



Research Article

A Comparative Evaluation of Microbiological Quality and Nutritional Composition of Indigenous Complementary Foods and Commercial Infant Formulas in Kano State

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ABSTRACT

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Complementary foods are vital in infant nutrition, especially in regions where malnutrition and foodborne illnesses are prevalent. In Kano, Nigeria, indigenous complementary foods are widely consumed due to affordability and cultural acceptance, yet concerns remain about their nutritional adequacy and microbiological safety. This study compared three indigenous complementary foods and three commercial infant formulas sold in Tarauni Local Government Area. Microbiological analyses assessed aerobic mesophilic bacterial and fungal counts, coliform presence, and pathogen identification using standard methods. Nutritional evaluation covered proximate, mineral, and vitamin content. Data were analyzed using one-way ANOVA at $p < 0.05$. Results showed higher microbial loads in indigenous samples (up to 1.08×10^7 CFU/mL bacteria and 1.11×10^7 CFU/mL fungi) compared to commercial formulas (as low as 1.0×10^3 CFU/mL), with pathogenic bacteria like *E. coli*, *S. aureus*, and *Shigella spp.* present. Commercial formulas had significantly higher calcium (up to 228 mg), potassium (540 mg), vitamin A (650 μ g), and vitamin D (90 μ g), while indigenous foods showed lower levels, especially of fat-soluble vitamins. The findings underscore a critical safety and nutritional gap. It is recommended that local food vendors be trained on hygienic handling practices, and that indigenous complementary foods undergo nutrient fortification, better drying techniques, and regulatory oversight. Enhancing these aspects can improve the nutritional adequacy and safety of traditional weaning foods, supporting infant health and development.

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INTRODUCTION

National Agency for Food and Drug Administration and Control (NAFDAC) identifies the first 1,000 days as a critical window for optimal growth and development, advocating exclusive breastfeeding for six months and continued breastfeeding with appropriate complementary foods up to two years or beyond (NAFDAC, 2021). Optimal infant feeding practices during this period are essential for providing adequate nutrition, strengthening immune function, and supporting cognitive and physical development. Globally, under nutrition remains a significant contributor to childhood morbidity and mortality, accounting for approximately 45% of deaths among children under five (WHO, 2023).

In low- and middle-income countries, including Nigeria, the complementary feeding phase when solid or semi-solid foods are introduced alongside breastfeeding presents a particularly vulnerable period. UNICEF (2024) identifies this transition as a “critical window of opportunity,” yet poor feeding practices, coupled with the consumption of nutritionally inadequate and microbiologically unsafe foods, frequently undermine child survival and growth outcomes. Recent findings by Adeboye, *et al.* (2024) emphasized that indigenous complementary foods commonly consumed in informal markets often harbor microbial contaminants due to poor hygiene practices, improper storage, and unsafe preparation techniques. Complementary foods are defined as any liquids, semi-solids, or solids, other than breast milk or infant formula, introduced to an infant’s diet from six months of age to meet increasing nutritional demands (WHO, 2023). Infant formulas, conversely, are commercially manufactured products formulated to provide essential nutrients in proportions designed to substitute or complement breast milk when breastfeeding is not feasible (Codex Alimentarius Commission, 2023). Both categories of infant foods require rigorous microbiological and nutritional evaluation, as infants possess immature immune systems and are particularly susceptible to foodborne pathogens and nutritional deficiencies (Adeboye *et al.*, 2024; Global Alliance for Improved Nutrition [GAIN], 2023).

In Nigeria’s rapidly urbanizing centers, such as Kano, complementary feeding practices face considerable challenges. Indigenous complementary foods sold in informal urban

markets are frequently prepared and handled under unhygienic conditions, increasing the risk of contamination by pathogens including *Escherichia coli*, *Salmonella spp.*, *Staphylococcus aureus*, and toxigenic fungi (Adeboye *et al.*, 2024). Studies in Northern Nigeria, including those by Garba *et al.* (2020) and Danjuma *et al.* (2019), have confirmed high microbial loads and nutrient gaps in locally formulated weaning foods. Although commercial infant formulas are subject to regulation, factors such as poor storage, high cost, and limited accessibility can compromise their safety and quality in low-resource communities (GAIN, 2023).

