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Scientific Review: The Contribution of Moringa Leaf Nutrients in Preventing Stunting

Sylvester Jonathan Malino*, Annisa Nur Erliansyach, Nashwa Alifia Azmi

Departement of Food Technology and Agricultural Product, Faculty of Food Security, Universitas Negeri Surabaya, Surabaya, Indonesia

*Corresponding Author: 25142154067@mhs.unesa.ac.id

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ABSTRACT
Moringa oleifera leaves are widely recognized as a nutrient-dense local food with considerable potential to support maternal and child nutrition, particularly in populations vulnerable to stunting. The leaves contain high levels of protein, calcium, iron, folate, vitamins A and C, and various bioactive compounds that play critical roles in growth, immune function, and anemia prevention. However, the nutritional effectiveness of moringa is not determined solely by its nutrient composition, as factors such as bioavailability, processing methods, and dietary context substantially influence nutrient utilization. This scientific review compiles and synthesizes recent evidence on the nutritional composition, bioavailability, and intervention outcomes of *Moringa oleifera* leaf supplementation across critical life stages, including pregnancy, the first 1,000 days of life, and early childhood. Findings from intervention studies indicate that moringa supplementation, administered in various processed forms, is associated with improvements in maternal nutritional status, hemoglobin levels, and child growth indicators, including height-for-age Z-scores. Nevertheless, variability in study design, dosage, processing techniques, and duration of intervention contributes to inconsistent outcomes. Overall, the reviewed evidence suggests that *Moringa oleifera* leaves represent a promising complementary food-based strategy for stunting prevention when integrated into balanced diets and broader nutrition programs, while further standardized and long-term studies are needed to optimize their application.

INTRODUCTION

Stunting, or failure to thrive in children under five years of age due to chronic malnutrition, recurrent infections, and inadequate psychosocial stimulation, is an urgent global public health issue (Dwi et al., 2025b). In low- and middle-income countries, stunting remains a critical challenge (Dwi et al., 2025b). Globally, this condition affects more than 22% of children and has long-term detrimental consequences on immune function, cognitive development, and future economic productivity (Science et al., 2021). In Indonesia, the Ministry of Health, through the Indonesian Nutrition Status Survey (SSGI), recorded a stunting prevalence of 19.8% in 2024. Optimal stunting prevention efforts focus on the First 1000 Days of Life (1000 HPK) from conception to age two but continued nutritional interventions through the toddler period remain crucial to support catch-up growth and mitigate long-term effects (Zia et al., 2021).

Effective strategies for stunting prevention require adequate food intake, infection control, and supplementation of essential nutrients such as protein, iron, zinc, and vitamins (Dwi et al., 2025b). In the context of finding affordable and sustainable solutions in resource-limited areas, Moringa leaves (*Moringa oleifera*) has emerged as a promising nutritional intervention (Dwi et al., 2025b). This plant is known as the "miracle tree" and is a nutrient-dense source rich in components essential for growth (Zia et al., 2021). Moringa leaves are rich in protein, various essential amino acids, vitamins (especially A and C), and minerals such as iron and calcium (Dwi et al., 2025b). In addition, the antioxidant and anti-inflammatory compounds in Moringa, such as polyphenols and flavonoids, play a role in improving gut health and nutrient absorption, which are essential in conditions of chronic malnutrition (Zia et al., 2021).

Various intervention studies have explored the potential of Moringa to combat stunting and its risk factors (Zia et al., 2021). Moringa leaf supplementation in pregnant women has been reported to improve maternal nutritional status, increase hemoglobin levels, prevent oxidative stress, and has even been shown to significantly reduce the incidence of stunting in children up to 36-42 months of age (Science et al., 2021). Additionally, Moringa leaf extract has also shown significant effectiveness in improving Height-for-Age Z-scores (HAZ) and reducing the prevalence of stunting in toddlers aged 23-59 months (Dwi et al., 2025b).

Although experimental evidence and narrative reviews have demonstrated the great potential of Moringa-based interventions, a more in-depth synthesis analysis is still needed. A systematic review focusing on the specific nutritional contributions of Moringa leaves and their mechanisms in preventing stunting across the spectrum of vulnerable ages (pregnant women, lactating mothers, and toddlers) will provide a Although previous studies have highlighted the potential benefits of *Moringa oleifera*, existing evidence remains fragmented in several important ways. Most nutritional analyses report nutrient concentrations without evaluating how these values compare to the daily requirements of pregnant women and young children, making it difficult to determine moringa's actual contribution to preventing stunting. In addition, intervention studies vary widely in dosage, preparation methods, and intervention duration, resulting in inconsistent outcomes and limited generalizability. Mechanistic research on how moringa influences growth-related pathways such as IGF-1 regulation, erythropoiesis, and inflammatory modulation also remains underrepresented in prior reviews. These gaps indicate the need for a comprehensive synthesis that integrates nutrient profiling, clinical evidence, and biological mechanisms to clarify the extent to which moringa can realistically support stunting prevention across vulnerable populations.

