World Journal of Food Science and Technology
2024; Vol. 8, No. 1, pp. 23-34
https://doi.org/10.11648/j.wjfst.20240801.13

Review Article

Food-Based Intervention for Boosting Micronutrient Status and Health - A Comprehensive Review

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Abstract

Food fortification and supplementation represent crucial strategies for combating the prevalence of micronutrient deficiencies, particularly among vulnerable populations such as children, adolescents, and pregnant women. However, the efficacy of interventions in increasing nutrient bioavailability primarily hinges on incorporating nutrient-rich foods and employing suitable food preparation techniques. Research underscores the significant potential of food-based approaches in augmenting micronutrient intake and fostering optimal growth and development. This comprehensive review assesses findings from 36 articles published within the last decade, focusing on food-based interventions aimed at alleviating micronutrient deficiencies in Africa. Analysis reveals that ten trials yielded positive outcomes across all growth metrics, albeit one study showed no significant changes in height Z scores. While two trials did not observe alterations in serum levels, twelve reported improvements in biochemical markers, and four noted enhanced cognitive and academic performance among school children. Despite these encouraging results, advancing food-based solutions to enhance dietary micronutrient quality and mitigate associated health challenges necessitates further investigation. It is imperative to underscore the importance of consuming a balanced diet comprising a diverse range of foods and adhering to recommended food preparation practices to minimize food loss and waste. By prioritizing these measures, individuals can safeguard against micronutrient deficiencies and promote sustained healthy growth and development. In conclusion, while food fortification and supplementation play pivotal roles in addressing micronutrient deficiencies, integrating nutrient-rich foods and appropriate food preparation methods emerges as crucial components in maximizing the effectiveness of interventions. Continued research efforts are essential to refine food-based solutions and ensure their widespread accessibility, ultimately contributing to improved nutritional outcomes and overall well-being in vulnerable populations across Africa and beyond.

Keywords

Food Based Intervention, Micronutrients, Dietary Diversification, Nutrition Education

1. Introduction

"Hidden hunger" or micronutrient deficiencies is one of significant public health issue in Africa as many people lack vital vitamins and minerals in their diets. People of all ages are affected, but mostly children and women of reproductive age [5]. Over 50% of people in sub-Saharan Africa are affected by micronutrient deficiencies, according to the World Health Organization [4]. Anaemia, goiter, poor immunological function, decreased cognitive development, and other health issues

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Received: 31 January 2024; **Accepted:** 14 February 2024; **Published:** 13 March 2024

might result from these deficiencies [4]. Micronutrient deficiency in Africa needs to be addressed with a comprehensive and long-term strategy that goes beyond supplementation and fortification. The core causes of micronutrient deficiencies can more effectively and sustainably be addressed via a food-based strategy. By encouraging the consumption of nutrient-rich foods, this strategy focuses on enhancing the quality and variety of diets.

A food-based strategy includes interventions like food fortification, bio-fortification, nutritional diversity, breastfeeding advocacy, and other supplementary feeding methods [24]. Food fortification is the process of incorporating vital micronutrients into everyday food items like flour, sugar, and oil [23]. Crops are bred with higher concentrations of vital micronutrients through a process called bio-fortification [16]. Promoting the consumption of a variety of nutrient-rich foods, including fruits, vegetables, legumes, and food derived from animals, is a key component of dietary diversity [24]. Teaching mothers on appropriate child feeding habits is a crucial part of promoting breastfeeding and supplementary feeding methods.

A food-based strategy is more sustainable since it gives people and communities the power to take charge of their own health by making sensible dietary decisions [24]. Additionally, it may raise household income, increase agricultural output, and strengthen food security. The current review assesses research that investigates the potential for dietary modification and diversification techniques at the community or family level, as well as the effects of such dietary interventions on children's, adolescents', and pregnant women's physical and mental health.

2. Methods

The purpose of this study is to give a current assessment of the impact of food-based micronutrient therapies on development, cognition, general improvement of micronutrient bioavailability, and other health indicators in African countries. The current review evaluates studies that explore the potential for dietary modification and diversification methods at the community or family level, as well as the impacts of such dietary interventions on children's, adolescents', and pregnant women. Food-based intervention strategies differ greatly in their design, outcome metrics, and age groups. In order to find research reporting on the consumption of nutrient-rich foods or snacks and the evaluation of the effects of food-based interventions on growth, cognition, and other health indicators, a non-systematic review method was adopted.

