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University of Eldoret, Kenya, Mount Kenya University, Kenya, Chukwuemeka Odumegwu Ojukwu University, Nigeria, Kyambogo University, Uganda and University of Makeni, Sierra Leone

Cultivating and Promoting Functional Foods to Address Micro-nutrient Deficiencies in Nigeria: A Review of Agricultural and Dietary Strategies

Nwagbo Comfort Chinenye[1], Ugwu Ijeoma Angela[2], Anyadioha Josephat Ikechukwu[3], Okeke Margaret Ngozi,[4] [5]Nwafor Paul Maduabuchi

[1, 5]*Department of Food Science and Technology, Faculty of Agriculture, Chukwuemeka Odumegwu Ojukwu University*

[2]*Nutrition Research and Education Unit, Integrated Healthcare Professionals Ltd, Citibase 61-67 Lewisham High Street Lewisham, London SE13 5Jx*

[3]*Department of Food Science and Technology, Madonna University, Enugu, Enugu State, Nigeria*.
anyadioha@madonnauniversity.edu.ng

[4]*Department of Agricultural Economics, Faculty of Agriculture, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Anambra State.*

Corresponding Email: cn.nwagbo@coou.edu.ng

Abstract

Functional foods deliver health benefits beyond basic nutrition, making them critical tools in addressing nutritional deficiencies and mitigating public health challenges. This paper examined the cultivation and consumption of functional foods as a solution to the burden of micronutrient deficiencies in Nigeria. Emphasizing an interdisciplinary approach, this study explored agricultural strategies such as biofortification, sustainable farming, and the promotion of indigenous crops to enhance the availability of nutrient-dense foods, food security and a healthier population. The role of agricultural extension services is central to this discussion, as they educate farmers on cultivation of functional crops and promotion of nutrition-sensitive interventions using public health initiatives to bridge the gap between food production and nutritional outcomes. This paper equally addressed the socio-economic, cultural, and policy challenges that limit the widespread adoption of functional foods in Nigeria. Policy recommendations are presented to strengthen collaboration between the agricultural, nutrition, and public health sectors. Additionally, the paper advocated for enhancing public-private partnerships and consumer education to scale up functional food consumption. Addressing these barriers through functional foods can be a key to combating nutritional deficiencies, and improving public health outcomes.

Keywords: *Functional food development, Public Health Nutrition, Indigenous functional foods, Food security in Nigeria.*

INTRODUCTION

Nigeria, the most populous nation in Africa, is burdened with persistent micro-nutrient deficiencies. The most affected populations are pregnant women, children, the elderly, and rural dwellers. Malnutrition in children in particular causes 60% diarrheal diseases, 50% pneumonia, 45% measles, 55% malaria cases, and 60% mortality cases. In sub-Saharan Africa alone, there are 51 million cases of malnutrition (Leyva-Guerrero et al., 2012). A multi-sectoral approach is needed to effectively curtail this negative trend.
Micro-nutrient deficiency, otherwise known as "hidden hunger" can be defined as a physiological condition characterized by inadequate effects on millions of Nigerians, especially children, pregnant women and rural dwellers (Kiani et al. 2022). The most significant of micro-nutrient deficiencies among children in Nigeria for instance, are vitamin A, iron and zinc with prevalence rates of 29.5%,

28% and 25.3% respectively. These deficiencies contribute to varied disease outcomes such as impaired growth, weakened immune system, anemia and increased mortality. Increased morbidity and mortality outcomes are deterrent factors on any country's developmental goals and economic progress. Some of the contributory factors of micro-nutrient deficiencies are limited dietary diversity, poverty and inadequate access to nutrient-rich foods (Jendyose, 2024). To mitigate this enormous challenge, the gap between food production and consumption must be bridged with innovative, sustainable, and context-specific strategies (Kiani et al. 2022).

