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Hidden Hunger in Nigerian Poultry: Micronutrient Deficiencies and Metabolic Risks

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Abstract
Micronutrient deficiencies represent a persistent yet often overlooked challenge within Nigeria's rapidly growing poultry industry. Despite advancements in feed formulation and flock management, subclinical shortages of essential trace minerals and vitamins—termed "hidden hunger"—continue to impair metabolism, immune competence, skeletal integrity, and reproductive performance. This review comprehensively examines the biological roles of key micronutrients, the incidence and biochemical manifestations of deficiencies in Nigerian flocks, and contemporary factors that exacerbate hidden hunger, including climate stress, mycotoxin contamination, modern genetic progress, and gut microbiota disruption. Advances in supplementation strategies, such as the use of organic trace minerals, antioxidant fortification, and precision nutrition, are critically evaluated alongside current industry practices. Persistent gaps in regulation, feed quality control, and farmer education are highlighted, with research and policy recommendations proposed to address the evolving nutritional demands of commercial poultry. Achieving sustainable poultry production in Nigeria hinges on proactive micronutrient management, dynamic supplementation practices, and integrated farm-to-feed quality assurance systems.

Keywords: Micronutrient deficiency; heat stress; poultry nutrition; gut microbiota; organic minerals; mycotoxins; hidden hunger; oxidative stress; Nigerian poultry industry

Introduction

Poultry production is a cornerstone of Nigeria's agricultural economy, contributing significantly to protein intake, rural employment, and national food security (FAO, 2021) [14]. With rapid population growth and urbanization, the demand for poultry meat and eggs has escalated, necessitating intensive farming systems that maximize bird productivity. However, beneath the surface of rising outputs lies a critical challenge: the silent yet devastating impact of micronutrient deficiencies.

Micronutrients—trace minerals and vitamins—are essential for maintaining the metabolic, skeletal, immune, and reproductive health of poultry. Unlike overt macronutrient deficiencies that manifest visibly through stunted growth or poor feed conversion, micronutrient deficiencies often remain subclinical, gradually impairing physiological functions over time (Surai, 2018) [32]. This phenomenon, referred to as "hidden hunger," undermines flock health, compromises productivity, and inflates production costs without immediate recognition. While the Nigerian poultry industry has made strides in feed technology and veterinary care, evidence increasingly shows that hidden hunger persists, fueled by factors such as feed ingredient variability, poor storage conditions, heat stress, mycotoxin contamination, and evolving bird genetics. Recent studies emphasize the growing importance of managing oxidative stress, gut health, and mineral bioavailability as core strategies to overcome these challenges (De Grande *et al*., 2020; Bedford & Apajalahti, 2022) [13, 10]. This review seeks to comprehensively examine the contemporary landscape of micronutrient deficiencies and metabolic disorders in Nigerian poultry production. It critically evaluates current industry practices, explores emerging scientific advancements, and proposes actionable strategies for sustainable improvement.

Overview of Micronutrient Requirements in Poultry

Micronutrients, although required in minute quantities, are fundamental to virtually every biological process in poultry. They serve as enzymatic cofactors, structural components of tissues, antioxidants, and modulators of immune responses (Leeson & Summers, 2001; NRC, 1994) [22, 26].

1. Essential Trace Minerals

Micronutrients, though required only in minute amounts, are essential to nearly every biological process in poultry. They act as enzymatic cofactors, structural elements of tissues, antioxidants, and regulators of immune responses (Leeson & Summers, 2001; NRC, 1994) [22]. Among the essential trace minerals, selenium plays a critical role in antioxidant defense through its involvement in glutathione peroxidase activity, contributing significantly to muscle integrity and fertility (Surai, 2018) [32]. Zinc is vital for supporting over 300 enzymatic reactions, maintaining epithelial tissue integrity, and modulating immune responses (Kidd, 2004) [20]. Iron is indispensable for hemoglobin synthesis and the transport of oxygen, while copper is necessary for iron metabolism and the formation of connective tissues. Manganese is crucial for bone mineralization and supports antioxidant enzyme systems. Recent studies emphasize the higher bioavailability and overall systemic benefits of organic mineral forms compared to inorganic ones, leading to an increasing preference for supplements such as organic selenium and chelated zinc (Świątkiewicz *et al*., 2014; Zhang *et al*., 2021) [34].