Beyond microbial safety, nutritional adequacy is equally vital. Many indigenous complementary foods lack sufficient energy, high-quality proteins, and essential micronutrients such as iron, zinc, and vitamin A, contributing to widespread malnutrition, growth faltering, stunting, and increased susceptibility to infections (Tessema *et al.*, 2023; UNICEF, 2024). While previous Nigerian studies (e.g., Adesokan and Odetoyinbo, 2013; Ogundele *et al.*, 2018) have evaluated either microbiological or nutritional quality, few have conducted combined analyses on both parameters using complementary foods and infant formulas sold in urban informal markets like Tarauni LGA in Kano.

This study, therefore, seeks to address this gap by concurrently evaluating the microbiological safety and nutritional composition of indigenous complementary foods and commercial infant formulas available in Kano, Nigeria. Although previous studies in Nigeria have examined either the microbial contamination or nutritional profile of infant foods separately, few have integrated both dimensions in a single comparative analysis involving both indigenous and commercial products within an urban informal market context like Tarauni LGA. The findings will provide context-specific evidence essential for informing food safety interventions, improving infant feeding practices, and supporting public health policy in similar urban environments (WHO, 2023).

MATERIAL AND METHODS

Sample Collection

A total of six complementary food samples were analyzed for this study, comprising three indigenous complementary foods and three commercial infant formulas commonly consumed by infants in Tarauni Local Government Area, Kano State. The indigenous complementary foods

were purchased from informal food vendors. Samples included:

Sample A (Tom Brown): a locally formulated cereal blend made from tiger nut, dates, crayfish, groundnut, soybean, beans, and millet.

Sample B: a cereal mixture consisting of wheat, rice, and groundnut.

Sample C: a traditional blend containing maize, millet, sorghum, soybean, and groundnut.

A purposive sampling technique targeting the most commonly available and widely consumed complementary foods in the study area was used. While the sample size may limit statistical generalizability, the primary aim of the study was exploratory and comparative — to evaluate representative products from informal and formal sources as typically encountered by caregivers. This approach aligns with previous field-based assessments of weaning foods in similar Nigerian settings (Adesokan and Odetoyinbo, 2013; Garba *et al.*, 2020).

The three commercial infant formulas were selected based on their popularity and availability in Tarauni Local Government Area, Kano State. These included:

Sample 1 – a fortified milk-based infant formula intended for infants aged 6–24 months, containing iron, calcium, vitamin A, and vitamin D, as stated on the label.

Sample 2 – an industrially produced cereal-based infant formula made with wheat flour, skimmed milk, vegetable oils, and enriched with vitamins and minerals such as zinc and vitamin C.

Sample 3 – a locally packaged powdered custard blend containing maize starch, sugar, and synthetic flavorings, with limited micronutrient information on the label.

For confidentiality and consistency, these products were anonymized as Sample 1, Sample 2, and Sample 3 throughout the study. Product details were documented for traceability.

All samples were purchased in their typical retail condition from open markets and vendor stalls within Tarauni LGA, transported to the Department of Microbiology laboratory in sterile, labeled, airtight containers. All samples were analyzed within 24 hours of purchase to ensure sample integrity.

Sample preparation

All six complementary food samples analyzed in this study were in powdered form. For microbiological analysis, 10 grams of each powdered sample were aseptically weighed into

sterile stomacher bags and homogenized with 90 mL of sterile peptone water to obtain a 10^{-1} dilution, following the method described by Harrigan and McCance (2014). From this, serial ten-fold dilutions were prepared up to 10^{-4} using sterile peptone water. All procedures were conducted under aseptic conditions to avoid external contamination.

For nutritional analysis, the powdered samples were thoroughly mixed to ensure uniformity and stored in clean, labeled, airtight containers at room temperature until required for proximate, mineral, and vitamin analyses, in line with protocols outlined by the Association of Official Analytical Chemists (AOAC, 2019). All microbiological and nutritional analyses were conducted in duplicates.

