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The potential of Indonesian indigenous functional foods as a sustainable strategy for stunting alleviation: A systematic review of quasi experimental research

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ABSTRACT

Background: Stunting remains a major chronic nutritional problem in Indonesia, despite a decline in prevalence from 27.7% in 2021 to 19.8% in 2024. Protein deficiency plays a critical role in the pathogenesis of stunting due to its essential function in growth hormone regulation and tissue development. This study aimed to identify the potential of protein-based indigenous functional foods as a sustainable strategy for stunting alleviation among under-five children.

Methods: This systematic review was conducted in accordance with the PRISMA guidelines using a narrative synthesis approach. Literature searches were performed in PubMed, Scopus, ScienceDirect, Google Scholar, and Garuda for studies published between 2015 and 2025. Inclusion criteria comprised intervention studies involving stunted or undernourished under-five children, the use of locally sourced protein-rich functional foods as nutritional interventions, and reported growth-related outcomes. Exclusion criteria included non-intervention studies, policy-only studies, unclear intervention descriptions, and insufficient outcome data. Interventions varied in form (snacks, supplementary foods, beverages), duration (4–12 weeks), and comparators (control groups or pre–post designs). Primary outcomes assessed included changes in height-for-age (HAZ), body height, body weight, and selected biochemical indicators.

Results: A total of 11 studies met the inclusion criteria. Most interventions demonstrated positive effects on growth indicators, particularly increases in body weight and modest improvements in height or HAZ scores over intervention periods ranging from 4 to 12 weeks. Several studies also reported improvements in biochemical markers related to protein and micronutrient status, such as serum albumin, zinc, and hemoglobin. Height gains were generally smaller than weight gains, reflecting the short duration of most interventions.

Conclusions: Indigenous protein-rich functional foods show consistent beneficial effects on the nutritional status of stunted under-five children and represent a promising, culturally acceptable, and sustainable strategy for stunting reduction. Future interventions should emphasize longer intervention durations, micronutrient fortification, sustainability assessment of local food sources, and integration into national child nutrition policies.

KEYWORDS

Child malnutrition, nutritional interventions, traditional foods, food security, nutrition policies, dietary protein.

INTRODUCTION

Stunting is a chronic severe malnutrition condition that persists in most developing countries, including Indonesia. Stunting represents a form of growth failure characterized by short stature and is an accumulation of nutrient inadequacy lasting from prenatal until age two. Children with stunting (dwarfing) have an insufficient length or height compared to their peers[1]. According to the World Health Organization (WHO), stunting is indicated by length or height that is below or less than -2 Standard Deviations (SD) on the growth curve, thus categorized as short[2]. In line with this, Presidential Regulation No. 72 of 2021 concerning the Acceleration of Stunting Reduction defines stunting as a child growth and

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development disorder caused by chronic nutritional deficiency and recurrent infections[3]. The Indonesian Nutrition Status Survey showed that the prevalence of stunting in 2021 decreased from 2019 to 27.7%. The decline continued, reaching 19.8% in 2024, with the majority occurring in children aged 2–3. Although the prevalence is continuously decreasing, this figure still has not met the target the Ministry of Health set, which aims for 14%[4].

One of the most impactful contributing factors to stunting is the deficiency in protein intake. Research journals state that protein is influential, especially in supporting the quality of the first 1000 Days of Life program[5]. Protein is one of the macronutrients that functions as a receptor to influence DNA functions and control the growth process. Under-five children have higher protein requirements than other age groups. Therefore, insufficient protein intake can potentially impair the production of Insulin-like Growth Factor (IGF)-1, which subsequently affects the restricted growth rate of under-five children. It indicates that children require adequate nutrient intake, including protein, to accelerate their growth[6].

Although the discussion about the potential of protein sources from these foods has been extensively explained in several previous studies, there is apparently a lack of further research to analyze the most promising alternative protein sources for stunting alleviation innovation[7]. Therefore, this study aimed to identify the types of local food with the main protein potential and the best intervention forms for stunting alleviation.

METHODS

This study employed a systematic review design with narrative synthesis to examine the utilization of local functional food ingredients as complementary food for stunted children. The review process adhered strictly to the PRISMA guidelines, ensuring methodological rigor and transparency in study selection and reporting.