Functional foods are fortified or natural-bioactive rich foods that positively impact on physiological functions beyond basic nutritional requirements, thereby reducing disease risk (Jendyose 2024). Functional foods are increasingly gaining recognition as essential in addressing global malnutrition challenges, especially in low- and middle-income countries as Nigeria (Brazilian Society of Food and Nutrition, 2014). This is because functional foods are great sources of nutrients such as iron, omega-3 fatty acids, zinc and vitamin A. Their consumption provides a preventive strategy against micronutrient deficiency-related diseases (Slavin, 2018). Examples of functional foods include vitamin A-rich orange-fleshed sweet potatoes, iron-fortified beans, zinc-enhanced maize, omega-3 fatty acid-rich foods (e.g flaxseed, chia seeds), biofortified crops and phytochemical-rich foods (e.g berries and dark chocolate) (Petrović, et al., 2019). Again, the consumption and cultivation of functional foods in Nigeria could bolster local food systems, the economy and public health. These will provide a strengthened framework to combat micronutrient deficiencies. Unfortunately, Nigeria has not yet attained sufficient cultivation and consumption of functional foods to meet the nutritional needs of the populace. These are due to barriers such as limited research on the effective scalable and cost-effective seed distribution to smallholder farmers; limited study on the impact of infrastructure deficits on functional food yields; the dearth of data on the efficacy of extension services for the promotion of functional foods; insufficient data on the profitability of functional food crops compared to staple foods; insufficient data on policy effectiveness in biofortification integration. Some of the barriers to functional food consumption include a lack of data in local acceptability; cost-effectiveness; nutritional awareness, availability, scalable solutions, and the influence of urbanization in the consumption of functional food.

The objectives of this paper are to study the current prevalence and burden of micro-nutrient deficiencies in Nigeria; evaluate critical research gaps in the cultivation and consumption of functional foods and provide strategies for their improvement towards micro-nutrient reduction. Using a systematic literature review with narrative synthesis, this study consolidates findings from peer-reviewed research, government reports and gray literature to propose an integrated approach that suits Nigeria's unique needs.

METHODS

This study employed a systematic literature review with a narrative synthesis in analyzing the research questions. The research questions were: (1) what is the prevalence and impact of micronutrient deficiencies in Nigeria; (2) what agricultural strategies support the cultivation of functional foods in Nigeria? and (3) what dietary strategies promote their consumption? The search strategy included the use of specific terms and combinations such as: "functional foods", "functional foods consumption in Nigeria", "Functional food cultivation in Nigeria", "micronutrient deficiencies and functional foods", "biofortification", "agriculture in Nigeria", "dietary intake in Nigeria", "nutrition intervention in Nigeria", "Biofortification in Nigeria and Sub-Saharan Africa", "Sustainable farming practices for functional foods"; "Public health challenges and Indigenous functional food systems"; "Policy recommendations for functional food systems". Relevant literature was sourced from scientific databases such as PubMed, Scopus, Google Scholar and Web of Science. The search was done in October 2024. The study population of this review includes consumers, especially vulnerable groups such as children, pregnant women and the elderly, who are most affected by nutritional deficiencies; smallholder farmers or producers of biofortified and indigenous food crops in Nigeria. The intermediary study population includes Agricultural extension agents, policymakers, sector stakeholders and researchers. This diverse population reflects the multifaceted approach to drive cultivation, accessibility and consumption of functional foods in Nigeria.

The inclusion criteria included peer-reviewed studies, policy reports, conference proceedings and documents on micronutrient deficiencies in Nigeria or Sub-Saharan Africa; functional foods (biofortified and nutrient-dense crops) cultivation; dietary interventions or consumer acceptance of functional foods in Nigeria or comparable low-resource settings and English language publications within 10 years from the time of the study. Exclusion criteria was studies unrelated to Nigeria or Sub-Saharan Africa; research lacking practical application to cultivation and consumption and non-substantive sources (opinion pieces without data). The titles and abstracts were first screened based on keywords and summaries and the remaining studies were investigated for relevance and quality using a checklist (e.g study design, sample size and Nigerian-specific data). A citation management tool, Zotero was used to organize the references and ensure accuracy. Selected articles were organized based on related themes. Comparative analysis was performed to identify gaps in the literature and opportunities for future research. The review acknowledged limited availability of region-specific studies on functional foods; variability in methodologies among included studies and exclusion of non-English studies, which may have valuable insights.