Therefore, this scientific review aims to: (1) Analyze and synthesize relevant scientific literature on the nutritional content of *Moringa oleifera* that is essential for child growth and development, and (2) Evaluate the clinical effectiveness of Moringa leaf interventions in preventing and combating stunting. The results of this review are expected to provide a strong scientific basis for integrating Moringa supplementation as a viable (sustainable) and cost-effective complementary nutrition strategy in stunting prevention programs (Dwi et al., 2025b).

METHODS

This research was conducted using a scientific review method with a descriptive qualitative approach. The data used in this study were secondary data obtained from various scientific publications that discuss the nutritional potential of *Moringa oleifera* leaves and their role in preventing stunting. This method was chosen because it allows researchers to comprehensively analyze research findings from different studies that have previously examined the relationship between Moringa nutrients and child growth outcomes.

The literature search process was carried out through several online academic databases, including Google Scholar, PubMed, and ScienceDirect. Article searching was performed using keywords such as "*Moringa oleifera*", "moringa leaves", "stunting", "child nutrition", "1000 days of life", and "nutritional intervention". These keywords were combined in various ways to obtain articles that were most relevant to the research topic. To ensure the novelty and relevance of the data, the articles selected were limited to publications from the last ten years, with priority given to those published within the last five years.

Inclusion criteria:

1. Original research articles and review articles that discuss the nutritional content of Moringa leaves and/or their effect on stunting or child growth
2. Studies involving pregnant women, lactating mothers, infants, and toddlers
3. Articles published in national and international peer-reviewed journals
4. Full-text articles that were accessible.

Data extraction was carried out by identifying key information from each selected article, including author, year of publication, research design, research subjects, type of Moringa intervention, observed variables, and the main findings related to nutritional status and stunting indicators such as height for age Z-score (HAZ), hemoglobin levels, and child growth outcomes. The collected data were compiled systematically to support the analysis process. The data obtained were then analyzed using a descriptive qualitative method. The analysis was carried out by comparing the results of each study, summarizing the main findings, and interpreting the patterns that emerged from the reviewed literature. The discussion focused on the relationship between the nutritional components of Moringa leaves such as protein, vitamins, minerals, and bioactive compounds and their role in supporting child growth and reducing the risk of stunting. Conclusions were drawn based on the overall consistency of the findings reported in the analyzed articles.

RESULTS AND DISCUSSION

The discussion section begins with an overview of previous studies examining the nutritional composition of *Moringa oleifera* leaves and their relevance to stunting prevention among pregnant women and young children. Synthesizing existing evidence provides a foundational understanding of how moringa's micronutrient profile and reported intervention outcomes contribute to mitigating growth faltering. This preliminary mapping supports the analytical depth of subsequent sections, which explore biological mechanisms, nutrient adequacy comparisons, and implications for public health nutrition. Table 1 summarizes key research findings related to moringa, highlighting its nutritional potential and documented impact on maternal and child health.

Table 1. Summary of studies related to *Moringa oleifera* and stunting prevention

No	Source (Authors, Year)	Study Title	Purpose and Methods	Key Findings and Conclusions
1	Aziz et al., 2025	The Nutritional Potential of *Moringa oleifera* Leaves as a Solution for Preventing Stunting	Scientific evaluation of the nutrient composition of moringa leaves using laboratory nutrient profiling and comparison with dietary requirements.	Moringa contains high levels of protein, iron, calcium, folate, vitamin A, and vitamin C. These nutrients support the prevention of micronutrient deficiencies associated with stunting.
2	Bridgemohan et al., 2010	Nutrient Analysis of *Moringa oleifera* as a High Protein Supplement for Animals	Quantitative nutrient analysis of moringa leaves (dry weight basis) using laboratory analytical methods.	Results confirmed that moringa leaves contain high concentrations of minerals and vitamins, forming a foundational reference for evaluating moringa's nutritional potential in human health contexts.
3	Saini et al., 2016	Folate Profiling in Moringa Leaves	Identification and quantification of active folate forms using LC-MS and assessment of total folate content.	Moringa contains approximately 900 µg folate per 100 g dry weight, significantly contributing to DNA synthesis, cell growth, and fetal development, especially relevant for preventing stunting from pregnancy.
4	Nugraha et al., 2024	*Pengaruh Ekstrak Daun Kelor terhadap Status Gizi Balita*	Quasi-experimental study providing moringa extract to toddlers to assess improvements in nutritional outcomes.	Supplementation improved weight gain and overall nutritional status among toddlers, demonstrating moringa's contribution to supporting child growth.
5	Basri et al., 2021	Effect of Moringa Supplementation During Pregnancy on the Prevention of Stunting	Intervention study administering moringa leaf capsules to pregnant women.	Moringa supplementation increased maternal hemoglobin, BMI, and infant birth weight, thereby reducing risk factors associated with stunting.
6	Rustiah et al., 2023	*Pemanfaatan Kelor dalam Program Gizi Masyarakat*	Community-based nutrition program integrating moringa into complementary feeding practices.	Moringa significantly improved dietary nutrient density and is recommended as a complementary food to support stunting prevention efforts.
7	Putra et al., 2021	Nutrigenomic and Biomolecular Effects of Moringa	Review of biomolecular pathways influenced by moringa nutrients.	Moringa bioactive compounds regulate IGF-1 expression, antioxidant pathways, and cellular proliferation, which collectively support linear growth among children.

