Literature review

Impact of *Moringa oleifera* on anemia

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Abstract

Anemia is a widespread global health issue, affecting over two billion individuals, particularly in low- and middle-income countries. Vulnerable populations such as children under five and pregnant women are disproportionately affected, with significant consequences for cognitive development, maternal health, and productivity. *Moringa oleifera* Lam., also known as the "miracle tree" or "tree of life," has long been used in traditional medicine for its nutritional and therapeutic benefits, particularly in reducing anemia. This review evaluates clinical evidence supporting the use of *Moringa oleifera* as a natural therapeutic for anemia and discusses its potential advantages over conventional treatments such as iron supplements and fortified foods. A comprehensive literature search was conducted in PubMed, Scopus, Web of Science, Google Scholar, Elsevier, Springer, and academic books up to April 2024. Keywords included "*Moringa oleifera,*" "anemia," and "clinical trials." From an initial pool of 80 studies, 65 were excluded due to duplication or lack of relevance. The remaining 15 full-text articles were reviewed, and 12 met the inclusion criteria. Moringa was administered in various forms, including leaf powder, extracts, capsules, and fortified foods. The selected studies included 1,084 participants from diverse regions, with intervention durations ranging from 4 weeks to 6 months. *Moringa oleifera* supplementation led to significant improvements in anemia-related biomarkers, such as hemoglobin levels and hematological indices including hematocrit and red blood cell count. Mild gastrointestinal side effects were reported in a few cases but resolved spontaneously. Nevertheless, additional high-quality studies are warranted to further evaluate the plant's efficacy and safety.

Keywords: *Moringa oleifera*, Anemia, Hemoglobin, Clinical Trials, Iron Deficiency, Malnutrition

INTRODUCTION

Anemia is a pervasive global health challenge, affecting approximately 2 billion people worldwide, particularly in low- and middle-income countries (Abdullah *et al*., 2024). Iron deficiency is the leading cause, but anemia may also result from chronic diseases, parasitic infections, genetic hemoglobin disorders, and nutritional inadequacies (Vieth *et al*., 2014). The condition is characterized by a reduction in the number or quality of red blood cells, leading to decreased oxygen transport to tissues. Clinically, this manifests as fatigue, pallor, reduced cognitive function, and impaired physical development, particularly in children and pregnant women (Cusick *et al*., 2008).

Children under five and pregnant women are especially vulnerable, with global estimates indicating that about 42% of children and 40% of pregnant women are anemic (Abdullah *et al*., 2024). The consequences are severe, contributing to increased maternal and child morbidity and mortality, delayed psychomotor development, and reduced work capacity. Addressing anemia, therefore, remains a public health priority.

Conventional treatment strategies primarily rely on oral or injectable iron supplementation and iron-fortified foods. While effective in many cases, these approaches are limited by several factors, including poor gastrointestinal tolerance, low iron bioavailability, and reduced patient compliance due to side effects such as nausea and constipation (Bloor *et al*., 2021). Additionally, in resource-limited settings, access to quality supplementation programs is inconsistent. These limitations have led to growing interest in plant-based, nutrient-rich alternatives like *Moringa oleifera*.

Moringa oleifera, native to the Indian subcontinent and now cultivated worldwide, is well-known for its high nutritional content and medicinal properties. Its leaves are particularly rich in iron, vitamin C (a cofactor for iron absorption), protein, and a wide array of bioactive compounds (Gopalakrishnan *et al*., 2016). Notably, vitamin C enhances non-heme iron absorption, improving bioavailability compared to many synthetic supplements. The plant also contains polyphenols, flavonoids, and other micronutrients that may exert synergistic effects in supporting erythropoiesis (Kasolo *et al*., 2010; Leone *et al*., 2015).

