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Exploring the Nutritional and Medicinal Potential of Indian Spinach (*Basella rubra* L.): A Comprehensive Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Indian Spinach (*Basella rubra* L.), a vibrant member of the *Basellaceae* family, is characterized by its red stems, leaves, and petioles. This plant is a powerhouse of essential vitamins, phytochemicals, and minerals, underscoring its significant nutritional and therapeutic value. *Basella rubra* exhibits a range of curative properties, including anti-inflammatory, antibiotic, antidiabetic, and wound healing activities. Its substantial antioxidant potential and immune-stimulating properties further elevate its therapeutic efficacy. In traditional Ayurveda, *Basella rubra* is esteemed for

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treating anemia, diarrhea, and skin infections, highlighting its integral role in natural medicine. Despite these profound benefits, *Basella rubra* remains underappreciated in the broader context of medicinal and nutritional research. This comprehensive review delves into the botanical, nutritional, and medicinal attributes of *Basella rubra*, also known as Indian spinach or poi. The paper brings to light its diverse health benefits and traditional uses, advocating for intensified research into its full pharmacological potential. Furthermore, the development of value-added products from *Basella rubra* could significantly boost its market value. By emphasizing its extensive medicinal and nutritional properties, this review calls for increased scientific inquiry and commercialization efforts to fully exploit the benefits of *Basella rubra*. Recognizing and harnessing the potential of this underrated crop could play a pivotal role in advancing nutritional health and developing new therapeutic agents, thereby contributing to a more sustainable and health-oriented agricultural economy.

Keywords: Basella rubra; medicinal importance; nutritional value; Indian spinach.

1. INTRODUCTION

Traditional healthcare practices, which rely on plants, animals, and minerals for healing, are often the only option for many in rural areas. This widespread use highlights the potential of medicinal plants like *Basella rubra* for new drugs. Despite modern medicine, natural products remain a valuable source for pharmaceutical research [1]. Many nutritious leafy greens are neglected in our diets because we lack awareness of their nutritional value, and a growing disinterest in vegetables is prevalent among younger people. These under-appreciated plants offer local benefits and have been used for various purposes like medicine or fiber, but haven't gained mainstream popularity [2]. It is fleshy in nature and herbaceous with trade leaf, thriving in hot climates and even poor soil, Malabar spinach (*Basella alba* and *Basella rubra*) is a nutritional powerhouse. Its leaves are packed with essential minerals (calcium, iron, magnesium, etc.), beneficial plant compounds (flavonoids), and protein building blocks (amino acids) [3,4] Red *Basella* (*B. rubra*) has reddish stems and leaves, while Green *Basella* (*B*. *alba*) is all green.

These two species are widely grown in West Bengal, the Southern part of India, and the Northern East i.e., Assam. The green species are cultivated mostly in the Northern region of UP and Punjab. Traditionally used in both Chinese and ancient Indian medicine, *Basella* species possess medicinal properties for constipation, diuresis and inflammation [5,6,7,8]. In India, farmers traditionally grow poi (*Basella*) by saving seeds from the best plants or using tip cuttings from existing vines. Unlike some crops, there's no formal breeding program for it.

1.1 Botanical Description

Indian spinach *Basella rubra* L. also goes by the name “poi” and is also called Malabar spinach which is grown as annual leafy green vegetables in the *Caryophyllales* order i.e., *Basella*ceae family [9] and some varieties tabulated in Table 2. Despite being a perennial vine, *Basella* thrives in hot climates and exhibits rapid growth. This adaptation allows it to be cultivated as a cool-season vegetable [10]. *Basella* plant has various forms, including *Basella alba* with dark green, round or oval leaves and *Basella rubra* with vibrant red leaves and stems. Other species include *B. cannifolia*, *B. cordifolia*, *B. nigra* and *B. saponica* [11]. *Basella* is known for its long, fleshy stem which can reach up to 8-10 meters in length, succulent, thin, smooth, and shiny [10]. It is a prolific grower, producing numerous secondary shoots often exceeding 100 shoots. Its root system is fibrous and spreads laterally. Leaves remain spiral at the stem. Leaves are oblong in shape; the length of the leaves is more [1], the breadth is less, the leaves’ stalk is small and side branches are also found. The flower color is white, reddish and pinkish [12]. Fruits are smaller in size and have both red and black in colour. Seeds are blackish brown having a rough texture. Distinguishing morphological characters of *Basella alba* (green) and *Basella rubra* (red) tabulated in Table 1.