PREVALENCE AND BURDEN OF NUTRITIONAL DEFICIENCIES IN NIGERIA

Nutritional deficiencies remain a significant public health challenge in Nigeria. Various demographics in the country are subsequently affected. Some of the causes of micronutrient deficiencies in Nigeria are food insecurity, poverty, limited dietary diversity, inadequate public health interventions and poor agricultural practices. The most commonly identified micronutrient deficiencies are vitamin A, iron and zinc affecting mostly vulnerable populations such as pregnant women, children and the elderly.

Iron deficiency, largely responsible for anemia affects 23 to 37 % of Nigerians, especially children less than 59 months and pregnant women (International Institute of Tropical Agriculture, IITA, 2024). Iron deficiency has remained the most prevalent nutritional deficiency in Nigeria, resulting to impaired cognitive and physical development and inflammation in children and pregnancy complications such as low birth weight and maternal morbidity and mortality. The major dietary sources of iron are whole grain cereals, fish, green leafy vegetables, liver, meat, nuts and pulses (Oluwatoyin and Adebukola, 2018).

Zinc deficiency which affects 35.8 % of preschool children in Nigeria (especially in rural places lacking dietary animal protein) contributes to impaired immune function, stunted growth and increased risk of infections and death in young children (FGoN and IITA, 2024. The major dietary sources of zinc are meat, nuts, seafood, seeds, legumes and dairy (https://www.healthline. com/nutrition/best-foods-high-in-zinc#section1).

Vitamin A deficiency predisposes people to infections like cold, measles, etc due to lowered immunity and increases the risk for blindness. There is a high prevalent rate of vitamin A deficiency (21-54 %), with under-five-aged children and pregnant women mostly affected (FGoN and IITA, 2024). Despite the implementation of vitamin A supplementation and fortification programs in Nigeria, the deficiency persists probably due to limited access to vitamin A-rich foods like liver, fruits and vegetables.

MECHANISM OF ACTION OF FUNCTIONAL FOODS IN NUTRITION DISEASE PREVENTION AND REDUCTION

There have been divergent opinions on the definition of functional foods (Acham et al., 2018). Functional foods was defined by the United States Department of Agriculture (USDA) and Agriculture Research Service (ARS"*Natural or processed foods that contain known or unknown biologically-active compounds; which, in defined, effective non-toxic amounts, provide a clinically proven and documented health benefit for the prevention, management, or treatment of chronic disease*" (USDA, 2016). Functional foods can be described as any food (s) containing any one or more of the following attributes: (i). contains added constituents such as a nutrient (e.g calcium), a non-nutrient (e.g omega-3 fatty acids for cardiovascular health) or a herb (to reduce inflammation); (ii) reduced toxic component (e.g removal of saturated fatty acids by addition of omega-3 fatty acids); (iii) contains naturally improved constituents by growing conditions (e.g biofortified foods); (iv) enhanced nutrient bioavailability (e.g probiotics in fermented foods); and (v) modified natural components to improve health (e.g infant formula containing hydrolysed protein for easy digestibility) (Suleiman et al., 2018). The bioactives and micronutrients in functional foods can influence health through various mechanisms such as enhanced immune functions and reduced inflammation and oxidative stress (Vijayakumar, 2021). The ability of functional foods to manage micronutrient deficiencies can be defined by the percentage of the daily recommended intakes (RDI) of the micronutrients that they can provide as shown in Table 1. For instance, the RDI of iron and zinc, are 8 and 8 mg/day, respectively (National Institute of Health, 2019).

Micronutrient deficiencies can be managed for example by using iron-fortified grains; vitamin A-enriched oils, cassava tubers and potatoes, and folate-rich plant foods. Functional foods enhanced with exogenously added bioactive compounds like vitamins, minerals, fibers, and antioxidants can provide targeted nutritional benefits that help address the specific health needs of populations facing food insecurity and micronutrient deficiencies. For instance, staple foods fortified with iron, vitamin A, and zinc can significantly alleviate conditions like anemia and weakened immunity, which are common in regions with limited access to diverse diets. Some indigenous Nigerian ingredients such as moringa and baobab are naturally rich in vitamins, minerals, and antioxidants. Food-based therapies can be developed from these functional plant foods in the management of degenerative diseases (James et al., 2020).

