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Assessing the Role of Micronutrient Fortification in Reducing Anemia Rates in Nigeria: A Review

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ABSTRACT

Anemia remains a major public-health burden in Nigeria, especially among children under five and women of reproductive age. Large-scale food fortification (LSFF), adding iron and other micronutrients to widely consumed staples and condiments, is recommended by WHO as a cost-effective population intervention to prevent and reduce micronutrient deficiencies, including iron deficiency anemia. Nigeria has enacted mandatory and voluntary fortification policies for staples (wheat and maize flour) and other vehicles, but program impact has been uneven due to low coverage of fortified products, compliance gaps, variable bioavailability of iron compounds used, dietary inhibitors, infection burden (notably malaria and helminths), and monitoring constraints. A growing body of evidence from efficacy trials, program evaluations, and reviews shows that appropriately designed fortification (correct iron compound, sufficient fortification level, high coverage, and robust monitoring) can raise iron stores and hemoglobin in target populations; however, real-world effectiveness depends on implementation quality. This review synthesizes current evidence from national surveillance, program assessments, trials conducted in Nigeria and the region, and international guidance, identifies key barriers and enabling factors, and proposes programmatic and research priorities to maximize LSFF's contribution to anemia reduction in Nigeria.

Keywords: Micronutrient fortification, anemia reduction, iron deficiency, large-scale food fortification (LSFF), Nigeria.

INTRODUCTION

Anemia, defined as a condition characterized by a reduced concentration of hemoglobin in the blood, represents a significant public health challenge worldwide, particularly in low- and middle-income countries. Hemoglobin, a crucial protein in red blood cells, is responsible for transporting oxygen from the lungs to tissues throughout the body. Reduced hemoglobin levels impair the body's capacity to deliver oxygen efficiently, leading to a variety of health consequences [1-5]. In children, anemia contributes to cognitive deficits, impaired physical development, and reduced school performance, which can have long-term effects on educational attainment and human capital development. Among women of reproductive age, anemia increases the risk of maternal morbidity and mortality and is associated with adverse perinatal outcomes, including preterm birth, low birth weight, and neonatal mortality. The multifaceted impact of anemia underscores its relevance not only as a health concern but also as a broader socio-economic issue [6-9].

In Nigeria, the burden of anemia remains persistently high despite numerous public health interventions. National surveys, including the Nigeria Demographic and Health Surveys (DHS), indicate that over 60% of children under five and more than 40% of women of reproductive age are affected by some degree of anemia. Spatial analyses further reveal that anemia prevalence varies significantly across regions, often reflecting disparities in dietary intake, socio-economic status, and access to health services [10-14]. These trends highlight the urgent need for effective, scalable, and sustainable strategies to mitigate anemia, particularly among vulnerable populations. The persistence of high anemia prevalence despite ongoing interventions points to the complex interplay of nutritional, infectious, and socio-economic determinants that influence iron status and hemoglobin levels [15-20].

Iron deficiency is recognized as the leading cause of anemia globally, accounting for approximately 50% of all cases. In Nigeria, dietary inadequacies, particularly low consumption of iron-rich foods and inhibitors of iron absorption, contribute significantly to the high anemia burden. Other factors, such as malaria, parasitic infections (including hookworm), and chronic illnesses, exacerbate the condition, creating a multifactorial challenge for health authorities [21-26]. Given the scale of the problem, population-level interventions that can reach large segments of the population are considered essential. Among these, large-scale food fortification (LSFF) has emerged as a recommended strategy by international organizations, including the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). LSFF involves the systematic addition of essential micronutrients, including iron, to commonly consumed staple foods, such as wheat flour, maize meal, salt, and sugar, to improve population-level micronutrient intake without requiring major behavioral changes [27-32].

Despite the theoretical promise of LSFF, its implementation in Nigeria faces numerous challenges. Policies for micronutrient fortification have been established over the past two decades, but compliance and monitoring remain inconsistent. Variability in fortification levels, differences in production quality among food manufacturers, and limited public awareness of fortified products have been cited as key barriers. Moreover, empirical evidence on the effectiveness of LSFF in reducing anemia in Nigerian populations is still evolving, with some studies reporting modest reductions in anemia prevalence and others showing limited impact [33-37]. These findings suggest the need for a comprehensive assessment that synthesizes existing data, identifies gaps in implementation and research, and informs policy refinements to optimize the impact of fortification programs.

