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REVIEW ARTICLE

Ethno medicinal plant-based approach to treat anaemia: A systematic review

Charu Mendiratta[1, 2*], Swati Vyas[1]

[1]Department of Home Science, IIS (Deemed to be University), Jaipur 302 020, Rajasthan, India
[2]School of Allied Health Sciences, Jaipur National University, Jaipur 302 017, Rajasthan, India

*Correspondence email - charumendiratta31@gmail.com

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Abstract

Iron deficiency anaemia (IDA) remains one of the leading global health concerns, particularly affecting adolescent girls and women. It is characterized by insufficient red blood cells or haemoglobin levels, primarily caused by iron deficiency and it significantly impacts physical and cognitive health. This study aims to explore the potential of ethnomedicinal plants in managing anaemia by evaluating bioactive compounds and nutrients found in plants such as *Moringa oleifera*, *Psidium guajava*, *Trigonella foenum-graecum*, *Hibiscus sabdariffa*, *Punica granatum*, *Amaranthus spp.*, *Beta vulgaris*, *Phyllanthus emblica* and *Lepidium sativum*. A systematic review methodology, guided by the PRISMA framework and utilizing the PSALSAR and PICOC models, was employed to assess the efficacy of these plants in improving haemoglobin and other haematological parameters. Results from studies from databases such as PubMed, Scopus and Google Scholar suggest that these plant-based interventions have improved haemoglobin levels by promoting iron absorption and bioavailability. Thus justifying a medicinal approach to treat anaemia with a sustainable perspective using traditional local resources based on the promising potential of plant-based remedies, being cost-effective solutions for combating anaemia, especially in resource-limited settings and emphasizing the need for further clinical and community-based research to integrate these interventions into public health strategies.

Keywords: anaemia; bioactive compounds; dietary interventions; ethno medicinal plants

Introduction

Iron deficiency anaemia (IDA) continues to be one of the top five causes of years lived with disability in humans, particularly in women (1). Anaemia poses a notable concern to public health as it has the potential to impact individuals of any age and geographic location. Anaemia is when the body's physiological demands are unmet due to insufficient red blood cells (RBCs) and their ability to carry oxygen. In medical terms, anaemia occurs when the count of RBC falls below the typical range of less than 4.2 million/µL or when the haemoglobin level falls below 12 g/dL in women and 13 g/dL in men (2). Iron deficiency is the primary cause of anaemia, responsible for at least 50 % of all cases (3, 4). The absorption of iron is influenced by various factors such as the body's iron levels, the rate at which new red blood cells are produced, the type and quantity of iron present in the diet (heme iron or inorganic iron), as well as the presence of substances that either enhance or inhibit iron absorption in the diet (5). Insufficient consumption of bioavailable iron is a common cause of Iron Deficiency (ID); nevertheless, periods of increased growth requirements, like during childhood and adolescence when red blood cell mass expands, can also lead to low iron levels (6–9). Groups susceptible to development issues include women in their childbearing years or are currently pregnant (10). Around 430 million individuals aged 10-24 years worldwide, which is approximately one in four individuals, experience anaemia, with the highest prevalence observed in low- and middle-income countries. India has one of the largest cohorts of adolescents globally, with 253 million individuals aged between 10 and 19 years (11). According to The NFHS estimates from 2005-2006 to 2019-2021, the prevalence of anaemia among Indian adolescents aged 15-19 years has increased, with girls rising from 55.8 % to 59.1 % (12). The Global Burden of Disease (GBD) study provides valuable insights into the burden of anaemia in different countries and regions (204 countries and territories, 7 super-regions and 21 regions) over 30 years from 1990 to 2019. GBD 2019 estimated that globally, anaemia affected 27.5 % of the population in 2019, with a higher prevalence in women than men. In the context of income levels, GBD 2019 found that the prevalence of anaemia was highest in low-income countries (31.7 % of the population) and lowest in high-income countries (11.3 % of the population). The prevalence of anaemia in middle-low-income and middle-high-income countries was 28.7 % and 22.2 % of the population, respectively (13).

Materials and Methods

This systematic review was based on the preferred reporting items for systematic reviews and meta-analysis PSALSAR and PIOCO framework methodology was used.

PSALSAR framework

Steps	Outcome	Method
Protocol	Defined study scope	Outlining the purpose, participants, treatments, results and significant parameters of the study
Search	To find pertinent research, a thorough search is done in scientific databases	Search databases: Pubmed, Google Scholar, etc
Appraisal	Quality and relevance evaluation of studies	Appraise studies using risk of bias and quality assessment tools
Synthesis	Integration of data on plant-based interventions	Synthesize data from selected studies to identify trends in plant efficacy
Analysis	Statistical analysis, result discussion, conclusion	Use of quantitative and qualitative analysis, deriving conclusion
Report	Report summarizing findings and implications	Write a report on findings, implications and conclusions

PICOC framework

Element	Details
Population	The study populations primarily included adolescent girls, young women (including pregnant women) and rats with anaemia. Additionally, some studies focused on nursing students, traditional rice farmers and children, all assessed for the effects of plant-based interventions on haemoglobin levels and other haematological parameters
Intervention	The interventions included plant-based remedies like moringa, guava, fenugreek, rosella, pomegranate, amaranth, beetroot, amla and garden cress to improve haemoglobin levels
Comparator	Control group, standard iron supplements, or placebo (where applicable)
Outcome	Increase in haemoglobin levels and haematological parameters
Context	Settings such as clinical trials

