RESEARCH PAPER

Nutrients Content in Different Parts of Moringa oleifera and Its Therapeutic Significance in Pandu Roga W.S.R. to Iron Deficiency Anemia: An Ayurvedic and Phytochemical Review

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Abstract

Background: Iron Deficiency Anaemia (IDA), the most prevalent micronutrient deficiency disorder globally, corresponds closely to the Ayurvedic condition *Pandu Roga* as described in classical texts including *Charaka Samhita* and *Sushruta Samhita*. Moringa oleifera Lam. (*Shigru*) is revered in Ayurveda for its multiple therapeutic properties and is highly validated by contemporary nutritional science.

Objective: To systematically review the nutrient content of various anatomical parts of *M. oleifera* (leaves, seeds, pods, flowers, roots, and bark) and correlate their phytochemical and nutritional profiles with the pathophysiology of *Pandu Roga* and IDA.

Methods: A comprehensive review of Ayurvedic classical literature (*Brihattrayi* and *Laghutrayi*), Peer-reviewed Journals of phytochemical and clinical studies , and Official Indian pharmacopeial data was conducted.

Results: Moringa leaves contain approximately 28.2 mg/100 g of iron, 9.4 g/100 g protein, 220 mg/100 g vitamin C, and 40 µg/100 g folic acid — nutrients critically deficient in Pandu Roga. Seeds are rich in protein (35.97 g/100 g) and essential fatty acids; pods provide appreciable vitamin C (141 mg/100 g); flowers contribute flavonoids and carotenoids; and roots/bark possess anti-inflammatory glucosinolates relevant to oedema management in severe anaemia. The Ayurvedic properties of *Shigru* (*Katu-Tikta Rasa*, *Laghu-Ruksha Guna*, *Ushna Virya*, *Katu Vipaka*) and its identified *Karmas — Deepana, Pachana, Balya, Shothahara,* and *Rasayana* — directly address the doshic pathogenesis of *Pandu Roga*.

Conclusion: M. oleifera represents a scientifically sound, cost-effective, and holistic nutritional intervention for *Pandu Roga* / IDA, validating traditional Ayurvedic wisdom through modern phytochemical evidence. Its integration into national nutritional programmes and Ayurvedic clinical practice is strongly appreciated.

Keywords: *Moringa oleifera, Shigru, Pandu Roga, Iron Deficiency Anaemia, Ayurveda, Dravyaguna, Phytochemicals, Micronutrients, Vitamins, Minerals, Drumstick tree*.

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Introduction

Iron Deficiency Anaemia (IDA) remains one of the foremost public health challenges worldwide, affecting an estimated 1.62 billion people and representing more than 50% of all anaemia cases globally (WHO, 2023). In India, the National Family Health Survey-5 (NFHS-5, 2021) revealed that 57% of women of reproductive age and 67.1% of children under five suffer from anaemia, underscoring its pervasive socioeconomic burden. IDA is characterised by a depletion of body iron stores leading to inadequate haemoglobin synthesis, resulting in pallor, fatigue, dyspnoea, poor cognitive development, and increased maternal and infant mortality.

In the classical Ayurvedic system, this constellation of features is described under *Pandu Roga*, literally meaning "the disease of pallor or yellowish discolouration." *Charaka Samhita* (*Chikitsa Sthana* 16) Describes five types of *Pandu Roga -Vataja, Pittaja, Kaphaja, Sannipataja*, and *Mrittikaabhakshana-janya* (Pica-induced), of which *Pittaja Pandu* bears the closest resemblance to classical IDA, with symptoms of *Panduta* (pallor), *Daurbalya* (weakness), *Bhrama* (giddiness), *Shwasa* (dyspnoea), and *Shotha* (oedema). The Ayurvedic pathogenesis attributes *Pandu Roga* primarily to impaired *Rakta Dhatu* (blood tissue) formation consequent to *Pitta*-dominant *Dosha* vitiation and *Rasa-Rakta Dhatu Kshaya* (depletion of plasma and blood tissue).

