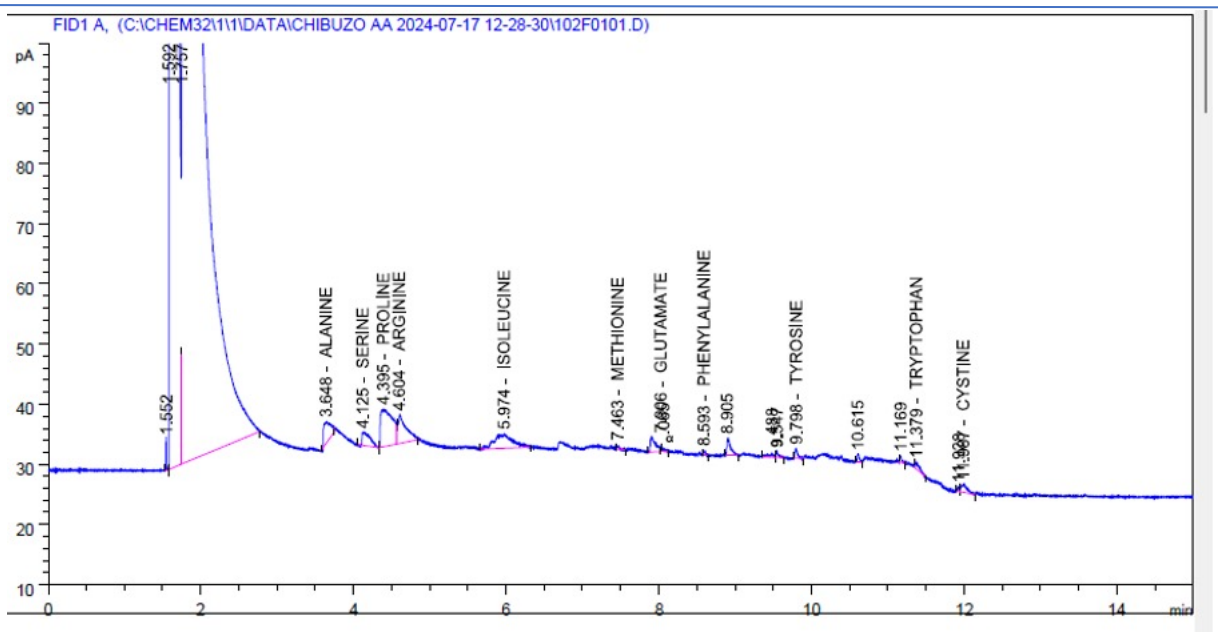

Figure 2a: HPLC chromatogram of amino acids composition in Blend A

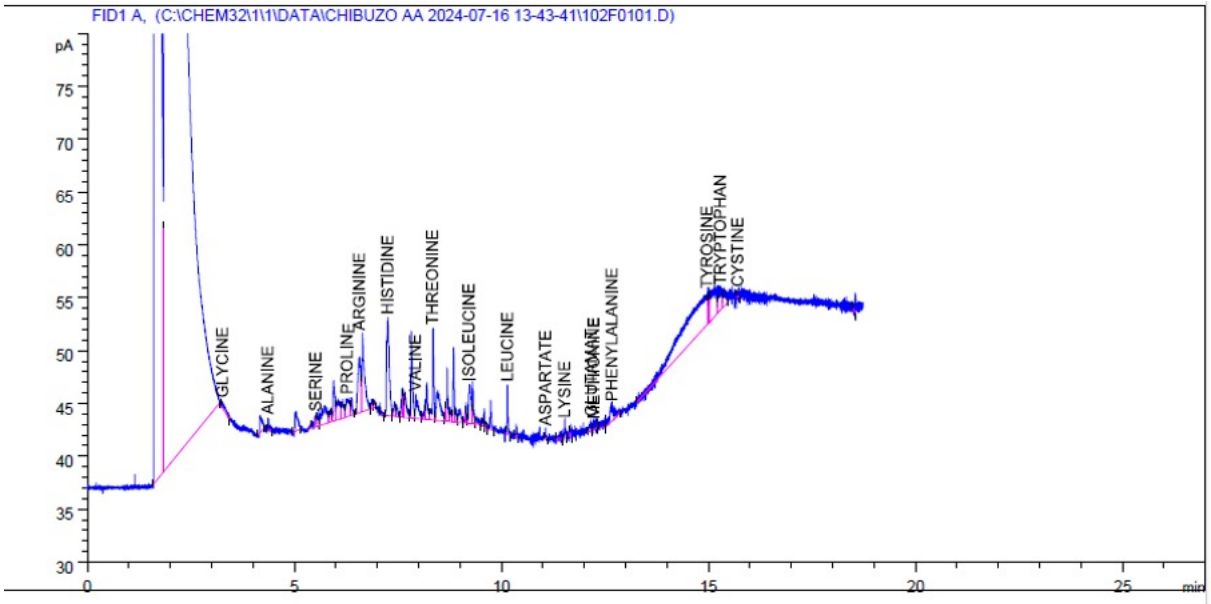

Figure 2b: HPLC Chromatogram showing amino acid composition of Blend B

DISCUSSION

The findings from this study demonstrate that the reformulation and fortification of locally available food ingredients can yield nutritionally balanced complementary foods suitable for infant feeding and rehabilitation of malnourished children. The fatty acid and amino acid profiles obtained from the GC–MS and HPLC analyses confirm the presence of essential macronutrients in both formulations, reflecting their potential to meet the dietary requirements of growing infants. The detection of essential amino acids such as histidine, tryptophan, methionine, isoleucine, and phenylalanine, alongside polyunsaturated fatty acids including arachidonic, docosahexaenoic (DHA), α-linolenic, and linoleic acids, indicates a nutritionally valuable combination of local rice, egg yolk, fish, and fruit-based ingredients. These results align with previous research highlighting that appropriate formulation using