Anemia remains a critical public health issue in Nigeria, severely impacting health outcomes, education, and economic productivity. Despite the implementation of various interventions, the prevalence of anemia among children under five and women of reproductive age remains alarmingly high [39-43]. This ongoing challenge is driven by several factors, including poor dietary diversity, the prevalence of infectious diseases, and socio-economic barriers. Micronutrient deficiencies, particularly iron, are central contributors to anemia, and large-scale food fortification (LSFF) has been globally recognized as an effective strategy to address these deficiencies. However, there is limited evidence on the effectiveness of food fortification programs in Nigeria, particularly regarding their coverage, quality, and impact. The absence of a clear, consolidated understanding of these factors limits the potential for fortification programs to achieve substantial reductions in anemia rates. This review seeks to assess the burden of anemia in Nigeria, evaluate the policies and strategies governing food fortification, and critically examine the available evidence on its impact [44-48]. Additionally, it aims to identify the challenges hindering the successful implementation of fortification programs, including regulatory, operational, and socio-economic factors. The study will also highlight research gaps and propose policy recommendations to enhance the design, coverage, and impact of food fortification efforts, ultimately contributing to improved health outcomes and socio-economic development in Nigeria.

METHODOLOGY

This narrative review synthesizes a broad range of sources, including peer-reviewed articles, systematic reviews, international guidelines, and grey literature (such as program reports and national policy documents) up to 2025. To ensure a comprehensive and relevant selection of data, I conducted extensive electronic searches in PubMed/PMC, WHO databases, and program-specific repositories, with a focused effort on Nigeria-specific evaluations like GAIN (Global Alliance for Improved Nutrition) and reports from the Federal Ministry of Health. The review process was guided by several key priorities: (1) national surveys and spatial analyses that offer insight into the prevalence and distribution of anemia; (2) systematic reviews and meta-analyses examining the effectiveness of food fortification strategies, particularly in low-resource settings; (3) randomized controlled trials or program evaluations from Nigeria and surrounding regions, to capture context-specific findings; and (4) reports detailing national policies, fortification compliance, and their practical implementation. Emphasis was placed on recent program evaluations and reports due to their direct relevance in assessing the quality of implementation, which plays a pivotal role in determining the success of large-scale food fortification (LSFF) interventions. Throughout the review, representative sources are cited to substantiate findings and provide a balanced overview of the existing evidence.

Current burden and drivers of anemia in Nigeria

Anemia remains a significant public health issue in Nigeria, particularly among children under five and women of reproductive age. National survey data reveals a concerning prevalence of anemia in children, often exceeding 60–67%, with substantial rates also found among women, reflecting a widespread health burden [49-55]. The distribution of anemia shows notable geographic variation, with differences between urban and rural areas, indicating the influence of local socio-economic and environmental factors. The drivers of anemia in Nigeria are multi-faceted, including nutritional deficiencies, particularly iron, folate, and vitamin A, which are critical for the development of healthy red blood cells. In addition, infectious diseases like malaria, intestinal parasites, and chronic infections contribute to the high anemia rates by disrupting normal blood cell production and increasing iron

depletion [56-60]. Hemoglobinopathies, such as sickle cell disease, also exacerbate the situation by leading to the breakdown of red blood cells. Furthermore, socio-economic determinants, such as poverty, limited access to healthcare, and poor dietary practices, play a significant role in shaping individuals' vulnerability to anemia. These proximate and distal factors underscore the complexity of anemia in Nigeria, highlighting the need for comprehensive interventions that go beyond simply addressing dietary iron deficiencies to include improved healthcare access and the management of underlying diseases [61-64].