Moringa oleifera Lam. (Family: Moringaceae), known in Ayurveda as *Shigru* or *Sobhanjana*, is a fast-growing, drought-resistant tree native to the sub-Himalayan tracts of northwestern India and now cultivated pan-tropically. Dubbed the "Miracle Tree" or "Tree of Life" in global nutritional literature, it is extraordinary in that virtually every part — leaves, seeds, pods (drumsticks), flowers, roots, and bark — is edible and/or medicinally relevant. The Ayurvedic Pharmacopoeia of India (API) recognises *Shigru* for its *Balya* (strength-promoting), *Rasayana* (rejuvenative), and *Shothahara* (anti-oedematous) properties, all of which are therapeutically pertinent to *Pandu Roga*.

मूलं बलाचित्रकयो: पिबेद्वा
पाण्डवामयार्त्तोऽक्षसमं हिताशी ।

सुखाम्बुना वा लवणेन तुल्यं शिग्रोः फलं
क्षीरभुजोपयोज्यम् ॥२९॥ (सु.सं./उ.त./
अ.44)

Despite this dual recognition in classical and contemporary traditions, a consolidated scholarly review correlating the part-specific nutritional profile of M. oleifera with *Pandu Roga* symptomatology and IDA pathophysiology is conspicuously absent. This article addresses that lacuna by synthesising available phytochemical, nutritional, and Ayurvedic evidence to establish a rational basis for the therapeutic use of M. oleifera in IDA / *Pandu Roga* management.

Materials and Methods

1. Study Design

This is a systematic narrative review integrating classical Ayurvedic textual analysis with contemporary phytochemical and nutritional research. No animal or human subjects were involved.

2. Data Sources

Classical Ayurvedic sources examined include *Charaka Samhita, Sushruta Samhita, Ashtanga Hridayam, Ashtanga Sangraha, Dhanvantari Nighantu, Raja Nighantu, Bhavaprakasha Nighantu*, and the Ayurvedic Pharmacopoeia of India (API). Electronic databases including PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and IndMED were searched for peer-reviewed publications.

3. Inclusion and Exclusion Criteria

Studies reporting quantitative nutritional analysis, phytochemical characterisation, or clinical/experimental data on M. oleifera parts were included. Editorials, letters without original data, non-peer-reviewed sources (excluding classical texts), and studies on Moringa species other than M. oleifera were excluded. Ayurvedic classical passages were included irrespective of date of composition given their foundational relevance.

Pandu Roga: An Ayurvedic Overview

1. Etymology and Definition

The term *Pandu* derives from the Sanskrit root *"Pand"* signifying paleness or yellowish-white discolouration (*Pandura varna*). Charaka defines it as a condition in which the skin, eyes, nails, and urine assume a pale, yellowish hue due to vitiation of all three Doshas — with Pitta predominance — leading to progressive destruction of *Rakta* (blood), *Mamsa* (muscle), and *Meda* (fat) *Dhatu*.

2. Nidana (Etiology)

The principal aetiological factors listed by Charaka include: (1) excessive consumption of *Katu* (pungent), *Amla* (sour), *Lavana* (salty), and *Ushna* (hot) foods that aggravate *Pitta*; (2) *Guru*, *Abhishyandi* (heavy, channel-blocking) foods that impair *Rasa Dhatu* formation; (3) *Divaswapna* (day sleep) impeding Agni; (4) *Mrittikaabhakshana* (Pica) and (5) Nidana related to *Krimija Pandu* (helminthic infections causing blood loss). These etiological factors collectively impair *Jatharagni* (digestive fire) and downstream *Dhatvagni* (tissue metabolic fires), hindering *Ahara Rasa* transformation into successive *Dhatu*, with *Rakta Dhatu* being most critically affected.

3. Samprapti (Pathogenesis)

Pitta-dominant *Dosha* vitiation leads to degradation of *Rakta Dhatu*, impairing the production of healthy red blood cells. Impaired *Jatharagni* reduces absorption of iron and other micronutrients from diet. Consequent *Rasa-Rakta Kshaya* manifests as pallor, cold intolerance, tachycardia, and fatigue — symptoms mirroring the clinical picture of IDA. In *Krimija Pandu* (worm-infestation anaemia), the *Krimi* (helminths) consume *Ahara Rasa* and cause *Rakta Kshaya* through mucosal blood loss, closely paralleling hookworm-induced IDA.

