REVIEW ARTICLE

The Impact of Soy Fortification in Early Childhood Foods on Child Nutrition Outcomes: A Systematic Review

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ABSTRACT

Child malnutrition remains a significant public health challenge that disproportionately affects children in low- and middle-income countries (LMICs). The problem is further intensified by widespread food insecurity and limited access to affordable animal-source protein in many of these settings. Soy-fortified complementary foods have therefore emerged as a promising nutritional intervention due to their high nutritional value, local availability, affordability, and general acceptability among communities. This review examined the impact of soy fortification in early childhood foods on child nutrition outcomes. The review followed the PRISMA 2020 guidelines and involved a comprehensive search of peer-reviewed studies published between 2012 and 2025 across several databases, including the Cochrane Library, Google Scholar, PubMed, Embase, and PLOS One. Fourteen eligible studies conducted in LMICs were included, comprising randomized controlled trials, test-feeding experiments, non-inferiority trials, and experimental formulation and sensory evaluation studies. Most of the reviewed interventions demonstrated significant improvements in key anthropometric indicators such as weight-for-age, height-for-age, weight-for-height, and mid-upper arm circumference, as well as reductions in the prevalence of wasting and underweight. Soy-based formulations were also associated with improved recovery rates among children with severe and moderate acute malnutrition and increased serum concentrations of essential micronutrients such as zinc and iron. In addition, soy-fortified products generally showed higher acceptability and improved nutritional quality compared to traditional complementary foods. However, the effectiveness of these products depended largely on formulation quality and the bioavailability of nutrients. Despite some variability in findings across studies, the overall evidence strongly supports the integration of soy-fortified foods into community-based nutrition programs aimed at addressing child undernutrition. These findings provide valuable guidance for policymakers and healthcare providers by highlighting soy-based formulations as an evidence-based intervention to improve child growth, nutrition, and survival.

Keywords: *Child nutrition, nutrition outcomes, soy fortification, soy-fortified foods, systematic review*

INTRODUCTION

Malnutrition is a major public health issue that has drawn attention over the recent years, affecting children globally. According to the World Health Organization, malnutrition entails various forms such as undernutrition (underweight, stunting, wasting), overnutrition, vitamin or mineral deficiency, and resulting diet-related noncommunicable diseases (World Health Organization, 2024). Approximately 150 million children under 5 were stunted, 46 million were wasted, and 40 million were overweight/obese globally in 2022. Similarly, about half of child mortality was associated with undernutrition, particularly in low- and middle-income countries (LMICs) (Alaba et al., 2023). Despite a significant decline in childhood stunting globally, the sub-Saharan region has witnessed a significant rise of approximately 9 million children, from 50.3 million in 2018 (Otekunrin, 2024). Previous studies have reported varying malnutrition prevalences across the world (Khaliq et al., 2022; Menalu et al., 2021).

Early childhood, the period from six months to five years, is recognized as a nutritionally vulnerable phase in which dietary interventions significantly shape growth and development. As a result, dietary needs increase due to rapid growth, yet food insecurity and unhealthy feeding practices are often linked to poor nutrient intake (Brandt et al., 2023). Undernutrition during early childhood has been associated with adverse and long-lasting health outcomes such as delayed physical growth, cognitive development, impaired academic performance, elevated susceptibility to infections due to weakened immune systems, and reduced productivity in adulthood (Samia et al., 2025; Soliman et al., 2021). Despite the critical role of exclusive breastfeeding for the first six months, it's essential to ensure appropriate and timely introduction of complementary foods to bridge nutrient gaps. In most LMICs, early childhood foods such as cassava, sorghum, maize, rice, etc., have poor-quality iron, proteins, and other essential nutrients (Ijarotimi, 2022; Oladiran & Emmambux, 2022).

