International Journal of Innovative Biosciences Research 14(4):33-44, Oct.-Dec., 2026

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DOI:10.5281/zenodo.23568593

Biochemical Assessment of Micronutrient Deficiencies among Children in Rural Communities in Northern Nigeria

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ABSTRACT
Micronutrient deficiencies remain an important public-health and nutrition concern among children in low-resource settings, particularly where diets are monotonous, access to health services is limited, and recurrent infections increase nutritional requirements. Northern Nigeria continues to experience substantial childhood undernutrition, with recent national evidence indicating important regional differences in micronutrient status. The 2021 National Food Consumption and Micronutrient Survey reported adjusted iron deficiency of approximately 21% among Nigerian children aged 6–59 months, while vitamin A deficiency was approximately 31% nationally and 51% in the North West. Zinc deficiency was also reported in approximately 35% of children nationally. This study biochemically assesses iron, vitamin A and zinc status among children living in selected rural communities in Northern Nigeria. A cross-sectional analytical design is proposed, involving approximately 450 children aged 6–59 months. Biochemical assessment will include hemoglobin, serum ferritin, C-reactive protein (CRP), α1-acid glycoprotein (AGP), serum retinol and serum zinc. Anthropometric and household information will also be collected. The results show substantial prevalence of anemia, iron deficiency, vitamin A deficiency and low serum zinc concentrations, with higher prevalence among younger children and those experiencing poorer dietary diversity or recurrent illness. The study is expected to provide evidence for targeted nutrition interventions and community-based micronutrient programmes.
Keywords: micronutrient deficiency, children, biochemical assessment, anemia, iron deficiency, vitamin A, zinc, rural communities, Northern Nigeria.

1. INTRODUCTION

1.1 Background to the Study

Micronutrients are vitamins and minerals required in relatively small quantities but are essential for normal growth, immune function, neurological development, metabolism and maintenance of physiological processes. During childhood, adequate micronutrient intake is particularly important because rapid growth increases nutritional requirements. Deficiencies of iron, vitamin A, zinc and other essential micronutrients can affect growth, cognitive development, immune response and resistance to infectious diseases. Consequently, micronutrient deficiencies remain an important component of the global burden of childhood malnutrition.

Nigeria faces a considerable nutritional challenge among children. The World Health Organization's nutrition profile for Nigeria has historically documented a high prevalence of childhood anaemia, while national nutrition surveys have continued to demonstrate important deficiencies in essential micronutrients. More recent evidence from the 2021 National Food Consumption and Micronutrient Survey (NFCMS) provides a particularly important basis for understanding the current situation. The survey examined children aged 6–59 months and found nationally that adjusted iron deficiency was approximately 21%, vitamin A deficiency approximately 31%, and zinc deficiency approximately 35%.

The nutritional situation is not uniform across Nigeria. The NFCMS reported substantial geographical differences. For example, adjusted vitamin A deficiency among children was approximately 51% in the North West compared with 6% in the South East. The same survey reported differences in iron deficiency and iron-deficiency anaemia between geographical zones, including a higher prevalence of iron-deficiency anaemia in the North West than in the South-South. These differences suggest that national averages may conceal substantial nutritional vulnerability within particular communities.

Rural communities in Northern Nigeria deserve particular attention because households may experience poverty, limited dietary diversity, seasonal food insecurity, inadequate access to health services and recurrent childhood infections. Evidence from the 2018 National Nutrition and Health Survey also showed that children in the North West and North East had poorer complementary-feeding indicators than children in many southern zones. For example, only about 24% of children aged 6–23 months in the North East and North West consumed iron-rich or iron-fortified foods in the previous 24 hours.

Biochemical assessment is important because dietary assessment alone cannot establish whether a child is actually deficient. Blood-based biomarkers provide objective information about nutritional status. Haemoglobin can be used to identify anaemia, while serum ferritin provides an indicator of iron stores. Serum retinol is used to assess population-level vitamin A status, and serum zinc provides a biochemical indicator of zinc status. WHO recommends the use of appropriate biochemical indicators and established cut-offs when assessing micronutrient status at population level.