NIGERIAN INDIGENOUS FUNCTIONAL FOODS IN THE REDUCTION OF NUTRITION DEFICIENCIES

Biofortified and Enriched foods

Biofortification, a strategic means to enhance the nutritional value of staple crops through genetic modification, conventional plant breeding, and agronomic practices, has emerged as a key intervention for addressing micronutrient deficiencies (Abah et al, 2015). Biofortification has long-term and sustainable effectiveness for both rural and urban communities. It provides poor farmers with affordable nutrient-rich crops and geographic-specific cultivars. Orange-fleshed sweet potatoes, pearl millet, iron-fortified beans, provitamin A-enriched maize, and cassava have shown promise to increase micronutrient intake, especially vitamin A, iron, and zinc. A quantity of 125g of biofortified orange-fleshed sweet potato (OFSP) cultivar is sufficient to provide the daily vitamin A needs of children aged between 4 to 8 years and is efficient in reducing vitamin A deficiency (Mir, et al., 2024).

HarvestPlus biofortification program of beans consumed by Rwandan women caused an in vivo and in vitro increase in iron within 4.5 months (Haas et al., 2016), while the iron biofortification program of pearl millet in India improved cognitive development in teenagers (Scott et al., 2018). Vitamin A, zinc and iron biofortification were planned for cassava, maize and millet in Nigeria (Okwuonu et al, 2021). An improved sorghum variety, Deko (12KNICSV-188) had 126 ppm tripled iron content compared to the traditional 40 ppm in the local varieties (ICRISAT, 2016) while Zabuwa (12KNICSV-22) had an improved additional 54 ppm iron. Santos et al (2018) treated micronutrient deficiencies using vitamins, minerals, and trace elements-fortified food in a rural community population-based intervention. Iron and zinc biofortified cassava showed the potential of providing 40–50% and 60–70% for iron and zinc respectively in children aged 1- to 6 years and nonlactating, nonpregnant West African women (Aguilar, et al. 2019).

A studied portion (125 g) of both three varieties of raw and cooked orange-fleshed sweet potatoes provided more than 100 % of the daily vitamin A's Recommended Dietary Allowances (RDA) (400 mg RAE) for children aged 4–8-year-old. These are encouraged to be used in the production of complementary foods (Rosero et al., 2022s).

Palm oil is regarded as a functional food due to its rich composition of carotenoids and with pro-vitamin A activity (Nwagbo et al., 2020). Red palm oil is a rich source of carotenoids with great bioavailability. It has been used in the control of vitamin A deficiency in children and pregnant women (Loganathan et al., 2017) and compares favorably with biofortified garri (cassava product) (zhu, et al., 2015). Moringa leaf powder has about 92% more iron than beef (Masitlha et al., 2024)

INDIGENOUS FUNCTIONAL FOOD CULTIVATION AND CONSUMPTION IN NIGERIA FOR NUTRITIONAL DISEASE PREVENTION

The major staples in Nigeria comprises of cassava, yam and sweet potato which although are excellent sources of carbohydrates, are lacking in micronutrients and protein and cannot adequately combat the prevalent latent and obvious hunger (Okwuonu et al., 2021).
The effective use of functional foods in addressing and reducing the burden of nutrient-related diseases requires continued research and development. It is therefore imperative to promote the production and consumption of functional foods with enhanced bioactive components as a means of tackling nutritional deficiencies, especially in

Table 1: Examples of some Functional Food Crops grown in Nigeria and their Vitamin A, Iron and Zinc Composition