Nutritional deficits have remained a significant challenge impacting nutritional interventions. Various food fortification approaches have been adopted to address these nutritional deficits, especially protein fortification. Promising results regarding soybean (Glycine max)-based fortification into early childhood foods (Fernandes et al., 2020). Soybeans are a locally available, affordable, and nutrient-dense legume with 39-43% protein content. Similarly, soy is rich in amino acids, including lysine, and micronutrients such as zinc, vitamin B, iron, etc., which are missing in most cereal-based diets. Soy has superior quality of protein and bioavailability with protein efficiency ratios (PER) of more than 2.0. (van den Berg et al., 2022). Soy fortifications such as corn-soy blends (CSB+), soy-fortified sorghum porridges, soy-rice-based weaning formulas, etc., have shown significant improvement in weight-for-age (WAZ), height-for-age (HAZ), and hemoglobin levels (Grasso et al., 2023; Rapando et al., 2020; Wandia & Wanzala, 2025). Few studies conducted regarding soy-based interventions have adopted varying approaches such as study designs, food formulations, and intervention periods, which have significantly limited the unified ability for their adoption and implementation by policymakers, healthcare providers, and program implementers. This has been exacerbated by the variation of outcome measures from different approaches used, limiting the ability to draw clear evidence-based conclusions regarding the effectiveness and impact of soy fortification in early childhood nutrition. Therefore, this study reviewed the current studies on the impact of soy-fortified foods on child nutrition outcomes.

METHODS

Design and Search Strategy

This systematic review was conducted to assess the impact of soy-fortified foods on child nutrition outcomes. The review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (O'Dea et al., 2021). A comprehensive search for relevant peer-reviewed articles was conducted through various electronic databases such as Cochrane Library, Google Scholar, PubMed, Embase, and PLOS One. The search strategy combined controlled vocabulary and free text terms related to soy fortification and child nutrition outcomes. Additionally, the search strategy involved the use of keywords such as "soy-fortified foods," "soy-blend," "soy fortification," "soy-based food," "child nutrition," "malnutrition," "soy intervention," "anthropometry," and "soy nutrition." Boolean operators (AND, VS, OR) were applied to refine results. Manual searches were done through the use of subject-relevant review articles, bibliographies, and cross-references to identify additional sources of information. The search was restricted to articles that were published and written in English and published between 2012 and 2025.

Inclusion criteria and exclusion criteria

This review included original peer-reviewed studies that adopted randomized controlled trials (RCTs), pre- and post-intervention, and quasi-experimental approaches. Additionally, studies that adopted less

vigorous approaches, such as observational designs, were careful and detailed in their evaluation to understand the context of intervention implementation, with those focused on study subjects included. Studies involving human participants, children under seven years old, and evaluated soy-based intervention on health outcomes such as anthropometric measurements or nutritional status were included. However, studies that were editorial, commentaries, or reviews; involved non-soy interventions; and were non-peer-reviewed articles or dissertations that lacked validation were excluded. Similarly, studies that lacked nutrition-related outcome measures and full-text availability were also excluded.

Protocol Registration

A review protocol was developed a priori to define the objectives, eligibility criteria, search strategy, outcome measures, and analytical framework prior to study selection. These approaches strengthen methodological transparency and minimize reporting bias. The protocol was not prospectively registered in PROSPERO or any other international registry. This represents a deviation from full PRISMA 2020 recommendations and is acknowledged as a methodological limitation. However, all predefined procedures were adhered to during study identification, screening, extraction, and synthesis to minimize reporting bias and enhance transparency (Figure 1). The completed PRISMA checklist was developed and is provided as supplementary material.

Study Selection Data Extraction Process

All the available articles were subjected to standardized triage protocol for primary screening of the studies. The studies' abstracts and full texts were systematically screened by two independent reviewers based on agreed data extraction guidelines and approaches. The third available reviewer resolved any disagreements that arose between the two primary reviewers during the study selection process. After retrieval of the relevant full-texted studies, each study was subjected to double data abstraction and documented in a standardized data extraction form developed based on the population, intervention, comparator and outcomes (PICO) framework. The population of interest entailed children (under five and school-going), preferably from low- and middle-income countries (LMICs). The review's intervention of focus was soy-fortified foods of any formulation. The participants who received non-soy-fortified or standard dietary intervention were regarded as comparators. Primary outcomes included changes in anthropometric indices such as height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), weight-for-height z-scores (WHZ), and mid-upper arm circumference (MUAC), while secondary outcomes comprised hemoglobin concentration, acceptability of diet, feeding behavior, and other nutrition-related indicators. Additionally, the form entailed the study's basic information, such as author(s), year of publication, title, study design, and country of intervention, and intervention details, such as soy-based formulation. The certainty of evidence for each outcome was assessed qualitatively based on study design, risk of bias, consistency of findings, directness, and completeness of outcome reporting, following principles adapted from the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.

