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BIOfortifications as a panacea to hidden hunger in Nigeria

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ABSTRACT

Hidden hunger, or micronutrient deficiency, remains a critical public health challenge in Nigeria, disproportionately affecting vulnerable populations, including children and adolescents. This review examines biofortification as a sustainable and cost-effective strategy to combat micronutrient deficiencies by enhancing the nutritional content of staple crops such as cassava, maize, and sweet potatoes. Through conventional breeding, genetic engineering, and agronomic practices, biofortified crops like vitamin A-enriched cassava and iron-rich beans have demonstrated significant potential to improve dietary intake and health outcomes. Despite successes, challenges such as limited farmer adoption, consumer awareness gaps, and supply chain constraints hinder widespread implementation. The review synthesizes evidence on the progress, benefits, and barriers of biofortification in Nigeria, highlighting its socioeconomic and nutritional impacts. Recommendations include strengthening policy frameworks, increasing funding, and fostering interdisciplinary collaboration to scale up biofortification efforts. By integrating biofortification with complementary interventions like dietary diversification and nutrition education, Nigeria can achieve long-term solutions to hidden hunger, ensuring food security and improved public health.

Key words: Hidden hunger, Nigeria, Biofortification, Staple crops, Conventional breeding, Genetic engineering, Public health, Food security

INTRODUCTION

Hidden hunger, or micronutrient deficiency, represents a pervasive global health challenge, disproportionately affecting developing nations such as Nigeria. Characterized by insufficient intake of essential vitamins and minerals—including iron, zinc, iodine, and vitamins A, B12, and D—this condition contributes to impaired physical and cognitive development, heightened disease susceptibility, and long-term socioeconomic burdens (Valenca et al., 2017; Okwuonu et al., 2021; Ofori et al 2022.) Among Nigerian children, protein-energy malnutrition and micronutrient deficiencies are particularly prevalent, with far-reaching implications for national productivity and healthcare systems (Sharma et al 2017). Even populations with adequate caloric intake, such as patients with type 2 diabetes, may face compounded health risks due to micronutrient deficiencies that disrupt metabolic pathways (Kumar et al 2019). While conventional interventions like supplementation and nutrition education have demonstrated efficacy (Valenca et al., 2017; Okwuonu et al., 2021), their scalability and sustainability remain limited. Biofortification has emerged as a transformative strategy to address these gaps. By enhancing the nutrient density of staple crops—such as cassava, maize, and sweet potato—through agronomic practices, conventional breeding, or genetic engineering, biofortification offers a cost-effective and culturally adaptable solution (Samuel et al., 2023). In Nigeria, where cassava serves as a dietary cornerstone for over 180 million people, biofortified varieties have been successfully introduced, reaching an estimated 13 million beneficiaries by 2021(Majumder et al., 2019; Ofori et al

2022). Programs like HarvestPlus highlight the potential of biofortified crops, such as iron-rich beans and vitamin A-enriched sweet potatoes, to improve nutritional outcomes (Sharma et al 2017; Samuel et al., 2023). However, challenges persist, including farmer adoption barriers, resource limitations, and the need for stakeholder collaboration to ensure processing stability and consumer acceptance (Kumar et al 2019;Samuel et al., 2023). This review critically examines the role of biofortification in mitigating hidden hunger in Nigeria, evaluating its progress, challenges, and comparative advantages over traditional interventions. By synthesizing evidence on genetic and agronomic biofortification methods, dissemination strategies, and socioeconomic impacts, we aim to identify pathways for scaling this innovation within integrated agricultural and policy frameworks(Valenca et al., 2017; Okwuonu et al., 2021).

1. BIOFORTIFICATIONS; HOW IT WORKDS

Biofortification is a cost-effective and sustainable approach to enhance the nutritional quality of crops through conventional breeding, genetic engineering, or agronomic practices (Raut et al., 2024; Yadav et al., 2020). It aims to combat micronutrient deficiencies, particularly iron, zinc, vitamin A, and folate, which affect over 2 billion people worldwide (Raut et al., 2024). Compared to fortification, biofortification is more economical as it requires a one-time investment with low recurrent costs (Yadav et al., 2020). The process involves increasing nutrient concentrations in edible plant parts during growth, offering a sustainable solution to malnutrition (Baddigam Kasi Reddy et al., 2024). Biofortification strategies include conventional breeding, genetic engineering, and agronomic approaches using micronutrient fertilizers (Baddigam Kasi Reddy et al., 2024). While promising, challenges remain, including acceptance issues and regulatory complexities. Future efforts should focus on interdisciplinary collaboration and increased funding to effectively address global malnutrition (Baddigam Kasi Reddy et al., 2024).