S/N	Food Crop	Local Nigerian names	Micro-nutrient	Source
1	Bambara nut	Gurjiya (Hausa), Epa roro (Yoruba) and okpa (Igbo)	Zinc (0.06 - 0.42 mg/100g) Iron (4.07 - 5.13 mg/100g)	Adeoye et al. (2021) Johnson et al., 2022; Okafor et al., 2022; Chelangat et al., 2023
	Biofortified cassava	Gurjiya (Hausa), Epa roro (Yoruba) and Akpu (Igbo)	Vitamin A (1310 – 2188 µg/100g)	Olarewaju et al (2017) Adegbite and Chikere-Njoku, C. (2022).
2	Bush Mango (Irvingia gaboneensi)	Rogo (Hausa), Ege(Yoruba) and ogbono (Igbo)	Zinc (0.04 - 0.275 mg/100g) Iron (0.4-0.68 mg/100g) Vitamin A (163.12- 204.52µg/100g)	Akajiaku et al.. (2024)
3	Tigernut (**Cyperus esculentus L.)**	Aya (Hausa), Ofio (Yoruba) and Akiausa (Igbo)	Zinc (1.39 mg/100g) Iron (2.82 mg/100g) Vitamin A (163.12- 204.52µg/100g)	Suleiman, et al (2018)
4	Biofortified sweet potato (Ipomoea batatas (L.) Lam.)	Dankalin zuma (Hausa), Odunkun(Yoruba) and Nkoro/Ji bekee(Igbo)	Vitamin A (147.31-314.00 µg/g)	Rosero et al (2022)
5	Red Palm (Elaeis guineense) Oil	Man Aladi/ Mai ja (Hausa), Epo pupa (Yoruba) and Mmanu nri Igbo)	Vitamin A (600–750 ppm)	Loganathan et al., (2017)
6	**Melon seed (Citrullus colocynthis L.)**	Egusi (Hausa), Egusi (Yoruba) and Egusi (Igbo)	Iron (144.7mg/100g), zinc (21.05mg/100g)	2Khalid et al (2021)
7	Soybeans (Glycine max)	Madara gyada (Hausa), soyamilk(Yoruba) and soyamilk (Igbo)	Zinc (11.6% per 100g) Iron (8.43 mg/100 g) Vit A (847.87 µg/100 g)	Agyenim-Boateng et al. (2023)
8	Moringa (Moringa oleifera)	Zogale (Hausa), Ewe igbale (Yoruba) and Moringai (Igbo)	Vitamin A, Iron (7.7 mg/100 g Fe) (25% RDA) Zinc (0.8 mg/100 g) (10 % RDA)	Masitlha et al. (2024)
9	Bitter leaf **(Vernonia amygdalina)**	Shuwaka (Hausa), Ewuro (Yoruba) and Onugbu (Igbo)	Iron 5.0 g/mg; Zinc 85.0 g/mg	Shewo and Girma (2017)
10	Groundnut (Arachis hypogea)	Yada (Hausa), Epa (Yoruba) and ahuekere (Igbo)	iron (33–68 mg/kg), Zinc (44–95 mg/kg)	Janila et al. (2015)
11	Yellow Maize (Zea mays)	Masara(Hausa), Agbado(Yoruba) and oka (Igbo)	Iron (2.71 mg/100g); 2.21 (mg/100g) Vit A (11 µg/100 g) Provitamin A (214 IU/100 g)	USDA (2016)
12	Carrots (Daucus carota)	Karas(Hausa), Karooti(Yoruba) and Karot(Igbo)	Vitamin A (459 µg/100 g) Zinc (23.6 mg/100g) Iron (209 g/kg)	Anozie et al., (2024)
13	Pumpin leaf (Telfairia occidentalis)	Ganye kabewa (Hausa), Sokoyokoto(Yoruba) and ugu (Igbo)	Iron (9.55-9.83 mg/100 g)	Ibitoye et al. (2023)

rural places with limited access to health care. By integrating these enhanced functional foods into the local diets using food fortification, biofortification, nutrition education, dietary diversification, and modification, communities can benefit from increased nutritional intake without the need for significant dietary shifts, especially where food preferences are culturally rooted and resources are scarce (Abubakar et al., 2017). The consumption and cultivation of functional foods address immediate nutritional deficiencies and build long-term resilience against malnutrition, especially in low-resource settings. These crops are inherently nutrient-dense and adapted to the Nigerian climate, requiring less water and external inputs, and their cultivation in sufficient quantities will ensure their accessibility and affordability. Research carried out by Mwanga et al (2021) between 2009 to 2020 among 14 collaborating countries in sub-Saharan Africa developed 158 sweet potato varieties from a combination of exotic and local varieties. The results showed increased genetic gains for vitamin A, iron, zinc and virus resistance in the developed varieties. Out of the enhanced sweet potato varieties, 98 were orange-fleshed, 55 varieties were bred for accelerated breeding and 27 varieties were drought-tolerant, while two varieties had enhanced iron and zinc contents.