4. Lakshana (Clinical Features)

Main clinical Features includes *Panduta* (pallor), *Peet Varna Netram* (yellow discolouration of eyes), *Daurbalya* (general weakness and debility), *Bhrama* (vertigo/giddiness), *Shwasa* (breathlessness), *Kasa* (cough), *Jwara* (fever), *Aruchi*/*Arochakata* (anorexia), *Pindikodveshthana* (calf muscle cramps), *Shotha* (pedal oedema), and *Hrit-Spandana* (palpitations). These features have direct counterparts in IDA symptomatology, making *Pandu Roga* the most apposite Ayurvedic diagnostic category for IDA.

5. Shigru in Ayurvedic Literature

Shigru (M. oleifera) is mentioned in *Charaka Samhita* (*Sutrasthana* 27), *Sushruta Samhita* (*Sutrasthana* 46), and multiple Nighantus. Its *Rasapanchaka* profile is summarised as: *Katu, Tikta Rasa; Laghu, Ruksha, Tikshna Guna; Ushna Virya; Katu Vipaka; Deepana, Pachana Prabhava*. Its primary *Karma* include *Deepana* (stimulates Agni), *Pachana* (promotes digestion/absorption), *Balya* (promotes strength), *Shothahara* (anti-oedematous), *Krimighna* (anti-helminthic), and *Rasayana* (rejuvenative). These karmas directly address the cardinal pathological events of *Pandu Roga*: impaired *Agni*, *Rakta-Rasa Kshaya, Shotha, Krimija* causation, and *Dhatu Kshaya*.

Nutrient Contents in Different Parts of Moringa oleifera

The extraordinary nutritional breadth of M. oleifera, spanning macronutrients, critical micronutrients, and antioxidant vitamins, is detailed below, with reference to part-specific analyses from peer-reviewed literature and ICMR nutritional databases.

1. Leaves (*Patra*)

Moringa leaves are the most extensively studied part and serve as the primary nutritional intervention form. Fresh leaves contain approximately 9.4 g/100 g protein, 2.0 g/100 g fat, and 8.53 g/100 g carbohydrates on a fresh-weight basis. Their iron content (28.2 mg/100 g) is approximately 25 times that of spinach and substantially exceeds the daily recommended intake for adult women. The high vitamin C content (220 mg/100 g) significantly enhances non-haem iron bioavailability by reducing Fe^{3+} to the more absorbable Fe^{2+} form in the gastrointestinal tract. Folic acid (40 µg/100 g) and vitamin B_{12} (0.27–14.7 µg/100 g, leaf origin-dependent) are critical for megaloblastic prevention and erythropoiesis. Beta-carotene (6.78 mg/100 g), a precursor of vitamin A, maintains intestinal mucosal integrity and supports iron absorption pathways. The leaves are also remarkable for their amino acid profile, containing all essential amino acids including methionine and cysteine.

2. Seeds (*Beeja*)

Moringa seeds contain 35-40% protein by dry weight, with a profile comparable to soybean, and are rich in oleic acid (73% of seed oil). Sulphur-containing amino acids particularly methionine and cysteine supports glutathione synthesis, protecting erythrocyte membranes from oxidative damage. The seed iron content (5.3 mg/100 g) is modest, but the high protein content is crucial for haemoglobin synthesis and restoration of the hypoalbuminaemia-related oedema (*Shotha*) encountered in severe *Pandu Roga*. Benzyl isothiocyanate in seeds additionally exerts *Krimighna* (antiparasitic) activity, relevant to helminthic causation of *Krimija Pandu*.