Microbiological Analysis

Aerobic Mesophilic Bacterial Count

The aerobic mesophilic bacterial count was determined using the pour plate method on Nutrient Agar (NA) as described by Harrigan and McCance (2014). From prepared serial dilutions (10^{-1} to 10^{-4}), 1 mL of each dilution was aseptically pipetted into sterile Petri dishes, followed by the addition of about 15 mL of molten, cooled nutrient agar. The plates were gently swirled and allowed to solidify before incubation at 37°C for 24 hours. Colonies were counted using a digital colony counter and expressed as colony forming units per milliliter (CFU/mL). The incubation temperature (37°C) and duration align with standard protocols for isolating mesophilic organisms, which thrive optimally at human body temperature and represent the major microbial contaminants of concern in food intended for infants (FAO/WHO, 2007; AOAC, 2019).

Total Fungal Count

Fungal counts were performed using Potato Dextrose Agar (PDA) supplemented with chloramphenicol (0.1 g/L) to inhibit bacterial growth. 1 mL of each dilution was plated using the pour plate technique, and plates were incubated at 28°C for 5 days. These conditions are recommended for the cultivation of filamentous fungi and yeasts commonly found in food products, particularly in tropical climates (Harrigan and McCance, 2014; AOAC, 2019). Fungal colonies were counted and expressed as CFU/mL.

Most Probable Number (MPN) for Coliforms

Coliform count was determined using the Multiple Tube Fermentation Technique as per ISO

4831:2006 guidelines. 1 mL aliquots of appropriate dilutions were inoculated into tubes containing Lactose Broth with inverted Durham tubes and incubated at 37°C for 24 hours. Tubes showing gas production and color change were recorded as positive. The number of positive tubes was used to estimate the MPN/100 mL using standard MPN tables (Fawole and Oso, 2007). The use of 37°C is standardized for detecting fecal and total coliforms, which are known to grow best at this temperature (ISO 4831:2006).

Isolation and Identification of Pathogens

To isolate and identify potential pathogenic bacteria, subcultures were made from distinct colonies obtained from the Nutrient Agar plates onto selective and differential media, including MacConkey Agar, Salmonella-Shigella Agar (SSA), and Mannitol Salt Agar (MSA). The plates were incubated at 37°C for 24 hours and observed for characteristic colony morphology. Fungal isolates were subcultured onto PDA and incubated at 28°C for 5 days.

Presumptive bacterial isolates were further characterized by Gram staining and a series of biochemical tests, including Catalase, Coagulase, Indole, Citrate utilization, Urease, and Triple Sugar Iron (TSI) reactions following Cheesbrough (2010).

Fungal identification was based on colony appearance and microscopic morphology after staining with lactophenol cotton blue, according to Harrigan and McCance (2014).

Nutritional Analysis

Proximate Analysis

The proximate composition of the samples including moisture content, ash, crude protein, crude fat, crude fibre, and carbohydrate was determined using the methods described by the Association of Official Analytical Chemists (AOAC, 2019).

Moisture content was determined by drying 5g of each sample in a hot air oven at 105°C until a constant weight was obtained.

Ash content was estimated by incinerating 2g of the dried sample in a muffle furnace at 550°C for 4 hours.

Crude protein was evaluated using the Kjeldahl method, with nitrogen content multiplied by a factor of 6.25.

Crude fat was determined using the Soxhlet extraction method with petroleum ether as the solvent.

Crude fibre was assessed by sequential digestion of defatted samples with 1.25% H₂SO₄ and 1.25% NaOH, followed by ashing.

Carbohydrate content was calculated by difference:

100 - (Moisture + Ash + Crude Protein + Crude Fat + Crude Fibre)

Mineral Analysis

The mineral content of the samples, including calcium (Ca), iron (Fe), zinc (Zn), magnesium (Mg), sodium (Na), and potassium (K), was determined using Microwave Plasma Atomic Emission Spectroscopy (MP-AES) following the method described by AOAC (2019).

Sample preparation involved wet digestion of 2g of each powdered sample with a mixture of concentrated nitric acid (HNO₃) and perchloric acid (HClO₄) in a ratio of 2:1. The mixture was heated on a hot plate until a clear solution was obtained.