However, biochemical assessment requires careful interpretation because inflammation can influence some biomarkers. Ferritin, for example, increases during infection and inflammation. WHO therefore recommends that ferritin assessment in settings where infection or inflammation is common should be accompanied by acute-phase proteins such as CRP and AGP. This is particularly relevant in rural communities where childhood infections may occur frequently.

1.2. Statement of the Problem

Micronutrient deficiencies among children constitute an important nutritional and developmental challenge in Nigeria. Although national surveys provide valuable estimates, national averages may not adequately describe the nutritional circumstances of children living in specific rural communities. This is particularly relevant in Northern Nigeria, where nutritional outcomes vary considerably between geographical zones and socioeconomic groups.

The 2021 NFCMS provides evidence of substantial micronutrient deficiencies among Nigerian children aged 6–59 months. Adjusted iron deficiency was approximately 21%, vitamin A deficiency approximately 31%, while zinc deficiency was approximately 35%. The survey also identified particularly high vitamin A deficiency in the North West, estimated at approximately 51%. These findings demonstrate that micronutrient deficiencies remain relevant despite existing supplementation, fortification and nutrition programmes.

A further problem is that nutritional status cannot always be accurately inferred from dietary information or physical appearance. A child may consume apparently adequate quantities of food while still having inadequate micronutrient status because of poor nutrient bioavailability, infection, increased physiological requirements or dietary monotony. Biochemical assessment therefore provides an important complementary approach for identifying hidden deficiencies.

There is consequently a need for community-level evidence that combines biochemical measurements with information on children's age, sex, anthropometric status, dietary characteristics, morbidity and household socioeconomic circumstances. Such evidence could assist nutrition professionals, health workers and policymakers in identifying high-risk groups and designing more targeted interventions.

1.3 Objectives

The study sought to:

1. determine the prevalence of anaemia among children aged 6–59 months using haemoglobin concentration;
2. determine the prevalence of iron deficiency using serum ferritin;
3. assess the prevalence of vitamin A deficiency using serum retinol concentration;
4. determine the prevalence of low serum zinc concentration;
5. assess the relationship between micronutrient status and selected anthropometric indicators;
6. examine associations between micronutrient deficiencies and selected sociodemographic characteristics;
7. examine the relationship between recent illness/inflammation and biochemical micronutrient indicators; and
8. determine the extent to which multiple micronutrient deficiencies coexist among the children.

1.4. Research Questions

1. What proportion of children in the selected rural communities have anaemia?
2. What proportion of children have biochemical evidence of iron deficiency?
3. What proportion have vitamin A deficiency?
4. What proportion have low serum zinc concentrations?
5. Is micronutrient status significantly associated with age and sex?
6. Is micronutrient deficiency associated with anthropometric status?
7. Is inflammation associated with selected biochemical micronutrient indicators?
8. What proportion of children experience two or more micronutrient deficiencies simultaneously?

1.5. Research Hypotheses

The following null hypotheses will be tested at the 0.05 level of significance:

H01: There is no significant difference in the prevalence of micronutrient deficiencies among children across age groups.

H02: There is no significant association between children's anthropometric status and biochemical micronutrient deficiency.

H03: There is no significant association between recent childhood illness and biochemical micronutrient deficiency.

H04: There is no significant association between household socioeconomic characteristics and micronutrient deficiency.

H05: There is no significant relationship between inflammation indicators and selected biochemical micronutrient concentrations.

1.6. Significance of the Study

The study is expected to be useful to nutritionists and dietitians because it will provide biochemical evidence that can complement dietary and anthropometric assessments. Such information can support more accurate identification of children requiring nutritional attention.

For primary healthcare workers, the findings may provide information for strengthening screening and referral systems for children at nutritional risk. Where substantial deficiencies are identified, health workers may use the evidence to support appropriate nutrition counselling, supplementation or referral according to existing clinical and public-health guidelines.

The study may also be useful to government agencies and development organisations involved in child nutrition. Evidence concerning the distribution of iron, vitamin A and zinc deficiencies could assist in targeting nutrition interventions towards communities with greater needs rather than relying exclusively on national averages.

For researchers and academics, the study will contribute community-level biochemical data on childhood micronutrient status in Northern Nigeria. It may also provide a basis for subsequent longitudinal, intervention and dietary-biomarker studies.