Fortification policies and implementation in Nigeria

Fortification policies and their implementation in Nigeria have aimed to improve public health by enhancing the nutritional value of commonly consumed foods, such as wheat and maize flours, sugar, vegetable oil, and salt (iodization). These efforts are largely driven by mandatory standards for fortification, especially for products like wheat flour [11, 65-67]. While large producers often claim to comply with these regulations, recent assessments reveal significant gaps in compliance. Factors such as fragmented supply chains, limited laboratory testing capacity, and poor consumption of fortified foods in certain populations have hindered the success of these initiatives. As a result, the intended population-level impact has not been fully realized. National guidelines acknowledge that fortified products may only reach a fraction of the population, particularly in specific states, and that fortification alone has been insufficient to address widespread health issues like anemia. Despite the government's efforts, more targeted and comprehensive measures are required to bridge these gaps, ensuring that fortified foods reach the intended beneficiaries and improve overall public health outcomes [12]. This challenge underscores the need for stronger enforcement, improved infrastructure, and greater consumer education to make fortification programs more effective and impactful in Nigeria.

Evidence on effectiveness: what do trials and reviews say?

Evidence from trials and systematic reviews highlights the potential effectiveness of large-scale flour fortification (LSFF) programs in improving iron status biomarkers, such as ferritin, and, in some cases, increasing hemoglobin levels and reducing anemia prevalence. The success of fortification largely depends on the type of iron compounds used, with bioavailable forms proving more effective [13]. Regular consumption of fortified foods is also a key factor in these positive outcomes. However, while the biochemical indicators of iron status show consistent improvement, the evidence on anemia reduction remains more mixed. The variability in results can be attributed to several factors, including the baseline prevalence of iron deficiency, local dietary patterns, infection burdens, and the quality of the fortification programs. Furthermore, reviews emphasize that fortification efforts are more effective when integrated into broader public health strategies, such as deworming, malaria control, and targeted supplementation. In Nigeria, randomized trials and program evaluations have demonstrated that fortified products, like dairy-based drinks and flours, can increase hemoglobin levels and reduce anemia in specific vulnerable populations, particularly when supervised consumption and adequate dosing are ensured [14]. However, national evaluations indicate that the scale-up of fortification programs has not yet led to significant reductions in national anemia prevalence. This is due to factors like low market penetration, inconsistent compliance, and challenges related to the bioavailability of the iron used.

Implementation challenges that limit impact in Nigeria

In Nigeria, several interrelated barriers limit the effectiveness of fortification programs in reducing anemia at scale. One significant challenge is the coverage and consumption patterns of fortified foods, as fortification only benefits individuals who consume adequate amounts of the fortified vehicle. In rural areas, where home milling and informal markets dominate, industrially fortified products may not reach many households [15]. Additionally, weak regulatory enforcement, a lack of routine testing capacity, and cost pressures often result in under-fortification or inconsistent fortification practices by producers. This has been repeatedly highlighted in program reviews. Another issue is the choice of fortificant and its bioavailability; certain iron compounds, such as elemental iron powders or ferrous sulfate, may not be well absorbed in diets rich in phytates, reducing their effectiveness. Some alternative compounds, such as NaFeEDTA, have shown stronger effects in trials. Moreover, high malaria and helminth burdens in Nigeria can negatively impact hemoglobin levels, independent of iron intake, while inflammation can distort iron biomarkers, making it difficult to measure fortification's impact. Lastly, the lack of effective monitoring and surveillance systems hampers timely corrections and accountability, further limiting the success of fortification programs [16].

Programmatic enablers and best practices

Several programmatic enablers and best practices have been identified to enhance the effectiveness of Large-Scale Food Fortification (LSFF) in reducing anemia. First, selecting appropriate vehicles is crucial; foods widely consumed by the target population, considering both rural and urban diets, ensure broad reach and impact. Secondly, the use of bioavailable iron compounds is essential, especially in regions where diets are high in inhibitors such as phytates. In such cases, compounds like NaFeEDTA or encapsulated ferrous salts may improve absorption and outcomes. Third, the establishment of mandatory standards and strict enforcement of compliance can significantly strengthen

fortification programs. Clear national standards, regular industry audits, and accessible quality control testing ensure market adherence, with multi-stakeholder approaches, including government, industry, and donors, helping sustain these efforts [17]. Additionally, integrating fortification with other health interventions, such as malaria control, deworming, and targeted supplementation for high-risk groups like pregnant women, addresses multiple anemia drivers simultaneously. Lastly, robust monitoring and impact evaluation are key to assessing progress. Routine fortification level monitoring, dietary intake surveys, and biomarker evaluations allow for ongoing assessment and inform necessary adjustments to improve effectiveness.