Stunting as a chronic nutritional problem

Stunting is a form of chronic growth disorder characterized by height for age (HAZ) less than -2 standard deviations from the WHO reference curve. This condition reflects long-term malnutrition since early life, especially during the first 1000 days of life (HPK). Stunting not only affects stunted physical growth, but is also associated with cognitive development disorders, reduced learning capacity, increased susceptibility to infectious diseases, and reduced productivity in adulthood.

The results of the 2024 Indonesian Nutrition Status Survey (SSGI) show that the national prevalence of stunting among children under five has decreased to 19.8%, lower than previous projections (Indonesian Ministry of Health, 2025). The book "SSGI 2024 in Figures" explains that this data was compiled to serve as a basis for planning, monitoring, and evaluating policies to accelerate stunting reduction at the national to district/city levels, while also mapping the determinants related to the nutritional status of children under five (Kementrian Kesehatan RI, 2025).

Despite the decline, the figure of 19.8% still shows that nearly one in five toddlers in Indonesia suffers from stunting, and this condition remains categorized as a serious public health problem. When compared to previous data, Riskesdas 2018 reported a stunting prevalence of 30.2% (Nugraha et al., 2024). This illustrates an improving trend, but there is still a significant burden that requires comprehensive, sustainable, and locally-based nutritional interventions.

Etiologically, stunting is multifactorial. Contributing factors include inadequate energy and protein intake, micronutrient deficiencies (e.g., iron, zinc, vitamin A, folate), recurrent infections, poor sanitation and access to clean water, infant and child feeding practices (PMBA) that do not comply with recommendations, and low socioeconomic status (Putra et al., 2021; Nugraha et al., 2024). In the Indonesian context, improving the nutritional status of young children requires a combination of nutrition-specific interventions (such as micronutrient supplementation and improved complementary feeding) and nutrition-sensitive interventions (such as improved sanitation, education, and family economic empowerment). One potential specific intervention is the use of moringa leaves (*Moringa oleifera*) as a local food source rich in nutrients that support child growth and development.

Nutritional content of moringa leaves and its relevance to stunting

This section examines the nutritional contribution of *Moringa oleifera* leaves in the context of stunting prevention through a quantitative assessment of nutrient content and a critical evaluation of nutrient bioavailability. The analysis aims to distinguish between the theoretical nutritional potential of moringa, as indicated by nutrient composition data, and the proportion of nutrients that can be effectively absorbed and utilized by the human body. Such differentiation is essential to avoid overestimation of moringa's nutritional impact and to provide a scientifically grounded basis for interpreting intervention outcomes.

Moringa leaves (*Moringa oleifera*) are widely known as a local food source with very high nutritional density. Various studies show that moringa leaves contain protein, calcium, iron, vitamin A, vitamin C, and various bioactive compounds that play an important role in supporting child growth and development. A review article on the nutritional potential of moringa leaves reports that, on average, dried moringa leaves contain about 26–35 g of protein per 100 g of dry weight, about 27–36 mg/100 g of iron, and more than 2,000 mg/100 g of calcium, with very high levels of vitamins A and C (Aziz et al., 2025). Moringa leaves are also often described as having several times more vitamin A than carrots, more calcium than milk, and more iron than spinach (Nugraha et al., 2024).

In addition to macronutrients, moringa leaves contain various micronutrients and other bioactive components, including minerals (calcium, iron, sodium), vitamins C and E, beta carotene, and antioxidants such as flavonoids, phenolic acids, glucosinolates, isothiocyanates, and saponins (Putra et al., 2021). This composition makes moringa leaves a food that not only fulfills basic nutritional needs but also provides functional effects as an antioxidant, anti-inflammatory, and anti-anemic agent.

In the context of stunting prevention, protein, calcium, iron, and vitamins A–C content play a direct role in determining linear growth. Protein and essential amino acids such as arginine and histidine are needed for tissue synthesis and bone growth, especially in children who are protein deficient (Nugraha et al., 2024). Calcium plays a role in bone mineralization and height growth, while iron and vitamin C are important for hemoglobin formation, anemia prevention, and optimization of oxygen supply to tissues. Vitamin A plays a role in maintaining the immune system and mucosal integrity, thereby reducing the risk of recurrent infections that often worsen nutritional status and inhibit growth.

This subsection presents a quantitative comparison between the daily nutritional requirements of pregnant women and toddlers and the nutrient content of *Moringa oleifera* leaves. The analysis focuses on nutrients that are strongly associated with growth, linear development, and stunting prevention, including protein, iron, folate, vitamin A (provitamin A carotenoids), calcium, and zinc.