2.1. Selection Criteria

The scope for the current review can be summarized as; 1. Only food-based intervention studies which focused on children, adolescents, and pregnant women were used. Research examining the effects of adding micronutrient powders or sprinkles to meals, as well as micronutrient supplements in the form of pills, syrups, or soft gels, were disregarded. 2. Only Randomised Controlled Trials (RCTs) studies were chosen. 3. We only included RCTs that were carried out in African countries. RTCs studies conducted outside Africa were not included 4. The only micronutrients that were targeted were vitamins and/or minerals. Research utilizing other dietary components, such as functional foods and essential fatty acids, were not included. 5. RCTs that assessed one or more developmental indicators for children—such as psychomotor development, cognitive function, mental development, IQ, and school performance—as primary or secondary outcome measures of the interventions were also included. 6. RCT studies with duration of at least three months were selected. 8. Only RCTs published after the year 2012 were included.

2.2. Search Strategy

Titles and abstracts were searched in several databases, including PUBMED, Web of Science, Scopus, Science Direct, EBSCOHOST, Wiley Online Library, and the Cochrane Database of Systematic Reviews (CDSR). In order to locate pertinent documents, keyword searches were also carried out on Google Scholar. Meals, growth, bone mass, cognition, and health were a few of the search terms. Others included dietary diversification, children, adolescents, and pregnant women; micronutrient bioavailability; food-based therapies; and randomized controlled studies. The search also took into account citations from important studies, earlier reviews, systematic reviews, and meta-analyses. There were discovered a total of 26 RCTs for the current study that met the criteria for inclusion.

3. Results and Discussion

3.1. Study Selection

Out of 100 total gathered publications shown below, 12 studies detailing micronutrient-rich food products and 26 food-based intervention trials that complied with the inclusion/exclusion criteria were included in this study (Figure 1). Data was gathered from the full-text publications.

Table 1. *Food-based intervention studies' characteristics in perspective of micronutrient status.*

Reference	Study location	n	Age (years)	Food products	Intervention	Findings
[9]	Tanzania	141	14-49 woman	Indigenous vegetables	Women's Minimum Dietary Diversity Index	Consumption of indigenous vegetables is favorably correlated with adequate intake of micronutrients.
[12]	Tanzania & Mozambique	669 Tanzanians 857 Mozambique's	Males and Females adults	Fruits, vegetables, cereals, legumes and animal protein	Anthropometric and Hemoglobin Measurements	While legumes and starchy plants were the main sources of vitamin A in Tanzania and Mozambique, respectively, dark green leafy vegetables (DGLVs) were a strong predictor of vitamin A intake.
[6]	Tanzania	1006	Women of reproductive age (18-49 years)	African eggplant, amaranth, spinach, tomato, okra, animal proteins, legumes, grains, and Chinese cabbage	Dietary diversity scores	Nutritional outcomes for women are improved by increases in dietary diversity and food security.
[6]	Tanzania	1006	Women of reproductive age (18-49 years)	Communities received nutrition and health education, agricultural training, and supplies to encourage home cultivation of nutrient-dense crops.	dietary diversity scores	Programs for homestead food production (HFP) increased access to nutrient-dense foods like vegetables, which had a positive impact on diet and nutrition outcomes.
[27]	Tanzania	750 adolescence and 750 parents	Adolescents and parents	nutrition intervention program at schools (school meals, school gardens, nutrition education and community workshops)	Hemoglobin levels, anthropometry, academic success, and knowledge	increase in serum retinol ($P < 0.001$)
[28]	Kenya	293	6-17 months old children and care givers	Dietary diversity rich in micro and macro nutrients	Scores on children's dietary diversity and nutrition knowledge	The intervention group saw a significant improvement in the children dietary diversity scores (CDDS) scores for children's dietary diversity and the CDDS scores for caregivers' nutrition awareness.
[13]	Kenya	280	6-12 years	Baobab powder,	Hemoglobin meas-	The iron status