A comprehensive bibliographic search was conducted using the Publish or Perish software as a reference management and citation retrieval support tool, integrated with searches

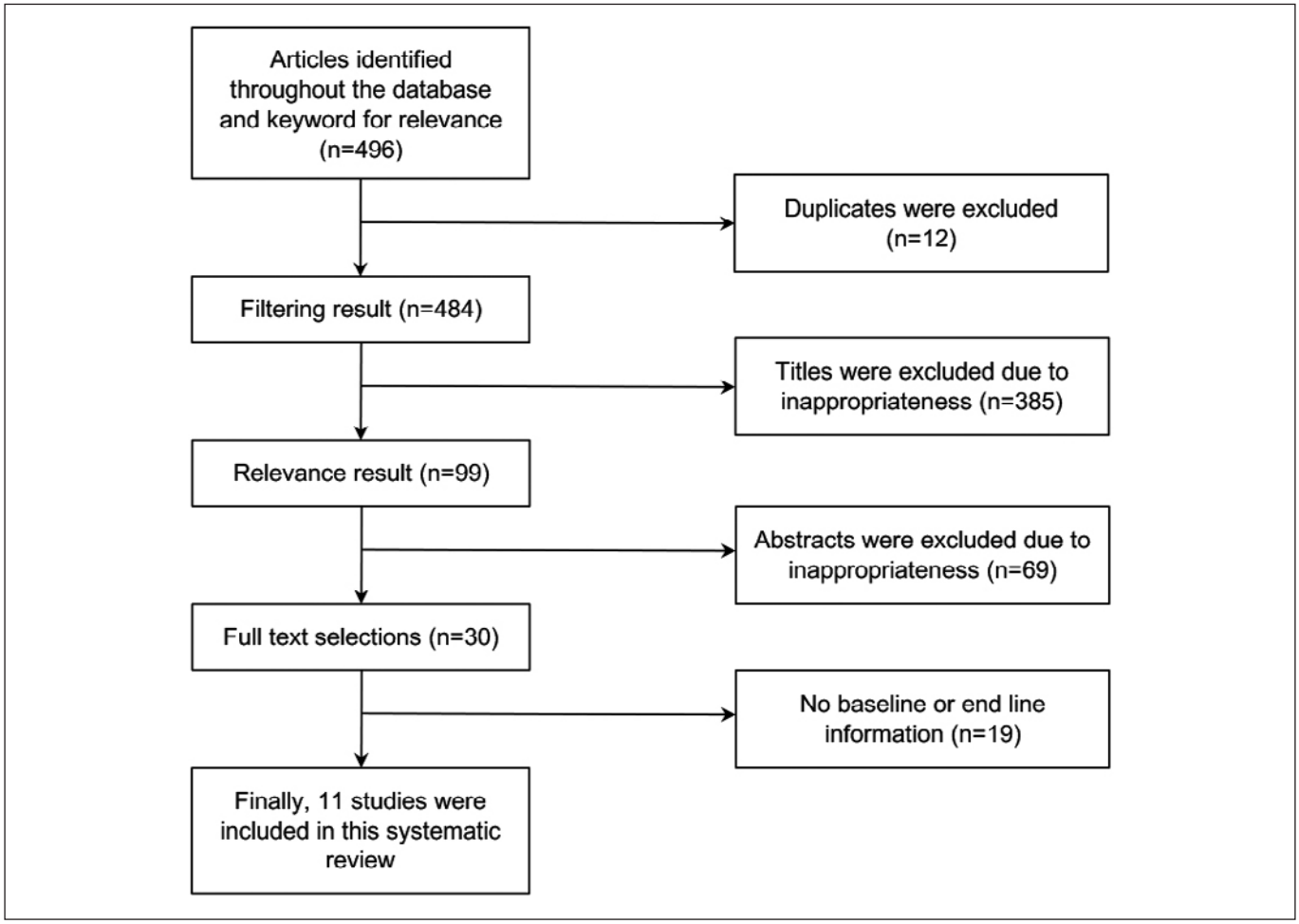

Figure 1. PRISMA Flow Diagram

across PubMed, Scopus, ScienceDirect, Google Scholar, and Garuda databases. The search targeted studies published from January 2015 to October 2025, with the final search of all databases performed in October 2025. The keywords and Boolean operators used included combinations of: "stunting intervention" AND ("local functional food" OR "food innovation" OR "protein-based" OR "traditional food" OR "complementary feeding" OR "Asian food") AND "child growth" AND "developing country". Full search strings for each database were recorded to ensure replicability.

