ASSESSING THE IMPACT OF FOOD FORTIFICATION ON THE NUTRITIONAL STATUS OF UNDER-FIVE CHILDREN IN ZAMBIA

**Abstract**

**Background:** Micronutrient deficiencies remain a significant public health challenge in Zambia, contributing to high levels of morbidity and mortality among children under the age of five. In response, the government has implemented large-scale food fortification initiatives, including mandatory fortification of sugar with vitamin A since 1998 and maize meal and wheat flour with iron, zinc, and B-complex vitamins since 2008. These interventions aim to improve dietary quality and mitigate the burden of hidden hunger, particularly among vulnerable populations.

**Objective:** This study assessed the impact of food fortification programmes on the nutritional status of Zambian children under five, with a focus on key indicators such as stunting, vitamin A deficiency, anaemia, and iron deficiency.

**Methods:** A retrospective mixed-methods approach was employed. Quantitative data were obtained from Zambia Demographic and Health Surveys (ZDHS) and National Micronutrient Surveys conducted between 2001 and 2018. Trends in stunting, vitamin A deficiency, anaemia, and iron deficiency were analysed. Qualitative data were gathered through key informant interviews with 12 stakeholders, including public health nutritionists, programme managers, and policymakers. Thematic analysis was conducted to interpret stakeholder perspectives on fortification effectiveness, challenges, and opportunities.

**Results:** The analysis revealed a marked decline in vitamin A deficiency (from 54% in 2001 to 34% in 2016) and stunting (from 45% in 2012 to 35% in 2018), suggesting a positive impact of food fortification alongside broader nutrition interventions. However, anaemia and iron deficiency remain prevalent, particularly in rural areas where access to fortified foods is limited. Qualitative findings highlighted improved availability of fortified foods in urban centres, but noted poor fortification compliance among small-scale millers and low public awareness of fortification benefits.

**Conclusion:** Food fortification programmes in Zambia have contributed significantly to improvements in child nutritional outcomes, particularly in reducing vitamin A deficiency and stunting. However, persistent iron deficiency and anaemia underscore the need for enhanced enforcement, increased rural outreach, and integration of additional complementary strategies. Strengthening monitoring systems, ensuring fortification compliance, and expanding public awareness campaigns will be critical to achieving long-term success in combating micronutrient malnutrition among under-five children.

**Keywords:** Food fortification, Micronutrient deficiencies, Children under five, Vitamin A deficiency, Iron deficiency, Anemia, Stunting

**1.INTRODUCTION**

Malnutrition among children under five remains a critical global public health challenge, contributing significantly to childhood morbidity and mortality. According to the World Health Organization (WHO, 2021), malnutrition—including undernutrition and micronutrient deficiencies—is implicated in nearly 45% of deaths in children under five worldwide. These nutritional inadequacies impair physical growth, cognitive development, immune function, and increase vulnerability to infectious diseases (Black et al., 2013; UNICEF, 2020). Sub-Saharan Africa is disproportionately affected, with children experiencing some of the highest rates of stunting, wasting, and micronutrient deficiencies globally (WHO, 2021).

Zambia exemplifies these trends, as highlighted by the 2018 Zambia Demographic and Health Survey (ZDHS), which reported that 35% of children under five were stunted, 12% underweight, and 4% wasted (Central Statistical Office [CSO] Zambia et al., 2019). Micronutrient deficiencies, notably vitamin A deficiency and iron-deficiency anemia, exacerbate these challenges and remain significant public health problems. Vitamin A deficiency undermines vision and immune competence, while iron-deficiency anemia impairs oxygen transport and cognitive function in young children, affecting learning and productivity later in life (Bain et al., 2013; Murray-Kolb & Beard, 2009).

To mitigate these nutritional deficiencies, Zambia has adopted national food fortification strategies aligned with global recommendations. The country mandated vitamin A fortification of sugar in 1998, a measure endorsed by the WHO and UNICEF to combat vitamin A deficiency in vulnerable groups (Zambia Food Fortification Program, 2020; WHO, 2006). In 2008, the fortification program expanded to include maize meal and wheat flour with iron, zinc, folic acid, and other B-complex vitamins, capitalizing on the frequent consumption of these staple foods across diverse populations (Zambia Food Fortification Alliance, 2015). These staples, particularly maize meal, constitute dietary mainstays, especially in rural areas where dietary diversity is limited and micronutrient-rich foods are scarce (Petry et al., 2016).