Risk of Bias Assessment and Data Synthesis

Methodological quality and risk of bias were independently assessed by two reviewers using validated, design specific appraisal tools. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 tool, while quasi experimental and observational studies were appraised using the Joanna Briggs Institute critical appraisal checklists. Domains assessed included selection bias, allocation concealment, blinding, incomplete outcome data, selective reporting, and confounding. Any discrepancies between reviewers were resolved through consensus, with arbitration by a third reviewer where necessary. Risk of bias assessments were incorporated into the interpretation of findings to avoid overestimation of intervention effects. A narrative synthesis strategy was adopted due to heterogeneity in the intervention formulations, types, study designs and outcome measures used. The interventions used by selected studies were categorized by product type and specific context of use to reduce risk of over generalization. Findings of the review were synthesized based on intervention type and reported outcomes. Where sufficient homogeneity existed, comparison of results was conducted descriptively across studies.

Ethical Considerations

There was no ethical approval that was required for this review, as it relied on existing peer-reviewed published data and did not involve primary data collection or human participant recruitment.

RESULTS

A total of 1,273 records were identified through database searches and trial registers, including Google Scholar (n = 772), PubMed (n = 165), PLOS One (n = 132), Embase (n = 114), and the Cochrane Library (n = 84. Out of 1,285 identified

records, 397 records were removed before screening due to duplication reasons (n = 283), marked as ineligible by automation tools (n = 103), and 11 were removed other reasons. A total of 876 remaining records went through a comprehensive primary screening. Out of 876 screened records, 819 records were excluded due to various reasons such as lack of relevant findings (n=741), not addressing the review's objectives (n = 52), and reviews or abstract without empirical data (n = 26). Out of 57 remaining records that underwent retrieval, 13 were excluded as the full-text were not retrieved. A total of 44 full-text records were screened for eligibility in the second phase, with 30 records were excluded due to data inefficiency (n=17) and ineligible study designs (n=13). Therefore, the review included 14 original peer-reviewed studies as shown in Figure 1.

Figure 1:

PRISMA 2020 Flow Diagram of Study Selection for Soy Fortified Foods and Child Nutrition Outcomes
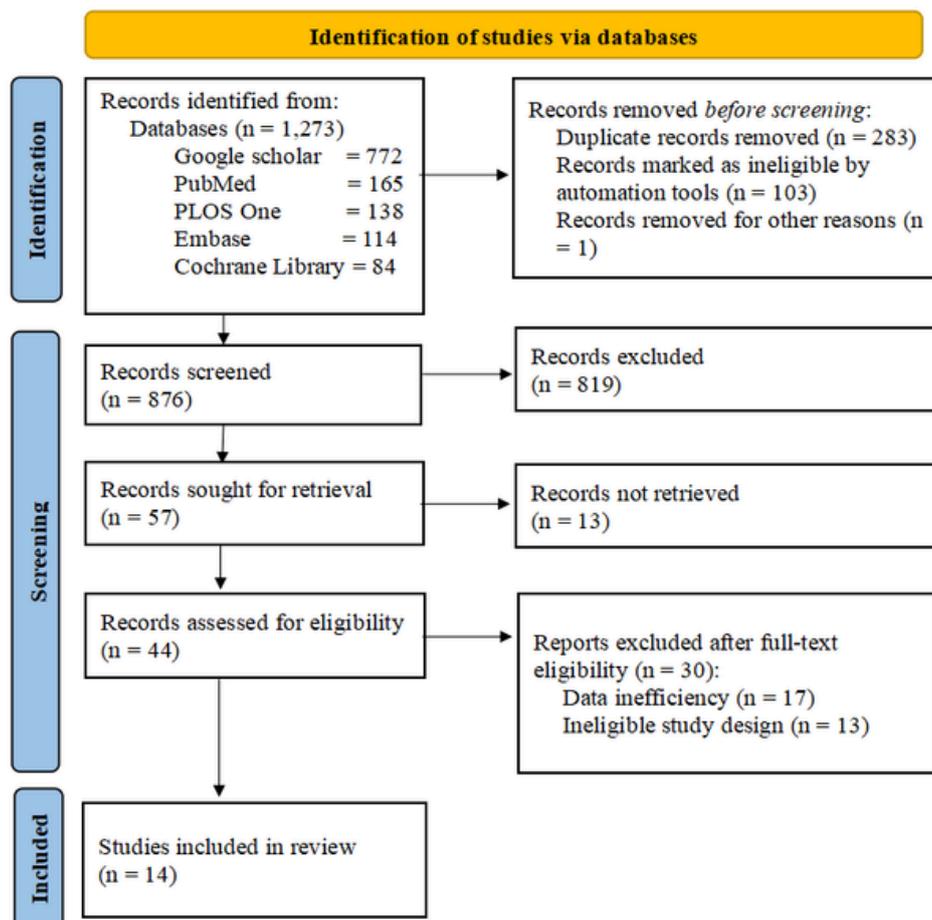
The studies that met the inclusion criteria were coded and summarized in Table 1, including general information such as author, intervention country, study design, study participants, and intervention details such as intervention, comparators, key outcomes of focus and key findings/results. Out of 14 included studies, most studies were conducted in Kenya (Kiio et al., 2022; Kipkemoi Ronoh, 2017; Othoo et al., 2021; Susan et al., 2022), Uganda (Amegovu et al., 2014; Kajjura et al., 2019), Republic of Congo (Bisimwa et al., 2012), Bangladesh (Christian et al., 2015), Cameroon (Ngaha Damndja et al., 2024), Zambia (Irena et al., 2015), Burkina Faso (Kampstra et al., 2018), Malawi (LaGrone et al., 2012), Rwanda (Niyibituronsa et al., 2014), and Ethiopia (Nane et al., 2021). The 14 studies consisted of five cluster RCTs (Bisimwa et al., 2012; Christian et al., 2015; Irena et al., 2015; Kajjura et al., 2019; Kiio et al., 2022), two non-inferiority RCTs (LaGrone et al., 2012; Nane et al., 2021), one cross-over trial RCT (Kampstra et al., 2018), two unspecified RCTs (Niyibituronsa et al., 2014; Othoo et al., 2021), two complete randomized experiment design (Kipkemoi Ronoh, 2017; Susan et al., 2022), test feeding trail experiment (Amegovu et al., 2014), and experimental formulation and sensory trial (Ngaha Damndja et al., 2024). All the studies clearly identified the comparators and interventions, except for Christian et al.(Christian et al., 2015). Robustness of findings was assessed qualitatively by comparing outcomes across study

designs, intervention types, and risk-of-bias levels. The narrative synthesis accounted for differences in study quality and design to minimize overestimation of effects and ensure credible interpretation of evidence.

Most of these studies reported significant positive impact of soy-fortified foods on childhood nutrition and health, particularly in the improvement of anthropometric and micronutrient outcomes. Anthropometric outcomes showed moderate confidence due to consistent improvements and low to moderate risk of bias, while micronutrient and acceptability outcomes were low to moderate, reflecting heterogeneity, small samples, and incomplete reporting. Several studies reported gains in weight, HAZ, WAZ, WHZ, and MUAC, and reduction in stunting, underweight among malnourished children receiving soy-based fortified intervention at endline (Christian et al., 2015; Irena et al., 2015; Kajjura et al., 2019; Kampstra et al., 2018; Kipkemoi Ronoh, 2017; Nane et al., 2021; Susan et al., 2022). Similarly, some reported improvement in recovery rate from malnutrition, which was higher among children under soy-based fortified early childhood foods interventions compared to comparators (Irena et al., 2015; LaGrone et al., 2012; Othoo et al., 2021). Spirulina-Corn-Soy-Blend significantly accelerated iron deficiency recovery rates to by 15.4 per 100 persons per day (average of 8 days) compared corn-soy blend and the placebo (4.6 and 1.8 per 100 persons per day) (Othoo et al., 2021). Similarly, corn-soy blends with micronutrient powder significantly increased serum zinc concentration among iron deficient children (Kiio et al., 2022). Soy-fortified products improved acceptability, palatability and feeding behaviour among malnourished children compared to most conventional supplementary foods (Amegovu et al., 2014; Ngaha Damndja et al., 2024). Additionally, Irena et al.(Irena et al., 2015) found that milk-free soy-maize-sorghum ready-to-use therapeutic foods (RUTF) were significantly inferior in the recovery rate and weight gain compared to peanut-based RUTF.