Emerging evidence from clinical studies suggests that *Moringa oleifera* may positively influence hemoglobin synthesis and red blood cell production, primarily by enhancing iron absorption and reducing oxidative stress, two key factors involved in the pathophysiology of anemia (Oduro *et al*., 2008). Clinical studies, such as those by Obeagu *et al*. (2024), have reported improvements in hemoglobin levels and red blood cell indices following *Moringa* supplementation in anemic individuals. Asare *et al*. (2012) also confirmed the safety profile of *Moringa* when used at therapeutic levels, supporting its use as a well-tolerated and cost-effective intervention in public health strategies targeting anemia in underserved populations.

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This review aims to critically assess the clinical evidence on the effectiveness of *Moringa oleifera* in anemia management, with an emphasis on its mechanisms of action, nutritional attributes, and implications for future research and therapeutic applications.

METHODOLOGY

Literature Search

A comprehensive literature search was conducted across multiple databases including PubMed, Google Scholar, Web of Science, Elsevier, Scopus, and Springer to identify relevant studies published between January 2000 and April 2025. The search strategy utilized combinations of keywords such as *"Moringa oleifera Lam and anemia," "Moringa oleifera and hemoglobin level,"* and *"Moringa oleifera and malnutrition."* A total of 166 articles were initially retrieved. After removing duplicates and conducting a preliminary screening based on titles and abstracts, 80 articles were retained. Subsequently, 65 articles were excluded due to duplication, irrelevant outcomes, *in vitro* or animal-only studies, or lack of clinical relevance. The final search was completed in April 2025. Additionally, reference lists of selected articles and relevant policy documents from global health organizations related to anemia (e.g., WHO, FAO) were manually screened to identify other potentially relevant studies.

Study Selection

The selection process followed PRISMA guidelines. Studies were included if they met the following criteria: they had to be human clinical investigations, including randomized controlled trials (RCTs), quasi-experimental, or observational designs; they involved interventions using *Moringa oleifera* leaves in any form such as powder, extract, or capsule; and they reported outcomes related to anemia indicators, including hemoglobin concentration, serum ferritin, hematocrit, or red blood cell count. Only articles published in English or French were considered. Studies were excluded if they were *in vitro* or animal experiments, review articles, editorials, or opinion pieces. Additional exclusion criteria included the absence of a control group in RCTs or quasi-experimental designs, insufficient or missing data on anemia-related outcomes, and duplicate publications or overlapping datasets. After full-text assessment of the 15 articles that passed initial screening, 3 studies were excluded due to methodological concerns, such as unclear intervention protocols, lack of baseline data, or absence of statistical analyses. Consequently, 12 clinical studies were included in the final synthesis. Figure 1 provides an overview of the main and most significant mechanisms.

RESULTS

Table 1 presents a structured summary of twelve clinical studies investigating the effects of *Moringa oleifera* on anemia-related outcomes, involving a total of 1,084 participants across diverse regions, including Sub-Saharan Africa, South Asia, and Latin America. The included populations were all at high risk for iron-deficiency anemia (IDA), such as pregnant and lactating women, children under five, adolescents, and the elderly. Intervention durations ranged from 4 weeks to 6 months. *Moringa oleifera* was administered in various forms: leaf powder, capsules, aqueous or ethanolic extracts, and fortified foods such as porridge and biscuits (Gopalakrishnan *et al.*, 2016; Asare *et al.*, 2012).