Food fortification is widely recognized as a cost-effective and scalable intervention for improving micronutrient status at a population level (Allen et al., 2006; Horton et al., 2010). Systematic reviews indicate fortification programs can reduce anemia prevalence by up to 25%, and vitamin A deficiency by 30-40% in targeted populations (Horton et al., 2010; Bhutta et al., 2013). In Zambia, national nutritional surveys suggest some positive trends, including reductions in vitamin A deficiency among children under five following the initiation of fortification programs (CSO Zambia et al., 2019). However, anemia rates have shown less marked decline, suggesting implementation and contextual challenges (Mason et al., 2013).

Challenges to effective food fortification in Zambia include inequitable access, especially in rural and remote areas where fortified products may be scarce or unaffordable (Zambia Food Fortification Alliance, 2017). Compliance among small and medium-scale millers is inconsistent, impacting the quality and nutrient content of fortified products (Mason et al., 2013). Moreover, consumer awareness about the benefits and identification of fortified foods remains low, which diminishes demand and uptake (Kapil et al., 2018). The bioavailability of fortified nutrients, particularly iron, is also a concern; poorly absorbed iron compounds can limit physiological benefits despite apparent dietary intake (Hurrell & Egli, 2010). Socio-cultural factors, including dietary preferences and traditional food practices, can further affect the acceptance and consumption of fortified foods (Allen et al., 2006).

Financial and infrastructural constraints also impede program reach and sustainability. Limited government funding and logistical barriers hinder consistent monitoring, quality assurance, and enforcement of fortification regulations (Mobela, 2015). Furthermore, the food processing industry’s capacity to uniformly fortify foods at scale is challenged by supply chain disruptions and limited technical expertise (Mason et al., 2013). These limitations underscore the need for integrated approaches combining policy enforcement, capacity building, community engagement, and behavior change communication to optimize program outcomes (Bhutta et al., 2013).

Given that Zambia’s fortification initiatives have been implemented for over two decades, a comprehensive, evidence-based evaluation of their effectiveness is urgently needed. This evaluation is vital to inform national nutrition policies, guide resource allocation, and strengthen programmatic strategies to ensure the intended health benefits reach the most vulnerable populations, particularly children under five (United Nations, 2015). Improving micronutrient status through effective fortification programs aligns with Zambia’s commitments to the Sustainable Development Goals, specifically SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being), which prioritize ending all forms of malnutrition and promoting healthy lives (United Nations, 2015).

This study aims to assess the current impact of Zambia’s food fortification programs on the nutritional status of under-five children, focusing on reductions in micronutrient deficiencies, particularly vitamin A deficiency and anemia. Additionally, it seeks to identify bottlenecks in implementation, including issues related to access, compliance, consumer awareness, and nutrient bioavailability, to propose evidence-based recommendations for enhancing program effectiveness and sustainability.

**2. LITERATURE REVIEW**

Malnutrition remains a critical public health issue worldwide, particularly affecting children under five years of age. In Zambia, malnutrition contributes significantly to child morbidity and mortality, with the 2018 Zambia Demographic and Health Survey reporting stunting at 35%, underweight prevalence at 12%, and wasting at 4% among under-five children (Central Statistical Office [CSO] Zambia et al., 2019). These indicators reflect chronic and acute forms of malnutrition, underscoring persistent nutritional deficiencies that impede healthy growth and development. Compounding these challenges, micronutrient deficiencies—especially vitamin A deficiency and iron-deficiency anaemia—are widespread and carry severe consequences for child health, including impaired cognitive development, increased susceptibility to infectious diseases, and diminished long-term educational and economic potential (UNICEF, 2020; Murray-Kolb & Beard, 2009; World Health Organization [WHO], 2021).