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indigenous food sources can produce cost-effective complementary diets with adequate nutrient density for optimal child growth and health (FAO, 2018; Mahmoud & El-Anany, 2014). The balanced lipid and amino acid composition also demonstrates the feasibility of developing sustainable infant nutrition interventions using locally accessible raw materials.

The fatty acid analysis revealed a rich presence of polyunsaturated fatty acids (PUFAs) in both blends, although Blend A contained higher overall fatty acid abundance due to the inclusion of egg yolk and fruits. Polyunsaturated fatty acids such as linoleic, linolenic, arachidonic, eicosapentaenoic (EPA), and docosahexaenoic acids play crucial roles in cellular and neurological development, membrane structure, and metabolic regulation (FAO, 2018). These findings corroborate the report of Mahmoud and El-Anany (2014), who observed high PUFA levels in complementary foods formulated from rice, faba beans, and vegetable oils. However, the lower concentrations of saturated and monounsaturated fatty acids in the present formulations suggest improved lipid quality, aligning with the recommendation that dietary fats for infants should contain a greater proportion of unsaturated fatty acids (Coultate, 2002). Furthermore, linoleic acid (C18:2) and α-linolenic acid (C18:3), both essential fatty acids that cannot be synthesized by the body, were detected in significant quantities. Linoleic acid, an omega-6 fatty acid, serves as a precursor for arachidonic acid, a key substrate for eicosanoid synthesis, while α-linolenic acid, an omega-3 fatty acid, is essential for brain and retinal development in infants (Mahmoud & El-Anany, 2014). The predominance of these unsaturated fatty acids indicates that both blends can contribute meaningfully to the essential lipid requirements of infants aged six months and above.

The amino acid composition further supports the nutritional adequacy of the formulated diets. Blend A contained substantial quantities of essential amino acids such as isoleucine (10.36 mg/100 g), methionine (2.60 mg/100 g), phenylalanine (3.11 mg/100 g), and tryptophan (1.15 mg/100 g), whereas Blend B exhibited higher diversity and concentration, particularly for phenylalanine (39.72 mg/100 g) and tryptophan (12.13 mg/100 g). The inclusion of Titus fish in Blend B significantly enhanced its amino acid spectrum, providing improved protein quality and digestibility compared to Blend A. Non-essential amino acids such as proline, arginine, glutamate, and tyrosine were detected in both blends, contributing to tissue synthesis, metabolic regulation, and immune function. The results are consistent with the findings of Uloma et al. (2014) and Ejigui et al. (2007), who reported that the inclusion of animal and legume-based proteins in cereal-based complementary foods enhances the amino acid balance. Although Blend A lacked certain essential amino acids such as leucine, threonine, and valine, its combination with fruits and egg yolk still provided considerable nutritional benefits.

Overall, the combined results indicate that both complementary food blends possess nutritional qualities capable of supporting infant growth and development when used alongside breastfeeding. Blend A provided higher lipid energy due to the presence of fruit oils and egg-derived fats, while Blend B demonstrated superior protein quality and amino acid diversity due to the inclusion of fish. The observed profiles suggest that locally formulated complementary foods can meet the amino acid and fatty acid requirements of infants as specified by WHO (1985) and the National Academy of Sciences (2025). These formulations, therefore, present a viable, affordable, and culturally acceptable alternative to commercial infant foods, especially for low-income communities in Nigeria and other developing regions. Reformulating

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such diets with improved protein sources—such as legumes, crayfish, or soy-based ingredients—may further enhance their amino acid profiles and overall nutrient density. The present findings affirm the need for continued utilization of local agricultural and animal resources in developing nutritionally adequate and sustainable infant feeding solutions that can address malnutrition, improve health outcomes, and contribute to food security in resource-limited settings.

CONCLUSION

The present study demonstrates that locally formulated complementary foods developed from rice, egg yolk, Titus fish, avocado pear, and fruits possess nutritionally balanced amino acid and fatty acid profiles essential for infant growth and development. The GC–MS and HPLC analyses confirmed the presence of key polyunsaturated fatty acids (DHA, EPA, and linoleic acid) and essential amino acids (isoleucine, methionine, phenylalanine, and tryptophan), indicating high nutritional potential. Both formulations exhibited compositional adequacy consistent with international dietary recommendations. These findings affirm that indigenous food resources can be scientifically optimized to produce cost-effective, culturally acceptable, and nutritionally adequate complementary foods capable of addressing malnutrition and enhancing infant health in resource-limited settings.

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