After cooling, the digest was diluted to a known volume with deionized water and filtered.

The concentrations of the selected minerals were then determined using a Microwave Plasma Atomic Emission Spectrometer (Agilent 4200 MP-AES) according to the manufacturer's guidelines.

Vitamin Analysis

The determination of vitamin content in the samples was carried out for Vitamin A, Vitamin B1, Vitamin B3, Vitamin B5, Vitamin B6, Vitamin B9, Vitamin C, Vitamin D, and Vitamin E. The analyses were conducted using standard spectrophotometric methods as described by AOAC (2019). Although High-Performance Liquid Chromatography (HPLC) and Liquid Chromatography–Mass Spectrometry (LC-MS/MS) offer superior sensitivity and specificity, the use of spectrophotometry in this study was informed by limited access to advanced instrumentation. Similar spectrophotometric methods have been widely employed in food-based vitamin analyses in low-resource settings (Onabanjo and Oguntona, 2014; Osibote *et al.*, 2020), and are considered valid for estimating vitamin levels in preliminary or comparative studies, especially when performed under standardized conditions and with proper calibration.

Determination of vitamin A concentration:

Koche method was used. 1 g of the sample was macerated with 200 mL of petroleum ether for 10 min and allowed to stand for 1 h with intermittent shaking every 1 min. The mixture was centrifuged

for 5 min and 3 mL of the supernatant was transferred into triplicate test tubes. Each supernatant in the test tube was evaporated to dryness and the residue was redissolved in 0.2 mL of acetic anhydride/chloroform (1:1) and 2 mL of 50% trichloroacetic acid (TCA) in chloroform. The

absorbance of the resulting solution was then taken at a wavelength of 620 nm at 15 and 30 sec against the corresponding blank. The vitamin concentration of the samples was calculated as follows:

$$\text{Vitamin A content (Koche)} = \frac{\text{Absorbance of test} \times \text{Concentration of standard}}{\text{Absorbance of standard} \times \text{weight of sample}}$$

Determination of vitamin C (ascorbic acid) concentration: The AOAC 17 method was used. 1g of the sample was macerated with 20 mL of 0.4% oxalic acid for 10 min and centrifuged for 5 min. The supernatant (1 mL) was transferred into triplicate test tubes to which 9 mL of 2,6-

dichlorophenol indophenol (12 mg LG1) had been previously added and then mixed thoroughly by shaking. The absorbance of the resulting solution was taken at 520 nm at 15 and 30 sec against the corresponding blank. The vitamin concentration of the samples was calculated thus;

$$\text{Concentration of vitamin C (AOAC 17)} = \frac{\text{Abs.} \times \text{Df} \times \text{volume of cuvette}}{\epsilon}$$

Where Abs. = Absorbance of sample

Df = Dilution factor

ϵ = Extinction factor

Vitamin B1, B3, B5, B6, and B9 levels were estimated using acid extraction followed by UV spectrophotometric quantification at their respective maximum absorption wavelengths as outlined in AOAC (2019).

Vitamin D and Vitamin E contents were estimated using the colorimetric method. The samples were extracted with petroleum ether, and the absorbance was measured at 520 nm following reaction with 2,2-dipyridyl reagent (for Vitamin E) and at the appropriate wavelength for Vitamin D, following AOAC protocols.

Statistical Analysis

All experimental determinations were carried out in triplicates, and the results were expressed as mean \pm standard deviation (SD). Data obtained from the microbiological and nutritional analyses were subjected to one-way analysis of variance (ANOVA) to determine significant differences among the samples at a significance level of $p < 0.05$.

The statistical analyses were performed using IBM SPSS Statistics software version 20 (IBM Corp., Armonk, NY, USA)

RESULTS

Aerobic Mesophilic Bacterial Count of Indigenous and Commercial Infant Foods

The results of the aerobic mesophilic bacterial counts of the indigenous and commercial infant foods are presented in Table 1. Among the indigenous samples, Sample B had the highest bacterial count (1.08×10^7 CFU/mL), followed by Sample A (7.0×10^6 CFU/mL), while Sample C had the lowest (5.3×10^6 CFU/mL). Statistical analysis showed no significant difference among the indigenous samples ($p = 0.359$), indicating that the bacterial counts were not significantly affected by the sample type.