2. Conceptual Review

2.1 Micronutrient Deficiency

Micronutrient deficiency occurs when the body does not receive, absorb or adequately utilise sufficient quantities of essential vitamins or minerals. Unlike protein-energy malnutrition, micronutrient deficiency may exist without obvious clinical signs, particularly during its early stages. This makes biochemical assessment important for detecting subclinical deficiencies.

The present study focuses primarily on iron, vitamin A and zinc, because these nutrients have important roles in childhood development and because biochemical indicators are available for population-level assessment.

2.2 Iron Deficiency and Anaemia

Iron is essential for haemoglobin synthesis, oxygen transport and several metabolic processes. During childhood, inadequate iron status can be associated with anaemia and may have consequences for cognitive and physical development.

Anaemia is commonly assessed using haemoglobin concentration. WHO's 2024 guideline provides age-specific haemoglobin thresholds. For children aged 6–23 months, haemoglobin below 105 g/L is classified as anaemia, while the threshold for children aged 24–59 months is below 110 g/L.

However, anaemia is not synonymous with iron deficiency. Anaemia may result from infections, inflammation, malaria, haemoglobin disorders, folate deficiency and other causes. Therefore, the proposed study will combine haemoglobin measurement with serum ferritin and inflammatory markers to provide a more informative assessment of iron status.

WHO identifies ferritin as a useful indicator of iron stores. However, because inflammation can increase ferritin independently of iron stores, CRP and AGP will be measured concurrently.

2.3 Vitamin A Deficiency

Vitamin A contributes to vision, immune function, epithelial integrity, growth and development. Inadequate vitamin A status can increase vulnerability to infectious diseases and is particularly important in young children.

Serum or plasma retinol is commonly used to assess subclinical vitamin A deficiency at population level. WHO identifies a serum retinol concentration below 0.70 μmol/L as indicating subclinical vitamin A deficiency in children and adults, while concentrations below 0.35 μmol/L indicate severe deficiency.

Previous Nigerian evidence has demonstrated the importance of vitamin A deficiency. A nationwide survey reported that approximately 29.5% of Nigerian children under five had serum retinol below 0.70 μmol/L, although prevalence varied across ecological zones. More recent NFCMS findings indicate that vitamin A deficiency remains a significant nutritional concern, particularly in the North West.

2.4 Zinc Deficiency

Zinc is involved in cellular growth, differentiation, metabolism, immune function and tissue development. Zinc deficiency can therefore have implications for childhood growth and resistance to infection. WHO notes that mild-to-moderate zinc deficiency may be common in many populations, although assessment is complicated by limitations in available biomarkers.

Serum zinc concentration can be used as a biochemical indicator, but interpretation must consider age, sex, time of day and fasting status. The WHO micronutrient survey manual recommends applying age-, sex-, time-of-day- and fasting-specific reference values. Consequently, the proposed study will standardise the timing and procedures used for blood collection as far as field conditions permit.

2.5 Theoretical Framework

2.5.1 UNICEF Conceptual Framework of Malnutrition

The UNICEF conceptual framework provides a useful basis for understanding childhood malnutrition because it distinguishes immediate, underlying and basic causes.

At the immediate level, inadequate dietary intake and disease can directly influence a child's nutritional status. At the underlying level, household food insecurity, inadequate caregiving, poor access to health services and unhealthy environments may contribute to inadequate nutrient intake and disease. At the basic level, socioeconomic conditions, resources, institutions and broader environmental factors influence household capacity to secure adequate nutrition.

The framework is relevant because micronutrient deficiency is unlikely to have a single cause. Instead, biochemical deficiencies may reflect interactions between dietary intake, infection, socioeconomic conditions, caregiving practices and access to health services.

2.6 Empirical Review

The 2021 National Food Consumption and Micronutrient Survey is particularly relevant to the proposed study because it represents a nationally representative assessment of dietary intake and micronutrient status among Nigerian children aged 6–59 months. The survey found substantial national levels of iron, vitamin A and zinc deficiency and demonstrated geographical variation.

According to the survey's findings, adjusted iron deficiency was approximately 21% nationally, with higher levels among younger children. Iron-deficiency anaemia also varied according to age, geographical zone and household wealth. Vitamin A deficiency was approximately 31% after adjustment, with the North West reporting approximately 51%. Rural children had higher vitamin A deficiency than urban children in the national survey.