2. Essential Vitamins

In addition to minerals, essential vitamins are critical to poultry health and performance. Vitamin A is necessary for vision, the health of epithelial tissues, and immune function. Vitamin D3 is essential for regulating calcium and phosphorus metabolism, both of which are fundamental to

skeletal development. Vitamin E acts as a potent antioxidant, stabilizing cell membranes and enhancing immune defense (Khadim & Al-Fartusie, 2021). The B-complex vitamins catalyze vital metabolic reactions involved in the metabolism of carbohydrates, fats, and proteins. Modern commercial poultry breeds, which are characterized by rapid growth rates and high reproductive outputs, require not merely adequate but finely optimized levels of micronutrient intake to maintain physiological balance and achieve peak performance under intensive farming conditions (Leeson, 2005) [22].

Incidence and Diagnosis of Micronutrient Deficiencies in Nigeria

Despite improvements in commercial feed production, field reports and diagnostic studies reveal that micronutrient deficiencies remain widespread in Nigeria's poultry sector (Adedokun & Olojede, 2019).

1. Field Observations

Common clinical presentations include:

- Increased mortality in broilers linked to selenium and vitamin E deficiencies.
- Skeletal deformities (e.g., perosis) associated with manganese and zinc deficits.
- Poor hatchability and embryonic mortality in breeders linked to vitamin A and selenium deficiencies (Fasanmi *et al*., 2009).
- Anemia and lethargy in layers due to iron deficiency (Awobajo *et al*., 2021).

Emerging studies also report increasing incidences of subclinical deficiencies undetected by traditional veterinary assessments, further complicating production efficiency (Akhavan-Salamat, & Ghasemi, 2019)).

These manifestations often occur despite standard feed supplementation, suggesting either bioavailability issues, degradation losses, or mismatch between feed formulations and actual flock demands.

2. Biochemical Diagnosis

Biochemical markers provide a more sensitive assessment of micronutrient status than clinical signs alone:

- Elevated malondialdehyde (MDA) and reduced glutathione peroxidase activity signal oxidative stress due to selenium/vitamin E deficiencies.
- Low hematocrit and hemoglobin concentrations suggest iron or copper deficiency.
- Decreased serum zinc levels are linked with impaired immune function and wound healing (Surai, 2018) [32].

Routine blood biochemistry, feed mineral assays, and tissue mineral analysis during postmortem examinations are critical tools for early diagnosis and intervention but remain underutilized in Nigerian practice (Ghosh *et al*., 2012) [16].

Biochemical and Metabolic Disorders Associated with Micronutrient Deficiencies

Micronutrient deficiencies exert profound effects on poultry physiology, often leading to cascading metabolic failures that compromise health and productivity.

1. Oxidative Stress and Antioxidant Enzyme Depletion

Deficiencies in selenium, vitamin E, and zinc critically impair the antioxidant defense system, leading to the accumulation of reactive oxygen species (ROS) and cellular damage. Birds experiencing oxidative stress exhibit elevated malondialdehyde (MDA) levels and decreased activities of superoxide dismutase (SOD) and glutathione peroxidase (GPx) (Surai, 2018) [32]. This oxidative burden not only compromises muscle integrity and reproductive performance but also predisposes birds to infectious diseases (Yatoo *et al*., 2021; Ghazi *et al*., 2012) [38, 15].

Heat stress has been shown to amplify oxidative stress, making antioxidant supplementation an even more critical intervention (Lin *et al*., 2006; Saeed *et al*., 2019) [31].

2. Skeletal Deformities and Mineralization Failure

Inadequate manganese, zinc, and vitamin D3 intake disrupts bone development, resulting in skeletal abnormalities such as perosis (slipped tendon), rickets, and osteoporosis (Olumide & Odunsi, 2016) [28]. Poor skeletal health not only impairs bird welfare but also substantially affects feed efficiency and carcass quality.