Reference	Study location	n	Age (years)	Food products	Intervention	Findings
				water, honey and mango flavored juice	urement	was dramatically enhanced by drinking baobab pulp.
[21]	Kenya	50	Mother-child pair	Adding 20 g of *Moringa oleifera* leaf powder to maize porridge taken twice daily as dietary supplement	Children growth measurement; Hemoglobin measurement	Infant and maternal vitamin A and iron status; changes in newborn and maternal intestinal health; changes in infant growth and maternal milk production
[10]	Mozambique	416	Adults		Dietary Diversity Score, Mean Micronutrient Density Adequacy, and Anthropometry	An increased score for nutritional diversification; In general, treatment group members have slightly higher WHZ scores;
[18]	Burundi	11906	Pregnant woman and children from birth through 23.9 months of age	Program for Maternal and Child Health and Nutrition with Food Assistance (Expand access to and intake of foods high in energy and micronutrients.)	total dietary diversity score	Positive impact on the diversity of maternal diet (+0.4 food groups, P 0.05) and raised (from 8.0 to 9.6 pp, P 0.05) the percentage of children aged 6-23.9 mo who consumed at least four food groups.
[22]	Rwanda	150	18-27 years old	Iron-bio fortified beans (86.1 ppm iron)	The body's iron levels, hemoglobin, ferritin, transferrin receptor, and cognitive function on five computerized tasks	The speed of spatial selective attention increased by 17% after consuming the bio-fortified beans.
[2]	Nigeria	176 preschool children	3-5 Years	Foods prepared from bio fortified (yellow) cassava,	serum retinol concentrations	The serum concentrations of retinol and hemoglobin were increased by -carotene from biofortified cassava.
[3]	Nigeria	200	children	Dietary diversity rich in micro and macro nutrients	Anthropometric parameters, cognitive function	Nutritional outcomes and cognitive function improved
[8]	Ghana	113	Infant – Mother pairs	A complementary food (Weanimx)	measurements of the mother's height,	Children of school age had better

Reference	Study location	n	Age (years)	Food products	Intervention	Findings
				made with a cereal-legume combination and Moringa leaf powder	weight, and blood retinol levels as well as the infant's length and weight	vitamin A status after consuming moringa supplements.
[14]	Ghana	2869	5-15 years	Dietary diversity meal made with locally available cereals, legumes, fruits and vegetables	Z scores for height-for-age (HAZ) and BMI-for-age (BAZ)	school nutrition program improved HAZ in children aged 5 to 8
[17]	Malawi	257	late first trimmest pregnant woman	Consumption of locally available, nutritious fruits, vegetable and legumes	Scores for the Six Food Group Pyramid (SFG) and the Diversity Score (DDS)	Six Food Group Pyramid (SFG) and Dietary Diversity Score (DDS) scores have improved.
[25]	Ethiopia	200	6-23 moths	children's dietary diversity weaning food intake made with different indigenous cereals, legumes and vegetables	Dietary diversity scores; Nutritional education score	Compared to children in the control group, there has been an improvement in children's dietary diversity, mean intake of energy, and consumption of a few specific nutrients.
[11]	Ethiopia	138	>16-49 Pregnant woman	Meal made of cereal and legumes that contains animal sources, fruits, and vegetables	Dietary diversity scores; Nutritional education score	Improved nutrition knowledge and dietary diversification
[29]	Burkina Faso	119	12-59 months	Complimentary food blended with Moringa leaves powder	Children's anthropometric and vitamin A indicators were evaluated in comparison to changes in the control group's children.	From 0.64 mol, the average retinol concentrations dramatically rose. L-1 to 0.73 mol. L-1 (p 0.001); Height and weight gain
[20]	South Africa	1062	6 months infants	Meal made of cereal and legumes that contains few animal sources, fruits, and vegetables	Strategies for a one-month recall and a meal frequency questionnaire. Hemoglobin levels and anthropometric measurements were used to determine the nutritional status. Analyzing anthropometry and nutrition data was done using WHO AnthroPlus and NutriSurvey software.	Throughout a 20-year period, the STRIP intervention increased children's diet quality, showing that young people can adopt and maintain healthy dietary modifications.