Table 2. Daily requirements of essential nutrients for stunting prevention (pregnant women & toddlers)

Essential Nutrients to Prevent Stunting	Daily Requirements for Pregnant Women	Daily Requirements for Toddlers (1–3 years old)	References
Protein	75–85 g	20 g	Kementerian Kesehatan Republik Indonesia, 2019
Iron (Fe)	27 mg	7 mg	World Health Organization, 2016
Folate	600 µg	150 µg	World Health Organization, 2016
Zinc (Zn)	11–12 mg	3 mg	Kementerian Kesehatan Republik Indonesia, 2019
Calcium (Ca)	1200 mg	650 mg	Kementerian Kesehatan Republik Indonesia, 2019
Vitamin A	800 µg RAE	300 µg RAE	Kementerian Kesehatan Republik Indonesia, 2019
Vitamin C	85 mg	40 mg	Kementerian Kesehatan Republik Indonesia, 2019
Vitamin B6	1.9 mg	0.5 mg	Kementerian Kesehatan Republik Indonesia, 2019

Note : RAE = Retinol Activity Equivalent, µg = Microgram

Table 3. Summary of the main nutritional content of moringa leaves and their relevance to stunting prevention

Nutrient	Content per 100g DW	Main role	Reference
Protein	20–30 g	Supports linear growth through IGF-1 stimulation and muscle development (Aziz et al., 2025 Putra et al., 2021).	Aziz et al., 2025; Bridgemohan et al., 2010
Iron (Fe)	20–28 mg	Prevents anemia, improves oxygen transport, and supports brain development (Aziz et al., 2025; Putra et al., 2021).	Aziz et al., 2025); Bridgemohan et al., 2010
Folate	899.9 µg	Enables DNA synthesis, cell division, fetal growth, and prevents low birth weight (Saini et al., 2016).	Saini et al., 2016
Zinc (Zn)	0.6–3 mg	Essential for cell growth, immune regulation, and bone elongation (Putra et al., 2021).	Aziz et al., 2025; Bridgemohan et al., 2010
Calcium (Ca)	600–2000 mg	Builds bone mass and supports skeletal development (Aziz et al., 2025).	Aziz et al., 2025; Bridgemohan et al., 2010

Nutrient	Content per 100g DW	Main role	Reference
Vitamin A (RAE)	750–1200 µg RAE	Improves immunity, reduces infection-related growth faltering, and supports cell differentiation (Aziz et al., 2025).	Aziz et al., 2025
Vitamin C	120–200 mg	Enhances iron absorption and supports collagen formation for bone growth (Aziz et al., 2025).	Aziz et al., 2025
Vitamin B6	0.2–1 mg	Supports protein metabolism and neurological development saponins (Putra et al., 2021).	Putra et al., 2021

DW = Dry weight
IGF-1 = Insulin-like Growth Factor 1
RAE = Retinol Activity Equivalent
µg = Microgram

To strengthen the interpretation of the nutritional relevance of *Moringa oleifera* leaves in stunting prevention, it is essential to systematically compare the daily nutrient requirements of pregnant women and young children with the actual nutrient content provided by moringa. Nutrient composition data alone do not fully capture the practical contribution of moringa to nutritional adequacy unless they are contextualized against established dietary reference intakes for vulnerable population groups. The following graph illustrates this comparison by presenting three parallel values for each key nutrient: (1) the recommended daily intake for pregnant women, (2) the recommended daily intake for toddlers aged 1–3 years, and (3) the nutrient concentration contained in moringa leaves based on validated scientific analyses.

This visualization facilitates a clearer and more integrative understanding of the extent to which moringa-derived nutrients may contribute to meeting daily physiological requirements during critical periods of growth and development. It highlights nutrients for which moringa shows substantial potential to support dietary adequacy, as well as nutrients that, despite being present in moringa, may not be sufficient to meet daily needs without additional complementary food sources. By juxtaposing nutrient requirements and nutrient availability within a single analytical framework, the graph provides an evidence-based overview of moringa's role as a supportive functional food. This approach also underscores the importance of incorporating moringa within a balanced and diversified dietary pattern rather than relying on it as a sole source of essential nutrients in maternal and child nutrition strategies aimed at reducing stunting risk.

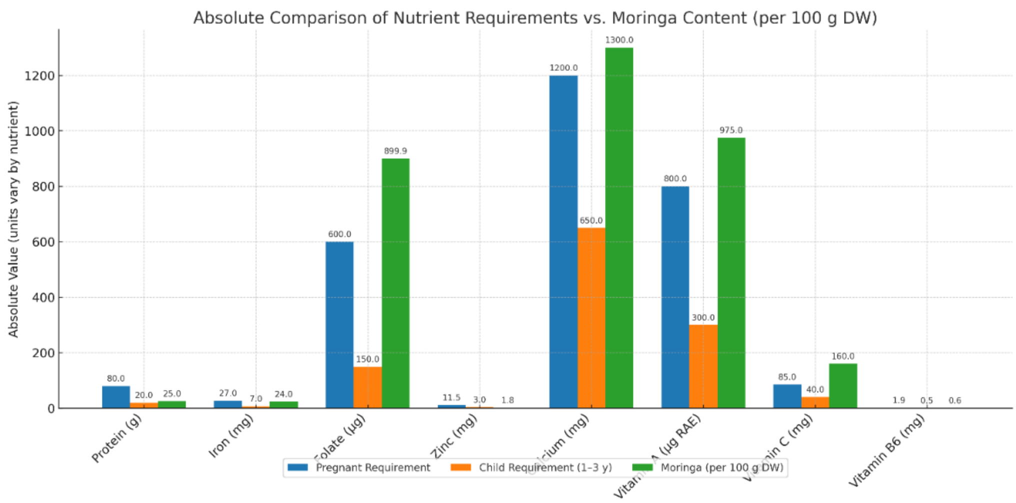

Figure 1. Comparison of daily nutrient requirements for pregnant women and toddlers with the nutritional content of *Moringa oleifera* leaves per 100 g dry weight.