Figure 3:

Stacked bar chart showing primary occupation distribution according to mothers' educational level.
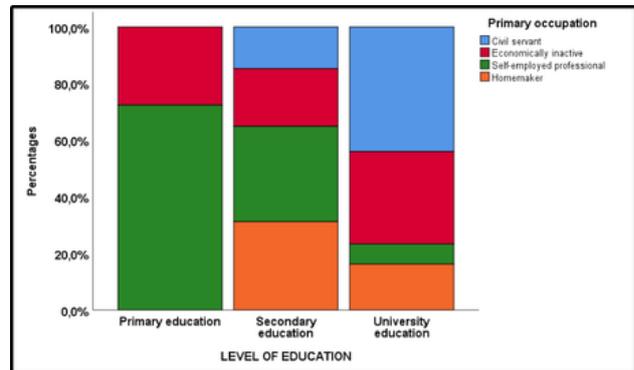
Infant Feeding Knowledge of Mothers

Overall, although most mothers were aware of selected infant feeding recommendations, none achieved a good overall knowledge score (Table 1).

Most mothers correctly identified six months as the recommended duration of exclusive breastfeeding; however, the majority still fell into the low or moderate knowledge categories. A statistically significant association was observed between reported duration of exclusive breastfeeding and overall knowledge score ($p < 0.001$).

Regarding complementary feeding, most mothers reported introducing foods at six months. No statistically significant association was found between age of complementary feeding introduction and overall knowledge score ($p = 0.126$). One extreme value (99 months) was identified and considered a reporting error; this value was excluded from inferential interpretation but retained descriptively in the table.

Although mothers were able to cite appropriate food groups for infants aged 6-12 months, no significant association was observed between the types of foods cited and overall knowledge score ($p = 0.540$). Similarly, no significant associations were found between knowledge scores and beliefs regarding sugar/salt introduction ($p = 0.174$) or sources of information ($p = 0.736$).

Overall, a predominance of low to moderate knowledge levels was observed across all knowledge domains assessed.

Table 1:

Summary of literature on soy-fortified foods on child nutrition and related indicators