For a successful food-based approach to combating nutritional diseases in Nigeria, emphasis must be placed on increased access, availability, and nutrient diversification by consuming a variety of nutrient-dense foods (Oparinde et al., 2017). The development of novel food products from bio-fortified foods can alleviate micronutrient deficiencies. However, efforts should be made to ensure that novel food products from bio-fortified crops meet consumer acceptance. Consumer acceptance is essential to the progress of biofortified crop development (Bouis, et al, 2017). Lawal et al (2021) developed acceptable yellow cassava pasta enriched with green leafy vegetables.

Processing methods affect the bioavailability of nutrients in functional foods. According to Okpalama, et al (2024), cooking increased the total carotene in green leafy vegetables such as *T. occidentalis*, *A. hybridus*, *T. triangulare*, *P. mildbraedli* and *G. africanum* respectively by 184.10%, 123.70%, 524.45%, 171.87% and 110.66%, but reduced their Zinc and Iron contents.

The use of indigenous functional foods in the reduction of malnutrition can be feasible, sustainable and seamlessly integrated into existing agricultural practices, especially in rural communities. Nigeria can effectively combat malnutrition, amplify functional benefits and enhance productivity of indigenous crops through selective breeding.

Sustainable farming practices such as crop rotation, organic fertilization and reduced pesticide usage can improve nutrient density of crops by improving soil quality and biodiversity. Sustainable farming methods can be used to achieve food security and nutrient-rich harvest. For example, regenerative agricultural practices which emphasize soil health and ecosystem balance, enhance the nutrient content of crops and sustain their productivity over time. This bolsters functional food cultivation and enhances the sustainability of food systems that prioritizes indigenous crops with significant health-promoting properties.

SOME IDENTIFIED BARRIERS IN FUNCTIONAL FOOD CULTIVATION AND CONSUMPTION IN NIGERIA

Socioeconomic factors hinder the cultivation and accessibility of functional foods in Nigeria. Many smallholder farmers who form the backbone of Nigeria's agricultural sector do not have access to adequate funding, modern farming tools and infrastructure to support large-scale functional food cultivation. Other factors include high production costs, low household income and limited access to credit and insurance (Okwuonu et al., 2021). Again, functional foods are often sold at premium prices compared to conventional staples, which makes them unaffordable to low-income families who are at the worse end of malnutrition. To address these socioeconomic barriers, concerted financial support and policy mechanisms must be employed to subsidize nutrient-dense crops and promote rural development programs that empower local farmers to participate in functional food markets. The production of Bambara groundnut has remained low due to the unavailability of improved varieties. Some identified barriers in the adoption of bio-fortified cassava varieties are fast-decaying rates and high moisture content of the roots and the high cost of the stem (Onyeneke et al., 2020).

Another major constraint to functional food cultivation and consumption in Nigeria is policy and institutional constraints (Oparinde et al., 2017). Notwithstanding the growing recognition of the profound health benefits of biofortified and indigenous nutrient-rich crops, there are no clear policies to promote them and expand their market integration and reach. Inadequate research funding, limited extension services, and limited government incentives for farmers cultivating biofortified and functional crops are some notable examples of policy and institutional constraints. Again, food safety regulations and standards on available functional foods remain underdeveloped, affecting consumer confidence and market acceptance. Institutional and inter-agency collaboration to develop a cohesive strategy for functional food production, distribution and consumption are equally limited or non-existent.