Eligibility criteria of the study

Inclusion criteria

- Individuals diagnosed with anaemia, specifically those with haemoglobin (Hb) levels below the normal range:
- Adolescent girls (13-19 years): Hb < 12 g/dL
- Pregnant women: Hb < 11 g/dL (WHO definition of anaemia in pregnancy)
- Young women and adults: Hb < 12 g/dL in females
- Animal models (e.g., rats) with induced anaemia
- Nature of Intervention: Studies assessing the efficacy of plant -based interventions, including *Moringa oleifera*, *Psidium guajava*, *Trigonella foenum-graecum*, *Hibiscus sabdariffa*, Punica granatum, *Amaranthus* spp., *Beta vulgaris*, *Phyllanthus emblica* and *Lepidium sativum*.
- Study Design: This review included studies with pre-experimental, quasi-experimental and experimental designs (randomized controlled trials, double-blind placebo-controlled trials, cluster randomized trials and animal models such as phenylhydrazine-induced anaemia in rats, yeast cells and in vitro studies). Eligible studies assessed the impact of dietary or plant-based interventions on anaemia and reported haematological parameters (e.g., Hb, RBC, HCT). Studies were included regardless of the form of the intervention (e.g., powder, capsule, juice, extract, flour, or food-based preparations such as biscuits or chikkies), provided the dosage and duration were mentioned.
- Outcome measure: Improvement in haemoglobin levels and haematological parameters (RBC, MCV, MCH) to assess intervention effectiveness.
- Studies published in English.

Exclusion criteria

- Individuals with severe health conditions unrelated to anaemia, such as chronic diseases affecting haemoglobin metabolism (e.g., renal failure, cancer, severe infections).
- Non-anaemic individuals (Hb levels within normal ranges).
- Studies focusing on pharmaceutical or artificial interventions (excluding plant-based dietary solutions).
- Incomplete or poor-quality data
- Studies lacking transparent methodology, baseline and end-line measures or statistical analysis
- Doses of plant supplements to be low to expected physiological level
- Non-English publications
- Studies with no full text available or published in predatory journals.

Search Strategy

The search strategy involves using databases like PubMed, Scopus and Google Scholar with keywords such as *"Moringa oleifera"*, *"Psidium guajava"*, *"Trigonella foenum-graecum"*, *"Hibiscus sabdariffa"*, *"Punica granatum"*, *"Amaranthus spp."*, *"Beta vulgaris"*, *"Phyllanthus emblica"*, *"Lepidium sativum"*, "anaemia", "iron deficiency", "plant-based intervention", "haemoglobin improvement", "haematological effects", "anaemic treatment", "natural remedies", "dietary supplements", "adolescent girls", "pregnant women" and "clinical trials." Studies are selected based on inclusion criteria (human/animal trials, plant-based interventions and outcomes related to anaemia) and exclusion criteria (non-plant interventions, no control group, or irrelevant studies).

Data extraction

Data extraction involves systematically collecting relevant details from each study to ensure a thorough analysis. This includes identifying the study design (e.g., RCT), the characteristics of the population, such as sample size, age and health status and the specifics of the intervention, including the plant-based treatments used, dosage and duration. The comparator, or control group, is also noted, such as whether a placebo was used. Primary and secondary outcomes (e.g., changes in haemoglobin levels) are extracted, along with the results, to assess the effectiveness and potential side effects. Finally, the quality of each study is evaluated to determine the risk of bias, ensuring a comprehensive understanding of the intervention's impact on anaemia.

Results

Identification of studies via databases

The PRISMA flowchart illustrates the process of study selection for a systematic review. Initially, 2567 records were identified from databases. After removing 1799 duplicate records, 1799 records were screened for relevance. Of these, 1567 records were excluded due to irrelevance or unsuitable content, leaving 232 reports for eligibility assessment. During the eligibility phase, 206 reports were excluded for various reasons: 64 reports had irrelevant abstracts, 64 were excluded upon full-text review and 78 were excluded due to data or methodological limitations. Ultimately, 26 studies met the inclusion criteria and were included in the review (Fig. 1).

Determinants of anaemia

Several factors can lead to the development of iron deficiency anaemia, such as poor gut health, insufficient dietary intake of iron, low iron bioavailability, inadequate levels of folic acid, Vitamin C, Vitamin A and Vitamin B12, as well as the presence of hookworm infestation and malaria (Table 1).