Recent field studies in tropical climates report an increased incidence of leg disorders even in well-fed birds, suggesting a need for revisiting mineral standards (Attia *et al*., 2016) [8].

3. Immune Suppression and Poor Vaccine Response

Zinc, selenium, and vitamin A are pivotal in maintaining robust immune function. Their deficiencies impair lymphocyte proliferation, antibody production, and mucosal barrier integrity, leading to reduced vaccine efficacy and increased vulnerability to infections (Kidd, 2004; Yatoo *et al*., 2021) [38, 20].

Additionally, micronutrient imbalances have been associated with dysbiosis, leading to compromised gut-associated lymphoid tissue (GALT) responses (Pan & Yu, 2014) [30].

4. Reproductive Performance Decline

In breeders, marginal deficiencies of selenium and vitamin E have been linked to reduced fertility rates, poor semen quality, increased embryonic mortality, and hatchability failures (Adedeji & Olayeni, 2017; Surai, 2018) [2, 32]. Longitudinal data now suggest that oxidative stress at the ovarian and testicular levels significantly impacts reproductive outcomes (Bednarczyk *et al*., 2011) [11].

Contemporary Factors Aggravating Micronutrient Deficiencies

Beyond traditional nutritional gaps, modern poultry production faces new environmental and systemic challenges that exacerbate hidden hunger.

1. Climate Stress (Heat Stress)

Tropical climates like Nigeria subject poultry to chronic heat stress, which elevates metabolic rate and reactive oxygen species (ROS) production, increasing the demand for antioxidants such as selenium, vitamin C, and vitamin E (Lin *et al*., 2006; Saeed *et al*., 2019) [31]. Heat-stressed birds show reduced feed intake, altered mineral metabolism, and suppressed immunity, necessitating dynamic adjustments in micronutrient supplementation (Habibu *et al*., 2017) [17].

Recent findings also suggest that heat stress impairs gut barrier function, aggravating mineral malabsorption and oxidative injury (Olanrewaju *et al*., 2008) [27].

2. Mycotoxin Contamination of Feed

Aflatoxins, fumonisins, and ochratoxins are prevalent contaminants in Nigerian feed ingredients due to poor postharvest storage. These mycotoxins not only cause direct toxicity but also impair micronutrient absorption and exacerbate oxidative stress (Manafi *et al*., 2011; Hassan & Awad, 2020) [18, 24].

For instance, aflatoxin exposure significantly reduces serum vitamin A and zinc levels while increasing hepatic oxidative damage (Manafi, 2015) [23].

Preventive strategies such as toxin binders and controlled storage environments are increasingly critical.

3. Genetic Progress and Modern Broiler Breeds

Modern broiler strains, such as Ross 308 and Cobb 500, exhibit unprecedented growth rates, reaching market weight in 35–40 days. However, their accelerated metabolism heightens oxidative stress burden and micronutrient requirements (Attia *et al*., 2017) [7].

Traditional premix formulations based on slower-growing breeds are often insufficient. Recent advances recommend dynamic mineral fortification strategies tailored to genotype-specific demands (Leeson, 2005) [22].

4. Gut Microbiota and Micronutrient Absorption

Emerging research reveals that the intestinal microbiota plays a pivotal role in nutrient digestion and micronutrient absorption (Pan & Yu, 2014; Bedford & Apajalahti, 2022) [30, 10].

Dysbiosis—often induced by stress, antibiotic use, or mycotoxins—impairs mineral and vitamin uptake, compounding deficiency risks. Supplementation with probiotics, prebiotics, and synbiotics has shown promise in restoring gut health and improving mineral bioavailability (Bednarczyk *et al*., 2011; Khan *et al*., 2012) [11, 19].

Advances in Micronutrient Supplementation Strategies

Recognizing these contemporary challenges, the poultry nutrition industry has advanced several strategies to enhance micronutrient delivery and utilization.