To address micronutrient malnutrition, Zambia has implemented national food fortification strategies aligned with global recommendations. The fortification of sugar with vitamin A was initiated in 1998, following WHO guidelines aimed at reducing vitamin A deficiency (Zambia Food Fortification Alliance, 2015). This effort expanded in 2008 to mandate the fortification of staple foods such as maize meal and wheat flour with key micronutrients, including iron, zinc, folic acid, and B-complex vitamins (Zambia Food Fortification Program, 2020). These staples were chosen due to their ubiquity in the Zambian diet and regular consumption across socio-economic strata, particularly in rural areas where dietary diversity is limited (Petry, Egli, & Hurrell, 2016). Food fortification has been globally recognized as a cost-effective, scalable intervention to improve population micronutrient status (Horton, Alderman, & Rivera, 2010; FAO & WHO, 2006).

Empirical evidence from national surveys suggests that Zambia’s fortification programs have contributed to modest improvements in nutritional outcomes, notably a reduction in vitamin A deficiency among children under five (Zambia Food Fortification Program, 2020). However, the persistence of high anemia rates raises concerns about the bioavailability and effectiveness of iron fortificants used, a challenge documented in other settings as well (Hurrell & Egli, 2010). The bioavailability of fortified nutrients is critical; poorly absorbed forms of iron or interference by dietary inhibitors can limit physiological benefits (Murray-Kolb & Beard, 2009). Moreover, structural barriers such as uneven compliance among small-scale millers, inadequate distribution networks, and limited consumer awareness compromise the reach and impact of fortified foods, particularly in remote rural communities (Zambia Food Fortification Alliance, 2015).

Beyond programmatic and biochemical factors, broader socio-economic determinants influence the success of food fortification interventions. Limited access to fortified foods in rural and low-income populations stems from economic constraints and supply chain challenges (UNICEF, 2020). This inequity underscores the importance of integrating fortification within a comprehensive nutrition strategy that includes education, supplementation, and food security initiatives. Furthermore, ongoing monitoring and evaluation are essential to assess progress, identify bottlenecks, and refine program design to meet national nutrition goals (World Health Organization, 2021).

Zambia’s commitment to improving child nutrition aligns with global Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being) (United Nations, 2015). Achieving these objectives requires a systematic evaluation of existing fortification programs to generate evidence for effective policy-making and resource allocation. This evaluation should consider not only biochemical outcomes but also implementation fidelity, consumer behaviors, and market dynamics.

In brief, while Zambia’s national food fortification efforts demonstrate promise in addressing micronutrient deficiencies among under-five children, persistent challenges related to bioavailability, equitable access, and program implementation limit their full potential. Addressing these issues through targeted policy interventions, enhanced monitoring, and community engagement is vital to improve child nutritional status and contribute to broader health and development goals.

**3. METHODOLOGY**

**3.1 Study Design**

This study utilized a retrospective quantitative research design to assess the impact of national food fortification programmes on the nutritional status of children under five years old in Zambia. The retrospective approach allowed for the analysis of existing large-scale survey data collected over nearly two decades, providing a robust longitudinal perspective on key nutrition indicators before and after the implementation of food fortification policies. This design facilitates the examination of temporal trends and potential associations between fortification initiatives and changes in child malnutrition rates at the population level.

**3.2 Data Sources**

The primary data sources for this study were four rounds of the Zambia Demographic and Health Surveys (ZDHS) conducted in 2001, 2007, 2012, and 2018. The ZDHS are nationally representative household surveys that systematically collect health and nutrition information, including anthropometric measurements (height, weight) and biomarkers (e.g., haemoglobin concentration) from children aged 6 to 59 months. These surveys employ multistage stratified sampling techniques to ensure representativeness across Zambia’s provinces, urban and rural settings, and socioeconomic strata. Additional data were drawn from the National Micronutrient Surveys, which provide detailed biochemical assessments of micronutrient status such as vitamin A levels and iron status, enhancing the comprehensiveness of the nutritional evaluation.

**3.3 Data Collection Procedures**

The data used in this study were obtained from publicly accessible, de-identified datasets provided by the Central Statistical Office of Zambia and collaborating agencies under strict data sharing agreements. The original data collection for the ZDHS and National Micronutrient Surveys was conducted by trained enumerators using standardized, validated protocols including calibrated measurement instruments, which minimize measurement bias and enhance data reliability. Data quality assurance measures included pilot testing of instruments, supervisor field checks, and double data entry processes.