Consequences of anaemia

Iron deficiency anaemia has significant medical and social implications on a global scale. It affects cognitive performance in young children, results in adverse outcomes of pregnancy for both mothers and newborns, decreases physical and working capacities in adults and causes cognitive decline in the elderly (32). The negative impact of anaemia can extend beyond adolescence and have long-term consequences. Adolescents who suffer from anaemia are prone to developing anaemia during pregnancy as well. This can lead to a range of negative impacts on both pregnancy and childbirth (33). Anaemic adolescent girls are more likely to exhibit stunting, which refers to the failure to reach their expected height and growth potential (34). Anaemia during adolescence is a nutritional issue that can have significant, irreversible adverse effects on growth, cognition, work performance and reproductive health (35, 36). Adolescent girls with anaemia who become pregnant are at increased risk of maternal mortality and morbidity, as well as poor birth outcomes like stillbirth, low birth weight and prematurity (37). Additionally, anaemia in pregnant adolescents can negatively affect their infants' iron status (9, 38). Anaemia is when the body lacks enough healthy red blood cells to carry adequate oxygen to the body's tissues. This can result in tiredness or weakness because the body is not getting enough oxygen to function correctly (39). Anaemia can have a significant impact on reproductive health and quality of life. Other consequences of iron deficiency are associated with the influence of low levels of iron on DNA replication and the cell cycle (oral lesions, hair loss, nail abnormalities), immune function (increased vulnerability to infections), myelin genesis and neurotransmissions (restless leg syndrome) and suppression of cytochrome P_{450} production (disrupted drug metabolism) (40). Iron deficiency anaemia is commonly linked with various chronic illnesses, including chronic kidney disease, chronic heart failure, cancer and inflammatory bowel disease (41, 42). Research indicates that anaemia has an effect on COVID-19 (43, 44). Therefore, it is essential to address anaemia during adolescence to prevent adverse outcomes and ensure optimal health and well-being.

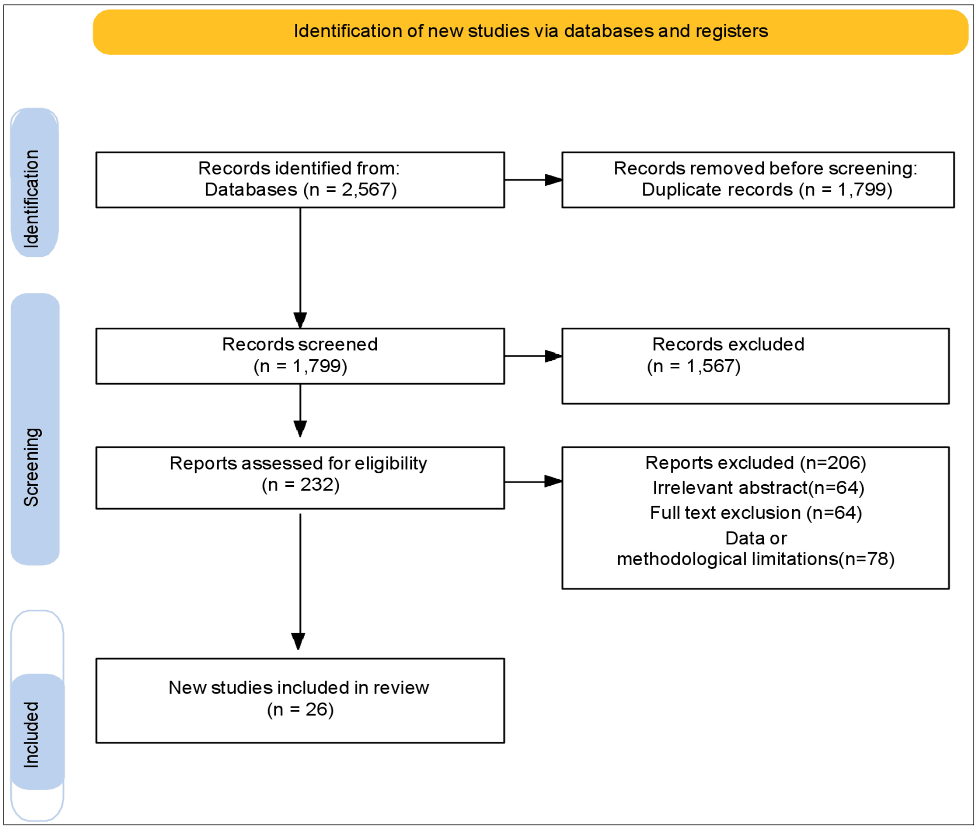

Fig. 1. Prisma framework.

Table 1. Determinants of anaemia

Triggers	Effect	Reference
Poor gut health	This study examined the role of gut microbiota in the development of iron deficiency anaemia and found that gut dysbiosis, or an imbalance in the gut microbiota, can reduce the absorption of iron and other nutrients, contributing to the development of anaemia. It was concluded that maintaining a healthy gut microbiota may be an essential strategy for preventing and treating anaemia	(14-16)
Insufficient dietary intake of iron	When the body's iron intake is insufficient, the storage of iron is quickly used up and depleted to fulfil the body's needs. As a result, there is a decrease in the synthesis of haemoglobin, leading to the development of anaemia. Low dietary iron intake significantly increases anaemia among adolescents. Skipping meals and having a low meal frequency also cause anaemia in adolescents	(17-19)
Low iron bioavailability	The quality of the diet influences the absorption of non-heme iron from the gastrointestinal tract. Several dietary factors can impact the availability of iron for transportation and considering the combined effect of both inhibitors and enhancers of iron absorption helps to evaluate the dietary quality as either high or low in terms of bioavailability	(20-22)
Blood loss /Menstruation	A significant increase in the likelihood of anaemia was observed with the occurrence of excessive bleeding during menstruation. Prolonged menstruation can also lead to the depletion of iron stores in the body and contribute to the development of anaemia.	(23-25)
Presence of hookworm infestation	hookworm infestation can cause anaemia due to chronic blood loss and interference with the absorption of nutrients, including iron	(26-28)
Malaria	Malaria infection can cause anaemia, including iron deficiency anaemia, through multiple mechanisms, including haemolysis, direct destruction of red blood cells and interference with iron absorption and storage	(29-31)