Based on quantitative comparisons reported in previous studies, moringa leaves exhibit high concentrations of several micronutrients that are commonly deficient in populations affected by stunting. Folate content in dried moringa leaves has been reported to reach approximately 900 µg per 100 g dry weight, indicating a substantial contribution to folate requirements during pregnancy and early childhood (Saini et al., 2016). Similarly, moringa leaves contain considerable amounts of provitamin A carotenoids, which are relevant for immune function, cellular differentiation, and growth regulation (Schönfeldt et al., 2014.).

Mineral content analysis demonstrates that moringa leaves provide appreciable levels of calcium and iron, nutrients essential for skeletal development and oxygen transport, respectively (Bridgemohan et al., 2010). Protein content in moringa leaves further supports their potential role in growth promotion, given the importance of adequate protein intake for tissue synthesis and linear growth. However, the extent to which these nutrient levels contribute to daily requirements varies across nutrients and target groups, highlighting the need for careful interpretation of quantitative values. While these findings indicate that moringa leaves possess a favorable nutritional profile, nutrient concentration alone does not reflect the actual physiological contribution of moringa consumption. Consequently, quantitative data must be interpreted alongside an assessment of nutrient bioavailability to determine the realistic nutritional impact of moringa-based interventions.

Bioavailability of *Moringa oleifera* Nutrients and Implications for Utilization

Although the quantitative analysis suggests that *Moringa oleifera* leaves are rich in key nutrients relevant to stunting prevention, the proportion of nutrients that can be absorbed and metabolically utilized depends on their bioavailability. Bioavailability is influenced by the chemical form of nutrients, the food matrix, processing methods, and the physiological status of the consumer (Schönfeldt et al., 2014.). Iron in moringa leaves is predominantly present in the non-heme form, which is generally characterized by lower absorption efficiency compared to heme iron. However, moringa also contains vitamin C, which functions as an absorption enhancer by facilitating the reduction of ferric iron to ferrous iron and improving solubility in the intestinal environment (Schönfeldt et al., 2014). Evidence from iron metabolism studies indicates that individuals with depleted iron stores exhibit increased intestinal iron transporter activity, which may enhance the absorption of non-heme iron under deficiency conditions (Ruelas et al., 2025). This mechanism provides a plausible explanation for the variable improvements in iron status observed across moringa intervention studies.

Folate represents another critical micronutrient in moringa leaves, yet its bioavailability is highly sensitive to processing conditions. Experimental evidence demonstrates that folate undergoes significant degradation when exposed to prolonged heat and oxidative conditions, resulting in reduced bioactive folate content (Saini et al., 2016). Consequently, differences in processing and preparation methods may substantially influence the effectiveness of moringa-based interventions targeting maternal and child nutrition. Provitamin A carotenoids present in moringa require dietary lipids for efficient intestinal absorption. In the absence of adequate fat intake, the conversion and uptake of carotenoids may be limited despite high total carotenoid content (Schönfeldt et al., 2014). Furthermore, the absorption of minerals such as calcium and zinc may be constrained by the presence of antinutritional factors, including phytates and oxalates, which form insoluble complexes and reduce intestinal uptake (Schönfeldt et al., 2014). Processing techniques such as fermentation or soaking have been shown to reduce phytate levels, thereby improving mineral bioavailability.

Collectively, these bioavailability considerations indicate that the nutritional contribution of *Moringa oleifera* leaves cannot be fully assessed based solely on nutrient composition data. Instead, bioavailability functions as a critical interpretative framework that bridges quantitative nutrient analysis and empirical intervention outcomes. This framework is essential for understanding both the potential and the limitations of moringa-based strategies in stunting prevention.

Scientific Evidence of *Moringa oleifera* Leaf Intervention in Pregnant Women, Toddlers, and Preschoolers

This section synthesizes scientific evidence from intervention studies evaluating the effects of *Moringa oleifera* leaf supplementation among pregnant women, as well as toddlers and preschool-aged children. Building upon the quantitative nutritional contribution and bioavailability framework discussed in Section 3.2, this section examines whether moringa-based interventions are associated with measurable improvements in nutritional status and growth-related outcomes during critical periods of early life. The reviewed studies encompass interventions conducted during pregnancy and the first 1,000 days of life (1000 HPK), as well as during early childhood, allowing for a comprehensive assessment of moringa's role in addressing nutritional risk factors related to stunting. By integrating evidence across these population groups, this section provides an evidence-based evaluation of the effectiveness of moringa leaf interventions in supporting optimal growth and development.