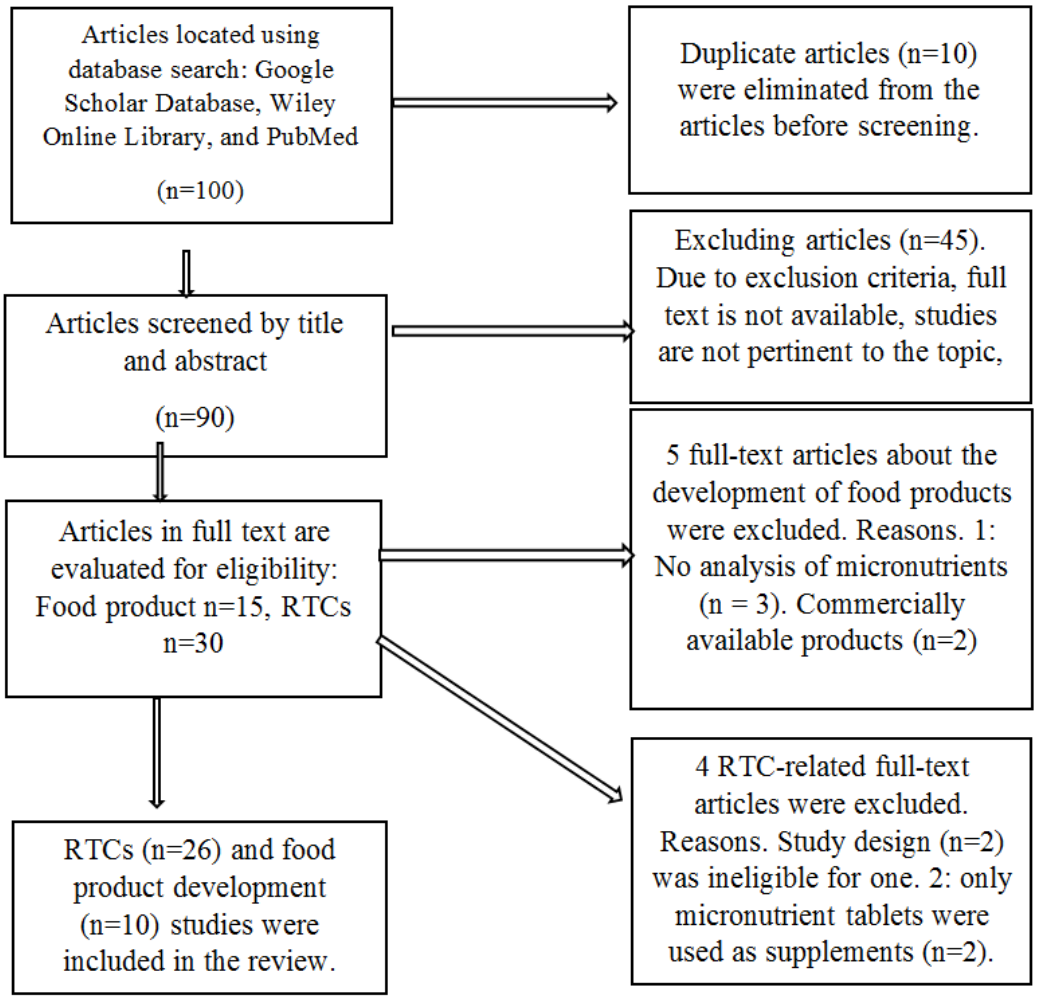

Figure 1. *Flow chart of study selection process.*

Overarching summary from all the studies:

(1) Food-based interventions have a potential to address micronutrient deficiency in target populations;

(2) The findings of these intervention studies underscore the benefits of consumption of micronutrient-rich foods to infants and women of reproductive agex;

(3) The consumption of locally available micronutrient-rich foods can improve the health of the populations;

(4) Nutrition Education proved significant to women, who usually prepare meals and are also engaged in food related businesses for income generation.

3.2. The Role of Food Based Intervention in Improving Micronutrients Intake

It has been demonstrated by numerous research that food-based interventions can significantly increase micronutrient sufficiency in Africa. A study carried out in Kenya assessed the role of school-based food intervention to reduce anemia. It was found that the food blended with baobab powder provided by schools dramatically improved students' iron status and decreased anemia [13]. Another study in Tanzania examined the effect of consumption of dark green leafy vegetables on children's vitamin A status [26] Results showed significant increase of children's vitamin A status. A study conducted in Uganda for six months, assessed the effects of a nutrition-sensitive agriculture program on dietary diversification and household food security. Interventions in the program included promoting bio-fortified crops and providing information on nutrition [1]. According to the study, the program dramatically increased dietary diversity and household food security, which enhanced women's and children's intake of micronutrients. Improvement in child nutrition can be achieved by interventions which focus at boosting the productivity and output of nutrient-dense food crops, such as vegetables and pulses. The impact of home gardening, nutrition education, and other interventions on the long-term nutritional and health outcomes of target beneficiaries have been studied in randomized controlled trials to generate epidemiologically valid insights.