Blood transfusion and oral administration of iron supplements are commonly used to treat anaemia due to their cost-effectiveness and higher efficacy. However, these methods have several drawbacks and side effects, particularly with oral therapy, such as insufficient absorption, lack of compliance, nausea, vomiting, constipation and stomach pain (45, 46). Moreover, improper dosages of iron supplements can lead to severe health-related complications such as specific neurological disorders, cardiovascular conditions and formation of oxidation, oxidative stress and cancer (47, 48). Consequently, it is imperative to discover a safe and effective alternative for anaemia management. According to recent studies, certain herbal phytochemicals have been found to induce resolution of anaemia through direct action.

In contrast, others exhibit pleiotropic effects by increasing resistance to oxidative stress through their antioxidant activity or triggering cellular mechanisms such as autophagy (49). Humans have been using plants as a source of medicine since ancient times and several modern drugs are derived from medicinal plants (45, 50). The treatment of anaemia with medication may face obstacles due to three factors. The first is an increasing awareness of the potential side effects of drugs. In addition, supplements have lower bioavailability than natural foods and the cost of medications may be prohibitive for low-income individuals. Therefore, natural plant products may offer a promising solution for anaemia (51).

Medicinal plants used for the treatment of anaemia

The treatment of anaemia through natural remedies has been an area of growing interest due to the limitations and side effects of conventional therapies like oral iron supplements and blood transfusions. Medicinal plants, rich in bioactive compounds, offer an alternative approach to managing anaemia by enhancing haemoglobin levels, improving iron absorption and mitigating oxidative stress. These plants have been used in traditional medicine for centuries and are now being validated by scientific studies for their efficacy. Below is a table summarizing various medicinal plants and their bioactive compounds that have been found to have anti-anaemic effects (Table 2).

Moringa oleifera (Common name: Moringa)

Bioactive compounds found in *Moringa oleifera* include flavonoids, saponins, catechol tannins, anthraquinones and alkaloids, which contribute to the plant's nutritional and therapeutic properties such as they show antioxidant, antimicrobial, anticancerous, anti-diabetic and anti-inflammatory effect (52). *Moringa oleifera* leaf extract also shows a significant increase in haemoglobin levels because of the high amount of iron in *Moringa oleifera* leaves (53). The increase in haemoglobin concentration following *Moringa oleifera* consumption can be accounted for by the elevated intake of protein or the presence of ascorbic acid and beta-carotene in *Moringa oleifera* powder's leaves, which are non-heme iron enhancers. Moreover, the protein content, consisting of amino acids, may aid in erythropoietin activity by furnishing the necessary amino acids for synthesizing porphyrin, globin and transferrin (54).

Psidium guajava (Common name: Guava)

The presence of flavonoids and carotenoids, including beta-carotene, lycopene, beta-cryptoxanthin, polyphenols and vitamin C in red *Psidium guajava*, can enhance the absorption of non-heme iron up to twenty percent (2 % - 20 %). *Psidium guajava* contains amino acids and vitamin C, which can convert ferrite (Fe^{+3}) to ferrous (Fe^{+2}) to facilitate iron absorption. Additionally, vitamin C can assist in transferring iron from transferrin in plasma to join the ferritin tissue, thereby increasing iron uptake (55). Polyphenolic compounds known as flavonoids exhibit antioxidant properties and can scavenge hydroxyl and superoxide radicals in blood cells, shielding membrane lipids and preventing cellular harm. *Psidium guajava* leaf-derived flavonoids can aid erythropoiesis and boost immune function. Moreover, the antioxidant compounds present in *Psidium guajava* leaf extract can counteract free radicals, inhibit unwanted oxidation or destruction of DNA, protein and fat and increase

Table 2. Plants with potential for treating anaemia

Name of plant	Family	Common name	Bioactive compound	Reference
Moringa oleifera	Moringaceae	Moringa leaves	flavonoids, saponins, tannins, catechol tannins, anthraquinones and alkaloids, iron, amino acids	(52)
Psidium guajava	Myrtaceae	Guava	Vitamin C, Fe, ascorbic acid, retinol, Cu, phosphorus, beta-carotene, lycopene, beta-cryptoxanthin	(55)
Trigonella foenum-graecum	Fabaceae	Fenugreek /Methi	alkaloids, flavonoids, polyphenols, sterols, terpenes, glycosides and saponins	(58)
Hibiscus sabdariffa	Malvaceae	Roselle	alkaloid, flavonoids, tannins, phenols and anthocyanins, vitamin C, magnesium and omega-3, vitamin A, iron, potassium, β-carotene and essential fatty acids	(59)
Punica granatum	Lythraceae	Pomegranate	Anthocyanins, organic acid(citric acid, ascorbic acid, maleic acid, hibsicic acid, oxalic acid, tartaric acid), phytosterols, , polyphenols, iron	(61)
Amaranthus A. Cruentus	Amaranthaceae	Amaranth	Quercetin, betalains, ascorbic acid, iron, protein, calcium, vitamins A, E and folic acid	(62)
Beta vulgaris	Amaranthaceae	Beetroot leaves	Iron, apigenin, vitexin, vitexin-2-O-xyloside and vitexin-2-O-rhamnoside, vitamin B6, vitamin B12 and folic acid	(63)
Phyllanthus emblica	Euphorbiaceae	Amla	Ascorbic acid	(65)
Lepidium sativum	Crucifers	Garden Cress seeds	Iron, Vitamin C, protein, lepidine, glucapaeolin, carotene, Palmitic, oleic, lineolic, arachidic, behenic, benzyl isothiocyanate acids	(66)