Scientific evidence of moringa leaf intervention in pregnant women and the 1000 HPK period

A cohort study analyzing data from a randomized controlled trial in South Sulawesi reported that supplementation with moringa leaf extract in pregnant women had a significant effect in reducing the incidence of stunting in children aged 36–42 months. In this study, pregnant women were divided into three groups: the 500 mg moringa extract group (EG), the 500 mg moringa powder group (PG), and the control group that received iron-folate tablets (60 mg Fe + 0.25 mg folic acid). Multivariate analysis showed that the EG group had a lower risk of stunting with a risk ratio (RR) of 0.431 (p = 0.003; 95% CI 0.246–0.754) compared to the control group, while the PG group showed no significant difference (Basri et al., 2021). This indicates that administration of moringa leaf extract during pregnancy can be an effective intervention to reduce the risk of stunting in children.

A systematic review conducted by Nugraha (2024) of 17 studies on moringa leaf interventions in Indonesia and several other countries concluded that moringa leaf interventions in the form of extracts or powder can: improve the nutritional status of pregnant women, increase hemoglobin levels, reduce oxidative stress, prevent low birth weight babies, increase breast milk production and quality, and improve the nutritional status of toddlers. Thus, moringa contributes to the prevention of major risk factors for stunting during the 1000 HPK period (Nugraha et al., 2024). In addition, several intervention studies reviewed in the review showed that moringa leaf supplementation in breastfeeding mothers can improve iron status and breast milk quality, thereby supporting infant growth and reducing the risk of chronic malnutrition in early life (Nadimin, 2021). Considering that maternal nutritional status and anemia are almost always associated with birth length and the risk of stunting, moringa leaf intervention in pregnant and breastfeeding mothers has strategic value in stunting prevention programs based on local food.

Table 4. Summary of research on moringa leaf intervention in pregnant women and the 1000 HPK period

Subjects & methods	Intervention formulation & dosage	Key findings related to stunting	Reference
Pregnant women, follow-up of children aged 36–42 months, randomized controlled trials	500 mg moringa leaf extract (EG) vs. 500 mg moringa powder (PG) vs. standard iron-folate	The EG group reduced the risk of stunting by RR 0.431; p = 0.003 (95% CI 0.246–0.754)	Basri et al., 2021
Review of 17 intervention studies involving 1000 HPK	Moringa leaf extract/powder in pregnant women, lactating women, and toddlers	Improved Hb, prevented LBW, increased breastfeeding and toddler nutritional status; contributed to reducing the risk of stunting	Nugraha et al., 2024

Note : HPK = First 1000 Days of Life, p = Probability Value, LBW = Low Birth Weight, RR = Risk Ratio, CI = Confidence Interval

Scientific evidence of moringa leaf intervention in toddlers and preschoolers

A quasi-experimental study in Tejakula Village, Buleleng Regency, Bali, involved ten malnourished toddlers aged 1–5 years who received 10 grams of moringa leaf extract per day for 14 days. The average weight before the intervention was 11.6 kg and increased to 12.4 kg after the intervention, with an average increase of 0.8 kg. The average height increased from 93.1 cm to 94.1 cm (an increase of 0.9 cm). The Wilcoxon Signed Ranks Test showed a p-value of 0.002 ($p < 0.05$), confirming that moringa leaf extract administration had a significant effect on the nutritional status of toddlers (Nugraha et al., 2024).

A randomized controlled trial in Kebomas Subdistrict, Gresik Regency, involved 40 toddlers aged 23–59 months who were divided into an intervention group (receiving moringa leaf extract supplementation) and a control group (receiving standard nutrition). Over a period of six months, researchers measured height-for-age Z-scores (HAZ) and found that the intervention group experienced a significant increase in HAZ compared to the control group ($p < 0.05$). In addition, toddlers in the intervention group showed improved appetite, increased hemoglobin levels, and overall improved nutritional status (Dwi et al., 2025).

The review article on the nutritional potential of moringa leaves also summarizes a number of intervention studies that used biscuits, puddings, and fortified foods based on moringa leaves in toddlers. One of the quasi-experimental studies reviewed reported an average increase in HAZ scores of +0.65 SD and a decrease in stunting prevalence from around 90% to 50% after a six-month intervention (p = 0.002) (Aziz et al., 2025). Another study in Madura showed that consuming moringa leaf biscuits for two months increased the weight of children by approximately +0.35 kg/month and height by +0.65 cm/month in approximately 31 toddlers (Aziz et al., 2025). A pre–post study without a control group on 30 toddlers in another location reported an increase in weight of 2.01 kg and height of 1.3 cm after regular consumption of moringa leaf-based foods (Aziz et al., 2025). Consistently, these results indicate that moringa leaf interventions whether in the form of extracts, powder, or processed products such as biscuits and puddings contribute to improvements in weight, height, and other nutritional status indicators in toddlers. These improvements in nutritional status further imply a reduction in the risk of stunting, especially when interventions are carried out regularly and integrated with nutrition education for parents.