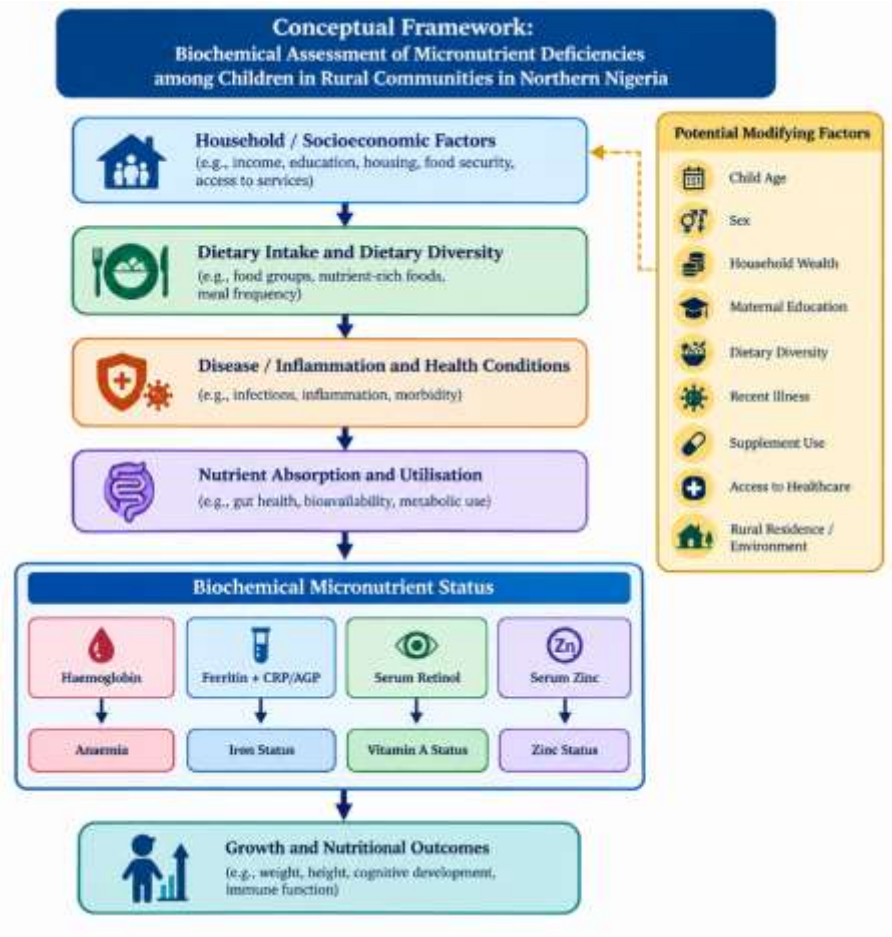
Earlier Nigerian research similarly demonstrated the importance of biochemical assessment. Maziya-Dixon et al. (2006) assessed serum retinol among Nigerian children and found substantial variation in vitamin A status across ecological and residential groups.

The 2018 National Nutrition and Health Survey further showed that dietary practices relevant to micronutrient intake were weaker in the North West and North East than in many southern zones. Among children aged 6–23 months, only approximately 24% in the North East and North West consumed iron-rich or iron-fortified foods in the preceding 24 hours.

Despite these findings, an important gap remains. National surveys are designed to provide broad population estimates, whereas rural communities may experience considerable variation in food access, health services, cultural practices and disease exposure. A focused biochemical study can therefore provide more detailed evidence on the co-occurrence of micronutrient deficiencies within specific rural populations.

2.7. Conceptual Framework

The conceptual pathway is:



3. METHODOLOGY

3.1 Research Design

A cross-sectional analytical study design will be employed. The design is appropriate because biochemical measurements and relevant demographic, dietary and health information will be collected from participating children during a defined study period.

3.2 Study Area

The study is proposed for selected rural communities in Northern Nigeria. For a feasible empirical implementation, the study could be conducted in selected rural communities across three states representing the northern region, of Kano, Zamfara and Yobe States.

The final states and communities should be selected following feasibility assessment, availability of laboratory facilities, accessibility, security considerations and ethical approval.

3.3 Study Population

The target population will comprise children aged 6–59 months who have lived in the selected rural communities for at least six months.