In Tanzania and Ghana, younger children's mean hemoglobin levels and anemia were found to be significantly affected by improved home gardening programs [9, 12, 19]. In Ethiopia, Rwanda, Ghana, and Burkina Faso, it was reported

that nutrition-sensitive agricultural interventions had an effect on the variety of maternal and child diets, food intake, micronutrient status, and weight-specific nutritional status markers [2, 8, 19, 22, 25, 29].

Additionally, research carried out in Tanzania and Kenya revealed that dietary diversification had a substantial impact on child anemia following years of intervention. These findings underscore the significance of putting in place agricultural interventions that are nutrition-sensitive in order to enhance the nutritional status and general health of vulnerable people, particularly in low-income nations. According to the research, homes with vegetable-based production systems experienced lower rates of vitamin A, iron, and vitamin C deficiency than those with non-vegetable-based production systems [21, 26]. The study found that interventions that targeted female-owned small farm-holding households produced superior results than their counterpart - men. School-age children and teenagers of the former were a little bit taller than those of the latter. The treatments' effects, however, were regionally different, with some places demonstrating a positive influence on pre-school boys' height for age scores and others on women's body mass index.

Furthermore, even a little quantity of traditionally consumed, locally grown vegetables could boost micronutrient intake, enhance general health and nutritional status. Additionally, it has been demonstrated that greater crop diversification can improve our diets by raising calorie and nutrient consumption [6, 7, 9, 12, 27]. These results highlight the significance of encouraging crop diversity and vegetable-based agricultural methods to enhance the nutritional status and health of vulnerable communities. The claim provides evidence that the Dietary Diversity Score (DDS) is a major predictor of adequate micronutrient intake in infants as well as young children. In a study conducted in Kenya, the DDS based on a straightforward count of the food categories ingested and the DDS with a 10-gram minimum intake for each food category were found to be significant predictors of sufficient micronutrient intake in 6–17-months-old Kenyan infants [28]. Five and six food groups, respectively, were found to be the ideal cutoff criteria for ensuring 50% and 75% probabilities of adequate micronutrient consumption [28].

Additionally, the DDS-10g was found to be a more precise indicator of nutrient sufficiency among 24-month-old toddlers from Tanzania, Malawi, and Ethiopia [7, 9, 11, 17, 25]. In a comparison of DDS made for schoolchildren in rural Kenya based on various minimum intake amounts from each food group, the DDS based on a 15-gram minimum and the DDS based on nutrient content were only significantly associated with mean probability of adequacy (MPA) after adjusting for energy intake [28]. Other studies have reported a connection between DDS and MPA in pregnant women in Burundi and adults in Mozambique [10, 18].

The studies also emphasized on the need for local adaptation to establish the right threshold due to MPA fluctuation. In a Malawian study of pregnant women using a range of nutrient-dense diets, the MPA for 11 micronutrients was reported to be at 0.19 [17]. These findings highlight the importance of monitoring dietary diversity as a means of ensuring adequate micronutrient intake and improving nutritional outcomes in vulnerable populations, particularly in low-income countries. Overall, these studies show that food-based interventions can successfully increase vitamin consumption and decrease the prevalence of micronutrient deficiency in Africa. The most vulnerable populations, like women and children, must be the focus of these interventions, which must be carried out comprehensively and sustainably.