Table 5. Summary of research on moringa leaf intervention in toddlers

Subjects & methods	Intervention formulation & duration	Indicators	Key findings related to stunting	Reference
Quasi-experimental, 1 group, 10 malnourished toddlers (1–5 years old) in Tejakula, Bali	Moringa leaf extract 10 g/day for 14 days	Weight, height	Average weight increased by 0.8 kg (11.6 → 12.4 kg), height increased by 0.9 cm (93.1 → 94.1 cm), $p = 0.002$	Nugraha et al., 2024
RCT, 40 toddlers aged 23–59 months in Kebomas, Gresik	Moringa leaf extract supplementation vs. standard nutrition for 6 months	HAZ, Hb, appetite, nutritional status	Significant increase in HAZ ($p < 0.05$), Hb and appetite improved, nutritional status improved	Dwi et al., 2025a
Review of several quasi-experimental studies	Various: powder, extract, biscuits, fortified foods; duration up to 6 months	HAZ, prevalence of stunting, weight, height	Increase in HAZ ≈ +0.65 SD; stunting prevalence decreased from 90% to 50%; significant increase in weight and height	Aziz et al., 2025

Note : RCT = Randomized Controlled Trial, Hb = Hemoglobin, HAZ = Height-for-Age Z-score, p = Probability Value, SD = Standard Deviation

Biological and nutrigenomic mechanisms of moringa leaves in preventing stunting

Nutrigenomic and biomolecular articles on *Moringa oleifera* show that the pathogenesis of stunting is not only related to macro and micro nutritional deficiencies, but also involves changes at the genomic, epigenetic, and biochemical levels (Putra et al., 2021). Nutrigenomics explains how nutrients can influence gene expression through mechanisms such as DNA methylation, histone modification, and transcriptional regulation.

One important pathway discussed is the role of folate in moringa leaves in the formation of S-adenosylmethionine (SAM) as the main methyl donor for DNA methylation. Folate in moringa leaf powder is metabolized through the one-carbon cycle to form SAM, which then enters the cell nucleus and triggers genomic methylation and histone modification. This process is associated with the regulation of genes involved in growth and tissue formation, including the activation of mTOR complex 1 (mTORC1) and the inhibition of excessive autophagy, thereby supporting protein synthesis and linear growth in children (Putra et al., 2021).

In addition to folate, omega-3 fatty acids such as α-linolenic acid in moringa leaves can be converted into EPA and DHA, which play a role in regulating gene expression through PPAR-γ receptor activation, increased beta-oxidation, reduced lipid accumulation, and decreased production of inflammatory mediators such as prostaglandin E2 and proinflammatory cytokines (Putra et al., 2021). The vitamin and mineral content in moringa leaves also acts as an important enzyme cofactor for maintaining the efficiency of various biochemical reactions, including those related to growth and development.

Conceptually, the mechanism of action of moringa leaf nutrients in preventing stunting can be illustrated in a diagram: moringa leaves as a source of protein, folate, omega-3 fatty acids, vitamins, minerals, and antioxidants → improvement in macro and micro nutritional status, optimization of growth gene expression, reduction in inflammation and oxidative stress → increased linear growth, improved hematological status, and reduced risk of stunting.

Utilization of moringa leaves as local food in the stunting prevention program

An article on the use of moringa leaves in areas with high stunting rates, such as Dompu Regency, West Nusa Tenggara, emphasizes that nutrient-rich local foods such as moringa leaves can be a relevant intervention strategy for early childhood. Moringa leaves are reported to be high in protein, calcium, iron, and vitamin A, and moringa-based food interventions such as porridge and biscuits can increase children's protein and iron intake (Fauziah et al., 2023). In addition, community acceptance of moringa-based foods is quite good, especially among housewives who are accustomed to processing local foods.

Another review highlights that educating mothers and posyandu cadres on how to process and utilize moringa leaves correlates with increased nutritional knowledge, consumption practices, and children's acceptance of moringa leaf products (Aziz et al., 2025). Product innovations—such as moringa-based biscuits, puddings, noodles, or PMT—facilitate the integration of moringa leaves into the daily diet of toddlers. Regular consumption of these products for several weeks to months has been shown to contribute to increased weight, height, and anthropometric Z-scores.

The use of moringa leaves has also been introduced in nutrition education activities at health posts and early childhood education centers through training on making moringa leaf PMT, moringa pudding as complementary food, and moringa nuggets as nutritious snacks. These activities not only increase children's nutritional intake but also build habits of consuming highly nutritious local foods from an early age (Fauziah et al., 2023).

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The benefits of moringa leaf intervention

In general, the literature shows a number of advantages of moringa leaf intervention in the context of stunting prevention:

1. Very high nutritional content, especially protein, calcium, iron, vitamins A and C, and antioxidants, which are directly related to linear growth determinants (Putra et al., 2021; Aziz et al., 2025).
2. Local availability and relatively low cost, making it suitable for sustainable intervention strategies in areas with limited access to nutritious food.
3. Flexibility in processing into various product forms (powder, extract, biscuits, pudding, PMT), which facilitates integration into children's diets.
4. Empirical evidence from several intervention studies showing improvements in nutritional status indicators (weight, height, HAZ) and a reduction in the risk of stunting (Basri et al., 2021; Dwi et al., 2025; Nugraha et al., 2024).