The inclusion criteria consisted of (1) peer-reviewed scientific journal articles with quasi experimental design studies; (2) studies involving under-five children (0–59 months) diagnosed with or at risk of stunting; (3) interventions focusing on local functional foods, including protein-rich foods, micronutrient-dense traditional foods, or formulation-based complementary feeding products; (4) clear reporting of intervention duration, mode of administration, and primary outcomes (e.g., height-for-age z-score, linear growth velocity, stunting prevalence); (5) publications in English or Indonesian during 2015–2025.

Exclusion criteria were (1) articles outside the year range; (2) non-full-text or non-open-access articles; (3) Studies unrelated to the assessment of local functional foods for stunting; (4) reviews, opinion papers, and non-quasi experimental intervention designs. A total of 496 articles were identified. After automatic and manual removal of duplicates (n = 12), title and abstract screening excluded 454 records due to irrelevance. During full-text assessment, 19 articles were excluded, primarily for not meeting outcome reporting criteria or lacking a clear intervention description. Finally, 11 studies fulfilled all eligibility criteria and were included in the narrative synthesis. A PRISMA flow diagram details the selection process.

The methodological quality of all included studies was evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Tools for quasi experimental design. This appraisal aimed to assess the rigor, validity, and risk of bias in the included articles, covering key aspects such as study design, participant selection, intervention implementation, outcome measurement, and data analysis. Studies were independently assessed by two independent reviewers, and any discrepancies were resolved through discussion to ensure objectivity and consistency. Studies failing to meet minimum quality thresholds (score ≥70%) were excluded from synthesis to ensure that the conclusions relied solely on high-quality and credible evidence.

RESULTS

Identification and Selection of Literature

The initial search yielded 496 records. After removal of duplicate articles, the remaining titles and abstracts were screened. A total of 485 records were excluded due to irrelevance to complementary feeding interventions, unavailability of full text, or being non-research formats (e.g., books, policy briefs). Subsequently, studies that did not meet methodological quality criteria based on the JBI appraisal were excluded. Finally, 11 studies were eligible for inclusion in this systematic review (Table 1).

Description and Related Studies

The studies included in this review are related to local protein-source functional foods used as complementary feeding for stunted under-five children. These studies were conducted in developing countries. Some studies did not entirely provide food interventions from local sources to stunted children but were more focused on stunting prevention in the form of policy and nutritional education. Therefore, the researcher conducted a synthesis of local protein-source foods that can be given as complementary feeding for stunted children.

Based on the selected articles, the types of functional foods given to stunted children are generally in the form of snacks or supplementary feeding. The expectation is that providing high-protein complementary food can improve the physiological condition of stunted under-five children.

Forms of Local Functional Food Intervention

Intervention through local functional food is fundamentally a strategy that utilizes the richness of local food, which naturally contains functional nutrients and non-nutrient substances, to address regional health problems or nutritional deficiencies. This approach not only focuses on health but also empowers local potential, preserves traditional food wisdom, and ensures sustainability because the raw materials are easily accessible and known by the local community. Table 2 outlines these various forms of intervention.

Various studies explore functional food and nutrition interventions in low- and middle-income countries to improve child and maternal health. One study highlighted supplementation, fortification, and integrated approaches for neurodevelopment[19], while a study in Ghana identified four food-system-based strategies: supply-side improvements, demand-side nutritional education, food environment improvements, and multisectoral policies[20,21]. Research results in Northern Nigeria emphasized vitamin A supplementation, diet diversification, and nutrition-sensitive programs[22,23]. Burgaz's research focused on Animal-Source Foods (ASFs) with subsidies and education[24], while another study outlined interventions like biofortification, specific nutrient supplementation[25], and community programs based on local ingredients[7]. The key findings suggest that a holistic approach, including a combination of technical, social, and policy interventions and the utilization of local food, plays a crucial role in overcoming challenges such as economic access, consumer preferences, and seasonal dependence.