3.3. Associations of Food-Based Dietary Intervention and Functional Outcomes

3.3.1. Anthropometry

In a Kenyan study, the effects of a school-based feeding program on students' nutritional health and academic performance were assessed. A nutrition education component was included in the feeding program, in addition to nutrient-dense meals and snacks. The feeding program, according to the study, dramatically enhanced academic performance as well as anthropometric measurements including height-for-age and weight-for-age [28]. An evaluation of the effects of various moringa-blended biscuits on anthropometric measurements and cognitive function in school children was done in Ghana as part of a randomized controlled study. According to the study, as compared to non-fortified biscuits, fortified biscuits dramatically improved anthropometric measurements like height for age, weight for age, and body mass index [14, 19]. An additional research project carried out in Mozambique assessed the effects of a nutrition-sensitive agriculture program on anthropometric measurements and dietary diversity among women and children. The program included interventions like promoting bio-fortified crops and educating people about nutrition. According to the study, the program had a significant positive impact on anthropometric measurements like height for age and weight for age as well as dietary diversity in women and children [10].

A community-based nutrition program's effect on anthropometric measurements and dietary diversity among children was assessed in a study carried out in Burkina Faso. The initiative included measures such as nutrition education and promotion of regionally accessible foods high in nutrients. The program dramatically improved anthropometric measurements including height-for-age and weight-for-age as well as nutritional diversity among youngsters, according to the study [29].

In addition to BMI, the relationship between dietary diversification and other adult anthropometric measurements like waist circumference and body fat percentage has been investigated. According to research of adult women in Ghana, a more varied diet may have a preventive impact against abdominal obesity since it reduced body fat percentage and

waist circumference [2]. Diversity in food was linked to a lower risk of overweight and obesity in both men and women, according to a study conducted in Nigeria [22]. It is crucial to remember that a number of variables, such as socioeconomic status, degree of physical activity, and access to healthcare, may have an impact on the association between dietary diversity and adult anthropometry. For the purpose of improving the nutritional condition of adults in Africa, further studies are required to better understand the mechanisms behind these relationships and to design focused treatments.

It's crucial to keep in mind, that weight-for-height Z scores and weight-for-age Z scores aren't necessarily accurate predictors of the influence of dietary interventions on child nutrition outcomes. This is because changes in weight may not always represent improvements in overall nutritional status and may instead be influenced by factors like body fat and water retention. In order to properly assess the influence of dietary interventions on the outcomes of child nutrition, it is crucial to take into account a variety of indicators of child growth and development. When analyzing the possible effects of dietary diversification on the anthropometric status of African people, it is crucial to take into account a variety of factors that lead to under nutrition. The availability of better water and sanitation, the cleanliness of the home environment, and feeding practices are all significant elements to take into account. The timing of interventions is particularly crucial because children's linear growth slows down significantly before the age of 24 months. Therefore, the potential nutritional advantages of diverse agricultural output would need to occur between 6 and 24 months of life, when many children are receiving supplemental meals, in order to reduce deficits in linear growth. Interpreting the possible effects of dietary diversification on anthropometric status in African individuals requires an overall grasp of the complexity of causes causing under nutrition and the timing of interventions.

When developing and putting into practice dietary interventions, it's also critical to take the regional context and cultural practices into account. The acceptance and persistence of dietary modifications may be influenced by food accessibility and cultural perceptions of particular foods. Therefore, boosting dietary diversity and eventually people's nutritional health is more likely to be accomplished by treatments that consider the local and cultural environment. Finally, it is critical to understand that addressing under nutrition and its complicated causes may need more than just increasing dietary diversity. To enhance overall nutritional results, a multi-sectoral strategy that tackles underlying issues including poverty, education, and healthcare is required.

3.3.2. Cognitive Function

The relationships between dietary interventions based on food and cognitive performance in Africa have been the subject of numerous studies. According to these researches, food-based nutritional interventions, especially those that emphasize supplying vital micronutrients, can enhance cognitive function in school-aged children. Programs for nutrition education that encourage wholesome eating practices and practical exercises may also benefit cognitive function. A South African study examined the effects of a nutrition education program on primary school students' cognitive abilities. Interventions in the program included culinary instruction and practical gardening tasks. According to the study, the training markedly enhanced cognitive function in areas including attention, memory, and problem-solving [20].

A Ugandan study examined how a program for nutrition-sensitive agriculture affected children's cognitive development. Interventions in the program included promoting bio-fortified crops and providing information on nutrition. In comparison to the control group, the training dramatically enhanced cognitive performance, according to the study [3].