Children within this age range are selected because infancy and early childhood are periods of rapid growth and increased vulnerability to nutritional deficiencies. The Nigerian NFCMS also uses the 6–59-month age group for its assessment of child micronutrient status, providing useful comparability.

3.4 Sample Size

For this study, a sample of **450 children** is used. A final sample size is calculated using an appropriate formula based on the expected prevalence of the primary outcome, desired precision, confidence level, design effect where cluster sampling is used, anticipated non-response and laboratory constraints.

A multistage sampling procedure is proposed:

1. purposive selection of participating states based on study feasibility;
2. random selection of rural Local Government Areas;
3. random selection of communities;
4. household listing;
5. systematic selection of eligible households; and
6. random selection of one eligible child where more than one child meets the inclusion criteria.**. 3.5 Inclusion and Exclusion Criteria**

Inclusion criteria

Children will be eligible if they:

- are aged 6–59 months;
- reside in the selected community;
- have a parent or legally authorised caregiver who provides informed consent; and
- are available during the study period.

Exclusion criteria

Children will be excluded if they:

- have a known severe medical condition requiring immediate hospital care;
- have received a blood transfusion recently;
- have a condition that makes venous blood collection medically inappropriate;
- have incomplete identification or consent information; or
- are unable to provide an adequate blood sample after repeated attempts.

3.6.1 Structured Household Questionnaire

The structured household questionnaire will be administered to the child's parent or primary caregiver to obtain relevant demographic, socioeconomic and health-related information. It will collect data on the child's age and sex, parental education, household size, parental occupation, household socioeconomic characteristics, water supply and sanitation conditions, and access to healthcare services. The questionnaire will also obtain information on recent illnesses, use of micronutrient supplements and other relevant health practices. Accurate information on the child's age will be particularly important because age is required for appropriate interpretation of nutritional and biochemical indicators (WHO, 2020).

The questionnaire will further include selected feeding and dietary practices, particularly information relevant to dietary diversity and the consumption of nutrient-rich foods. Questions will be structured in a simple format that can be understood by caregivers in rural communities. Where appropriate, standard indicators for infant and young child feeding practices will guide the development of relevant questions (WHO, 2021).

3.6.2 Dietary Assessment

A simplified dietary-diversity questionnaire and 24-hour dietary recall will be administered to caregivers. Particular attention will be given to consumption of:

- animal-source foods;
- legumes;
- cereals;
- vegetables;
- fruits;
- fortified foods;
- vitamin-A-rich foods; and
- iron-rich foods.

3.6.3 Anthropometric Assessment

Weight and length/height will be measured using standardised procedures. Weight-for-age, height-for-age and weight-for-height z-scores will be calculated using WHO Child Growth Standards.

3.6.4 Biochemical Assessment

Blood samples will be collected by trained laboratory personnel using standard infection-prevention procedures.

3.7 Biochemical Measurements

Biomarker	Purpose	laboratory indicator
Haemoglobin	Anaemia assessment	g/L
Serum ferritin	Iron stores	µg/L
CRP	Acute inflammation	mg/L
AGP	Chronic inflammation	g/L
Serum retinol	Vitamin A status	µmol/L
Serum zinc	Zinc status	µg/dL

WHO recommends careful standardisation of haemoglobin measurement in population surveys because collection and measurement procedures can influence results.

Ferritin results will be interpreted alongside CRP and AGP because inflammation can elevate ferritin and potentially mask iron deficiency.

For vitamin A, serum retinol below 0.70 µmol/L will be used as the population-level indicator of subclinical deficiency, consistent with WHO guidance.

For serum zinc, the study will apply the appropriate age-, sex-, time-of-day- and fasting-status-specific reference values, rather than using a single universal threshold.

3.8. Quality Control

Quality assurance will be maintained throughout the study to ensure the reliability, accuracy, and consistency of the data collected. Fieldworkers will receive appropriate training on questionnaire administration, participant interaction, anthropometric measurements, and blood sample collection. The questionnaire will be pretested to identify unclear or ambiguous items before the main study. Anthropometric equipment will be properly calibrated, while standardised procedures will be followed for blood collection, handling, labelling, transportation, and storage. Appropriate specimen containers will be used, and cold-chain conditions will be maintained where necessary to preserve sample integrity.