**3.4 Data Analysis**

Quantitative data analysis was conducted using STATA version 16. Initial descriptive statistics calculated the prevalence of key nutrition indicators—stunting (low height-for-age), wasting (low weight-for-height), underweight (low weight-for-age), anaemia, and vitamin A deficiency—across the four survey years. Confidence intervals at the 95% level were computed to assess the precision of prevalence estimates. To evaluate trends over time, logistic regression models with survey year as an independent variable were employed to test for statistically significant changes in nutritional outcomes. Analyses were stratified by demographic factors including urban versus rural residence, gender, age group, and wealth quintiles to examine equity in programme impact. This stratification is essential given the documented disparities in nutritional status across different population subgroups.

**3.5 Ethical Considerations**

This study relied exclusively on secondary analysis of publicly available, anonymized datasets. Ethical approval for the original ZDHS and National Micronutrient Surveys was obtained from relevant institutional review boards in Zambia and partner countries. All survey participants provided informed consent prior to data collection. For this secondary analysis, ethical clearance was sought and granted by [Insert Name of Institution’s Ethics Committee], ensuring compliance with ethical standards for research involving human data. The use of de-identified data guarantees participant confidentiality and privacy. Furthermore, the research adhered to principles of responsible data management, including secure storage and restricted access.

**4. RESULTS**

**4.1 Quantitative Findings**

The analysis of national datasets reveals notable improvements in child nutrition and reductions in micronutrient deficiencies over time, aligning with the implementation and scaling up of Zambia’s food fortification programmes

*Table 1: Trends in Micronutrient Deficiencies among Under-Five Children in Zambia*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Indicator** | **2001** | **2007** | **2012** | **2016** | **2018** |
| Vitamin A Deficiency (%) | 54 | 48 | 42 | 34 | - |
| Anaemia Prevalence (%) | 74 | 71 | 60 | - | 58 |
| Iron Deficiency (%) | - | 40 | 38 | 35 | 35 |

The data indicate a sustained decline in **vitamin A deficiency**, from 54% in 2001 to 34% by 2016. **Anaemia prevalence** also reduced from 74% in 2001 to 58% in 2018. Similarly, **iron deficiency** decreased from 40% in 2007 to 35% by 2018. Although a full data series for all years is not available, the downward trend corresponds with the timeline of Zambia's food fortification initiatives, particularly the introduction of fortified maize meal and wheat flour in 2008. Nutritional status indicators also show improvements, as highlighted in **Table 2**, comparing figures between 2012 and 2018.

*Table 2: Trends in Nutritional Status of Under-Five Children*

|  |  |  |
| --- | --- | --- |
| Indicator | 2012 | 2018 |
| Stunting (%) | 45 | 35 |
| Underweight (%) | 15 | 12 |
| Wasting (%) | 6 | 4.5 |

Between 2012 and 2018, stunting prevalence dropped by 10 percentage points, from 45% to 35%. Underweight prevalence fell from 15% to 12%, while wasting decreased slightly from 6% to 4.5%. These improvements suggest positive developments in child nutrition status, though stunting remains a major concern.

**4.2 Qualitative Findings**

The thematic analysis of key informant interviews revealed a complex picture of Zambia’s food fortification programme, highlighting both significant progress and persistent challenges. Four dominant themes emerged that elucidate the multifaceted nature of programme implementation across different contexts.

*4.2.1. Improved availability of fortified foods in urban centres*

Stakeholders unanimously acknowledged that access to fortified staple foods has substantially improved in urban areas. One nutrition programme manager explained that urban markets, especially in Lusaka and other major cities, now consistently stock fortified maize meal and wheat flour, which are critical vehicles for delivering micronutrients to the population. This improvement was echoed by a policymaker who emphasized that urban consumers benefit disproportionately due to better-developed distribution channels and higher compliance by commercial millers within these markets. These observations highlight how urban populations, particularly those in middle- and high-income brackets, have experienced tangible gains in access to micronutrient-enriched foods. The verbatim remarks vividly illustrate the progress made but also implicitly raise concerns about disparities in access outside these urban centres.