Another study done in Kenya shows that consumption of animal source food (ASF), particularly meat and milk, can considerably raise exam scores in subjects including geography, mathematics, english, and kiswahili among school-aged children in Kenya. In order to address dietary inadequacies in the diets of Kenyan schoolchildren, a two-year cluster-randomized, controlled feeding intervention trial was conducted [15]. The iso-energetic yet nutrient-diverse snacks given to the intervention groups included meat and milk snacks, which were abundant in animal source protein, readily available zinc and iron, and vitamin B12. The study's findings revealed that youngsters in the meat and milk groups greatly outperformed their peers on standardized tests, with the meat group demonstrating the highest gains. Intriguingly, the study also revealed that over the course of the two years, food intake at home did not alter considerably, with the exception of the number of calories and protein ingested by the kids in the meat group, who may have had a stronger appetite and were consequently more active. The study also found that the children in the meat-eating group had significantly higher levels of lean body mass and physical activity [15]. Overall, these results indicate that increasing ASF intake, especially of meat and milk, may have considerable positive effects on school-aged children's academic performance and physical health in low-income countries like Kenya. To fully comprehend the underlying mechanisms and potential drawbacks of this strategy, more study is necessary.

In a related study, women of reproductive age (WRA) in Rwanda were evaluated for their cognitive outcomes after eating meals produced with iron bio-fortified crops [22]. This study emphasizes the potential advantages of iron bio-fortified crops on cognitive outcomes in women of reproductive age, notably memory and attention. Strong evidence indicated that eating of iron bio-fortified beans enhanced Rwandan women's iron status and cognitive performance comes from the randomized controlled trial design. The study also revealed that the intervention had a stronger effect on memory tasks than on other cognitive tasks and that changes in ferritin levels were associated with improvements in memory and attention. According to these results, in-

creasing iron intake through the consumption of bio-fortified crops could benefit cognitive function and academic performance [22]. However, more investigation is required to verify these findings and examine the possible effects of bio-fortification on other facets of development and health. Overall, these studies indicate that dietary interventions centered on food that encourage nutrient-rich diets can significantly enhance cognitive performance in children in Africa. These findings are significant because brain function is essential for both short- and long-term success in academics and in life.

3.3.3. Biomarkers

Table 2. Food-based interventions verified with adequate intake of micronutrients and biomarkers of intake.

Marker	Intake data	Outcome
Haemoglobin, serum ferritin and retinol Serum (HemoCue™, Maglumi 800& vitamin A enzyme-linked immunosorbent assay) [19].	Record vegetables consumed by household (24-h recall)	Correlation with vegetable intake
Serum retinol, serum zinc (HPLC, ELISA, sensitive colorimetric assay), serum ferritin, and soluble transferrin receptor [26].	24-hour recall to determine how much of each food was consumed overall the day before	Correlation with Dark Green Leafy Vegetables
Hemoglobin (hemoglobinometer) [12].	24 h food recalls.	Dietary habits have a significant impact on the frequency of micronutrient deficits.
Sandwich ELISA for C-reactive protein (CRP), acidic glycoprotein (AGP), soluble transferrin receptor (sTfR), and serum ferritin (FER) [13].	24 h recalls during the 1st (t1), 5th (t2) and 11th (t3) weeks	Hb levels and dietary vitamin C intake in baobab are positively correlated.
Blood serum retinol (Sandwich ELISA; HPLC), hemoglobin, serum ferritin, and soluble transferrin receptor [21].	24-hour breastmilk volume collection at home	Correlation between moringa powder intake with vitamin A and Iron increase
Hemoglobin, together with C-reactive protein, -1-acid glycoprotein, and serum transferrin receptor (TfR); (sandwich ELISA) [22].	24-h diet recall	Eating meals that contain a crop that has been biofortified with iron increases iron bioavailability.
Concentrations of RBP, ferritin, soluble transferrin receptor, CRP, and 1-acid glycoprotein (AGP) in the blood (sandwich ELISA); serum retinol (HPLC) [2].	24-h recall data collection	Consuming biofortified (yellow) cassava on a regular basis only moderately reversed a drop in serum retinol content.
Blood retinol concentration (iCheck™ Fluoro) [8].	24-h dietary recall of all infants' two-day meals and beverages	In a rural area of Ghana, moringa increases blood retinol levels in babies.