1.2 Pigmentation of *Basella spp.*

Several studies and reviews have explored the encapsulation of betalains from both quinoa and *B. rubra* to improve their stability [5,15]. *Basella* leaves and fruits contain β – cyanin and phytochemicals. *Basella alba* when extracted in dye form shows red pigment due to gomphrenin-I which belongs to the family betalain [10]. Despite

Table 1. Distinguishing morphological characters of *Basella alba* (green) and *Basella rubra* (red) given by Chaurasiya et al. [10], Almeida [13]

Morphological characters	*Basella alba* (green)	*Basella rubra* (red)
Leaves	Dark green in color, acute ovate shape	Sharp leaf point, acute ovate and thick, heart-shaped i.e., cordate base.
Stem	Thick strong fleshy base, narrow branches	Narrow, long, tender, smooth and glossy and have more no. of branches
Flower	White or pinkish-red, short stalk	Either red or white flower, weak growing stalk
Bracts	Typically, small and have scales, short bracteoles	Short sharp leaf points i.e., apiculate, large bracteoles
Fruit	Generally, Black or purple colored covered within the calyx	Generally Black or red-colored, smaller in size.
Seed	Globular black in colour	Black in colour

Table 2. Some varieties list of Malabar spinach

Category	Variety	Characteristics	Source	Reference
Basella rubra (red)	a) VI047671-A1	Healthy growth habit, high agricultural output, broad greenish leaflet, pale radish veins, length of the internode is small, purple stems and delayed anthesis line.	World Vegetable Center	[10]
	b) L5	Color is due to the Anthocyanin pigment, mostly near the stem and rear side of the leaves.	V.R.D.S. Buzau, Romaniav	[14]
	c) Pulahan	Stem is reddish disc-shaped green leaves.	IPB-UPLB, Phillippines Los Banos	[12]
Basella alba (green)	a) Lutian	Green color stem, leaves are elliptical in shape.	IPB-UPLB, Phillippines Los Banos	[12]
	b) kalyani (hybrid)	Green color leaves and stems	Kishan seed farm	
	c)Pooin Deshi	Green color *Basella*	Bankinm prosad ghosh & co.	

being water-soluble, these betalain pigments from *B. rubra*, boast three times the coloring power (tinctorial strength) and better stability in acidic environments compared to anthocyanins from other sources. Additionally, the color profile (chroma) of *B. rubra* fruits offers a distinct alternative to commercially used beetroot, The betalains found in are a valuable source of health-promoting compounds. These pigments have been linked to positive effects on blood pressure and cardiovascular health [5,16,17].

2. NUTRITIONAL BENEFITS

Green leafy vegetables are a nutritional powerhouse, providing essential vitamins and minerals that contribute to overall well-being, packed with pigments, polyphenols, and flavonoids, they act as antioxidants, helping the body fight free radicals [18]. Typically, a 100-gram serving of leafy vegetables offers essential nutrients, including carbohydrates (2-3%), protein (3-5%), healthy fats (0.5-1.5%), dietary fiber (4-7%), and a significant amount of vitamin C (up to 60%) along with various minerals (5-35%) [18,17]. Red *Basella* is rich in Ca, Fe and vitamin A, *Basella rubra* leaves contain carotenoids, primarily beta-carotene, with smaller amounts of alpha-carotene and traces of other types [19]. *Basella* consumption might increase testosterone levels in men, leading to a possible boost in libido. In some traditions, crimson *Basella r*oots paste mixed with rice washing water is consumed for 30 days on an empty stomach in

the morning to regulate irregular menstrual cycles [20]. *Basella* leaf powder has a moisture content (12.06%), crude fiber content (10.36%), ash content (16.17%), crude protein content (40.03%) and carbohydrate (40.03%) [21]. *Basella* fruit contains specific types of beta-cyanins present: gomphrenin I, II and III, along with trace amounts of isogomphrenin I and II [22]. Same nutritional facts illustrated in Fig. 1.

3. MEDICINAL POTENTIAL OF *BASELLA*

Red *Basella* (*B. rubra*) fruits are packed with health-promoting compounds like phenolics and flavonoids. Studies show extracts from these fruits have antioxidant and anti-cancer properties against human cervical cancer cells and offer benefits against worms, high cholesterol, artery hardening, skin issues, diarrhea and dysentery, it also acts as a laxative, anti-viral, anti-cancer, anti-viral, hypoglycemic and wound healing [23,10]. Plant's potential health benefits stem from its rich composition of antioxidants (betacyanin, carotenoids), antiproliferative agents (bioflavonoids) and anti-inflammatory compounds (β-sitosterol and lupeol) [24,25]. The high levels of betalains, particularly betacyanins, suggest the potential of *B. rubra* as a nutraceutical with anti-cancer benefits [26,17]. *Basella* seeds also contain oil for their potential uses in food coloring, cosmetics, and even health research for nutraceuticals and pharmaceuticals [23,1,27].