Study	Country	Design	Study Population	Intervention	Comparator	Key Outcomes	Key Findings
Bisimwa et al. (2012)	DR Congo	Cluster RCT	Infants aged 6–12 months	Soybean-maize-sorghum RUCF	UNIMIX	HAZ, MUAC, WAZ, & hemoglobin concentrations	Significant improvement, but no statistically significant difference in weight, HAZ, MUAC, WAZ, & hemoglobin concentrations between the 2 groups
Christian et al. (2015)	Bangladesh	Cluster-RCT	Children aged 6-18 months	Daily fortified complementary foods (chickpea, rice-lentil RUSF, or WSB++)	NR	HAZ, WAZ, WHZ	Significant stunting reduction (by 5–6%), and improved HAZ (+0.07 to +0.10), and WHZ decline
Ngaha Damndja et al. (2024)	Cameroon	Experimental formulation & sensory trial	Infants (6–24 months); sensory panel of mothers	Pumpkin, spinach, soy	Pumpkin/spinach puree	Nutritional quality, viscosity, acceptability	Statistically improved acceptability, protein, iron, viscosity compared to comparators
Irena et al. (2015)	Zambia	Equivalence non-blinded cluster RCT	SAM diagnosed children aged 6-59 months	Milk-free soy–maize–sorghum-based RUTF	Peanut based RUTF (P-RUTF)	MUAC, weight, malnutrition recovery,	MUAC, weight, malnutrition recovery rate in the SMS-RUTF was significantly lower compared in the P-RUTF group
Kajjura et al. (2019)	Uganda	Cluster RCT	Infants aged 6-24 months	Soybean Supplementary porridge (n=104)	CSB+ (n=100)	HAZ, WAZ, and haemoglobin levels	Statistically significant improvement in WAZ, and lower haemoglobin levels among treatment group than control.
Kampstra et al. (2018)	Burkina Faso	RCT cross over trial	Children aged 12–23 months	Soy- fortified blended foods	Non- Soy-fortified blended foods	Weight, MUAC & Acceptability	Significantly improved weight, MUAC & acceptability compared to control
Kiio et al. (2022)	Kenya	cluster-RCT	Children aged 6–36 months	Corn-soy Blend	Non- Corn-soy Blend	Serum zinc concentration	Mean change in serum zinc concentration was significantly higher in CSB-MNP-A (18.7 ± 2.1) μg/dL compared to control group (11.8 ± 2.6 μg/dL).
LaGrone et al. (2012)	Malawi	Noninferiority RCT	Children aged 6–59 months	Corn-soy blend ++ RUSF	Soy RUSF/ & Soy/whey RUSF	MAM Recovery rate, MUAC	Similar MAM recovery rate for all foods, & higher significant MUAC gain in the Soy/whey RUSF
Susan et al. (2022)	Kenya	Complete Randomized Design experiment	Preschool children aged 4-5 years	Soybeans fortified (maize & sorghum) porridges	Pure maize flour porridge	MUAC, WAZ, and WHZ	There was significant reduction in prevalence of underweight and wasting, & improvement of MUAC among children received soy fortified porridges at end of 9 months. No significant change among control (pure maize flour porridge)
Amegovu et al. (2014)	Uganda	Test feeding trail experiment	Children aged 12 to 59 months	Corn soy blend plus (CSB+)	Sorghum Peanut blend (SPB)	Sensory Acceptability	CSB+ had a higher acceptability/taste score than SPB. Feeding duration of 300 mL of porridge was significantly lower for CSB+ than for SPB.
Othoo et al. (2021)	Kenya	RCT	Children aged 6–23 months	Spirulina-Corn-Soy-Blend (SCSB), Corn-Soy Blend (CSB)	Placebo flour	Iron deficiency recovery rate	Significantly higher recovery rate (15.4/100 persons per day) for SCSB compared to 4.6 and 1.8 per 100 persons per day for those who consumed CSB and the placebo, respectively. Children consuming SCSB had a lower mean recovery time of 8days compared to those consuming CSB (19 day) and placebo (33 days).
Kipkemoi Ronoh (2017)	Kenya	Longitudinal survey and Complete Randomized Design experimental	Pre-school Children aged 3-5Years	Soybean Fortified Porridges (maize-soybean blend and maize-sorghum-soybean)	100% maize flour	HAZ, WAZ, WHZ, weight, MUAC	Significant reduction in the levels of underweight (47.3%) and wasting (44.2%), and in the intervention groups. Significant weight and MUAC gain in the intervention group

Study	Country	Design	Study Population	Intervention	Comparator	Key Outcomes	Key Findings
Niyibituronsa et al. (2014)	Rwanda	RCT	children aged 6-24 months	Soy fortified products	Placebo	Weight	Significant effect on weight gain (mean 0.9 (±0.5) kg within 3 months of intervention). No significant difference between the 2 groups.
Nane et al. (2021)	Ethiopia	Non-inferiority trial RCT	Children aged 6 to 59 months	Corn-soy blend plus (CSB+)	Local-ingredients-based supplement (LIBS)	Recovery rate, weight, MUAC	Significant effects: weight gain, MUAC, & MAM recovery rate LIBS - non-inferior to CSB+ in treating MAM. Both significantly reduced MAM