1. Organic Trace Minerals

Organic minerals, such as zinc-methionine complexes, selenium yeast, and copper proteinate, exhibit higher bioavailability and stability than their inorganic counterparts (Ao *et al*., 2011; Bai *et al*., 2021) [6, 9].Field trials consistently report improved growth performance, feed conversion efficiency, and antioxidant status in birds fed organic minerals, especially under stress conditions (Wang *et al*., 2018) [37].

Furthermore, new nano-mineral formulations are being explored to further improve tissue retention and biological efficacy (Świątkiewicz *et al*., 2014) [34].

2. Antioxidant Vitamin Fortification

Dynamic fortification of diets with antioxidant vitamins—especially vitamins E and C—during periods of environmental or physiological stress has proven effective in mitigating oxidative damage (Lin *et al*., 2006; Yatoo *et al*., 2021) [38].

Synergistic supplementation, combining vitamin E with selenium, offers enhanced protection against lipid peroxidation and cellular damage (Alagawany *et al*., 2018) [3].

3. Precision Nutrition and Smart Feeding

The concept of precision nutrition tailors micronutrient delivery to the specific needs of birds based on age, breed, health status, and environmental conditions (Kidd *et al*., 2021) [21].

Modern approaches increasingly integrate data from production metrics, gut health biomarkers, and heat stress indices to dynamically adjust dietary formulations (Blount *et al*., 2021; De Grande *et al*., 2020) [12, 13].

Current Feed Industry Practices in Nigeria: Progress and Gaps

1. Progress in Commercial Feed Production

In recent years, Nigeria's feed industry has undergone substantial modernization, with the emergence of structured premix production companies, nutrient fortification awareness, and standardization efforts (FAO, 2021) [14].

Many large-scale commercial feed mills incorporate vitamin-mineral premixes into poultry feeds, aiming to meet NRC (1994) [26] nutrient recommendations.

There is also growing interest in organic mineral supplementation, driven by consumer demands for antibiotic-free and welfare-compliant poultry products (Attia *et al*., 2017) [7].

The availability of selenium yeast and chelated zinc premixes in the Nigerian market reflects this global trend toward higher quality supplementation (Tufarelli & Laudadio, 2017) [35].

2. Persistent Gaps and Challenges

Despite these gains, systemic shortcomings continue to threaten micronutrient adequacy:

- **Premix Degradation During Storage:** In tropical conditions, exposure to heat and humidity significantly degrades vitamins A, D, and E during transport and storage (Surai, 2018) [32]. Many feed mills fail to adjust for these predictable losses (McDowell, 2003) [25].
- **Economic Pressures:** Price fluctuations in the global vitamin and mineral markets push local feed manufacturers to lower inclusion rates or substitute cheaper, less bioavailable inorganic salts (Adebiyi *et al*., 2017) [1].
- **Quality Control Deficiencies:** Regulatory oversight remains weak. Randomized feed analysis by research institutions often finds discrepancies between labeled and actual micronutrient contents (FAO, 2021; Abd El-Hack *et al*., 2017) [14].
- **Lack of Breed-Specific Formulations:** Most commercial diets are not customized for the particular genetic lines of broilers or layers, despite modern birds having significantly different nutrient requirements (Leeson, 2005) [22].

There is an urgent need to align commercial feed practices with precision nutrition principles to close these systemic gaps (Kidd *et al*., 2021) [21].

Management and Diagnostic Strategies for Field Application

Given the complexity of factors affecting micronutrient status, a comprehensive, field-friendly strategy is essential.

1. Biochemical Monitoring

Routine blood biochemistry profiling—including measures of serum zinc, selenium, total antioxidant capacity, and hematological indices—should become standard practice in large commercial operations (Adebiyi *et al*., 2017) [1]. Recent innovations have made rapid field assays more affordable and accessible (Uddin *et al*., 2019) [2].

2. Dynamic Supplementation Programs

Instead of static, one-size-fits-all formulations, producers should adopt dynamic supplementation schedules that adjust antioxidant vitamins and trace minerals during stress events, peak production periods, or after vaccination campaigns (Kidd *et al*., 2021) [21].

Supplementation with organic trace minerals has been shown to maintain better tissue mineral status during fluctuating environmental conditions (Ao *et al*., 2009) [5].