Among the commercial samples, Sample 3 had the highest count (2.5×10^3 CFU/mL), followed by Sample 1 (1.5×10^3 CFU/mL), with Sample 2 having the lowest (1.0×10^3 CFU/mL). Similarly, there was no statistically significant difference among the commercial samples ($p = 0.353$).

Table 1: Aerobic Mesophilic Bacterial Count of Indigenous and Commercial Infant Foods in CFU/mL

Indigenous Infant Foods		Commercial Infant Foods	
Sample	Bacterial load(CFU/mL)	Sample	Bacterial load(CFU/mL)
A	7.0×10^6	1	1.5×10^3
B	1.08×10^7	2	1.0×10^3
C	5.3×10^6	3	2.5×10^3

Key: CFU/mL=colony forming unit/milliliter.

Aerobic Mesophilic Fungal Count of Indigenous and Commercial Infant Foods

Table 2 presents the aerobic mesophilic fungal counts. Among the indigenous foods, Sample B had the highest fungal load (1.11×10^7 CFU/mL), followed by Sample C (3.1×10^6 CFU/mL) and Sample A (2.45×10^6 CFU/mL). No statistically significant differences were observed ($p = 0.394$).

In commercial infant foods, Sample 3 recorded the highest fungal count (2.5×10^3 CFU/mL), while Samples 1 and 2 both had 1.5×10^3 CFU/mL and 1.0×10^3 CFU/mL respectively. Statistical analysis revealed no significant difference ($p = 0.27$).

Table 2: Aerobic Mesophilic Fungal Count of Indigenous and Commercial Infant Foods in CFU/mL

Indigenous Infant Foods		Commercial Infant Foods	
Sample	Fungal load(CFU/mL)	Sample	Fungal load(CFU/mL)
A	2.45×10^6	1	1.5×10^3
B	1.11×10^7	2	1.0×10^3
C	3.1×10^6	3	2.5×10^3

Key: CFU/mL=colony forming unit/milliliter

Coliform Count of Indigenous and Commercial Infant Foods

Coliform counts of the indigenous infant foods were found to be highest in sample B with 17 MPN/100mL of the sample. This is followed by sample C with 9 MPN/100mL and sample A with

2 MPN/100mL. The results of the coliform counts of the commercial infant foods depicted that all the samples analyzed have a coliform count of less than 2 MPN/100mL of the samples as described in Table 3.

Table 3: Coliform Count of Indigenous and Commercial Infant Foods in MPN/100mL

Indigenous Infant Foods		Commercial Infant Foods	
Sample	MPN/100mL	Sample	MPN/100mL
A	2	1	<2
B	17	2	<2
C	9	3	<2

Key: MPN = Most Probable Number

Isolation and Identification of Pathogenic Bacteria

Different bacteria were detected in some of the samples analyzed in the study. Samples A, and C were found to contain *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis*. However, sample B was found to

contain only *Shigella spp.*, in addition to *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis*. The results of the pathogenic fungi detected in the different samples analyzed showed that different fungi were detected in the different samples with the *Aspergillus niger* found in samples A, and B while *Aspergillus*

fumigatus was detected only in sample C. Also, *Aspergillus flavus* was detected in both sample A,

and C as described in Table 4.

Table 4: Pathogenic Bacteria and Fungi Isolated from Indigenous Infant Foods

Sample	<i>E. coli</i>	<i>S. aureus</i>	<i>S. epidermidis</i>	<i>Shigella spp.</i>	<i>A. niger</i>	<i>A. fumigatus</i>	<i>A. flavus</i>
A	+	+	+	-	+	-	+
B	+	+	+	+	+	-	-
C	+	+	+	-	-	+	+

Key: *E.coli*=*Escherichia coli*, *S.aureus*=*Staphylococcus aureus*, *S.epidermidis*=*Staphylococcus epidermidis*, +=present, -=negative

Mineral Element Analysis of the Indigenous Infant Foods

The mineral analysis (Table 5) revealed considerable variation among the indigenous complementary foods. Sample A contained the highest zinc (110.03 mg/kg) and potassium (6974.16 mg/kg), while sample C had the highest magnesium content (1840.32 mg/kg). Calcium levels were highest in sample B (149.27 mg/kg),

and copper was most concentrated in sample A (25.19 mg/kg).