Table 1. Synthesis of Studies Included in the Systematic Review on Local Functional Food Interventions for Stunted Children

No.	Author (Year)	Country	Study Design	Population	Local Functional Food Intervention	Main Outcomes
1	Yuniastuti et al. (2022)[8]	Indonesia	Pre–post experimental	30 stunted children (under five)	Moringa leaf and marine fish–based supplementary food (9 weeks)	Significant increases in serum zinc levels and height
2	Suksesty et al. (2020)[9]	Indonesia	Quasi-experimental	24 stunted children (12–59 months)	Mung bean juice and boiled egg (4 weeks)	Improvement in WAZ and WHZ; limited effect on HAZ
3	Editia & Sigahitong (2023)[10]	Indonesia	Pre-experimental	57 undernourished and stunted children	Moringa leaf ice cream (4 weeks)	Significant increase in body weight
4	Satiti & Wahyuningrum (2024)[11]	Indonesia	Quasi-experimental with control	60 stunted children (1–5 years)	Red spinach powder and tuna fish oil (duration not specified)	Significant weight gain and improved nutritional status
5	Susianto et al. (2023)[12]	Indonesia	Quasi-experimental with control	60 stunted children (24–59 months)	Tempeh nugget supplementary food (duration not specified)	Significant increases in body weight and height
6	Mas'ud et al. (2019)[13]	Indonesia	Quasi-experimental with control	60 stunted children (11–60 months)	Purple sweet potato and anchovy flour snack (4 weeks)	Increased energy intake and body weight; minimal height change
7	Darawati et al. (2024)[14]	Indonesia	Quasi-experimental	20 children (stunted vs. normal)	Ikametebiwawo Bars (local amino acid–rich food)	Improved serum albumin, body weight, and height
8	Solang et al. (2025)[15]	Indonesia	True experimental	21 children (stunted and non-stunted)	Fermented glutinous corn milk (6 weeks)	Improved biochemical indicators (albumin, Fe, Zn, Hb)
9	Pusparini et al. (2020)[16]	Indonesia	Quasi-experimental	≥30 stunted toddlers	Multi-nutrient biscuits ± psychosocial education (8 weeks)	Improved height and cognitive development
10	Nurpratama et al. (2024)[17]	Indonesia	Pre-experimental	Stunted children under five	Local food intervention with nutrition counseling	Significant height gain and improved maternal knowledge
11	Maisyaroh et al. (2023)[18]	Indonesia	Semi-quantitative experiment	Stunted children (0–59 months)	Dali Horbo complementary food (12 weeks)	Significant increases in body weight and height

WAZ = Weight-for-Age Z-score; HAZ = Height-for-Age Z-score; WHZ = Weight-for-Height Z-score.

Local Food Intervention on Body Weight

An increase in body weight is a key indicator of successful nutritional intervention in stunted under-five children because it reflects an improvement in energy balance and the intake of macronutrients, especially protein and fat. Based on the synthesis of the 11 reviewed articles, seven explicitly reported changes in body weight after providing local food intervention. Variations in food form, duration, and nutrient content resulted in a different magnitude of body weight increase, ranging from 0.1 to 1.94 kg, during the intervention period.

The study by Editia[10] showed the most prominent result with a mean body weight increase from 10.39 kg to 11.16 kg ($p<0.001$) after one month of providing moringa leaf ice cream. This effectiveness is likely influenced by the high content of protein (25–27%) and micronutrients such as iron, vitamin C, and calcium in moringa leaves, which play a role in energy metabolism and body tissue formation.