3.1 Medicinal Properties and Physiological Action

3.1.1 Wound healing properties

Basella species are rich in plant chemicals which may offer antioxidant properties. These antioxidants can help combat free radicals produced by the body [28]. While free radicals can damage cells, they also play a role in wound healing [29]. Safe and effective antioxidants applied directly to wounds are a promising approach for faster healing. *Basella*'s rich phytochemical content suggests it may play a role in regulating various stages of wound healing by managing excessive free radicals (ROS) [29,30]. *B. alba* leaf extract significantly sped up wound healing in rats. Treatment for 20 days led to complete healing, whereas control groups took 35-39 days [31,32].

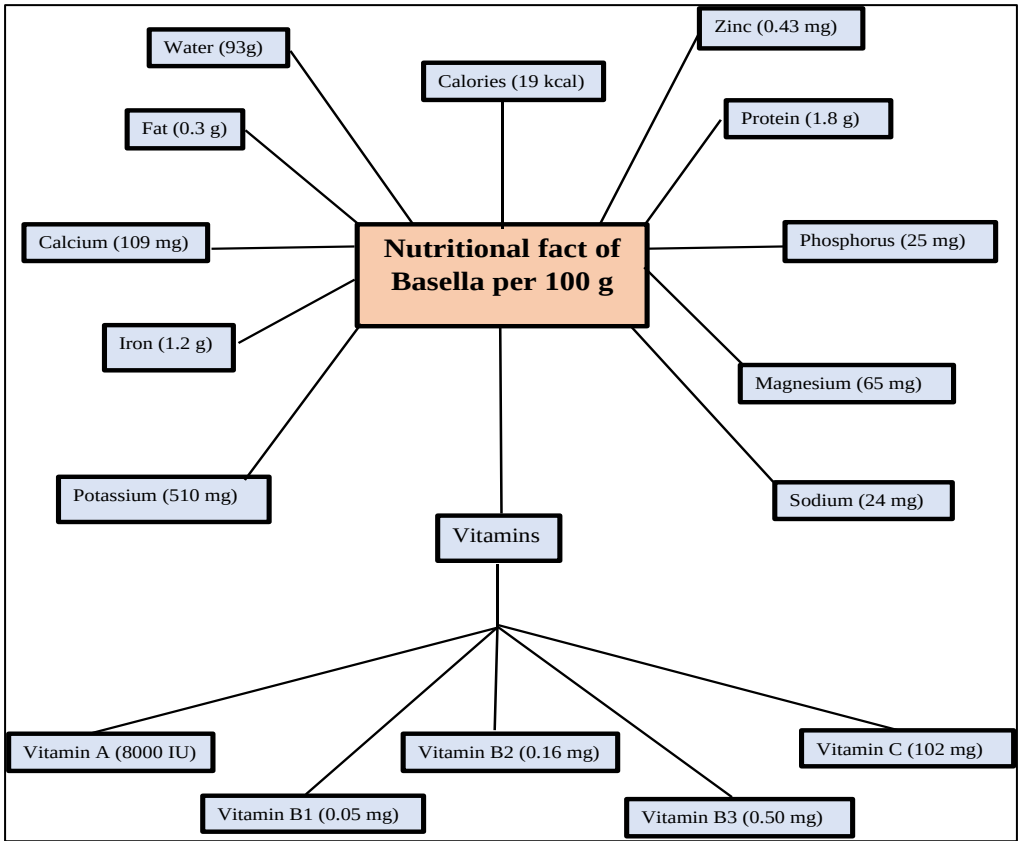

Fig. 1. Nutritional fact of *Basella* per 100 g [10]

3.1.2 Anti-microbial properties

The phytocomponents discovered through GC-MS analysis of different *Basella alba* leaf extracts and their corresponding biological effects *viz*., cyclotetracosane (hydrocarbon) [33] and l-Heptatriacotanol [34] have been documented [31]. Nguyen et al. [35] found that a substance extracted from *B*. *alba* has antiadhesive properties against *Helicobacter pylori*. The extract inhibited the adhesion of the bacteria to human stomach cells (AGS cells) in a dose-dependent way, with the strongest effect (67% inhibition) observed at a concentration of 2mg/ml. An ethanol extract of *B*. *alba* stem showed most effective at 100mg/ml concentration, inhibiting *Staphylococcus aureus* (15.65mm) and *Escherichia coli* (17.67mm) more than standard drug gentamycin, *Candida albicans* (20.2mm) and *Trichophyton rubrum* (15.25mm) more effectively than fluconazole at the same concentration [31,36].