the production of blood cells, thus preserving haemoglobin levels (56, 57).

***Trigonella foenum-graecum* (Common name: Fenugreek)**

Trigonella foenum-graecum contains a range of compounds such as alkaloids, flavonoids, polyphenols, sterols, terpenes, glycosides and saponins that possess antioxidant properties, facilitate tissue regeneration and enhance the durability of blood capillaries by reducing their permeability and increasing their resistance to haemolysis (58).

***Hibiscus sabdariffa* (Common name: Roselle)**

Hibiscus sabdariffa has been highly referenced as a species that can combat anaemia due to its high iron and ascorbic acid content. The ascorbic acid in *Hibiscus sabdariffa* aids in absorbing non-heme iron, which explains its potential as an anti-anaemic agent in traditional medicine (59). *Hibiscus sabdariffa* flower products contain significant amounts of four primary flavonoids: phenolic acids, Vitamin C and anthocyanin. These compounds possess potent abilities to scavenge free radicals and act as antioxidants, which may be linked to the haematopoietic potential of *Hibiscus sabdariffa.* Its antioxidant properties may protect the haematopoietic systems and the development of blood cells against reactive free radicals (60).

***Punica granatum* (Common name: Pomegranate)**

Punica granatum is an excellent source of vitamin C, which can help absorb iron from plant-based foods and improve the effectiveness of iron supplements. Tocopherol present in *Punica granatum* may help reduce oxidative stress and inflammation, which can contribute to anaemia. Polyphenols protect red blood cells from damage (61).

***Amaranthus A. Cruentus* (Common Name: Amaranth)**

The extract of *Amaranthus cruentus* has a protective effect due to flavonoids, specifically quercetin, which can prevent lipid peroxidation and hypotonic lysis. The antioxidant and ant haemolytic effects may be attributed to its flavonoid constituents and polyphenols, betalains, ascorbic acid and iron. Therefore, *Amaranthus cruentus* is a rich source of phytochemicals responsible for its anti-anaemic effect (62).

***Beta Vulgaris* (Common name: Beetroot)**

Apigenin, vitexin, vitexin-2-O-xyloside and vitexin-2-O-rhamnoside are phytochemicals in green Beta vulgaris exhibiting significant antioxidant activity. Iron, vitamin B6, vitamin B12 and folic acid in *Beta vulgaris* leaves may have contributed to the normalization of haematological indices. Research indicates that the vitamins and minerals found in the leaves of *Beta vulgaris* could be responsible for its potential hematinic effects (63). *Beta vulgaris* demonstrated antioxidant potential both in vivo and in vitro, likely due to its high content of flavonoids, tannins and gallic acid. Based on its antioxidant properties, the extract from *Beta vulgaris* leaf and stalk demonstrated potent hematinic and anti-anaemic effects (64).

***Phyllanthus Emblica* (Common name: Amla)**

Phyllanthus emblica contains high levels of vitamin C, essential for preventing anaemia, a condition characterized by a low red blood cell count. When consumed with iron-rich foods, vitamin C aids in iron absorption by increasing the acidity in the stomach. This, in turn, facilitates the production of haemoglobin and contributes to a healthy, anaemia-free life (65).

***Lepidium sativum* (Common name: Garden cress seeds)**

The highest non-heme iron source, *Lepidium sativum*, raises haemoglobin levels. High carbs, macro and micronutrients and antioxidants boost its use. *Lepidium sativum* iron content is readily absorbed in the small intestine and contributes to increased haemoglobin levels in the blood. Furthermore, the bioavailability of the iron content in *Lepidium sativum* may offer an advantage in treating and eradicating anaemia (66).

Discussion

The reviewed studies collectively highlight the efficacy of plant-based interventions in combating anaemia, demonstrating the vital role of various bioactive compounds in improving blood parameters. These plants offer a natural, safe and cost-effective alternative to conventional treatments, targeting key mechanisms involved in anaemia, such as enhancing iron bioavailability, promoting erythropoiesis and reducing oxidative stress.