Research by Satiti[11] provided strong evidence that the combination of local animal and plant-based foods, such as red spinach powder and tuna fish oil, was more effective in

Table 2. Forms of Local Functional Food–Based Nutritional Interventions for Stunted Under-Five Children

No.	Local Functional Food	Form of Intervention	Target Group	Duration (weeks)
1	Moringa leaf and marine fish[8]	Supplementary food	Stunted under-five children	9 weeks (63 days)
2	Mung bean juice and boiled egg[9]	Supplementary feeding	Stunted under-five children	4 weeks (30 days)
3	Moringa leaf ice cream[10]	Snack supplementation	Undernourished and stunted children	4 weeks (1 month)
4	Red spinach powder and tuna fish oil[11]	Combined micronutrient–macronutrient therapy	Stunted under-five children	8 weeks (2 months)
5	Tempeh nugget[12]	Local food supplement	Stunted under-five children	4 weeks
6	Purple sweet potato and anchovy snack[13]	Snack supplementation	Stunted under-five children	4 weeks (30 days)
7	Ikametebiwawo Bars[14]	High-protein complementary food	Stunted under-five children	6 weeks
8	Fermented glutinous corn milk[15]	Functional beverage	Stunted under-five children	6 weeks
9	Multi-nutrient biscuits ± parenting education[16]	Complementary feeding	Stunted toddlers	8 weeks (2 months)
10	Egg and milk[17]	Complementary feeding	Stunted under-five children	2 weeks (14 days)
11	Buffalo milk (Dali Horbo) mixed with jelly[18]	Complementary food	Stunted under-five children	12 weeks (3 months)

increasing body weight (Δ=1.94 kg; p<0.001) compared to the control. This combination provides a balance of protein, healthy fats (omega-3 fatty acids), and micronutrients (iron, zinc, and vitamin A), contributing to the increase in lean body mass.

Intervention using tempeh nuggets also resulted in a significant body weight increase, from 11.98 kg to 12.84 kg (p<0.001). This success confirms the role of tempeh as a local fermented food with high protein availability, good nutrient bioavailability, and natural probiotic content that supports gastrointestinal health and nutrient absorption[12].

Meanwhile, Mas'ud's[13] study reported a smaller increase (0.58 kg vs. 0.13 kg in the control) through providing a snack based on purple sweet potato and anchovy flour. Although the increase was not large, the result was still significant as it showed a positive trend toward energy-protein status, especially when the intervention was carried out for a short duration (30 days).

The Ikametebiwawo Bars intervention showed a body weight increase of 0.78 kg in 90 days (p=0.025), indicating a more stable and sustainable growth rate. This product is unique because it combines animal protein sources (mackerel) with plant protein (red beans, tempeh, sweet potatoes, pumpkin, and carrots), reflecting a multi-component local food model that supports balanced nutritional needs[14].

The research by Maisyaroh[18] showed a consistent body weight increase trend after the provision of Dali Horbo (processed buffalo milk), significant from the first to the third month (p<0.05). This result suggests a cumulative effect and metabolic adaptation to high animal protein intake. The casein and saturated fat contents in buffalo milk contribute to increased body mass, although it needs to be balanced with monitoring blood lipid levels to avoid long-term risks.

Conversely, the results of Nurpratama's study showed an insignificant increase (+0.1 kg; p=0.148) after a 14-day intervention. The short duration and non-standardized consumption intensity are likely limiting factors for success[17].

Local Food Intervention on Height

Providing food interventions in children using various forms and local food ingredients is expected to positively improve the nutritional status of stunted under-five children, including height as one of the physical growth indicators. Based on the synthesized journals, the varying intervention durations, from 14 days to 3 months, resulted in different outcomes for changes in children's height. Not all journals included height as an indicator of intervention success. Eight journals reported that the intervention successfully caused a significant change in the child's height, and one journal noted a magnitude of height change but did not perform statistical analysis on the change.

First, the intervention focused on providing fermented glutinous corn milk for six weeks resulted in the magnitude of height change was only 0.03 cm in female children in the non-stunted group[15]. Compared to other studies, this change is very small. The shortest intervention was conducted in Bekasi Regency for 14 days, providing a local food intervention based on eggs and milk. This study combined the food intervention with an education model. The mean change in height that occurred was 0.2 cm[17].