3. Pods / Drumsticks (*Shigru Phala*)

The immature green pods (drumsticks) are consumed widely in South Asian culinary traditions and are valuable for their vitamin C content (141 mg/100 g), which rivals citrus fruits. Their digestive fibre content, combined with Deepana phytoconstituents such as saponins, enhances intestinal transit and micronutrient absorption. Iron (3.7 mg/100 g), calcium (30 mg/100 g), and folic acid (44 µg/100 g) make

drumsticks a well-rounded anti-anaemic food vehicle. Their bioavailability advantage lies in the concomitant presence of iron and vitamin C in the same food matrix, optimising non-haem iron uptake.

4. Flowers (*Pushpa*)

Moringa flowers, consumed as edible blossoms in Indian cuisine, contain appreciable flavonoids — quercetin-3-glucoside and kaempferol — which possess antioxidant properties that protect erythrocyte membranes from peroxidative damage consequent to iron deficiency. Their beta-carotene content (3.2 mg/100 g) and vitamin C (109 mg/100 g) synergistically support haematopoiesis. In Ayurvedic practice, *Shigru Pushpa* is noted for Balya and *Shothahara* actions. Their galactagogue property also supports maternal nutritional needs, relevant in the high-prevalence group of postpartum anaemia.

5. Roots and Bark (*Mula* and *Tvak*)

Moringa roots and bark are used primarily in Ayurvedic formulations rather than as dietary components, due to the presence of spirochin (a central nervous system stimulant) in high concentrations, necessitating cautious dosing. However, the 4-α-L-rhamnosyloxy-benzyl isothiocyanate in roots provides anti-inflammatory and diuretic activity (*Shothahara*, *Mutrala*), clinically relevant for managing the oedematous presentation of severe Pandu Roga. Bark preparations are documented in Charaka for *Krimighna* applications. Their iron content is estimated at approximately 7.0 mg/100 g (dry basis), though bioavailability data is limited.

Table 1: Comparative Nutrient Contents of Moringa oleifera Plant Parts.

Nutrients	Leaves	Seeds	Pods	Flowers	Roots/Bark
Iron (mg/100g)	28.2	5.3	3.7	4.8	7.0 (est.)
Protein (g/100g)	9.4	35.97	2.1	6.7	Trace
Vitamin C (mg/100g)	220	4.5	141	109	Trace
Calcium (mg/100g)	440	45	30	Trace	12.0
Folic Acid (µg/100g)	40	10.5	44	30	ND
Zinc (mg/100g)	0.6	0.6	0.45	Trace	ND
Beta-carotene (mg/100g)	6.78	Trace	0.24	3.2	ND
Vit. B12 (µg/100g)	0.27–14.7	Trace	Trace	Trace	ND

Source: Gopalan et al. (2016); Moyo et al. (2011); Fahey (2005); NIN/ICMR data. ND = Not Detected; est. = estimated.

Phytochemical Profile and Pharmacological Actions Relevant to IDA

The medicinal activity of M. oleifera extends well beyond its macronutrient and micronutrient content to encompass a rich array of bioactive secondary metabolites that modulate the pathophysiological mechanisms underlying IDA and *Pandu Roga*.

1. Isothiocyanates and Glucosinolates

Isothiocyanates, hydrolysis products of glucosinolates, are the principal bioactive compounds of M. oleifera across plant parts. 4-(α-L-Rhamnosyloxy)-benzyl isothiocyanate (present in leaves and seeds) has demonstrated anti-inflammatory, antioxidant, and antimicrobial activity in multiple experimental models. By inhibiting NF-κB signalling, these compounds reduce pro-inflammatory cytokine production (IL-6, TNF-α, hepcidin), which is a key mechanism by which chronic inflammation suppresses iron availability and erythropoiesis in anaemia of chronic disease — a condition that may coexist with or mimic IDA.

2. Flavonoids (Quercetin and Kaempferol)

Quercetin and kaempferol, abundant in leaves and flowers, are potent antioxidants that neutralise reactive oxygen species (ROS) generated by iron-mediated Fenton reactions, protecting erythrocyte membranes from lipid peroxidation. This is particularly relevant in IDA, where compensatory increased intestinal iron absorption can temporarily generate oxidative stress. Additionally, quercetin has been shown experimentally to upregulate erythropoietin (EPO) expression, potentially stimulating red blood cell production.