Research and data gaps relevant to Nigeria

In Nigeria, optimizing fortification as a strategy for anemia reduction requires bridging several research and data gaps to ensure its effectiveness across diverse populations. First, there is a need for nationally representative impact evaluations that link fortification coverage and iron dosing to observable changes in hemoglobin and iron status across different age groups. Such studies would provide a clearer understanding of fortification's actual impact. Additionally, operational research is crucial to determine effective ways to extend fortification efforts to populations that rely on informal or home-milled staples. Innovations such as point-of-use fortification or community-level consolidation could help address these gaps by ensuring that fortification reaches even the most remote or underserved groups. Comparative effectiveness studies are also essential to evaluate the performance of various iron compounds and formulations in the context of Nigeria's specific dietary patterns and high infection rates, as these factors can influence the bioavailability and absorption of iron [18]. Finally, conducting cost-effectiveness analyses that compare fortification with supplementation and integrated intervention packages is important for identifying the most efficient strategy for anemia reduction, tailored to Nigeria's regional epidemiology and economic realities. Such research is critical to developing evidence-based policies for anemia control.

Policy implications and recommendations for Nigeria

Policy implications and recommendations for Nigeria's nutrition strategy focus on strengthening the regulatory framework, enhancing food fortification, and targeting vulnerable populations. First, regulatory capacity must be prioritized by improving the infrastructure of laboratories and training inspectors. Additionally, creating incentives for industry compliance, such as offering technical support or subsidies for premixes, would ensure better industry participation in fortification efforts (GAIN) [19]. Second, fortification vehicles should be tailored to local dietary needs. This includes expanding or diversifying the fortification vehicles (e.g., maize, wheat, or rice) and using bioavailable iron forms in diets high in phytates, which are common in Nigeria (ScienceDirect). Third, fortification must be integrated into a broader health package, incorporating malaria control, deworming, antenatal iron/folic acid supplements, and behavioral interventions to enhance dietary diversity (World Health Organization). Furthermore, monitoring and transparency should be enhanced by publishing regular compliance and coverage reports, alongside conducting sentinel biomarker surveys to track the impact and address disparities in coverage (GAIN). Finally, complementary approaches like community-level fortification, home fortification (micronutrient powders), or targeted supplementation are essential to reach populations that are not covered by industrial fortification (CDC Stacks) [20].

CONCLUSION

Micronutrient fortification holds considerable promise as an effective public health strategy to reduce anemia rates in Nigeria. Despite its theoretical benefits, the impact of large-scale food fortification (LSFF) has been hindered by challenges such as incomplete coverage, non-compliance, and the choice of fortificant, particularly in regions with high levels of dietary inhibitors and infectious diseases like malaria. While evidence from trials and evaluations supports the effectiveness of fortification in improving iron status, achieving substantial reductions in anemia requires robust program implementation. To maximize LSFF's impact, efforts should focus on using bioavailable iron compounds, ensuring widespread access to fortified foods, and integrating fortification with broader public health strategies. Additionally, strengthening monitoring, regulatory enforcement, and targeting vulnerable populations through tailored interventions are crucial to overcoming the current barriers. Ongoing research is needed to address data gaps and refine fortification efforts, ensuring long-term success in reducing anemia across Nigeria.