Akinsola et al (2022) showed that there was higher consumption (62.5%) of non-biofortified vitamin A cassava products than biofortified vitamin A cassava products (37.5%). The identified factors that influenced this were the relative prices, age, gender, education of household head, and household income. Studies on the acceptability of novel food products from bio-fortified foods like yellow cassava is also low. However, Eyinla et al. (2019) showed that cooking cassava into *garri,* a cassava product, reduced vitamin A composition, while short fermentation time increased vitamin A content of biofortified cassava variety (Eyinla et al. 2019). The decline in Bambara nut production was attributed to inadequate processing equipment. The use of bioprocessing techniques such as germination, fermentation and malting could however bridge this gap and enhance Bambara nut processing (Chude et al., 2023).

Consumer awareness and cultural dietary preferences also limit the acceptance and integration of functional foods in Nigeria. The awareness of the health benefits of biofortified and indigenous functional foods, especially in rural communities, is still sparse (Popoola et al., 2023). Instead, there are high preferences for a limited number of dietary staples like yam, cassava, and rice which are mostly calorie-dense, but nutrient-poor (Okwuonu et al., 2021). When consumers are uninformed and have misconceptions about functional foods, their dietary adoption becomes even harder. It is therefore essential to raise awareness using nutrition education with emphasis on the potential health benefits of locally-grown functional and biofortified foods, to achieve a dietary shift in favor of their higher consumption. The components, barriers, and expected outcomes of implemented strategies are shown in Fig. 1.

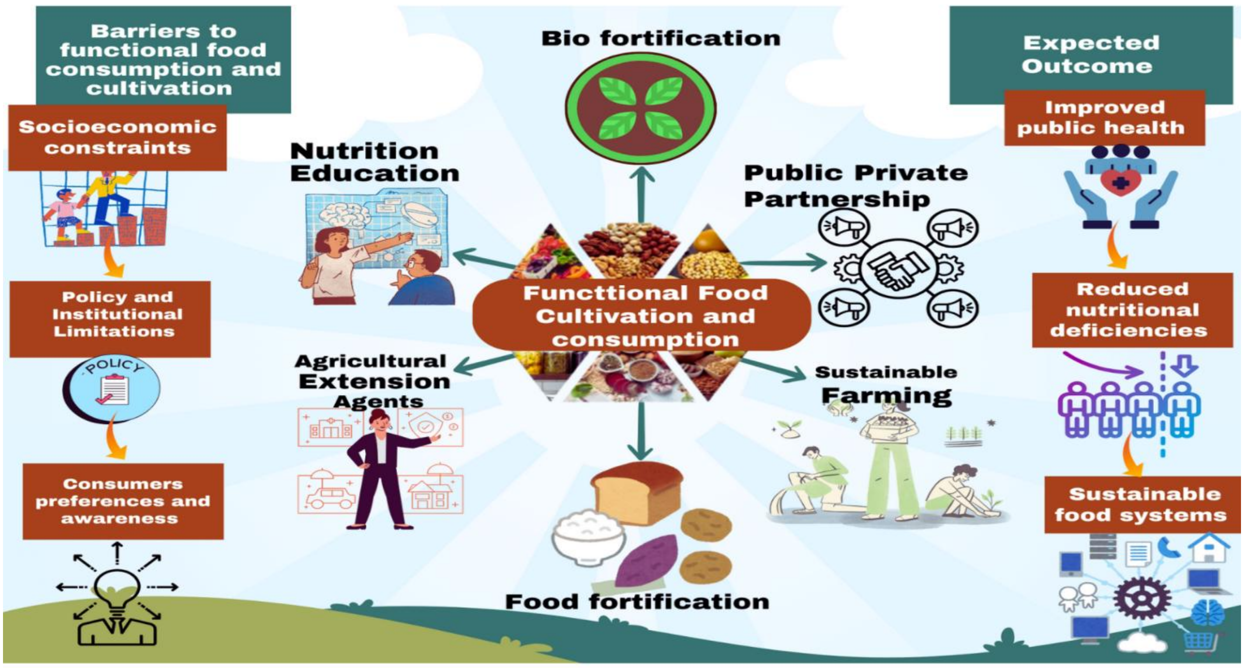

Fig 1: Graphical representation of Functional Food cultivation and consumption: Strategies, Barriers and Expected outcome

ROLE OF AGRICULTURAL EXTENSION AGENTS IN BRIDGING THE GAP BETWEEN CULTIVATION AND CONSUMPTION OF FUNCTIONAL FOODS.