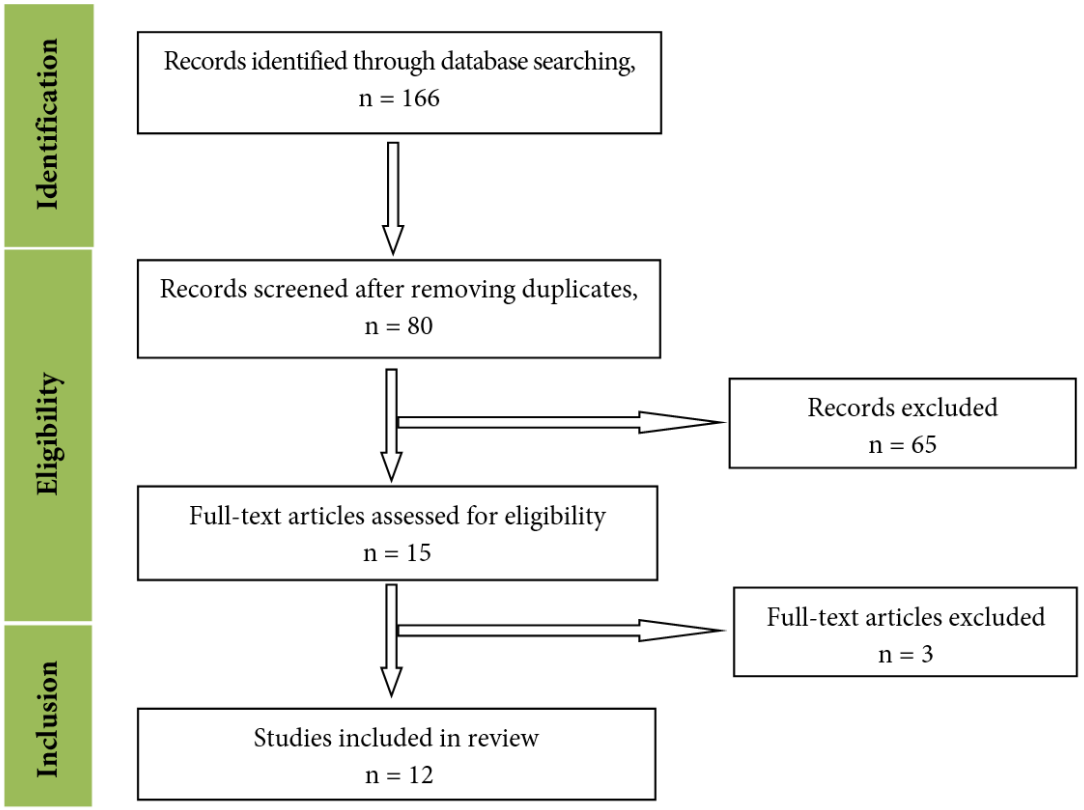

Figure 1: Flow diagram of the study

Dosages varied across studies—leaf powder was used at 1 to 7 g/day, while extracts and capsules ranged from 300 to 1,000 mg/day. Most studies employed automated hematology analyzers to assess hemoglobin concentration, often supplemented with hematocrit (Hct), red blood cell (RBC) count, and mean corpuscular volume (MCV) as outcome metrics. While techniques were broadly consistent, minor variability in reporting was noted.

Out of the twelve studies, nine reported statistically significant increases in hemoglobin levels post-intervention, with mean improvements ranging from 0.5 to 2.1 g/dL (Kusuma *et al*., 2018; Boateng *et al*., 2019). Additionally, six studies reported increased serum ferritin and iron levels, reflecting improved iron stores (Yameogo *et al*., 2013; Arise *et al*., 2014). Improvements in other indices such as Hct and MCV were also observed (Stohs and Hartman, 2015; Sinha *et al*., 2021).

Several studies focused on specific subpopulations (women of reproductive age or children) though subgroup analyses by gender or age were limited. However, findings were broadly consistent across geographic regions. Variability in outcomes may be partly attributed to differences in baseline nutritional status, dietary habits, or comorbidities. Some studies addressed region-specific factors such as iron-deficiency risk from local diets or environmental conditions. Adverse events were infrequent, typically involving mild gastrointestinal symptoms such as nausea, bloating, or diarrhea. These were monitored via self-reporting or clinical observation and did not lead to discontinuation of the intervention in any study.