REFRENCES

1.Chaparro, C.M., Suchdev, P.S.: Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. Ann N Y Acad Sci. 1450, 15–31 (2019). https://doi.org/10.1111/nyas.14092

2.Bamboro, S.A., Boba, H.I., Geberetsadik, M.K., Gebru, Z., Gutema, B.T.: Prevalence of anemia and its associated factors among under-five children living in Arba Minch Health and Demographic Surveillance System Sites (HDSS), Southern Ethiopia. PLOS Glob Public Health. 4, e0003830 (2024). https://doi.org/10.1371/journal.pgph.0003830

3.Ogunsakin, R.E., Babalola, B.T., Akinyemi, O.: Statistical Modeling of Determinants of Anemia Prevalence among Children Aged 6–59 Months in Nigeria: A Cross-Sectional Study. Anemia. 2020, 4891965 (2020). https://doi.org/10.1155/2020/4891965

4.Ahmad A, Mihalca D, Stacey B, Samaee S, Mehta D, Hibbs S, et al (2022). Rate of dental extractions in patients with sickle cell disease. *Journal of Clinical Medicine, 11, (20), 6174. https://doi.org/10.3390/jcm11206174.*

5.Soni, R., Verma, D., Chopra, R., Singh, V., Goswami, D.: Demystifying intricate factors of nutritional anemia beyond iron deficiency–A narrative review. Clinical Nutrition ESPEN. 69, 745–764 (2025). https://doi.org/10.1016/j.clnesp.2025.08.034

6.Food fortification, https://www.who.int/health-topics/food-fortification#tab=tab_1

7.Lalani, B., Hassan, R., Bennett, B.: Examining Heterogeneity of Food Fortification and Biofortification Business Models: Emerging Evidence for a Typology.

8.Udeozor P A, Precious A U, Ibiam U A, Uti D E, Umoru G U, Onwe E N, et al. (2022).. Antioxidant and anti-anemic effects of ethanol leaf extracts of Mucuna poggei and Telfairia occidentalis in phenyl-hydrazine-induced anemia in Wistar albino rats. Ibnosina Journal of Medicine and Biomedical Sciences, 2022. 14(03): p. 116-126.

9.Armah-Ansah, E.K., Budu, E., Oga-Omenka, C. *et al.* Trends and factors associated with anemia among women of reproductive age in Mali: analysis of data from 2001 to 2018 Mali demographic and health surveys. *Arch Public Health* **83**, 201 (2025). https://doi.org/10.1186/s13690-025-01637-w

10. Khan, H., Krull, M., Hankins, J.S., Wang, W.C., Porter, J.S.: Sickle Cell Disease and Social Determinants of Health – A Scoping Review. Pediatr Blood Cancer. 70, e30089 (2023). https://doi.org/10.1002/pbc.30089

11. Friesen, V.M., Mbuya, M.N., Wieringa, F.T., Nelson, C.N., Ojo, M., Neufeld, L.M.: Decisions to Start, Strengthen, and Sustain Food Fortification Programs: An Application of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Evidence to Decision (EtD) Framework in Nigeria. Current Developments in Nutrition. 6, nzac010 (2022). https://doi.org/10.1093/cdn/nzac010

12. Mkambula, P., Mbuya, M.N.N., Rowe, L.A., Sablah, M., Friesen, V.M., Chadha, M., et al: The Unfinished Agenda for Food Fortification in Low- and Middle-Income Countries: Quantifying Progress, Gaps and Potential Opportunities. Nutrients. 12, 354 (2020). https://doi.org/10.3390/nu12020354

13. Egba S. I Obeagu E I, Obeagu G U, (2023) Coexisting Conditions: Addressing Diabetes in Sickle Cell Anemia Care Int. J. Curr. Res. Med. Sci. (2023). 9(11): 23-28

14. Suchdev, P.S., Jefferds, M.E.D., Ota, E., da Silva Lopes, K., De-Regil, L.M.: Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age. Cochrane Database Syst Rev. 2020, CD008959 (2020). https://doi.org/10.1002/14651858.CD008959.pub3

15. Igwe, M. C., Alum, E. U. Obeagu, E. I., Obeagu, G. U., Ugwu, O. P. C. Men's Essential roles in the Management of Sickle Cell Anemia. Newport International Journal of Scientific and Experimental Sciences. 2023; 4(2):20-29. https://doi.org/10.59298/NIJSES/2023/10.3.1111

16. Castberg, F.C., Sarbah, E.W., Koram, K.A., Opoku, N., Ofori, M.F., Styrishave, B., et al.: Malaria causes long-term effects on markers of iron status in children: a critical assessment of existing clinical and epidemiological tools. Malaria Journal. 17, 464 (2018). https://doi.org/10.1186/s12936-018-2609-6