N/B: *CSB – Corn-Soy Blend, CSB+ – Corn-Soy Blend Plus, CSB-MNP-A – Corn-Soy Blend with Micronutrient Powder – A, HAZ – Height-for-Age Z-score, LIBS – Local-Ingredients-Based Supplement, MAM – Moderate Acute Malnutrition, MUAC – Mid-Upper Arm Circumference, NR – Not Reported, P-RUTF – Peanut-based Ready-to-Use Therapeutic Food, RCT – Randomized Controlled Trial, RUSF – Ready-to-Use Supplementary Food, RUTF – Ready-to-Use Therapeutic Food, SAM – Severe Acute Malnutrition, SCSB – Spirulina-Corn-Soy Blend, SMS-RUTF – Soy–Maize–Sorghum Ready-to-Use Therapeutic Food, SPB – Sorghum-Peanut Blend, UNIMIX – A commonly used fortified blended food, WAZ – Weight-for-Age Z-score, WHZ – Weight-for-Height Z-score, WSB++ – Wheat-Soy Blend Plus Plus.*

DISCUSSION

This review evaluated 14 studies conducted and published in the last 13 years across sub-Saharan Africa and South Asia on the impact of soy-fortified early childhood foods on childhood nutrition. According to a WHO report, these two regions are significantly affected by childhood malnutrition (World Health Organization, 2024). Therefore, in an effort to combat child malnutrition through dietary approaches, most studies have innovatively assessed the potential of food fortifications, particularly soy-fortified foods, as a promising solution. Most interventions implemented adopted cluster-RCTs, non-inferiority trials, and controlled feeding experiments, which are considered rigorous designs according to Law et al. (2024). Various studies have adopted varying intervention strategies and soy formulations to address undernutrition in local settings through strengthening and empowerment of communities to adopt locally accessible and available plant-based food vehicles. Notably, the included studies have shown methodological consistency, which has provided a crucial foundation for inter-comparisons, valuable for assessing the impact of an intervention. According to Hussein (2021), the adaptability and cost-effectiveness of soybeans makes their formulations more rampant in nutritional interventions in low- and middle-income countries (LMICs). Similarly, soy-fortified (plant-based) interventions are affordable in settings where animal-source proteins remain economically or culturally inaccessible.

This review revealed that most studies that assessed anthropometric outcomes reported consistent and significant improvement, especially in WAZ, HAZ, WHZ, and MUAC. Similarly, these studies revealed significant effectiveness of soy-based interventions in reversing wasting and underweight in early childhood; in particular, a study by Kipkemoi Ronoh (2017) revealed that soy-sorghum fortified intervention resulted in a significant reduction in the levels of underweight

(47.3%) and wasting (44.2%) in the intervention groups. These findings demonstrate the effects of protein fortification in addressing malnutrition in infants and young children across the world. A study by Christian et al. (2015) in Bangladesh revealed that soy-fortified and other plant-based fortified complementary foods using chickpea, rice-lentil RUSF, or WSB++ resulted in about a 5-6% significant reduction in stunting. However, a study in Kenya that used soy, maize, and sorghum fortification reported no significant reduction in stunting but a significant reduction in wasting and underweight (Susan et al., 2022). These differences in results might be attributed to variations in soy formulations, region, and dietary habits of study participants. Similarly, a study by Othoo et al. (2021) bserved that children who fed on a spirulina-corn-soy blend accelerated recovery from iron deficiency compared to conventional CSB or placebo, while studies like Irena et al. (2015), LaGrone et al. (2012), and Nane et al. (2021) demonstrated higher recovery rates from severe and moderate acute malnutrition (S/MAM) among children who fed on specific soy-fortified foods, including CSB+, RUSF, and milk-free soy-maize-sorghum RUTF, compared to non-soy-fortified foods. Soybeans are associated with high-quality plant-based essential amino acids and bioavailable nutrients, which effectively support rapid growth, tissue repair, and immune functioning, promoting significant recovery outcomes (Okoye et al., 2021.). Additionally, consistent with other studies (Hu et al., 2024; Kumar et al., 2023), this review revealed that soy protein significantly supports hematologic and growth recovery when coupled with iron and zinc fortification. As observed by Kiio et al. (2022), corn-soy fortified foods increased serum zinc concentration, affirming that soy is a macronutrient base and efficient carrier of various micronutrients. The synergistic effects of protein-dense soy and targeted formulations significantly resulted in positive nutritional outcomes.