3.1.3 Anti-viral properties

Basella rubra having acidic structured polysaccharides and its results on HSV type-2 (Herpes Simplex Virus) were studied by Reddy [31,37]. A glycoprotein with antiviral properties, specifically targeting potato virus, has been detected in *Basella alba* leaves [10]. Four neutral polysaccharides (BRN-1, BRN-2, BRN-3, and BRN-4) were isolated from *Basella rubra*, BRN-3, a polysaccharide isolated has antiviral activity against HSV-2. BRN-3 works by preventing the virus from attaching to host cells [1,37].

3.1.4 Anti-diabetic or anti-hypoglycemic properties

Consuming *Basella rubra* includes reducing oxidative stress (protecting cells from damage), acting as antioxidants, aiding in DNA repair, potentially helping with cognitive decline and diabetes, and offering radioprotective (protecting against radiation), anti-cancer (anti-proliferative), and anti-spasm effects [15,10]. *Basella rubra* leaves could lower blood sugar in rats. After one month, rats given *Basella* extract showed a significant decrease in blood sugar levels, suggesting it has anti-diabetic properties [1,38].

3.1.5 Anti-inflammatory properties

The anti-inflammatory effects of *Basella* plants come from various compounds they contain, including betacyanin, carotenoids, bioflavonoids, β-sitosterol, and lupeol [18,25]. Methanol extract from *B. rubra* leaves significantly reduced inflammation in rats with colitis caused by oxazolone. This suggests the extract has strong anti-inflammatory properties [39,40]. *Basella rubra* consists of various phytochemicals *viz*., coumaric acid, myricetin, quercetin and apigenin [41].

3.1.6 Anti-ulcer properties

Basella rubra leaves in treating stomach ulcers, rats were first given ethanol and pylorus ligation to induce ulcers. Then, they were treated with varying doses (10mg/kg and 20mg/kg) of an aqueous extract from *Basella rubra* leaves. The results showed a significant and dose-dependent reduction in ulcer formation, suggesting the extract has anti-ulcer properties that become stronger at higher doses. Studies show that extracts made from *Basella rubra* leaves have a strong and dose-dependent effect in reducing stomach ulcers (anti-ulcer) and protecting the stomach lining (cytoprotective). This effect is so strong that even chewing the raw leaves can bring relief from mouth ulcers (aphthae) [1,19].

3.2 Central Nervous System (CNS) Depressant Properties

Aerial parts or upper portion of *Basella alba* extracts when conducted on Swiss albino mice of both male and female sex, showed that the presence of methanol extract in *Basella alba* resulted in CNS depressant properties because of terpenoids which are present in the plant [31,42].

3.2.1 Role of Basella on kidney and liver

A study investigated if *Basella* leaf extract harms the kidneys or livers of rats. Rats were given the extract at various doses for two weeks. Examination of their organs showed no damage, suggesting the extract is safe for these organs at these doses [1,43].

3.3 Anti-oxidant Properties

Despite being discarded as waste, the red-purple fruit of *B. rubra* holds value. It contains betalain pigments and phenolics, which offer antioxidant, anti-cancer and antimicrobial benefits [39,44,17]. An extract made with ethyl acetate (EtOAc) from the leaves showed the strongest antioxidant activity compared to similar extracts from the fruit and stem [24,28]. Gomphrenin I, the main red

pigment in *B. rubra* fruits, gets more abundant as the fruit ripens. Ripe fruits contain the highest amount, with a yield of 36.1 mg per 100 g of fresh weight [1]. The methanol extract showed significant free radical scavenging activity in various assays, with DPPH being the most effectively neutralized (up to 94.8%) [45]. Adewale et al. [46] investigated *Basella alba* extract could protect rats from acrylamide, a toxin found in processed foods. They found that the ethanol extract significantly reduced markers of kidney and liver damage in rats exposed to acrylamide.

4. FUTURE PERSPECTIVES OF NUTRITIONAL AND MEDICINAL POTENTIAL OF INDIAN SPINACH

4.1 Advancing Pharmacological Research

The pharmacological potential of *Basella rubra* remains largely untapped. Future research should focus on isolating and characterizing bioactive compounds responsible for its medicinal properties. Advanced techniques such as high-throughput screening, metabolomics, and bioinformatics could be employed to identify novel compounds with therapeutic potential. Investigating the mechanisms of action of these compounds at the molecular level would provide deeper insights into their health benefits, paving the way for the development of new pharmaceuticals.