3. Mycotoxin Management

Investment in proper storage facilities, moisture monitoring, and mycotoxin binders in diets is non-negotiable (Manafi *et al*., 2011; Hassan & Awad, 2020) [24, 18]. In addition, integrating dietary antioxidants may mitigate some oxidative damages induced by residual mycotoxin exposure (Ghazi *et al*., 2012) [15].

4. Gut Health Maintenance

Supplementing feeds with probiotics, prebiotics, or synbiotics enhances gut microbiota resilience, promoting better mineral and vitamin uptake (Bedford & Apajalahti, 2022; Khan *et al*., 2012) [10, 19]. Synbiotic strategies show particular promise under high-temperature conditions (Bednarczyk *et al*., 2011) [11].

5. Farmer and Veterinarian Education

Continuous education campaigns targeting farmers, feed millers, and veterinarians are vital. Early recognition of subclinical signs of deficiency and emphasis on preventive nutrition must be ingrained into routine farm management practices (Ghosh *et al*., 2012) [16].

Research Gaps and Policy Recommendations

Addressing micronutrient deficiencies sustainably requires an integrative research-policy framework.

1. Research Gaps

- **Breed-Specific Nutrient Tables:** There is an urgent need for developing nutrient requirement models adapted to Nigerian commercial poultry breeds under tropical climates (Attia *et al*., 2017; Al-Fataftah & Abu-Dieyeh, 2007) [7, 4].
- **Bioavailability Studies:** Comparative field studies evaluating organic vs. inorganic mineral sources under local production conditions are sparse and should be prioritized (Bai *et al*., 2021; Świątkiewicz *et al*., 2014) [9, 34].
- **Microbiota-Nutrient Interaction Research:** Investigations into how Nigerian poultry gut flora modulates micronutrient absorption could open new frontiers for probiotic development (Bedford & Apajalahti, 2022; Khan *et al*., 2012) [10, 19].
- **Longitudinal Hidden Hunger Surveillance:** Long-term cohort studies tracking the impact of micronutrient adequacy on production efficiency and animal welfare are lacking (Ghosh *et al*., 2012; Blount *et al*., 2021) [16, 12].
- **Nano-Minerals Research:** Advances in nano-trace minerals suggest higher tissue retention and lower environmental excretion, but field validation studies are needed in Nigerian settings (Wang *et al*., 2018) [37].

2. Policy Recommendations

- **Mandatory Feed Quality Audits:** Regulatory agencies like NAFDAC should enforce regular laboratory verification of commercial feeds and premixes (FAO, 2021) [14].
- **Premix Certification Standards:** Introduce third-party certification schemes for premix quality, modeled after international ISO systems (Abd El-Hack *et al*., 2017).
- **Farmer Incentive Programs:** Rewarding farms adopting certified, nutrient-balanced feed formulations could encourage better practices (Manafi, 2015) [23].
- **Research-Industry Partnerships:** Foster collaboration between universities, research institutes, and private feed companies to fast-track innovation adoption (De Grande *et al*., 2020) [13].
- **Heat Stress Management Policies:** Government support for heat mitigation technologies (e.g., ventilation grants, shade net subsidies) could reduce oxidative stress-related nutrient losses (Saeed *et al*., 2019) [31].

Conclusion

Micronutrient deficiencies remain a silent but potent barrier to the sustainable growth of Nigeria's poultry sector. Despite apparent gains in production technology, hidden hunger continues to erode flock health, productivity, and profitability.

Modern challenges—including heat stress, genetic progress, mycotoxin exposure, and gut microbiota disruption—compound traditional nutritional gaps, necessitating a paradigm shift in feed formulation and farm management.

By embracing dynamic, precision-based nutritional strategies, investing in field diagnostics, enforcing stringent regulatory frameworks, and fostering knowledge transfer across the poultry value chain, Nigeria can close the micronutrient gap and unlock the full potential of its poultry industry.

The future of sustainable poultry production lies not merely in maximizing quantity but in optimizing the quality of nutrition at every level of production (Surai & Fisinin, 2015) [33].

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