The review revealed that soy-fortified foods significantly improved the taste, texture, and acceptability of the formulations, hence sustained intervention and adoption over time. Studies by Amegovu et al. (2014) and Ngaha Damndja et al. (2024) reported that caregivers and children preferred and favored soy-based fortified products, including CSB+ and pumpkin and spinach soy blends, compared to traditional formulations. These findings align with studies that revealed flavor-improved and nutrient-rich early childhood foods significantly enhance feeding adherence (Grasso et al., 2023). Acceptability of soy plays a significant role in the success of its interventions, particularly in settings where food insecurity is promoted by cultural or religious restrictions. However, a study by Irena et al. (2015) revealed that despite the significant impact of soy-fortified foods on child nutrition, the milk-free soy-maize-sorghum RUTF formulation demonstrated inferior recovery rates compared to standard peanut-based RUTFs. This provided evidence shows that the effectiveness of soy depends on the type and concentration of the formulation. Therefore, plant-based RUTFs require fortification with missing/essential amino acids or lipids to improve their efficacy or even match animal-based formulations.

Strengths and Limitation of the study

This systematic review has several strengths. The review provides relevant public health issues and synthesizes existing evidence over a decade on soy-fortified complementary foods in LMICs. The review adhered to PRISMA 2020 reporting standards, and a comprehensive multi-database search strategy, independent dual screening and data extraction, and the use of validated, design-specific risk of bias assessment tools strengthened methodological rigor. Additionally, the review categorized interventions by formulations or blends and context to minimize overgeneralization while strengthening interpretability. However, several limitations must be acknowledged. The protocol used was not prospectively registered based on PRISMA 2020 guidelines, which potentially introduced reporting bias. The review was restricted to English-language publications, and exclusion of grey literature might have resulted in language and publication biases, respectively. Heterogeneity in soy-based formulations, duration, dosage, outcome definitions, and population of study limited comparability and precluded meta-analysis. This review included quasi-experimental and observational studies, potentially introducing selection bias, confounding, detection bias, and performance bias. Additionally, included studies had variability in outcome measurement methods and follow-up periods, increasing susceptibility to attrition bias and measurement bias.

Conclusion

This systematic review affirms the significant role played by soy-fortified food interventions in addressing child malnutrition and significantly improving nutrition outcomes. Soy-fortified foods hold an undeniable public health relevance and nutritional efficacy. Across various evaluated soy-based formulations and study designs, soy-fortified early childhood foods have been consistently and significantly associated with improvements in anthropometric indicators, biochemical markers, and nutritional quality. Soy-fortified early childhood foods have demonstrated high recovery rates, especially for MAM, and are more acceptable and palatable compared to traditional blends. This promotes adherence and sustainability to intervention programs, resulting in the program's success and the adoption of the concept in the community. Notably, soy-based food interventions heavily rely on formulation quality, delivery context, and nutrient bioavailability, which have been demonstrated to significantly impact their effectiveness. Additionally, soy-fortified early childhood foods hold significant promise in addressing the burden of child malnutrition. It requires being tailored to specific dietary gaps, bioavailability, and cultural acceptability contexts of various regions. Soy-fortified foods potentially warrant positive functional and nutrition outcomes if tried on a large scale and over long durations, which can definitely guide their integration into national nutrition strategies and frameworks to address child malnutrition. Furthermore, continued research should focus on long-term effects, formulation optimization approaches, and associated cost-benefits to promote scale-up feasibility in national and international nutrition programs.

Key Message

1. Soy-fortified early childhood foods significantly improve child growth indicators and micronutrient status.
2. Soy-fortified early childhood foods enhance acceptability, palatability and nutritional quality which promote adherence and sustainability of feeding behaviors across various regions.
3. There is need to optimize soy-based formulations and diet-specific tailored interventions, as its effectiveness depends on quality of formulations, delivery context and nutrient bioavailability.

Funding

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

Data and materials are available from the corresponding author upon reasonable request.

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