Statistical analysis showed no significant difference in mineral composition between the samples ($p = 0.6106 > 0.05$), but there was a statistically significant difference in the concentration of individual mineral elements across all samples ($p = 0.00004 < 0.05$), indicating nutrient variability among the indigenous products.

Table 5: Mineral Element Analysis of the Indigenous Infant Foods (in mg/kg)

Samples	Zinc	Calcium	Iron	Copper	Potassium	Magnesium
A	110.03	133.78	95.35	25.19	6974.16	848.83
B	46.99	149.27	96.37	21.09	5055.52	787.01
C	44.55	29.89	95.36	24.40	3640.41	1840.32

Key: Values are expressed in milligram per kilogram (mg/kg) equivalent to parts per million (PPM).

Mineral Element Analysis of Commercial Infant Foods

The results of the mineral composition of the commercial infant foods are presented in Table 6. Sample 3 had the highest potassium content (540 mg), while sample 1 had the lowest zinc content (1.3 mg). Some elements, such as selenium and

iodine, were not detected in some of the samples. Statistical analysis revealed no significant difference between the overall mineral contents of the three samples ($p = 0.196 > 0.05$). However, a significant difference exists in the concentration of individual mineral elements across samples ($p = 0.05$), indicating variability in nutritional quality.

Table 6. : Mineral Element Analysis of Commercial Infant Foods in Milligram (mg)

Sample	Sodium	Iron	Zinc	Selenium	Calcium	Iodine	Potassium	Phosphorous
1	125.0	3.1	1.3	3.4	123.0	-	-	-
2	55.0	3.7	2.7	-	225.0	10.0	260.0	160.0
3	0.4	1.9	-	-	228.0	-	540.0	332.0

Vitamin Analysis of Indigenous Infant Foods

Table 7 shows the vitamin content of the indigenous infant food samples. Vitamin B9 was the most abundant, with values of 120 mg/dL (Sample A), 105 mg/dL (Sample B), and 88.0 mg/dL (Sample C). Vitamin D was the least, with

concentrations of 0.08 mg/dL, 0.05 mg/dL, and 0.04 mg/dL in Samples A, B, and C, respectively. Statistical analysis showed no significant difference in vitamin content between samples ($p = 0.418 > 0.05$), but a significant difference among the concentrations of individual vitamins ($p = 0.000000000011863 < 0.05$).

Table 7: Vitamin Analysis of Indigenous Infant Foods in mg/dL

Sample	Vit. A	Vit. B1	Vit. B3	Vit. B5	Vit. B6	Vit. B9	Vit. C	Vit. D	Vit. E
A	3.15	0.75	2.1	0.9	0.5	120	10.79	0.08	4.5
B	5.76	0.68	3.0	0.8	0.45	105	10.63	0.05	3.2
C	3.8	0.52	2.7	0.7	0.32	88.0	12.87	0.04	2.8

Key: Vit: Vitamin

Vitamin Analysis of Commercial Infant Foods in Microgram

Vitamin levels in the commercial infant foods are shown in Table 8. Sample 2 had the highest vitamin A content (650 μ g), while Sample 1 had the lowest vitamin B6 (0.05 μ g). Sample 3

recorded no detectable levels of vitamins A, B3, B9, C, D, or E.

There was no significant difference in vitamin content between samples ($p = 0.242 > 0.05$), and no significant difference among the vitamin types across samples ($p = 0.167 > 0.05$).