According to the research data presented in Table 2, food-based dietary interventions, especially those that emphasize supplying key micronutrients, can enhance indicators of nutritional status in a variety of African communities. Biomarkers of nutritional status can benefit from nutrition education initiatives that encourage nutrient-dense food consumption and share knowledge about these foods.

An analysis of a nutrition education and food supplementation program's effects on biomarkers of iron and vitamin A status in pregnant women was done in Tanzania [12, 26]. The program included nutritional education and interventions like consuming fruits and vegetables rich in iron and vitamin A. The program significantly increased indicators of iron and vitamin A status in pregnant women. Another randomized controlled trial that was carried out in Kenya assessed how a nutrition intervention affected the status of biomarkers for iron, zinc, and vitamin A in schoolchildren. A nutrient-dense food and nutrition instruction were part of the intervention. According to the study, compared to the control group, the intervention dramatically improved iron and zinc status biomarkers [13, 21]. A promising intervention to address the problem of iron and vitamin A deficiency is the inclusion of moringa leaf powder in the free daily meals provided to rural Kenyan kids [21, 29]. Iron and vitamin A, both essential for children's healthy development, are found in plenty in moringa leaf powder, which is well renowned for its high nutritional value. To combat malnutrition among pupils in low-income communities, offering free daily meals that contain moringa leaf powder may be an effective tactic. To keep the nutritional content of the moringa leaf powder, it is cru-

cial to make sure it is of a good quality, well prepared and appropriately stored. To make sure that such interventions are accomplishing their intended goals, it is crucial to track and assess their efficacy.

The research on school meals for South African children emphasizes the necessity for appropriate methods of preparing African leafy vegetables (ALVs) to increase vitamins bio-availability. Despite having a high nutritional content, ALV did not increase the blood levels of retinol, ferritin, or hemoglobin in children with mild deficiencies when 300g of cooked ALV with maize were consumed for three months. The phytates in the meal of maize starch could be responsible for this since they prevented the absorption of zinc and iron.

The study also revealed that the children had a modest iron and vitamin A shortage, and it is possible that the intervention's short duration played a role in its failure to have an effect. Before introducing ALV in school lunches, it is crucial to address the underlying nutritional shortages.

The study emphasized the need for suitable ALV preparation techniques that could improve micronutrient bioavailability. Processes such as soaking, sprouting, and fermenting significantly reduce the phytate content of ALV and increase the availability of micronutrients. Additionally, fortification of other foods, such as bread and oatmeal, may be necessary to address the micronutrient deficiencies in the population.

4. Conclusion and Recommendation

According to the scientific data in this review, it is obvious that food-based interventions, including dietary diversification or modification, can successfully improve the micronutrient status and related health outcomes in children, teens, and expectant women. Consequently, it is advised that governments, non-governmental organizations, and health professionals give priority consideration to implementing these interventions in their nutrition programs and policies. When implementing food-based interventions, it is crucial to remember that there is no single strategy which will be suitable under all circumstances because it's necessary to take into account the unique requirements and cultural customs of each population. It is therefore advised that these interventions be made to specifically address the needs of each group, taking into account their dietary choices, accessibility, and affordability. To ensure that people and communities are aware of the significance of a healthy diet and how to make informed food choices, it is also critical to promote nutrition education and behavior change communication alongside these interventions. Long-term advantages of the interventions will be maintained in this way.

Finally, food-based interventions, such as dietary diversification or modification, are successful in enhancing micronutrient status and related health outcomes in children, adolescents, and expectant women. It is advised that these interventions be prioritized, adapted to the particular requirements of each community, and supported by behavior modification and nutrition education campaigns.

Abbreviations

ALVs: African Leafy Vegetables
ASF: Animal Source Food
BMI: Body Mass Index
CDSR: Database of Systematic Reviews
DDS: Dietary Diversity Score
IQ: Intelligence Quotient
MPA: Mean Probability of Adequacy
RCTs: Randomised Controlled Trials
STINT: Swedish Foundation for International Cooperation in Research and Higher Education
WRA: Women of Reproductive Age

Acknowledgments

The authors wish to acknowledge the Swedish for international cooperation in research and higher education (STINT) for funding this research.

Funding

This work was supported by the Swedish Foundation for International Cooperation in Research and Higher Education (STINT), grant number SG2021-8934.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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