The longest intervention duration was approximately 3 months, providing Ikametebiwawo Bars and Dali Horbo Pudding[14,18]. In the intervention that provided Dali Horbo Pudding, a significant change in height occurred from the first to the third month of the intervention. However, the average magnitude of the child's height change was not clearly stated[14]. The study with the Ikametebiwawo Bars intervention focused more on changes in the child's blood biochemistry, but height was also one of the variables monitored. After three months, the mean change in height reached up to 1.35 cm in the intervention group. This change was significantly different from the mean change in height in the control group, which was only 0.8 cm after three months[18]. Based on the selected journals, the interventions mostly focused on the protein content. Interventions with these products consistently reported an increase in body weight, which usually appears faster, while the improvement in height requires a longer duration.

Local Food Intervention on Nutritional Status

Findings from several studies consistently highlight the importance of specific micro- and macronutrient supplementation based on local potential. For instance, supplementary feeding intervention using the combination of moringa leaves and marine fish proved effective in increasing serum zinc levels and the mean height of stunted under-five children after 63 days of administration. This improvement is crucial because zinc is an essential micronutrient closely related to increased height through the stimulation of growth hormones[8]. In line with this, combination therapy that blended red spinach powder (high in micronutrients) and tuna fish oil (high in macronutrients) also showed substantial effectiveness, indicated by a significant increase in the mean body weight (WAZ) of stunted under-five children (p-value<0.001)[11].

Although food interventions show success, the response to improving nutritional status in anthropometric indicators tends to vary between body weight and height, especially in short-term intervention periods. Research on the combination of mung bean juice and boiled chicken egg showed a strong and significant relationship with changes in the body weight of stunted under-five children within 30 days[9]. However, the same intervention did not show a significant difference in height changes[9], underscoring the characteristic of stunting as a chronic nutritional problem that requires a longer period of linear recovery. Additionally, the effort to provide a snack made from purple sweet potato and anchovy flour showed an increase in weight and height in the intervention group, but the increase was not statistically significant compared to the control group[13].

These findings conclude that food interventions achieve the most optimal results when integrated with the management of non-nutritional factors. Interventions combining the provision of multiple-nutrient biscuits with psychosocial parenting education significantly improved height and cognitive development of stunted under-five children. This result indicates that sustainable nutritional status improvement requires a holistic approach to address the direct (nutritional intake) and indirect (parenting and stimulation) causes of stunting.

Local Food Intervention on Blood Biochemical Levels

From the eleven reviewed articles, only three specifically examined changes in blood biochemical markers concerning local food-based interventions for stunted children. Local food-based interventions have demonstrated significant effects on the biochemical blood profiles of stunted children. Local food-based interventions have shown promising effects on the biochemical blood profiles of stunted children. Supplementary feeding with Moringa oleifera leaves and marine fish significantly increased serum zinc levels (4.34 µmol/L to 7.88 µmol/L) and improved linear growth among stunted toddlers in Rembang, Central Java. The increase in zinc concentration was strongly associated with enhanced secretion of growth-related hormones such as IGF-1, which promoted catch-up growth. This finding demonstrates that local protein- and micronutrient-rich foods can effectively improve nutritional biomarkers and anthropometric outcomes in malnourished children[8].

Similarly, fermented glutinous corn milk administered to toddlers in Gorontalo improved several biochemical indicators, particularly albumin (+0.2 g/dL), iron (+9.5 µg/dL in males; +3.3 µg/dL in females), zinc (+14 µg/dL), and hemoglobin (+0.35 g/dL), while maintaining calcium at normal levels. These improvements were more pronounced in stunted children than in their non-stunted counterparts, indicating that the intervention was most effective in populations with greater nutritional deficits. The bioactive compounds and protein content in fermented glutinous corn enhanced nutrient absorption and utilization, thereby supporting hematopoiesis and growth hormone metabolism[15].

In West Nusa Tenggara, the introduction of "Ikametebiwawo" bars, soft food bars made from local ingredients (e.g., mackerel, red beans, tempeh, sweet potatoes, pumpkin, and carrots), significantly increased serum albumin (p=0.007), body weight (p=0.025), and height (p=0.048) in stunted toddlers after a 90-day intervention. Although changes in hemoglobin and

lymphocyte counts were not statistically significant, the marked improvement in albumin levels highlights the role of high-quality protein in supporting growth and recovery from stunting. These studies underscore the potential of leveraging diverse local food sources to improve blood biochemical profiles and accelerate catch-up growth among stunted children[14].