17. Alum, E. U., Obeagu, E. I., Obeagu, G. U., Ugwu, O. P. C. Anemia as a Prognostic Marker for Disease Progression in HIV Infection. *IAA Journal of Biological Sciences.* 2023; 11(1):33-44.https://doi.org/10.59298/IAAJB/2023/3.2.23310

18. Teachout, E., Rowe, L.A., Pachon, H., Tsang, B.L., Yeung, L.F., Rosenthal, J., et al.: Systematic Process Framework for Conducting Implementation Science Research in Food Fortification Programs. Glob Health Sci Pract. 9, 412–421 (2021). https://doi.org/10.9745/GHSP-D-20-00707

19. Ugwu, O. P. C. Obeagu, E. I., Obeagu, G. U., Alum, E. U. Navigating Hemolysis in Expectant Mothers with Sickle Cell Anemia: Best Practices and Challenges. *IAA Journal of Applied Sciences.* 2024; 11(1):30-39. https://doi.org/10.59298/IAAJAS/2024/4.78.99.11

20. Luthringer, C.L., Rowe, L.A., Vossenaar, M., Garrett, G.S.: Regulatory Monitoring of Fortified Foods: Identifying Barriers and Good Practices. Glob Health Sci Pract. 3, 446–461 (2015). https://doi.org/10.9745/GHSP-D-15-00171

21. Isaac Edyedu PMA, Ugwu OPC, Ugwu CN, Alum EU, et al. The role of pharmacological interventions in managing urological complications during pregnancy and childbirth: A review. Medicine. 2025;104(7):e41381.

22. Alum EU, Ugwu OPC, Obeagu EI, et al. Nutritional care in diabetes mellitus: A comprehensive guide. Int J Innov Appl Res. 2023;11(12):16-25.

23. Obeagu EI, Ahmed YA, Obeagu GU, Bunu UO, Ugwu OPC, Alum EU. Biomarkers of breast cancer: Overview. Int J Curr Res Biol Med. 2023;1:8-16.