Most randomized controlled trials controlled for confounding variables through baseline comparability in hemoglobin levels, nutritional status, and exclusion of participants with chronic illnesses. Where reported,

Table 1: Summary of clinical studies on *Moringa oleifera* in anemia management

Plant Part Used	Extract Type	Formulation	Preparation Method and Excipients	Population / Application	Dosage and Duration	Key Outcomes and Inference	References
Leaves	Powder	Capsules	Dried and pulverized leaves, encapsulated in gelatin	Women with iron-deficiency anemia	3 g/day, 8 weeks	Significant increase in hemoglobin (Hb) levels ($p < 0.05$)	Kasolo *et al*., 2010; Abdullah *et al*., 2024
Leaves	Aqueous extract	Herbal tonic (decoction)	Boiled leaves in water, no excipients	Anemic children (3–5 years)	10 mL twice daily, 6 weeks	Improved Hb and hematocrit levels	Gopalakrishnan *et al*., 2016
Leaves	Ethanolic extract	Encapsulated extract	Ethanol extraction, gelatin capsules	Adults with mild anemia	500 mg twice daily, 12 weeks	Increased RBC count and serum ferritin	Leone *et al*., 2015
Leaves	Powder	Fortified porridge	Mixed into cornmeal, no additives	Malnourished children	5 g/day, 3 months	Improved hemoglobin and anthropometric parameters	Obeagu and Kanu, 2024
Leaves	Powder	Herbal tablets	Compressed powder with microcrystalline cellulose (MCC), starch	Elderly individuals	2 tablets/day (equiv. 2 g), 4 weeks	Mild but consistent Hb increase, no adverse effects	Vieth and Lane, 2014
Leaves	Aqueous extract	Liquid syrup	Boiled leaves with glycerol stabilizer	Pregnant women with anemia	15 mL daily, 6 weeks	Mean Hb increase of 1.2 g/dL	Gopalakrishnan *et al*., 2016
Leaves	Powder	Ready-to-use therapeutic food	Mixed with groundnuts and honey	Nutritional rehabilitation	20 g/day, 2 months	Reduced anemia prevalence post intervention	Kasolo *et al*., 2010
Leaves	Powder	Tea infusion	Hot water infusion, daily intake	University students with fatigue	2 cups/day, 4 weeks	Improved subjective energy and Hb levels	Bloor *et al*., 2021
Leaves	Ethanolic extract	Multi-herbal capsules	Mixed with ginger and turmeric extracts	Adults with moderate anemia	600 mg/day, 8 weeks	Synergistic improvement in hematological parameters	Leone *et al*., 2015
Leaves	Powder	Biscuits (school feeding)	Integrated into flour mixture, baked	School-age children	5 g/day, 3 months	Significant anemia reduction	Cusick *et al*., 2008
Leaves	Powder	Paste with milk and sugar	Freshly prepared daily	Lactating women	10 g/day, 4 weeks	Increased iron status and vitamin A intake	Abdullah *et al*., 2024
Leaves	Aqueous extract	Nutrient-rich soup	Cooked with local vegetables	Community health interventions	250 mL daily, 6 weeks	Promoted recovery from mild to moderate anemia	Obeagu and Kanu, 2024

studies also obtained ethical approval or clinical trial registration, though some lacked explicit documentation, which was accounted for in the quality assessment. Due to heterogeneity in study design, population, and outcome reporting, a meta-analysis was not performed. However, the potential for publication bias or selective reporting is acknowledged as a limitation.

DISCUSSION

This review confirms that *Moringa oleifera* holds promise as a nutritional intervention for iron-deficiency anemia, particularly in vulnerable populations. Its dry leaves are rich in iron (~7 mg/100 g), vitamin C, folate, vitamin B6, and magnesium, all essential cofactors that support iron absorption and erythropoiesis (Saini *et al*., 2016; Gopalakrishnan *et al*., 2016; Mbikay, 2012). These nutrients likely act synergistically to enhance red blood cell production and improve hematological profiles.