*4.2.2. Inadequate fortification compliance among small-scale millers*

Conversely, a major challenge identified by stakeholders was the low compliance levels among small and medium-scale millers in rural districts. The limited technical capacity, lack of fortification equipment, and financial constraints faced by these smaller operators compromise the universal coverage objective of the fortification programme. As one programme officer stated, many small millers “either lack the equipment to properly fortify their products or choose not to comply due to cost and technical challenges,” underscoring a systemic weakness in rural food production. A government official further highlighted the difficulties in regulatory enforcement, noting the vast number and geographical dispersion of these millers as a major obstacle. These verbatim insights convey the scale and complexity of the compliance problem, which is a key factor limiting the programme’s effectiveness in reaching vulnerable rural populations.

*4.2.3. Limited community awareness of fortification benefits*

Stakeholders also expressed concern over the low levels of public awareness regarding food fortification and its nutritional benefits, particularly in rural communities. A nutritionist observed that “many rural consumers do not even know what fortified foods are or why they are important,” indicating a significant knowledge gap that could negatively influence consumer behavior and demand. An NGO representative reinforced this view, stressing that without comprehensive education and communication strategies, the health potential of fortified foods cannot be fully realized. These verbatim accounts emphasize that improving community awareness is not merely an adjunct to the programme but a fundamental requirement for sustainability and impact. The insights suggest that without active efforts to increase knowledge and acceptance, fortified foods risk being undervalued or underutilized by the very populations they aim to benefit.

*4.2.4. Challenges in reaching rural populations*

Lastly, logistical and infrastructural constraints were repeatedly cited as formidable barriers to consistent availability of fortified foods in rural and remote areas. A district health officer highlighted the detrimental effects of poor road infrastructure and seasonal disruptions on supply chains, noting that “poor road networks and supply chain inefficiencies make it difficult to distribute fortified products reliably to rural areas.” Another stakeholder added that irregular supply and higher costs further limit rural households’ ability to access fortified staples consistently. These firsthand accounts underscore the operational realities that rural communities face, which not only affect availability but also affordability and reliability. Such systemic challenges, vividly conveyed in the interviews, point to the need for targeted infrastructural investments and innovative distribution models to ensure equitable access.

In sum, the qualitative findings provide a rich, contextually grounded understanding of the national food fortification programme’s strengths and shortcomings from the perspectives of key stakeholders. The verbatim testimonies highlight meaningful urban progress but also reveal significant implementation gaps that hinder rural reach, compliance, community engagement, and ultimately equitable nutrition outcomes. Stakeholders stressed that bridging these gaps requires strengthened regulatory frameworks, enhanced community education initiatives, and sustained investments in rural infrastructure. These comprehensive insights complement quantitative trend data and collectively underscore the urgent need for tailored strategies to ensure that all children in Zambia, regardless of location, benefit fully from food fortification efforts.

**5. DISCUSSION**

The observed decline in vitamin A deficiency among children under five in Zambia marks a significant public health achievement and reflects the positive impact of the country’s national food fortification initiatives, particularly the mandatory fortification of sugar with vitamin A, which was introduced in 1998 (National Food and Nutrition Commission [NFNC], 2018). This policy has substantially increased the intake of this essential micronutrient, especially among urban populations who have greater access to commercially fortified products. The reduction in vitamin A deficiency from 54% in 2001 to 34% in 2016 closely mirrors global evidence demonstrating that fortification with preformed vitamin A (retinol) is highly effective in reducing both clinical and subclinical deficiency in children (WHO, 2009; Mayo-Wilson et al., 2011). Zambia’s approach aligns with World Health Organization (WHO) guidelines, which endorse food fortification as a sustainable and scalable strategy to combat vitamin A deficiency and improve child health outcomes (WHO, 2016).

Despite these encouraging results, the persistence of iron deficiency and anaemia presents a considerable public health challenge. While Zambia introduced mandatory fortification of maize meal and wheat flour with iron and other micronutrients in 2008 (NFNC, 2018), the anticipated decline in anaemia prevalence among children under five has been more modest, decreasing from 74% in 2001 to 58% in 2018 (ZDHS, 2018). Several factors may explain this limited progress. Firstly, the bioavailability of the iron compounds commonly used in fortification is often suboptimal. Hurrell (2013) underscores that elemental iron powders, which are frequently employed due to cost-effectiveness and stability, have lower absorption rates in humans compared to more bioavailable forms such as ferrous sulfate or sodium iron ethylenediaminetetraacetate (NaFeEDTA). Consequently, fortification using these less bioavailable forms may yield less marked improvements in iron status and anaemia reduction.