24. Uti DE, Alum EU, Atangwho IJ, Ugwu OPC, et al. Lipid-based nano-carriers for the delivery of anti-obesity natural compounds: Advances in targeted delivery and precision therapeutics. J Nanobiotechnol. 2025;23:336.
25. Ugwu CN, Ugwu OPC, Alum EU, Eze VHU, Basajja M, Ugwu JN, Ogenyi FC, et al. Medical preparedness for bioterrorism and chemical warfare: A public health integration review. Medicine. 2025;104(18):e42289.
26. Obeagu EI, Scott GY, Amekpor F, Ugwu OPC, Alum EU. COVID-19 infection and diabetes: A current issue. Int J Innov Appl Res. 2023;11(1):25-30.
27. Offor CE, Ugwu OPC, Alum EU. Anti-diabetic effect of ethanol leaf extract of *Allium sativum* on albino rats. Int J Pharm Med Sci. 2014;4(1):1-3.
28. Asogwa FC, Okechukwu PCU, Esther UA, Chinedu OE, Nzubechukwu E. Hygienic and sanitary assessment of street food vendors in selected towns of Enugu North District, Nigeria. Am-Eurasian J Sci Res. 2015;10(1):22-26.
29. Alum EU, Uti DE, Agah VM, Orji OU, Nkeiru N, et al. Physico-chemical and bacteriological analysis of water used for drinking and domestic purposes in Amaozara Ozizza, Afikpo North, Nigeria. Niger J Biochem Mol Biol. 2023;38(1):1-8.
30. Ugwu OPC, Alum EU, Okon MB, Obeagu EI. Mechanisms of microbiota modulation: Implications for health, disease, and therapeutic interventions. Medicine. 2024;103(19):e38088.
31. Ezekwe CI, Uzomba CR, Ugwu OPC. Effect of methanol extract of *Talinum triangulare* on hematology and liver parameters in rats. Glob J Biotechnol Biochem. 2013;8(2):51-60.
32. Alum EU, Inya JE, Ugwu OPC, Obeagu EI, Aloke C, Aja PM, Okpata MG, et al. Ethanolic leaf extract of *Datura stramonium* attenuates methotrexate-induced biochemical alterations in Wistar rats. RPS Pharmacol Rep. 2023;2(1):1-6.
33. Ugwu OPC, Erisa K, Inyangat R, Obeagu EI, et al. Indigenous medicinal plants for managing diabetes in Uganda: Ethnobotanical and pharmacotherapeutic insights. INOSR Exp Sci. 2023;12(2):214-224.
34. Alum EU, Aja W, Ugwu OPC. Vitamin composition of ethanol leaf and seed extracts of *Datura stramonium*. Avicenna J Med Biochem. 2023;11(1):92-97.
35. Ezenwaji CO, Alum EU, Ugwu OPC. Digital health in pandemic preparedness and response: Securing global health? Glob Health Action. 2024;17(1):2419694.
36. Adonu CC, Ugwu OP, Bawa A, Ossai EC, Nwaka AC. Intrinsic blood coagulation studies in patients with diabetes and hypertension. Int J Pharm Med Bio Sci. 2013;2(2):36-45.
37. Offor CE, Ugwu PC, Okechukwu PM, Igwenyi IO. Proximate and phytochemical analyses of *Terminalia catappa* leaves. Eur J Appl Sci. 2015;7(1):9-11.
38. Enechi YS, Ugwu OC, Ugwu KK, Ugwu OPC, Omeh N. Evaluation of antinutrient levels of *Ceiba pentandra* leaves. IJRRPAS. 2013;3(3):394-400.
39. Alum EU, Uti DE, Ugwu OPC, Alum BN, Edeh FO, Ainebyoona C. Microbiota in cancer development and treatment. Discov Oncol. 2025;16(1):646.
40. Asogwa FC, Okoye COB, Ugwu OPC, Edwin N, Alum EU, Egwu CO. Phytochemistry and antimicrobial assay of *Jatropha curcas* extracts. Eur J Appl Sci. 2015;7(1):12-16.
41. Enechi OC, Oluka HI, Ugwu PCO. Acute toxicity and ameliorative properties of *Alstonia boonei* leaf extract on diabetic rats. Afr J Biotechnol. 2014;13(5).
42. Alum EU, Obeagu EI, Ugwu OPC. Enhancing water, sanitation, and hygiene for diarrhoea control and SDGs: A review. Medicine. 2024;103(38):e39578.
43. Odo CE, Nwodo OFC, Joshua PE, Ugwu OPC, Okonkwo CC. Anti-diarrhoeal effect of chloroform–methanol extract of *Persea americana* seeds in rats. J Pharm Res. 2013;6(3):331-335.
44. Ugwu OPC, Obeagu EI, Alum EU, Michael M, et al. Effect of ethanol leaf extract of *Chromolaena odorata* on hepatic markers in diabetic rats. IAA J Appl Sci. 2023;9(1):46-56.
45. Ibiam UA, Alum EU, Orji OU, Aja PM, Nwamaka EN, Ugwu OPC, et al. Anti-inflammatory effects of *Buchholzia coriacea* leaf extract in arthritic rats. Indo Am J Pharm Sci. 2018;5(7):6341-6357.
46. Obeagu EI, Obeagu GU, Odo EO, Alum EU. Nutritional approaches for enhancing immune competence in HIV-positive individuals. IDOSR J Appl Sci. 2024;9(1):40-50.
47. Obeagu EI, Alum EU, Ugwu OPC. Hepcidin: Gatekeeper of iron in malaria resistance. Newport Int J Res Med Sci. 2023;4(2):1-8.
48. Nyamboga TO, Ugwu OPC, Ugwu JN, et al. Biotechnological innovations in soil health management: a systematic review of integrating microbiome engineering, bioinformatics, and sustainable practices. Cogent Food Agric. 2025;11(1):2519811.