Agricultural extension agents are strategically important in educating farmers, filling the knowledge gap and building capacity on functional food health benefits and cultivation, especially when it concerns yield and nutritional quality-improving practices. Extension agents can empower farmers to prioritize functional foods cultivation by offering trainings on biofortified crops, sustainable farming techniques and indigenous nutrient-rich varieties. Technical support to adopt these practices and stay informed about latest innovations that improve yield, nutrient density and resilience of crops can also be provided (Dia and Kobani, 2024)). Extension agents can also play a crucial role in connecting farmers with practices and resources such as biofortified seeds and loans. By organizing cooperatives, extension agents can help small-scale farmers to pool resources, access collective markets and improve their bargaining power for their functional food products (Kobani and Alozie, 2019). They also play a role in disseminating information on quality standards and food safety to meet market requirements, gain consumer trust and expand the availability of functional foods both locally and globally.

RECOMMENDATIONS AND FUTURE DIRECTIONS

To foster the development of functional foods in Nigeria, it is essential to strengthen agriculture and nutrition policies that support the production, accessibility, and consumption of nutrient-dense and bio-fortified foods. Policy framework with coordinated approaches that integrate agricultural productivity with public health goals and stimulate demand for functional foods can address nutritional deficiencies in Nigeria and create income-yielding opportunities (Akinsola et al. 2022). This could include incentives for farmers that cultivate biofortified or nutrient-rich functional crops, subsidized functional food production systems, and extensive research funding on nutrient-dense crops. Quality standards for functional foods could be established to ensure safety and consistency and gain consumer trust. Awareness should be raised among consumers and farmers with the biofortified varieties made available to farmers. Interventions that promote the production and consumption of bio-fortified crops should be encouraged (Onyeneke et al., 2020).

Public-Private Partnership (PPP) is an essential avenue to scale and drive innovations in functional food cultivation, processing, marketing and supply chain logistics. Government agencies, research institutions, private sector organizations and NGOs could collaborate to accelerate the development and distribution of functional foods through infrastructure development; improved access to biofortified and nutrient-dense seedlings; lowered barrier to local and global market entry of cultivated functional foods; reduction of the production costs to increase accessibility and affordability and creation of a sustainable vale chain for functional and biofortified foods.

Consumer education on the nutritional advantages of functional and biofortified foods is critical in driving demand and promoting dietary preferences for nutrient-dense foods (Siwale,et al,2024. The key educational message should address common misconceptions, promote cultural relevance and inform on various meal preparation strategies to boost nutrient bioavailability. This can be achieved through public health campaigns, community outreach programs and partnership with the media. School-based nutrition programs targeting vulnerable, under-five aged children can further drive integration and consumption.

There is need for intensive research on crop improvement program to sustain and improve indigenous functional foods. The bioactives; their utilization in the development of functional foods and their interactions or stability during food processing as well as bioavailability need to be studied.

CONCLUSION

Functional food cultivation and consumption present a viable and sustainable strategy for the alleviation of public health burdens of nutritional deficiencies in Nigeria. By prioritizing nutrient-rich functional and biofortified foods and crops, sustainable agricultural practices, and the cultivation of indigenous varieties, Nigeria can improve food security and support the health of its population. Agricultural extension agents, public-private partnerships, and consumer education initiatives are pivotal in ensuring functional and biofortified food crop cultivation and ensuring their affordability, accessibility, and appeal to drive consumption. This must be done by addressing barriers exiting as socioeconomic limitations, policy constraints, and limited consumer awareness. An investment in functional food systems in Nigeria is an essential step toward a healthier and resilient nation. These approaches would promote public health, economic empowerment, environmental sustainability, and food security. Through coordinated efforts, Nigeria can develop a functional food system that meets the nutritional needs of its people and sets a precedent for addressing malnutrition across sub-Saharan Africa.

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