Table 8: Vitamin Analysis of Commercial Infant Foods (μ g)

Sample	Vit. A	Vit. B1	Vit. B3	Vit. B5	Vit. B6	Vit. B9	Vit. C	Vit. D	Vit. E
1	135	0.11	1.3	0.61	0.05	16	10	2.2	0.92
2	650	0.3	1.5	0.75	0.15	20	32.5	90	3.4
3	-	0.1	-	2.2	0.2	-	-	-	-

Key: Vit: Vitamin; μ g = micrograms; – = not detected.

Proximate Analysis of Commercial Infant Foods

Table 9 presents the proximate composition of the commercial infant foods. Carbohydrate content was highest in sample 3 (87.7 g), followed by sample 1 (74.0 g), and sample 2 (68.0 g). Protein content was highest in sample 2 (15 g), followed by sample 1 (11.0 g), and lowest in sample 3 (0.4 g). Fat content was also highest in sample 2 (10 g) and lowest in sample 3 (0.4 g). Dietary fiber was not detected in sample 3, but present in sample 1 (4.0 g) and sample 2 (2.8 g). Ash content was reported only for sample 2 (2.5 g). Energy content was highest in sample 2 (422 kcal), followed by sample 3 (355 kcal). Energy content for sample 1 was not indicated on the product label. There was no statistically significant difference in the proximate composition between the commercial sample ($p = 0.405 > 0.05$), but there was a significant difference among the different proximate components ($p = 0.039 < 0.05$).

Table 9: Proximate Analysis of Commercial Infant Foods in Milligram (mg)

Sample	CHO (g)	Protein (g)	Fat (g)	D. fiber (g)	Ash (g)	Energy (kcal)
1	74.0	11.0	6.8	4.0	-	-
2	68.0	15	10	2.8	2.5	422
3	87.7	0.4	0.4	-	-	355

Key: CHO: Carbohydrates, D: Dietary, kcal: kilo calorie

Proximate Analysis of Indigenous Infant Foods

The proximate composition of the indigenous complementary food samples is presented in Table 10. Sample C had the highest ash content (3.62%), followed by sample B (3.46%) and sample A (2.42%). For crude fiber, sample A had the highest value (11.05%) and sample C the lowest (5.58%). Crude fat was highest in sample A (19.98%) and lowest in sample C (14.83%).

Moisture content was highest in sample C (6.47%), followed by sample A (5.5%) and lowest in sample B (2.49%). The crude protein content was highest in sample B (19.71%), followed by sample A (18.59%), and lowest in sample C (11.76%).

Statistically, there was no significant difference in proximate content between the different samples ($p = 0.235 > 0.05$). However, there was a significant difference in the proximate parameters themselves ($p = 0.0003 < 0.05$).

Table 10: Proximate Composition of Indigenous Infant Foods (% w/w)

Sample	Ash	Crude fiber	Crude fat	Moisture	Crude protein
Sample A	2.42	11.05	19.98	5.5	18.59
Sample B	3.46	6.62	18.04	2.49	19.71
Sample C	3.62	5.58	14.83	6.47	11.76

DISCUSSION

This study highlights notable differences in the microbiological quality and nutritional composition of indigenous complementary foods and commercial infant formulas sold in Tarauni Local Government Area, Kano State, Nigeria.

The significantly higher microbial loads observed in indigenous complementary food samples compared to commercial infant formulas reflect poor hygienic handling, inadequate storage, and insufficient thermal processing. This aligns with prior studies by Onweluzo and Nwabugwu (2009) and Ihekoronye and Ngoddy (1985), which reported microbial contamination as a common challenge in locally prepared foods. The detection of *Escherichia coli*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Shigella spp.* in indigenous samples underscores risks of post-processing contamination. These pathogens are associated with diarrheal diseases and other infections, which are especially dangerous in infants whose immune systems are still developing.

In contrast, the absence of coliforms and pathogens in the commercial infant formulas demonstrates the effectiveness of industrial food safety controls, consistent with findings by Akinyemi *et al.* (2017). This contrast highlights the pressing need for hygienic training for local vendors and improved food handling regulations to enhance the microbiological safety of indigenous complementary foods.