DISCUSSION

The formulation of moringa leaf ice cream demonstrated not only significant improvement in body weight but also enhanced palatability and acceptability among under-five children, which are critical determinants of successful nutritional interventions[10]. The high protein (25–27%) and micronutrient content of moringa leaves particularly iron, vitamin C, and calcium likely contributed to improvements in energy metabolism and tissue synthesis. Similarly, the combination of animal- and plant-based protein sources (such as tuna fish oil and red spinach powder) has been shown to produce synergistic effects on growth, aligning with Headey's findings that animal-source foods are key drivers of child growth in developing countries[26]. These results underline the importance of diversified local foods that combine both plant and animal proteins to support optimal nutritional outcomes.

In addition, plant-based local food formulations such as tempeh nuggets and snacks made from purple sweet potato and anchovy flour highlight the potential of affordable and sustainable interventions for community-based stunting reduction programs. The anthocyanin content in purple sweet potato may further enhance immune function and oxidative metabolism, providing additional health benefits beyond macronutrient sufficiency. However, the magnitude of effect varies, with evidence suggesting that an intervention duration of at least 30–60 days is required to produce physiologically meaningful anthropometric changes, consistent with WHO supplementary feeding guidelines[27].

Among animal-source foods, eggs stand out as an economical and nutrient-dense option widely accessible in low- and middle-income settings[28,29]. Eggs contain essential amino acids, high-quality fats, and micronutrients such as vitamin A, B12, riboflavin, iron, zinc, and choline. Notably, choline supports cell function and tissue growth, while ovalbumin, the predominant egg white protein, activates the retinoid/retinoic acid pathway, contributing to cell differentiation and immune regulation. These mechanisms are consistent with observed increases in children's height, emphasizing the biological basis for egg-based interventions. Therefore, protein intake must be optimized not only in quantity but also in duration, as children with stunting require higher protein levels to achieve catch-up growth appropriate for their age[30].

Overall, this review reinforces that addressing chronic nutritional deficits demands a balanced intake of energy, protein, and micronutrients. The efficacy of local food interventions depends not only on the choice of raw ingredients but also on nutrient density, dosage, and the duration of intervention. Furthermore, integrating nutritional interventions with non-nutritional strategies such as improving maternal knowledge, parenting practices, and psychosocial stimulation can produce more sustainable improvements in child growth and development. Consequently, nutrition programs for under-five children in Indonesia should adopt locally sourced, nutrient-dense food models complemented by parenting education, ensuring comprehensive and long-term improvements in nutritional status[16].

A notable strength of the reviewed studies lies in their emphasis on locally available and culturally acceptable foods, which enhances sustainability, cost-effectiveness, and community adoption. The interventions demonstrated biological plausibility, as most foods were rich in protein and micronutrients essential for growth, and several employed experimental or quasi-experimental designs with pre–post analyses that allowed meaningful comparisons between intervention and control groups. However, key limitations remain, including short intervention durations (as brief as 14 days in some studies) that limited the observation of long-term anthropometric changes, variability in dosage and nutrient composition that complicated comparison across studies, and small sample sizes with limited standardization of compliance and dietary intake measurements, potentially introducing bias. Additionally, few studies conducted follow-up assessments to determine the sustainability of nutritional improvements. Future research should therefore focus on longer intervention periods, standardized nutrient formulations, and comprehensive outcome evaluations including biochemical and developmental indicators while strengthening methodological rigor and integrating behavioral or environmental components to build stronger evidence for the effectiveness of local food–based strategies in combating stunting.

CONCLUSION

Based on this systematic review, it can be concluded that Indonesian indigenous local food-based interventions rich in protein (e.g., moringa leaves, fish, tempeh, and eggs) in the form of processed snacks or supplementary food, are proven to be an effective and sustainable strategy for significantly increasing body weight, height, nutritional status, and blood biochemical levels (e.g., zinc and albumin) in stunted under-five children. Optimal success is achieved when the intervention is of a sufficiently long duration (>30 days), is nutrient-dense, has good acceptability, and is integrated with a holistic approach (e.g., parenting education).

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