4.2 Clinical Trials and Therapeutic Applications

While preclinical studies have demonstrated the health benefits of *Basella rubra*, clinical trials are essential to validate these findings in humans. Conducting well-designed clinical trials to assess the efficacy and safety of *Basella rubra* extracts and formulations could lead to their incorporation into mainstream medical practice. Exploring its potential in managing chronic conditions such as diabetes, inflammation, and cardiovascular diseases could significantly enhance its therapeutic value.

4.3 Enhancing Nutritional Profiles

Further research into the nutritional composition of *Basella rubra* can lead to the development of fortified foods and dietary supplements. By understanding the optimal conditions for cultivating *Basella rubra* with enhanced nutrient profiles, agricultural practices can be refined to maximize its health benefits. Genetic studies aimed at identifying and promoting nutrient-dense varieties could contribute to improved dietary recommendations and food security.

4.4 Commercialization and Value-Added Products

The market potential of *Basella rubra* can be significantly increased through the development of value-added products. Future endeavors could focus on creating functional foods, nutraceuticals, and cosmeceuticals derived from *Basella rubra*. These products can cater to the growing demand for natural and health-promoting ingredients. Collaboration between researchers, industry stakeholders, and policymakers will be crucial in establishing regulatory frameworks and quality standards for these products.

4.5 Sustainable Agriculture and Environmental Impact

Promoting the cultivation of *Basella rubra* as a sustainable crop can contribute to environmental conservation and economic development. Research into its agronomic practices, pest and disease resistance, and adaptability to various climatic conditions can optimize its cultivation. Additionally, exploring its potential as an intercropping plant or in agroforestry systems could enhance biodiversity and soil health.

4.6 Public Awareness and Education

Increasing public awareness about the nutritional and medicinal benefits of *Basella rubra* is vital. Educational campaigns, cooking demonstrations, and the inclusion of *Basella rubra* in school meal programs can encourage its consumption. Collaboration with nutritionists, dietitians, and culinary experts can help integrate *Basella rubra* into mainstream diets, promoting a healthier lifestyle.

In conclusion, *Basella rubra* holds immense potential as a nutritional and medicinal powerhouse. Through focused research, clinical validation, innovative product development, and sustainable agricultural practices, the full benefits of this versatile plant can be realized. The future of *Basella rubra* lies in a multidisciplinary approach that bridges traditional knowledge with modern science, ensuring its place in the global quest for health and wellness.

5. CONCLUSION

This review provides a comprehensive exploration of the medicinal and nutritional potential of *Basella rubra* L., commonly known as Indian spinach or poi. The evidence highlights the plant's rich composition of vitamins, phytochemicals, and minerals, making it a valuable source of nutrition with significant health benefits. *Basella rubra* demonstrates a wide range of therapeutic properties, including anti-inflammatory, antibiotic, antidiabetic, and wound healing activities. Additionally, its antioxidant and immune-stimulating capabilities further enhance its therapeutic profile, positioning it as a multifunctional plant with extensive medicinal applications. The activities conducted using *Basella rubra* have shown substantial potential and relevance to human health. The molecular-level studies reinforce its efficacy in treating various conditions, as recognized in traditional Ayurvedic medicine where it is used for ailments such as anemia, diarrhea, and skin infections. The data underline the plant's capability to contribute significantly to modern medicine, suggesting that further research into its bioactive compounds and mechanisms of action could unlock new pharmaceutical applications. Despite its proven benefits, *Basella rubra* remains an underrated crop, often overlooked in the context of both nutrition and medicine. This review concludes that there is immense untapped potential in the plant's chemical constituents, which warrant more extensive investigation. Developing value-added products from *Basella rubra* could significantly boost its market value and recognition. This could involve creating functional foods, dietary supplements, and therapeutic formulations that harness its health-promoting properties. Moreover, the sustainable cultivation of *Basella rubra* could play a role in enhancing food security and environmental conservation. By promoting its growth and consumption, we can address nutritional deficiencies and improve public health outcomes. Increasing public awareness and integrating *Basella rubra* into dietary practices can further elevate its status as a crucial nutritional and medicinal resource. In conclusion, *Basella rubra* L. emerges as a plant of considerable medicinal and nutritional value, deserving greater attention and research. Its diverse health benefits and potential applications in medicine and nutrition highlight the need for continued exploration and commercialization efforts. By bridging traditional knowledge with modern scientific research, the full potential of *Basella rubra* can be realized, contributing to a healthier and more sustainable future.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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