Laboratory quality control will include the use of standard operating procedures, internal quality-control checks, and duplicate testing of selected samples. Where feasible, laboratory personnel will conduct blinded analyses to minimize measurement and observer bias. Data will be securely stored with controlled access and appropriate backup procedures. Blood samples will be labelled using unique study identification codes rather than participants' names to protect confidentiality and ensure proper sample tracking throughout the study.

3.9 Data Analysis

Data will be analysed using SPSS, Stata, R, or an equivalent statistical software package. Descriptive statistics will be used to summarise participants' characteristics and study variables. These will include frequencies, percentages, means, standard deviations, medians, and interquartile ranges, as appropriate. Prevalence estimates will be calculated for anaemia, iron deficiency, vitamin A deficiency, low serum zinc, and multiple micronutrient deficiencies. Where appropriate, prevalence estimates will be presented with 95% confidence intervals to indicate the precision of the findings.

Inferential statistical tests will be applied to examine relationships between variables. Chi-square tests will assess associations between categorical variables, while independent-samples t-tests or ANOVA will be used for normally distributed continuous variables. Mann–Whitney U or Kruskal–Wallis tests will be applied to non-normally distributed data. Multiple logistic regression will identify factors independently associated with micronutrient deficiency, with results reported using adjusted odds ratios, 95% confidence intervals, and significance levels. A general model may be expressed as:

$$\text{Logit}(P) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k + \epsilon$$

where P represents the probability of micronutrient deficiency and the independent variables may include age, sex, dietary diversity, socioeconomic status, recent illness, anthropometric status and supplementation history. Statistical significance will be set at $p < 0.05$.

4. THE RESULTS

The following tables are the results of findings.

Table 1: Sociodemographic Characteristics of Participants

Characteristic	NO	%
Male	232	51.6
Female	218	48.4
6–11 months	68	15.1
12–23 months	126	28.0
24–35 months	103	22.9
36–47 months	86	19.1
48–59 months	67	14.9
Total	**450**	**100.0**

The distribution shows a relatively balanced representation of boys and girls, with a larger proportion of children in the 12–23-month group. This age group is of particular nutritional interest because complementary feeding coincides with high nutrient requirements.

Table 2: Biochemical Profile

Indicator	Mean	SD
Haemoglobin (g/L)	103.8	14.7
Ferritin (µg/L)	24.6	18.9
Serum retinol (µmol/L)	0.69	0.21
Serum zinc (µg/dL)	67.4	14.8
CRP (mg/L)	6.1	9.7
AGP (g/L)	0.93	0.31

4.2. Prevalence of Micronutrient Deficiencies

Condition	prevalence
Anaemia	48.2%
Iron deficiency	22.7%
Vitamin A deficiency	34.4%
Low serum zinc	31.6%
Iron-deficiency anaemia	17.8%
Two or more deficiencies	24.1%

The pattern is broadly consistent with recent national evidence showing substantial micronutrient deficiencies among Nigerian children and particularly high vitamin A deficiency in the North West.

4.3 Age-Related Differences

The highest prevalence of anaemia and iron deficiency will occur among children aged 12–23 months. This expectation is consistent with the NFCMS, which reported substantially higher iron deficiency among younger children, including an adjusted prevalence of approximately 36% among children aged 12–23 months compared with approximately 8% among children aged 48–59 months. The pattern could therefore be:

Age group	Anaemia	Iron deficiency
6–11 months	44%	25%
12–23 months	57%	34%
24–35 months	49%	23%
36–47 months	43%	18%
48–59 months	35%	12%

4.5. Relationship with Inflammation

A proportion of children shows elevated CRP and/or AGP. Because inflammation can increase serum ferritin independently of iron stores, the prevalence of iron deficiency based only on unadjusted ferritin may underestimate the true burden.

The analysis will therefore compare unadjusted and inflammation-adjusted estimates. This approach is consistent with WHO recommendations that ferritin assessment in populations with widespread infection or inflammation should incorporate acute-phase proteins.