2. BIOFORTIFIED CROPS IN NIGERIA

In Nigeria, several types of biofortified crops have been introduced to address widespread micronutrient deficiencies, with a particular focus on vitamin A, iron, and zinc. The most prominent biofortified crop is pro-vitamin A cassava, which is widely cultivated and adopted across various states, including Oyo, Enugu, Ogun, Kaduna, Abia, and Anambra (Atanasova et al., 2025; Amanze et al., 2024; Onyeneke et al., 2020; Ibitoye & Ogunwande, 2024; Ayinde et al., 2017). Popular varieties of biofortified cassava include TMS 01/0593, TMS 01/0539, TMS 01/0220, TMS07/0593, and TMS 1371, all bred to provide higher levels of vitamin A compared to traditional white cassava(Adetomiwa et al., 2020; Amanze et al., 2024). In addition to cassava, biofortified sweet potatoes and millet are available, offering enhanced levels of vitamin A and other micronutrients(Atanasova et al., 2025). Efforts are also underway to develop and deploy iron- and zinc-biofortified cassava through genetic modification, aiming to further reduce hidden hunger in the population(Okwuonu et al., 2021). The inclusion of these biofortified crops in school meals and household diets has been shown to improve intake of vitamin A, zinc, and iron, contributing to better health outcomes(Atanasova et al., 2025; Onyeneke et al., 2020). However, challenges such as limited awareness, higher prices, and supply constraints affect their widespread adoption(Atanasova et al., 2025; Onyeneke et al., 2020; Ayinde et al., 2017). Overall, biofortified cassava, sweet potatoes, and millet represent the

main types of biofortified crops currently available and promoted in Nigeria to combat micronutrient deficiencies(Atanasova et al., 2025; Okwuonu et al., 2021; Amanze et al., 2024; Onyeneke et al., 2020).

3. HIDDEN HUNGER IN NIGERIA; MICRONUTRIENT DEFICIENCIES

Hidden hunger, or micronutrient deficiency, is a significant issue in Nigeria, affecting adolescents and children in particular (Ibeanu et al., 2020; Uchendu & Atinmo Tola, 2011). It can lead to impaired physical growth, poor cognitive function, and increased susceptibility to infections (Ibeanu et al., 2020; Mehboob, 2022). Nigeria is among the 20 countries responsible for 80% of global malnutrition, with protein-energy malnutrition and micronutrient malnutrition being prevalent (Msughter, 2021). Causes include poverty, lack of nutritional knowledge, and poor infant feeding practices (Mehboob, 2022; Msughter, 2021). The economic impact is substantial, with stunted children earning up to 20% less than their counterparts (Msughter, 2021). Interventions such as nutrition education have shown promise in improving knowledge and consumption of micronutrient-rich foods among adolescents (Ibeanu et al., 2020). Addressing hidden hunger is crucial for individual health and national economic development, particularly in developing countries like Nigeria (Msughter, 2021).

4. HIDDEN HUNGER IN NIGERIA; NEED FOR SUSTAINABLE SOLUTIONS

Micronutrient deficiencies, or "hidden hunger," remain a major global health challenge, especially in developing countries, and require sustainable solutions to ensure long-term impact. Biofortification—enhancing the nutrient content of staple crops through selective breeding, agronomic practices, or genetic engineering—offers a cost-effective and sustainable approach, delivering micronutrient-rich foods to large populations and reducing reliance on continuous supplementation(Avnee et al., 2023; Koç & Karayiğit, 2021; Altaf et al., 2024; Blancquaert et al., 2017). Food-based strategies, particularly dietary diversification that increases access to a variety of nutrient-dense foods such as vegetables and legumes, are also recognized as sustainable and effective for addressing multiple micronutrient deficiencies over time(Nair et al., 2016; Olatunji & Afolayan, 2018; Chaudhary et al., 2022). Modern agricultural practices, including the use of biofertilizers and nanofertilizers, further support the enrichment of crops with essential vitamins and minerals while minimizing environmental impact(Kosti´c et al., 2022; Altaf et al., 2024). Large-scale food fortification programs, when integrated with sustainable diets and tailored to local food preferences, can improve public health and food security while considering environmental and cultural sustainability(Fatemi et al., 2023). Ultimately, a holistic approach that combines biofortification, dietary diversification, sustainable agricultural practices, and targeted fortification is essential for the long-term prevention and control of micronutrient deficiencies(Avnee et al., 2023; Koç & Karayiğit, 2021; Nair et al., 2016; Altaf et al., 2024; Fatemi et al., 2023).