Lack of moringa leaf intervention

However, a number of limitations also need to be critically considered:

1. Many intervention studies were conducted using quasi-experimental designs without control groups, small sample sizes, and short intervention durations (e.g., 10 toddlers for 14 days), so the results need to be generalized with caution (Nugraha et al., 2024).
2. Several review studies emphasize that although moringa leaves are very high in nutritional content, implementation in the field still faces obstacles such as bitter taste, distinctive aroma, and children's taste preferences, requiring product innovation and intensive nutrition education(Putra et al., 2021; Aziz et al., 2025).
3. Most evidence still focuses on improving short-term nutritional status indicators, while long-term evidence on adult outcomes (e.g., cognitive function, productivity) remains limited.
4. Standardization of dosage, frequency, and dosage form of moringa leaves for stunting prevention is not uniform across studies, so more structured dosage guidelines based on age and nutritional status are still needed.

Implications for Stunting Prevention Programs

The synthesis of evidence reviewed in this study indicates that *Moringa oleifera* leaves hold considerable potential to be integrated into stunting prevention programs through approaches that are nutritionally relevant, socially acceptable, and locally sustainable. Quantitative analyses of nutrient composition demonstrate that moringa leaves are rich in key macro- and micronutrients associated with growth and development, while bioavailability assessments highlight the importance of appropriate processing and dietary combinations to optimize nutrient utilization. When these nutritional characteristics are contextualized within intervention evidence, moringa emerges as a supportive functional food rather than a stand-alone solution for stunting prevention.

Evidence from community- and institution-based interventions suggests that the incorporation of moringa leaves into early childhood education settings can contribute to improved nutrient intake among preschool-aged children. Ihlas et al. (2025) reported that the utilization of moringa leaves in simple, locally prepared food products was associated with increased intake of protein, iron, and vitamin A, accompanied by high levels of acceptability among children. These findings underscore the importance of sensory characteristics and culturally appropriate food preparation in determining the success of food-based nutrition interventions, particularly for young children who are highly sensitive to taste, texture, and appearance.

From a programmatic perspective, early childhood education institutions represent a strategic platform for implementing moringa-based nutrition interventions. Structured feeding environments enable repeated exposure to nutrient-dense local foods, while simultaneously serving as channels for nutrition education targeting teachers and caregivers. The study further emphasizes that integrating moringa utilization into educational activities fosters community engagement and strengthens local food systems, thereby enhancing the sustainability of stunting prevention efforts beyond short-term supplementation (Dini et al., 2025)

At the household level, nutrition education interventions targeting pregnant women and mothers of young children play a critical role in maximizing the effectiveness of moringa-based strategies. Researchers demonstrated that structured counseling and food processing training significantly improved participants' knowledge regarding stunting and the nutritional benefits of moringa leaves (Amelia et al., 2025). This increase in knowledge was accompanied by high sensory acceptance of moringa-fortified food products, indicating that educational interventions can facilitate behavioral change and promote sustained utilization of moringa within daily diets, particularly during the first 1,000 days of life.

Taken together, these findings imply that effective stunting prevention programs should adopt a multi-level approach that combines moringa-based food interventions with targeted nutrition education across critical life stages. While moringa leaves provide an affordable and nutrient-dense local food resource, their contribution to stunting reduction is maximized when integrated within balanced dietary patterns, supported by appropriate processing methods, and reinforced through institutional and household-level education. Therefore, moringa should be positioned as a complementary component within broader nutrition-sensitive strategies aimed at improving maternal and child nutritional outcomes, rather than as a singular intervention to address stunting.

CONCLUSIONS

This scientific review demonstrates that *Moringa oleifera* leaves possess substantial nutritional potential and play a meaningful role as a local, food-based intervention in stunting prevention. Moringa leaves are rich in essential macronutrients and micronutrients, including protein, calcium, iron, folate, vitamins A and C, and various bioactive compounds, all of which are closely associated with linear growth, immune function, and anemia prevention. Evidence from intervention studies consistently indicates that moringa supplementation—administered in the form of extracts, powders, or processed food products—contributes to improvements in maternal nutritional status, hemoglobin levels, birth outcomes, and child growth indicators such as weight, height, and Height-for-Age Z-scores (HAZ), particularly during the first 1,000 days of life.

In addition to its favorable nutrient composition, moringa exerts biological effects through nutrigenomic and biomolecular mechanisms that support growth regulation, including enhanced protein synthesis, modulation of growth-related gene expression, and reduction of inflammation and oxidative stress. Nevertheless, existing evidence is constrained by methodological limitations, including heterogeneity in study design, small sample sizes, short intervention durations, and the absence of standardized dosage and preparation guidelines. Therefore, while moringa leaves represent an affordable, accessible, and sustainable complementary nutrition strategy, further large-scale, long-term, and well-controlled studies are required to establish standardized intervention protocols and to evaluate long-term functional outcomes. Overall, integrating moringa leaves into balanced dietary patterns and comprehensive stunting prevention programs offers a promising approach, particularly in resource-limited settings with high stunting prevalence.

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