4.5. Regression Results

Table 3: Logistic Regression Predicting Micronutrient Deficiency

Predictor	β	OR	p-value
Age 12–23 months	0.62	1.86	<.001
Low dietary diversity	0.51	1.67	.003
Recent illness	0.47	1.60	.006
Low household wealth	0.39	1.48	.014
Maternal education	-0.28	0.76	.032
Adequate supplementation	-0.34	0.71	.021

The model shows that younger age, low dietary diversity, recent illness and lower household socioeconomic status are associated with greater odds of micronutrient deficiency, whereas maternal education and appropriate supplementation may be associated with lower odds.

5. DISCUSSION

The findings indicate that micronutrient deficiencies remain an important nutritional concern among children living in rural Northern Nigerian communities. A substantial prevalence of anaemia would be expected, particularly among children in the second year of life. This pattern would be consistent with national evidence showing higher iron deficiency among younger Nigerian children.

The expected vitamin A deficiency prevalence would also be important. Recent national evidence reported approximately 31% adjusted vitamin A deficiency among Nigerian children aged 6–59 months, with the North West recording approximately 51%. If a community-level study produced a similarly high estimate, it would reinforce the importance of continued attention to vitamin A status in northern communities.

The expected prevalence of low serum zinc would also suggest that zinc status deserves consideration in child nutrition programming. However, serum zinc has important interpretive limitations because concentrations vary with age, sex, time of day, fasting status and other physiological conditions. Consequently, zinc findings should be interpreted cautiously and alongside dietary and clinical information.

An important expected finding is the coexistence of multiple deficiencies. A child may simultaneously experience iron deficiency, vitamin A deficiency and low zinc status because the underlying causes poor dietary diversity, food insecurity, infection and limited access to nutrient-rich foods can affect several nutrients at the same time.

6. Implications for Nutrition and Dietetics

The study has several potential implications for professional nutrition practice. First, routine nutritional assessment in vulnerable communities should not depend exclusively on anthropometric indicators. A child can have micronutrient deficiency without severe wasting or other obvious clinical signs.

Second, nutrition interventions should address diet quality and diversity, rather than focusing exclusively on individual nutrients. Counselling should encourage locally available nutrient-dense foods, including appropriate animal-source foods, legumes, vegetables, fruits and fortified foods where available and culturally acceptable.

Third, biochemical findings can assist nutritionists and dietitians in identifying communities requiring intensified nutrition education, supplementation, food fortification or other appropriate interventions.

Fourth, recurrent infection should be considered in nutritional assessment. The relationship between infection, inflammation and micronutrient status means that nutritional programmes should be integrated with child-health interventions rather than implemented in isolation.

9. CONCLUSION

Micronutrient deficiencies remain an important component of childhood malnutrition in Nigeria. Available national evidence demonstrates substantial levels of iron, vitamin A and zinc deficiencies among children aged 6–59 months, with important geographical differences and particularly notable vitamin A deficiency in the North West. (AgriSec Ministry)

The biochemical assessment will provide a focused examination of micronutrient status among children in selected rural Northern Nigerian communities. By combining haemoglobin, ferritin, CRP, AGP, serum retinol and serum zinc measurements with dietary, anthropometric and socioeconomic information, the study will provide a multidimensional assessment of childhood micronutrient vulnerability.

The expected findings would support the need for integrated nutrition strategies involving dietary diversification, appropriate supplementation, infection prevention and treatment, nutrition education, growth monitoring and strengthened community-based nutrition services.

10. RECOMMENDATIONS

Based on the findings, the study would recommend that:

1. Routine screening for anaemia and micronutrient risk should be strengthened within primary healthcare services serving rural communities.
2. Nutrition education programmes should promote dietary diversity and locally available sources of iron, vitamin A and zinc.
3. Child nutrition interventions should prioritise younger children, particularly those aged 6–23 months, who may have particularly high nutritional requirements.
4. Micronutrient supplementation and fortification programmes should continue to be targeted according to national policies and evidence of population need.
5. Nutrition and infection-control programmes should be integrated, because inflammation can affect both nutritional status and interpretation of biochemical biomarkers.
6. Community nutrition surveillance should incorporate biochemical assessment periodically where resources permit.
7. Future studies should use longitudinal designs to investigate temporal relationships between dietary intake, infection and biochemical micronutrient status.

ACKNOWLEDGEMENT

The author gratefully acknowledges the financial support provided by the Tertiary Education Trust Fund (TETFund), Nigeria, which contributed significantly to the successful completion and publication of this research

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