5. BIOFORTIFICATION EFFORTS IN NIGERIA

Biofortification efforts in Nigeria have made significant progress over the past decade, focusing on enhancing the nutrient content of staple crops like cassava, maize, sweet potatoes, and millet to address widespread micronutrient deficiencies (Birol et al., 2022; Nc et al., 2017). Since the launch of the national biofortification program in 2011, partnerships among government, research institutions, and private sectors have led to the release and adoption of

several biofortified crop varieties, benefiting an estimated 13 million Nigerians by 2021(Birol et al., 2022). These crops, particularly provitamin A cassava and maize, have been integrated into public policies, school meal programs, and social protection initiatives, demonstrating improvements in vitamin A, iron, and zinc intake among consumers(Birol et al., 2022; Atanasova et al., 2025; Nc et al., 2017). However, challenges remain, including limited availability and higher prices of biofortified crops compared to conventional varieties, low consumer awareness, and the need for substantial investment in education and supply chain improvements (Atanasova et al., 2025; Oteh et al., 2020). Adoption among farmers is influenced by factors such as access to credit, education, and information, with credit constraints notably hindering uptake among smallholders (Ogunleye et al., 2024; Kolapo & Kolapo, 2020; Samuel et al., 2023). Despite these barriers, studies show that biofortified crops can increase farm yields, improve household welfare, and have strong market potential, especially when consumers are informed about their health benefits (Kolapo, 2023; Oteh et al., 2020; Kolapo & Kolapo, 2020). Continued expansion and scaling of biofortification in Nigeria will require targeted policy support, innovative financing, and sustained public awareness campaigns to ensure both supply and demand for these nutrient-rich foods (Birol et al., 2022; Atanasova et al., 2025; Oteh et al., 2020; Ogunleye et al., 2024; Samuel et al., 2023).

6. IMPACT AND BENEFITS OF BIOFORTIFICATIN IN NIGERIA

Biofortified crops in Nigeria have shown promising impacts on nutrition, farmer welfare, and food systems, though challenges remain. The introduction of biofortified staples like cassava, maize, sweet potatoes, and millet has improved dietary intake of key micronutrients such as vitamin A, iron, and zinc, especially when integrated into school meal programs and traditional diets (Atanasova et al., 2025; Birol et al., 2022; Ilona et al., 2017). Adoption of biofortified cassava by smallholder farmers has led to increased farm yields, higher incomes, and improved welfare, contributing to poverty reduction and food security (Kolapo & Kolapo, 2020; Ilona et al., 2017). By 2021, an estimated 13 million Nigerians were benefiting from biofortified cassava and maize, with these crops now included in national policies and social protection programs (Birol et al., 2022). However, limited availability, higher prices, and low consumer awareness restrict the reach and impact of biofortified foods, with only a small percentage of consumers able to identify or prefer them (Atanasova et al., 2025; Oteh et al., 2023). Market growth and adoption are influenced by factors such as education, access to credit, institutional support, and effective communication about health benefits (Oteh et al., 2023; Oteh et al., 2020; Samuel et al., 2023). Despite these barriers, biofortified crops are widely accepted by farmers and have strong market potential, especially when awareness campaigns and policy support are in place (Ilona et al., 2017; Oteh et al., 2023; Oteh et al., 2020). Continued investment in education, supply chains, and innovative delivery strategies is essential to scale up the nutritional and economic benefits of biofortified crops across Nigeria (Atanasova et al., 2025; Birol et al., 2022; Oteh et al., 2023; Oteh et al., 2020).

7. CONCLUSION

Biofortification has emerged as a transformative approach to addressing hidden hunger in Nigeria, offering a sustainable and scalable solution to micronutrient deficiencies. The introduction of biofortified crops, such as pro-vitamin A cassava and iron-rich beans, has shown promising results in improving nutritional outcomes, enhancing farmer livelihoods,

and contributing to food security. However, challenges such as low adoption rates, limited consumer awareness, and logistical barriers persist. Addressing these issues requires a holistic strategy that combines technological innovation, policy support, and community engagement.

8. RECOMMENDATIONS

The Nigerian government should integrate biofortification into national agricultural and nutrition policies, ensuring alignment with programs like school feeding initiatives. Strengthen partnerships between research institutions, private sectors, and NGOs to enhance crop development and dissemination. Implement targeted awareness campaigns to educate farmers and consumers about the health and economic benefits of biofortified crops. Provide incentives such as subsidies, credit access, and training to encourage farmer adoption. Invest in infrastructure to improve the availability and affordability of biofortified crops, particularly in rural areas. Increase funding for research to develop new biofortified crop varieties tailored to local preferences and agroecological conditions. Explore interdisciplinary approaches, including agronomic biofortification and nanofertilizers, to enhance nutrient density. By addressing these areas, Nigeria can leverage biofortification as a panacea to hidden hunger, improving health outcomes and fostering sustainable development.

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