Moringa oleifera has been widely recognized for its anti-anaemic properties. Studies on *Moringa oleifera* flower extract show significant improvements in RBC counts, haemoglobin levels and haematocrit in phenylhydrazine-induced anaemic rats (87). The plant's flavonoids, saponins and iron content are key contributors to its ability to stimulate erythropoiesis and protect red blood cells from oxidative damage. *Psidium guajava* juice has consistently shown effectiveness in increasing haemoglobin levels, particularly in pregnant women (88). The high vitamin C and polyphenol content in *Psidium guajava* enhances the absorption of non-heme iron, making it an effective remedy for pregnancy-related anaemia and supporting its use as a preventive and curative measure. Similarly, *Trigonella foenum-graecum* demonstrates improvements in haemoglobin synthesis and RBC count due to its high content of saponins, flavonoids and alkaloids. *Trigonella foenum-graecum* has been proven to strengthen capillaries, reduce oxidative stress and promote blood cell formation, making it an excellent anti-anaemic agent (89). *Hibiscus sabdariffa* has also shown promising results in improving haemoglobin levels and packed cell volume. Research indicates that the aqueous leaf extract of *Hibiscus sabdariffa*, with its high iron and ascorbic acid content, significantly improved red blood cell production and protected erythrocytes from oxidative damage (90).

The findings on *Punica granatum* further support the importance of plant-based interventions. Research indicates that the polyphenols, tocopherol and vitamin C in pomegranate enhance iron absorption and protect red blood cells from oxidative damage, leading to improvements in haemoglobin levels (91). *Amaranthus cruentus*, as explored by previous studies, has significant benefits in increasing RBC count and haemoglobin levels (92). The plant's rich composition of flavonoids, phenolic compounds and iron improves haematological indices, reduces oxidative haemolysis and stimulates erythropoiesis. Research indicates that *Beta vulgaris* has positively affected both haemoglobin levels and physical performance (93). Beetroot's high iron content and its antioxidant properties contribute to improved blood parameters and muscle coordination, highlighting its dual role in addressing anaemia and enhancing physical health. *Phyllanthus emblica* has shown considerable promise in improving haemoglobin levels. The high vitamin C content in *Phyllanthus emblica* aids in iron absorption, while its polyphenols and antioxidants provide additional protective effects. Research indicates these properties help support overall blood health and alleviate anaemia (94). Finally, *Lepidium sativum* has proven effective in increasing haemoglobin levels due to its high iron bioavailability and rich antioxidant content. The plant's nutritional profile aids in improving iron absorption and red blood cell production, supporting its use as a natural remedy for iron deficiency anaemia (95).

Overall, the evidence from these studies did not specifically report significant side effects or limitations associated with consuming the mentioned ethno-medicinal plants. The focus was primarily on their efficacy in improving haemoglobin levels and managing anaemia. However, it is acknowledged that while these natural remedies are generally considered safe, individual responses may vary and further research is needed to comprehensively assess any potential adverse effects or interactions with other treatments (Table 3-11).

Conclusion

This study highlights the potential of plant-based interventions, such as *Moringa oleifera*, *Psidium guajava* and *Trigonella foenum-graecum*, in improving haemoglobin levels and managing anaemia. Bioactive compounds like iron, vitamin C and flavonoids enhance iron absorption, promote erythropoiesis and reduce oxidative stress, offering a safe and effective alternative to conventional treatments. These natural remedies are particularly beneficial for vulnerable populations and in resource-limited settings. Future research should

Table 3. Effect of *Moringa oleifera* on Anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
The impact of *Moringa oleifera* supplementation on anemia and other variables during pregnancy and breastfeeding: a narrative review	Quasi-experimental study	44 Female participants aged 14-19 years were selected using purposive sampling	HB ↑ 9.37 g/dL to 12.10 g/dL	Moringa leaf capsules (250 mg × 2/day) + Vitamin C (50 mg × 2/ day) for 14 days	(67)
Effect of *Moringa oleifera* leaves extract against hematology and blood biochemical value of patients with iron deficiency anaemia	Randomized, double-blind, placebo-controlled study	35 Women (16-49 years) (17 in the *Moringa Oleifera* group, 18 in the control group)	HB ↑ 10.93±1.02 to 11.57±1.12 (p=0.004) RBC ↑ 3.95±0.49 to 4.43±0.48 (p=0.001) HCT ↑ 33.01±3.24 to 35.19±3.36 (p=0.036)	1400 mg/day for 3 weeks	(54)
Moringa oleifera teabags increase hemoglobin in adolescent females	Pre-post-test one-group design	100 females Adolescents (13-15 years)	HB ↑ 10.71 g/dL to 11.63 g/dl after 30 days ($p < 0.05$)	6 g/day for 30 days	(68)
Moringa oleifera leaf flour biscuits increase the index of erythrocytes in pregnant women with anaemia.	Quasi-experimental	50 Pregnant Women (20-35 years) (Intervention group: 25, Control group: 25)	*Moringa oleifera* biscuits group: MCH ↑ 27.55 to 28.00, MCV ↑ 78.57 to 78.93 ($p < 0.05$) Control group: No significant change ($p > 0.05$)	2.8 g/day Moringa leaf flour for 60 days	(69)