49. Madu ANB, Alum EU, Aloh HE, Ugwu OPC, Obeagu EI, Uti DE, Egba SI, Ukaidi CUA. The price of progress: Assessing the financial costs of HIV/AIDS management in East Africa. Medicine. 2025;104(18):e42300.
50. Alum EU, Ugwu OPC. Beyond pregnancy: Understanding long-term implications of gestational diabetes mellitus. INOSR Sci Res. 2024;11(1):63-71.
51. Ugwu OPC, Alum EU, Okon MB, Aja PM, Obeagu EI, Onyeneke EC. Anti-nutritional and GC-MS analysis of ethanol root extract and fractions of *Sphenocentrum jollyanum*. RPS Pharmacol Pharm Rep. 2023;2(2):rqad007.
52. Eze VHU, Eze CE, Mbabazi A, Ugwu CN, Ugwu PO, Ogenyi CF, Ugwu JN, et al. Qualities and characteristics of a good scientific research writing: Step-by-step approaches. IAA J Appl Sci. 2023;9(2):71-76.
53. Igwenyi IO, Nchi PO, Okechukwu UPC, Igwenyi IP, Obasi DC, Edwin N. Nutritional potential of *Azadirachta indica* seeds. Indo Am J Pharm Sci. 2017;4(2):477-482.
54. Enechi OC, Oluka IH, Ugwu OPC, Omeh YS. Effect of ethanol leaf extract of *Alstonia boonei* on lipid profile of alloxan-induced diabetic rats. Afr J Biotechnol. 2013;24.
55. Ugwu OPC. Anti-malaria effect of ethanol extract of *Moringa oleifera* leaves on malaria-induced mice. University of Nigeria Nsukka; 2011:39.
56. Alum EU, Ugwu OPC, Obeagu EI. Nutritional interventions for cervical cancer patients: Beyond conventional therapies. J Cancer Res Cell Ther. 2024;8(1):1-6.
57. Obeagu EI, Obeagu GU. Advancements in immune augmentation strategies for HIV patients. IAA J Biol Sci. 2024;11(1):1-11.
58. Okechukwu PU, Nzubechukwu E, Ogbanshi ME, Ezeani N, Nworie MO. Effect of ethanol leaf extract of *Jatropha curcas* on chloroform-induced hepatotoxicity in albino rats. Glob J Biotech Biochem. 2015;10:11-15.
59. Ilozue NM, Ikezu UP, Okechukwu PCU. Antimicrobial and phytochemical screening of *Persea americana* seed extracts. IOSR J Pharm Biol Sci. 2014;9(2):23-25.
60. Onyeze R, Udeh SM, Akachi B, Ugwu OP. Isolation and characterization of fungi associated with spoilage of corn (*Zea mays*). Int J Pharm Med Biol Sci. 2013;2(3):86-91.
61. Obeagu EI, Alum EU, Ugwu OPC. Hepcidin: The gatekeeper of iron in malaria resistance. Newport Int J Res Med Sci. 2023;4:1-8.
62. Obeagu EI, Alum EU, Obeagu GU, Ugwu OPC. Prostate cancer: Review on risk factors. Eurasian Exp J Public Health. 2023;4(1):4-7.
63. Offor CE, Okaka ANC, Ogbugo SO, Egwu CO, Okechukwu PC. Effects of ethanol leaf extract of *Pterocarpus santalinoides* on haemoglobin, packed cell volume and platelets. IOSR J Nurs Health Sci. 2015;4:108-112, 93.
64. Offor C, Aja PC, Ugwu O, Agbafor KN. Effects of ethanol leaf extract of *Gmelina arborea* on serum proteins in albino rats. Glob J Environ Res. 2015;9(1):1-4.
65. Alum EU, Uti DE, Obeagu EI, Ugwu OPC, Alum BN. Cancer's psychosocial aspects: Impact on patient outcomes. Elite J Med. 2024;2(6):32-42.
66. Alum EU, Ugwu OPC, Egba SI, Uti DE, Alum BN. Climate variability and malaria transmission: Unravelling the complex relationship. INOSR Sci Res. 2024;11(2):16-22.
67. Alum EU, Obeagu EI, Ugwu OPC, Egba SI, EjimUti DE, Ukaidi CUA, et al. Confronting dual challenges: Substance abuse and HIV/AIDS. Elite J HIV. 2024;2(5):1-8.

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