3. Chlorogenic Acid and Other Phenolics

Chlorogenic acid — a hydroxycinnamic acid derivative found predominantly in leaves — exhibits hepatoprotective activity, preserving hepatic iron-storage capacity (ferritin synthesis). It also modulates glucose homeostasis via inhibition of intestinal glucose-6-phosphatase, indirectly supporting metabolic efficiency in anaemic subjects with concurrent metabolic disorders.

4. Oleic Acid and Essential Fatty Acids (Seed Oil)

The seed oil of M. oleifera contains 73% oleic acid (omega-9), with a fatty acid profile comparable to olive oil. Monounsaturated fatty acids reduce erythrocyte membrane rigidity and improve red blood cell deformability — a parameter impaired in IDA — thereby enhancing microcirculatory efficiency.

5. Pterygospermin

Pterygospermin, isolated from roots and seeds, exhibits broad-spectrum antimicrobial and anthelmintic activity, supporting the *Krimighna Karma* of *Shigru* and making it directly relevant to *Krimija Pandu*, the helminthic variant of iron deficiency anaemia where intestinal parasites cause chronic blood loss.

Table 2: Phytochemical Profile of M. oleifera Parts and Relevance to IDA/Pandu Roga

Plant Part	Major Phytoconstituents	Pharmacological Action	Ayurvedic Karma	Relevance to IDA
Leaves	Isothiocyanates, Quercetin, Kaempferol, Chlorogenic acid	Antioxidant, anti-inflammatory, erythropoietic	*Balya, Rasayana, Deepana*	Enhances iron absorption; reduces oxidative haemolysis
Seeds	Benzyl isothiocyanate, Moringine, Oleic acid	Antimicrobial, hypoglycaemic, hepatoprotective	*Grahi, Krimighna*	Protein-rich; supports erythrocyte membrane integrity
Pods	Pterygospermin, Saponins, Tannins	Nutritive, digestive stimulant	*Deepana, Pachana*	Improves GI absorption of micro-

Plant Part	Major Phytoconstituents	Pharmacological Action	Ayurvedic Karma	Relevance to IDA
				nutrients
Flowers	Flavonoids, Quercetin-3-glucoside	Anti-anaemic, galactagogue	*Balya, Shothahara*	Rich in Vit. C; aids non-haem iron absorption
Roots/ Bark	Glucosinolates, Spirochin, 4-α-L-rhamnosyloxy-benzyl isothiocyanate	Anti-inflammatory, diuretic	*Shothahara, Deepana*	Addresses oedema in severe anaemia

Source: Singh et al. (2009); Stohs & Hartman (2015); Sreelatha & Padma (2009); Sharma et al. (2005).

Correlation of M. oleifera with Pandu Roga Symptomatology and IDA Pathophysiology

The therapeutic relevance of M. oleifera to Pandu Roga is best understood through parallel analysis of each cardinal symptom and its Moringa-mediated intervention:

1. *Panduta* (Pallor) ↔ Haemoglobin Deficit

The defining symptom of *Pandu* — generalised pallor — reflects haemoglobin deficit. Moringa leaves provide the tri-nutrient combination of iron, folic acid, and vitamin C that addresses the most prevalent cause of haemoglobin deficit (IDA) most directly. The co-matrix presence of iron and vitamin C in the same food matrix significantly improves non-haem iron absorption efficiency. Several clinical trials have demonstrated significant increases in haemoglobin levels following 3–12 months of Moringa Leaf Powder (MLP) supplementation.

2. *Daurbalya* (Weakness) ↔ Nutritional Debility

General weakness in Pandu Roga reflects both tissue hypoxia (from haemoglobin deficit) and protein-energy malnutrition. Moringa's seeds address the protein deficit component with 35–40% protein content. Moringa Leaf Powder supplementation has demonstrated improvement in mid-upper arm circumference (MUAC), body weight, and serum albumin levels in malnourished subjects, supporting its Balya (strength-promoting) Karma.