The presence of fungal isolates, particularly *Aspergillus niger*, *Aspergillus fumigatus*, and *Aspergillus flavus*, is concerning due to their potential to produce mycotoxins. Aflatoxins, for example, are known to impair immune function, inhibit growth, and increase the risk of liver cancer. Their detection in indigenous samples raises urgent concerns, especially given the vulnerability of infants to mycotoxin-related toxicity. Previous studies (e.g., Bankole and Adebajo, 2003; Ezekiel *et al.*, 2019) have emphasized the public health implications of mycotoxin contamination in traditional foods. However, the complete absence of these fungi in commercial infant formulas supports their microbiological reliability.

Nutritionally, the study revealed disparities between indigenous and commercial products. Proximate analysis showed that commercial formulas generally had higher protein content, confirming earlier research (Bello *et al.*, 2020) that noted protein fortification in industrially produced infant foods. Protein is crucial for growth and tissue development in infants; therefore, the lower levels in indigenous samples suggest a risk of under nutrition if relied on exclusively.

Moisture content was higher in indigenous foods, contributing to their increased susceptibility to spoilage and microbial growth. This reinforces the need for enhanced drying and preservation techniques. While fat content was similar in indigenous samples and some commercial ones (e.g., Samples 1 and 2), one commercial formula

(Sample 3) had extremely low fat content. Since fats are essential for brain development, this raises questions about its suitability as a sole infant food source (Awogbenja *et al.*, 2018).

Mineral analysis highlighted greater calcium and potassium concentrations in commercial formulas, consistent with intentional fortification practices. Minerals such as calcium are essential for skeletal development, while potassium is critical for muscle and nerve function (WHO/FAO, 2004). Although indigenous foods contained appreciable levels of these minerals, they may not fully meet recommended daily requirements, especially in the absence of dietary diversity.

In terms of vitamins, the commercial samples demonstrated superior profiles, particularly in vitamins A, D, and C. However, vitamin analysis of the indigenous complementary foods (Samples A, B, and C) showed moderate levels of B-complex vitamins, vitamin C, and low concentrations of fat-soluble vitamins A and D. While indigenous samples contained appreciable levels of vitamin B9 and C, their vitamin A and D contents were notably lower compared to the fortified commercial infant formulas. This disparity suggests a potential risk of micronutrient deficiencies, especially for infants relying solely on these traditional foods. Since micronutrients play essential roles in immune function, brain development, and metabolic processes, the comparatively lower vitamin content in indigenous complementary foods highlights the need for targeted fortification or dietary diversification to meet infant nutritional requirements (Michaelsen *et al.*, 2009).

This study therefore, demonstrates that although indigenous complementary foods are more culturally acceptable and economically accessible, they fall short in microbiological safety and nutritional completeness.

CONCLUSION

This study revealed significant differences in the microbiological quality and nutritional composition of indigenous complementary foods and commercial infant formulas sold in Kano. While indigenous foods remain affordable and culturally relevant, their higher microbial loads and detection of pathogenic organisms pose serious health risks to infants. In contrast, commercial infant formulas demonstrated better microbiological safety and superior nutritional profiles, particularly in protein, essential minerals like calcium and potassium, and fat-soluble

vitamins such as A and D, all critical for infant growth and immune development.

A novel insight from this research is the identification of a nutritional and microbiological gap rooted not just in food type, but in processing, hygiene, and regulatory oversight. While indigenous foods have the potential to support infant nutrition, their current state—marked by inadequate fortification and contamination risks—limits their effectiveness.

These findings underscore the urgent need for interventions that enhance the safety and nutritional adequacy of indigenous complementary foods. Public health initiatives should prioritize:

Training for local food vendors and caregivers on hygienic preparation, safe storage, and handling practices

Development of low-cost, community-based fortification strategies to boost the nutrient content of traditional weaning foods

Regular monitoring and regulation of complementary foods sold in local markets by health authorities

Public awareness campaigns targeting mothers and caregivers to inform better infant feeding choices

Furthermore, future research should explore sustainable ways to improve the microbiological quality and nutrient density of indigenous formulations without compromising cultural acceptability or affordability. Bridging this gap is essential to support healthy infant development and reduce the burden of malnutrition and foodborne illnesses in the region.

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