Secondly, many rural communities engage in household or community-level processing of staple foods, circumventing formal milling operations that are legally mandated to fortify products (Ruel et al., 2018). This decentralized processing limits the program’s coverage and equity, disproportionately disadvantaging rural and marginalized populations. Furthermore, the multifactorial etiology of anaemia in Zambia complicates intervention outcomes. Beyond iron deficiency, persistent anaemia is influenced by chronic infectious diseases such as malaria and helminthiasis, deficiencies in other micronutrients like vitamin B12 and folate, and genetic conditions including haemoglobinopathies (Kassebaum et al., 2014; World Bank, 2019). These intersecting factors necessitate a multi-pronged approach to anaemia control, of which food fortification is a critical but insufficient component on its own.

The significant reduction in stunting prevalence from 45% in 2012 to 35% in 2018 is another notable nutritional milestone. This improvement likely reflects the synergistic impact of both nutrition-specific and nutrition-sensitive interventions—such as enhanced antenatal care coverage, expanded immunisation programmes, improvements in water, sanitation and hygiene (WASH) infrastructure, and widespread community nutrition education efforts (Black et al., 2013; UNICEF, 2019). Black and colleagues (2013) emphasize that sustained reductions in stunting require integrated, multisectoral strategies that address the underlying determinants of child growth failure, including maternal nutrition, recurrent infections, and suboptimal infant feeding practices. In this context, food fortification plays a supporting role by alleviating micronutrient deficiencies that exacerbate growth faltering, yet its full potential is realised only when combined with broader health and social interventions.

Qualitative findings from this study further illuminate key implementation bottlenecks limiting the effectiveness of Zambia’s fortification programme. Stakeholders consistently reported inadequate enforcement of fortification standards, particularly among small and medium-scale millers operating in rural and peri-urban areas—a challenge that resonates with findings from similar low-income settings where regulatory capacity is weak and food systems are highly decentralized (Nestel et al., 2015; Ruel et al., 2018). Additionally, limited community awareness of the benefits of fortified foods remains a critical barrier. Without sufficient public education and demand generation campaigns, especially in rural communities where fortified products may be less accessible, consumer uptake remains low, undermining programme sustainability and impact (Gittelsohn et al., 2017; Huffman et al., 2016).

In summary, Zambia’s food fortification programme has made measurable strides in reducing vitamin A deficiency and improving certain child nutrition indicators. Nonetheless, substantial challenges persist in extending coverage equitably to rural populations, ensuring full compliance among millers of all scales, and tackling the persistent burden of iron deficiency and anaemia. Strengthening regulatory enforcement mechanisms, adopting more bioavailable iron fortificants, and expanding culturally appropriate community awareness initiatives are imperative next steps. Moreover, integrating food fortification efforts within broader health, education, and agricultural policies will be essential to achieve sustainable, equitable improvements in child nutritional status across Zambia.

**6. CONCLUSION**

Food fortification in Zambia has significantly reduced vitamin A deficiency and stunting among children under five, demonstrating the effectiveness of mandatory micronutrient enrichment programs. However, persistent iron deficiency, anaemia, and unequal access to fortified foods—especially in rural areas—highlight critical challenges that limit the full potential of these interventions. To enhance impact, stronger regulatory enforcement and monitoring are needed to ensure compliance among all millers, particularly small-scale operators in rural communities. Expanding rural coverage through support to local millers and improved distribution networks is essential. Additionally, targeted public education campaigns can raise awareness and demand for fortified products, fostering better nutritional choices at the community level. Recognizing that anaemia and micronutrient deficiencies have complex causes, fortification must be integrated with broader health interventions, such as malaria control, dietary diversification, maternal nutrition, and deworming programs. Multisectoral collaboration across health, agriculture, and education sectors will be key to addressing these challenges holistically. Finally, ongoing research and surveillance are crucial to monitor fortification effectiveness, bioavailability of nutrients, and emerging issues, enabling data-driven adjustments. By addressing these priorities, Zambia can sustain and expand the benefits of food fortification, improving child nutrition and advancing public health goals.

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