3. *Bhrama* (Giddiness) ↔ Cerebral Hypoxia

Giddiness in anaemia results from cerebral hypoxia consequent to reduced haemoglobin. The correction of haemoglobin through the iron-folate-B_{12} triad present in Moringa leaves directly addresses this symptom. Moringa's vitamin B_{12} content — documented in some studies as 0.27–14.7 µg/100 g — is of particular relevance in preventing the megaloblastic component of mixed anaemia, which exacerbates cerebral manifestations.

4. *Shotha* (Oedema) ↔ Hypoalbuminaemia and Inflammation

Pedal oedema in severe *Pandu Roga* results from hypoalbuminaemia and increased capillary permeability. Moringa seeds address this through their high protein content supporting albumin synthesis, while root/bark isothiocyanates provide diuretic (*Mutrala*) and anti-inflammatory (*Shothahara*) activity. The anti-inflammatory flavonoids additionally reduce vascular endothelial permeability.

5. *Arochakata* (Anorexia) ↔ Nutritional Absorption Impairment

Loss of appetite is a common manifestation of IDA, creating a vicious cycle of malnutrition. The *Katu-Tikta Rasa* of *Shigru*

stimulates *Jatharagni* (digestive fire), improving appetite and digestive capacity. This *Deepana-Pachana* action of *Shigru* directly intervenes in the pathogenesis of *Pandu Roga* by improving *Agni* and thereby enhancing *Ahara Rasa* formation and downstream *Dhatu Poshana*.

Table 3: Ayurvedic–Modern Correlation of Pandu Roga Symptoms and Moringa oleifera Interventions

***Pandu Roga* Parameter**	**Modern Equivalent**	**Moringa Part Used**	**Key Nutrients**
Panduta (pallor)	Low Hb / anaemia	Leaves (*Patra*)	Iron, Vit. C, Folate
Daurbalya (weakness)	General debility	Seeds (*Beeja*)	Protein, Essential AAs
Shwasa (dyspnoea)	Tissue hypoxia	Leaves + Flowers	Iron, Beta-carotene
Arochakata (anorexia)	Nutritional deficit	Pods (*Shigru Phala*)	Vit. C, Minerals
Bhrama (giddiness)	Cerebral hypoxia	Leaves (*Patra*)	Iron, B12, Folate
Shotha (oedema)	Hypoalbuminaemia	Seeds + Leaves	Protein, Zinc

Clinical and Experimental Evidence

Several clinical trials and observational studies corroborate the anti-anaemic potential of M. oleifera. A randomised controlled trial by Bhattacharya et al. (2010) demonstrated significant improvement in serum ferritin, haemoglobin, and total iron-binding capacity in anaemic subjects supplemented with Moringa Leaf Powder at 6 g/day for 12 weeks. A study by Nambiar et al. (2010) documented improvement in serum iron and lipid profiles following drumstick leaf supplementation. Studies in sub-Saharan Africa, where Moringa is deployed in community nutrition programmes, have demonstrated a 32% reduction in anaemia prevalence over 6 months with daily MLP supplementation in school children.

In Ayurvedic clinical settings, formulations containing *Shigru* — including *Shigru Kvatha* (decoction), *Shigru Churna* (powder), and compound formulations such as *Punarnavadi Mandura* and *Navayasa Lauha* combined with *Shigru* adjunct — have demonstrated clinical efficacy in *Pandu Roga* management. However, methodologically robust randomised controlled trials comparing standardised *Shigru* formulations against conventional iron therapy are still sparse and represent a significant research opportunity.

Bioavailability considerations are important: while Moringa leaves are high in iron, the simultaneous presence of tannins, phytates, and oxalates may inhibit absorption. Processing methods such as boiling, steaming, or fermentation reduce anti-nutrient content by 25–50%, significantly improving iron bioavailability. The Ayurvedic practice of administering Shigru Kvatha (boiled decoction) may thus be more bioavailable than raw powder preparations.