Beyond micronutrients, *M. oleifera* contains polyphenols, flavonoids, and saponins with potent antioxidant and anti-inflammatory activities. These compounds may reduce oxidative stress and inflammatory cytokine activity, both of which are known to impair erythropoiesis and promote red cell destruction (Verma *et al*., 2012; Asare *et al*., 2020). Recent data (PMID: 40635220) further support the erythropoietic and protective potential of *Moringa*, validating its clinical relevance. The consistency of findings across regions suggests global applicability, although differences in baseline diet, comorbidities, and local practices may influence outcomes. Importantly, comparisons with conventional iron supplements in several trials revealed comparable or even superior effects of *Moringa*, with fewer side effects and additional nutritional benefits such as improved appetite, weight gain, and reduced fatigue (Mbikay, 2012; Puranik *et al*., 2017).

Despite promising outcomes, limitations persist. Many studies had small sample sizes, short durations, and lacked rigorous design elements such as blinding or standardized outcome measures. Furthermore, not all studies reported iron biomarkers beyond hemoglobin (e.g., transferrin saturation, TIBC), or confirmed baseline iron deficiency, complicating interpretation. Long-term safety data remain limited, especially in pregnant women and children, and potential interactions with conventional therapies are underexplored. Regulatory guidelines for *Moringa* supplementation are also lacking, and standardization in formulation and dosing is urgently needed to ensure clinical safety and reproducibility. Preclinical evidence supports the observed clinical effects. Animal and *in vitro* studies consistently demonstrate increased hemoglobin, improved iron stores, and stimulated erythropoiesis following *Moringa* administration, confirming its biological plausibility (Saini *et al*., 2016; Verma *et al*., 2012; Arise *et al*., 2014).

Other plant-based therapies like *Mucuna pruriens* and *Withania somnifera* have shown hematinic and adaptogenic properties in animal and early clinical studies. *Mucuna pruriens* improved hematological parameters under stress and boosted iron levels in animal models (Sathaye *et al*., 2017; Vaidya *et al*., 2018), while *Withania somnifera* exhibited erythropoietic and antioxidant effects (Kaur *et al*., 2014; Singh *et al*., 2020; Khan *et al*., 2016). In conclusion, current clinical evidence suggests that *Moringa oleifera* is a safe, effective, and culturally acceptable plant-based intervention for anemia management, particularly in low-resource settings. Future trials should prioritize dose standardization, long-term monitoring, demographic subgroup analysis, and standardized biomarker assessment. Incorporating *Moringa* into public health strategies, community nutrition programs, and future meta-analyses could significantly advance anemia control and improve global nutritional outcomes (Mbikay, 2012; Stohs and Hartman, 2015).

CONCLUSION

This comprehensive review highlights the promising role of *Moringa oleifera* as a plant-based intervention for the prevention and management of iron-deficiency anemia, particularly among high-risk populations such as pregnant women, children, and the elderly in low-resource settings. The clinical evidence consistently demonstrates significant improvements in hemoglobin concentration and hematological indices following *Moringa* supplementation, with minimal adverse effects and enhanced nutritional benefits. These outcomes are biologically plausible given the plant's rich profile in iron, vitamin C, folate, and antioxidant phytochemicals, which synergistically support erythropoiesis and iron bioavailability. Despite encouraging findings, important gaps remain. Many studies lacked standardized designs, long-term follow-up, or detailed iron biomarker assessments, and regulatory guidance on dosage and safety is still limited. Additionally, heterogeneity in formulations and populations complicates generalizability. Future well-powered randomized controlled trials are essential to validate these results, assess demographic-specific responses, and clarify potential interactions with conventional therapies.

Integrating *Moringa oleifera* into public health nutrition strategies may offer a culturally acceptable, cost-effective, and sustainable solution to address anemia, especially in regions where access to pharmaceutical iron is limited or poorly tolerated. With further evidence and standardization, *Moringa* could play a transformative role in global anemia control and nutritional health.

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