Table 4. Effect of *Psidium guajava* on anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
The effect of guava juice toward haemoglobin levels in pregnant women.	Quasi-experimental	58 anaemic pregnant women (Third-trimester) (29 in the guava juice group, 29 in the control group)	HB ↑ Intervention group: 11.24±0.85 vs. Control group: 10.33±1.18 Average change: Intervention group: 1.41±1.21 vs. Control group: 0.57±0.81	200 mL/day for 2 weeks	(70)
The effect of red guava (*Psidium guajava* L.) juice on pregnant women's haemoglobin level	Pre-experimental, one-group pre-test, post-test design	60 pregnant women with anaemia (Third-trimester)	HB ↑ 9.83 to 11.24 (1.41) p = 0.001	250 mL/day for 14 days	(71)
The effect of giving red guava juice to grade of pregnant women's haemoglobin.	Quasi-experimental, non-equivalent pretest-posttest design	15 Pregnant women with anaemia	HB ↑ 8.80 to 12.60 (3.8) (p = 0.000)	250 mL/day for 7 days	(72)
The effect of giving avocados (*Persea americana* Mill) and guava (*Psidium guajava* Linn) on haemoglobin levels in traditional rice farmers	Quasi-experimental, pretest-posttest with control group design	30 Female traditional rice farmers	*Psidium guajava* intervention: HB ↑ 11.3 to 12.4 (1.1) (p < 0.05) *Psidium guajava* + *Persea americana* Intervention: HB ↑ 10.2 to 13.0 (2.8) (p < 0.001)	100 g/day for 14 days	(73)

Table 5. Effect of *Trigonella foenum-graecum* on anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
Anti-anemic and haemopoietic evaluation of *Trigonella foenum-graecum* (fenugreek) in rodent model	Experimental animal model (phenylhydrazine-induced anaemia in rats)	30 Male Wistar rats	HB ↑ 51.6 % (p < 0.05) RBC ↑ 52.85 % (p < 0.05) WBC ↑ 54.9 % (p < 0.05) Dose: 400 mg/kg body weight	400 mg/kg body weight for 13 days	(58)
Effectiveness of fenugreek leaf powder with iron supplementation vs iron supplementation alone on increasing haemoglobin level among adolescent girls with anaemia at Koravallimedu, Puducherry	Two-group experimental pre-test and post-test design	60 Adolescent girls, aged 10-19 years	HB ↑ Experimental group: 9.45 ± 0.60 to 10.38 ± 0.73 vs. Control group: 9.44 ± 0.61 to 9.95 ± 0.68, t = 2.324, p < 0.05	5 g of fenugreek leaf powder mixed with 200 mL of water/day for 21 days	(74)
Nutritional and biological assessment of wheat biscuits supplemented by fenugreek plant to improve the diet of anaemic rats.	Experimental, animal model	42 Male albino rats	HB ↑ *Trigonella foenum-graecum* 5 %: 14.9 ± 1.1 g/dL, Germinated *Trigonella foenum-graecum* 5 %: 13.5 ± 0.7 g/dL, Control (+): 8.7 ± 0.9 g/dL	5 g/day for 4 weeks	(75)

Table 6. Effect of *Hibiscus sabdariffa* on anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
Effect of roselle (*hibiscus sabdariffa*) on changes in haemoglobin levels in pregnant women with anaemia taking iron supplement	Quasi-experimental, pretest-posttest control group design	42 Pregnant women, second trimester	HB ↑ Control group: 9.09 to 9.71 g/dL vs. Experimental group: 9.31 to 10.40 g/dL	115.2 mg/kg BW / day for 10 days	(76)
Effects of oral administration of aqueous extract of *Hibiscus sabdariffa* on some haematological parameters of wistar albino rats	Experimental study with treatment groups.	25 Male Wistar albino rats	Group E (1.8 g/100 mL + Vitamin C): 13.02 ± 0.45 g/dL Group C: 12.48 ± 2.12 g/dL Group D: 12.06 ± 1.13 g/dL Group B: 10.68 ± 2.57 g/dL Control: 8.34 ± 3.51 g/dL All groups receiving Rosella extract showed significant increases in Hb levels compared to the control	1.2g-1.8 g/100 mL for 28 days	(77)
Hibiscus sabdariffa meal improves the iron status of childbearing-age women and prevents stunting in their toddlers in northern ghana	Quasi-experimental design	120 Childbearing age women (15-49 years) and toddlers (6-24 months)	HB ↑ Intervention group: 11.84 to 12.08 g/dL vs. Control group: stable at 11.8 g/dL	Women (15-49 years): 1.9 kg per meal Toddlers (6-24 months): 0.4 kg per meal 3 times/week for 12 weeks	(78)

Table 7. Effect of *Punica granatum* on Anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
Pomegranate juice enhances iron dialysability and assimilation in *in-vitro* cell free and cell-based models	Laboratory-based in vitro and cell culture experimental study	Not applicable (cell-based models: Caco-2 and HepG2)	Iron dialysability: PJ ↑ 3x vs. Control, Ascorbic acid ↑ 1.6x Iron uptake: PJ ↑ ~50 % vs. Ascorbic acid Ferritin content: PJ ↑ 30 % vs. Ascorbic acid in Caco2 cells	Not specified (*In vitro*)	(79)
Pomegranate juice improves iron status and ameliorates iron deficiency induced cellular changes in *saccharomyces cerevisiae*	Laboratory-based yeast cell culture experimental study	Not applicable (yeast cells used as model organisms)	Iron status ↑ PJ: 7-fold ($p < 0.0001$), enhancing Fe2+ and heme forms of iron	10 % PJ in medium	(61)
Anticoagulant, antiplatelet and antianemic effects of Punica granatum (pomegranate) juice in rabbits	Experimental study	60 white rabbits	HB ↑ 30 days: Control: 9.72 g/dL 2 mL/kg *Punica granatum*: 12.32 g/dL 5 mL/kg *Punica granatum*: 14.88 g/dL 60 days: Control: 9.77 g/dL 2 mL/kg *Punica granatum*: 14.31 g/dL 5 mL/kg *Punica granatum*: 15.10 g/dL	5 mL/kg for 60 Days	(80)