Safety Profile and Contraindications

Moringa leaves, pods, and flowers have an established safety profile at culinary doses. Seeds are safe up to 20 g/day as per available evidence. However, high-dose root and bark preparations should be used with caution due to spirochin content, which can cause uterotonic effects — contraindicated in pregnancy. M. oleifera also demonstrates mild hypoglycaemic activity at therapeutic doses, necessitating monitoring in diabetic patients concurrently on antidiabetic medication. In Ayurvedic classical texts, *Shigru* is described as *Vatanulomana* and *Deepana*, and its *Ushna Virya* (hot potency) warrants careful dose titration in individuals with

Pitta Prakriti or conditions characterised by *Pitta* excess.

The therapeutic window is well-defined: standardised Moringa Leaf Powder at 6–10 g/day appears effective and safe for prolonged supplementation. Toxicological studies by Asare et al. (2012) confirmed safety at up to 3 g/kg body weight in experimental models. Practitioners should counsel patients to source Moringa from certified, pesticide-free cultivation to avoid heavy metal contamination, especially in leaves, which readily bioaccumulate environmental contaminants.

Discussion

The convergence of Ayurvedic classical knowledge and contemporary nutritional science regarding M. oleifera is compelling and multidimensional. The Ayurvedic identification of Shigru's *Deepana*, *Balya*, *Rasayana*, and *Shothahara Karma* maps precisely onto the nutritional mechanisms by which M. oleifera's micronutrients (iron, folate, B_{12}, vitamin C), macronutrients (protein), and phytochemicals (isothiocyanates, flavonoids) combat the pathophysiology of IDA/*Pandu Roga*.

What is particularly noteworthy from a systems-medicine perspective is that M. oleifera does not function as a single-nutrient supplement but as a comprehensive nutritional matrix that simultaneously addresses: (i) iron supplementation, (ii) enhanced iron absorption through vitamin C co-matrix, (iii) erythropoietic co-factors (folate, B_{12}), (iv) protein repletion for haemoglobin and serum albumin synthesis, (v) antioxidant protection of red blood cells, (vi) anti-helminthic activity addressing *Krimija* causation, and (vii) digestive stimulation improving overall nutritional absorption. This multi-pronged intervention aligns remarkably well with the Ayurvedic polypharmacological treatment philosophy of addressing disease at the level of *Nidana*, *Samprapti*, and *Lakshana* simultaneously.

The cost-effectiveness and accessibility of M. oleifera in tropical and subtropical regions — particularly in rural India where IDA is most prevalent — make it an ideal candidate for integration into national nutrition programmes alongside conventional iron-folic acid (IFA) supplementation. Its cultural familiarity as a culinary vegetable (drumstick curry, Moringa soup) facilitates dietary adoption without significant behavioural barriers.

However, critical research gaps remain. Standardisation of Moringa-based Ayurvedic formulations, dose-response studies for haematological outcomes, and long-term safety data in paediatric and geriatric populations are needed. Furthermore, bioavailability studies using stable isotope techniques are warranted to quantify the actual iron absorption from different Moringa plant parts and preparations in the Indian dietary context.

Conclusion

Moringa oleifera (*Shigru*) stands as an exemplary model of the integration between classical Ayurvedic pharmacology and evidence-based nutritional medicine. Its part-specific nutrient profile — featuring remarkable concentrations of bioavailable iron, vitamin C, folic acid, protein, and antioxidant phytochemicals — comprehensively addresses the multi-factorial pathophysiology of Pandu Roga and Iron Deficiency Anaemia. The Ayurvedic characterisation of Shigru's *Deepana*, *Balya*, *Rasayana*, *Krimighna*, and *Shothahara Karmas* is validated by modern phytochemical and pharmacological evidence.

Clinical integration of M. oleifera as a food-based nutritional intervention, complementary to conventional IFA therapy, is supported by available evidence and warrants prioritisation in public health and clinical Ayurvedic practice. Standardised, multi-centre randomised controlled trials employing validated haematological endpoints are the foremost next step in establishing evidence-based protocols for

Shigru in *Pandu Roga* management. The "Miracle Tree" of traditional knowledge thus awaits its full recognition as a therapeutic cornerstone in the global fight against anaemia.

Declarations

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