Table 8. Effect of *Amaranthus cruentus* on anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
Hematopoietic effect of *Amaranthus cruentus* extract on phenylhydrazine-induced toxicity in rats	Experimental study	30 Healthy adult albino rats between 10 and 12 months of age	HB ↑ Standard hematinic preparation: 10.65 ± 0.52 g/dL ($p < 0.001$) *Amaranthus cruentus* extract (400 mg/kg): 9.87 ± 0.47 g/dL ($p < 0.001$) on day 15	400 mg/kg for 15 days	(81)
Efficacy of processed amaranth-containing bread compared to maize bread on haemoglobin, anaemia and iron deficiency anaemia prevalence among two-to-five-year-old anaemic children in Southern Ethiopia: A cluster randomized controlled trial	Cluster randomized controlled trial (1:1 allocation)	100 children (2-5-year-old)	Complete case analysis: HB ↑ 10.13 to 11.62 g/L ($p = 0.003$) Intention-to-treat analysis: HB ↑ 10.10 to 11.33 g/L ($p = 0.006$)	105 g of amaranth grain per day for 6 months	(82)

Table 9. Effect of *Beta vulgaris* on anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
The anti-anemic effect of dried beet green in phenylhydrazine treated rats	Experimental study	40 Male rats	HB ↑ 8.01 to 14.33 g/dL	5 g of dried beet greens per day for 42 days	(63)
Laboratory evidence for the hematopoietic potential of *Beta vulgaris* leaf and stalk extract in a phenylhydrazine model of anemia	Experimental study with phenylhydrazine-induced anaemia modal	30 Male albino rats	HB ↑ Diseased group: 6.77 ± 1.25 g/dL (day 0) BVE-SD group: 8.47 ± 0.29 g/dL (day 4) to 11.47 ± 1.10 g/dL (day 12) BVE-LD group: 6.71 ± 0.26 g/dL (day 0) to 10.27 ± 0.90 g/dL (day 12)	100-200 mg/kg body weight per day for 12 days	(64)

Table 10. Effect of *Phyllanthus emblica* on Anaemia (Blood parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
A study to evaluate the effectiveness of amla juice with honey on levels of hemoglobin among BSc nursing students with anemia at selected nursing colleges in dindugal	Pre-experimental research design with one group pretest-posttest design	40 Females aged 18-21 years	HB ↑ 8.31 to 9.52 g/dL ($t = 25.910$, $p < 0.05$)	100 mL of Amla juice for 15 days	(83)
Effectiveness of amla, jaggery and pumpkin leaves extract on the level of haemoglobin, vitamin c and iron among adolescent girls with iron deficiency anemia	Experimental design with pre-test and post-test control group	120 Adolescent girls in the age group of 14-17 years	HB ↑ 9.942 to 10.99 g/dL Vitamin C ↑ 4.302 to 5.63 mg/dL Iron ↑ 77.6 to 99.58 μg/dL	30 mL extract for 60 days	(84)

Table 11. Effect of *Lepidium sativum* on Anaemia (Blood Parameters)

Title of the Study	Study design	Sample size	Results	Dose	Reference
Development of recipes from garden cress seeds and its effect on anaemic patients	Laboratory-based experimental study with a phenylhydrazine-induced anaemia model	30 Male albino rats	HB ↑ 9.19 ± 0.94 to 10.93 ± 1.38	5 g per day for one month	(66)
Effect of supplementation of *Lepidium sativum* (garden cress seed) incorporated chikkies on tribal anaemic adolescent girls (12-18 years) in Nilgiris district	Experimental study with a pre-test and post-test design	100 Adolescent girls, aged 12-19 years	HB ↑ 2.516 g/dL RBC ↑ 0.837 million cells/mm^3 PCV ↑ 7.548 % MCV ↑ 0.121 fL MCH ↑ 0.158 mcg	5 g per day for 30 days	(85)
Effect of administration garden cress seeds on hematological and immunological profile of chicks	Experimental study	24 Chicks	Control group (GC-0): HB: 7.74 ± 0.22 g/dL PCV %: 24.96 ± 0.17 Treatment groups: GC-1: HB 10.88 ± 0.41 g/dL, PCV % 29.01 ± 0.04 GC-2: HB 11.21 ± 0.35 g/dL, PCV % 28.34 ± 0.11 GC-3: HB 11.98 ± 0.16 g/dL, PCV % 27.98 ± 0.48 Significant increases after 40 days of supplementation	10 mg/kg BW for 40 days	(86)

optimize formulations and validate their efficacy through larger trials, integrating these interventions into sustainable public health strategies to combat anaemia globally.

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Authors' contributions

Both authors have contributed equally to and helped with the production of this work, helping to design the data, obtain the data, review it and provide their approval before the paper is submitted.

Compliance with ethical standards

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