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From deficiency to vitality: Herbal approaches to overcoming vitamin deficiencies

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Abstract
The growing demand for natural and sustainable nutritional supplements has propelled research into plant-based multivitamins. This review focuses on developing multivitamin formulations using spinach (*Spinacia oleracea*), moringa (*Moringa oleifera*), and taro leaves (*Colocasia esculenta*), recognized for their exceptional nutrient profiles. Spinach is a rich source of iron, vitamins A and K, and antioxidants, while moringa is renowned for its high vitamin C, calcium, and protein content. Taro leaves contribute dietary fibre, folate, and essential minerals like potassium and magnesium. This review consolidates data on the bioactive compounds, nutritional benefits, and pharmacological properties of these leafy greens, emphasizing their potential in combating micronutrient deficiencies.

Keywords: Plant-based multivitamins, spinach (*Spinacia oleracea*), moringa (*Moringa oleifera*), taro leaves (*Colocasia esculenta*), nutritional supplements, nutrient profiles, bioactive compounds, antioxidants, vitamins, minerals, dietary fibre, pharmacological properties, micronutrient deficiencies

Introduction

Finding innovative solutions to address the shortcomings and issues associated to daily living is urgently needed as society ages. Millions of people worldwide suffer from micronutrient deficiencies, also known as "hidden hunger," which are especially dangerous for vulnerable populations including children and expectant mothers. More than half of the world's population consumes inadequate amounts of the most important micronutrients. Deficiency in vitamins is one of them. Every age group in the general population, from newborns to elderly people, is experiencing vitamin deficiencies. Finding a well-known and accessible solution has therefore become difficult for us.

An excellent remedy can be found in Ayurveda. It has long been established that Ayurveda has the ability to heal from the inside out. Ayurveda uses natural materials, each with its own special qualities, to help the body regain and stay in equilibrium. Vitamins are abundant in green vegetables and herbs. Vitamins are abundant in leafy vegetables such as spinach, kale, collard greens, moringa leaves, amaranth leaves, curry leaves, etc.

Vitamins

Vitamins are organic substances that the body typically cannot produce in adequate quantities on its own but are necessary for a number of biochemical processes. They are necessary in trace amounts for illness prevention, growth support, and health maintenance [1]. In terms of the field of chemistry vitamins are not a single class of molecule; rather, they are members of groups of associated molecules referred to as vitamers. Tocopherols and tocotrienols are two of the eight vitamers that make up vitamin E, for illustration [2]. Thirteen various types of vital vitamins come into two categories: water-soluble vitamins (Vit C, Vit B1, Vit B2, Vit B3, Vit B5, Vit B6, Vit B7, Vit B9, and Vit B12) and fat-soluble vitamins (Vit A, Vit D, Vit E, and Vit K).

Table 1: Vitamin- Types, function, deficiency effect and sources [3, 4]

Type of Vitamin	Function	Deficiency effect	Sources
Vitamin A	Supports vision, immune function, and skin health	Night blindness, dry skin, increased infections	Carrots, spinach, sweet potatoes, fortified milk
Vitamin B_1 (Thiamine)	Essential for energy metabolism and nerve function	Beriberi, Wernicke's encephalopathy	Whole grains, pork, legumes, nuts.
Vitamin B_2 (Riboflavin)	Important for energy metabolism and skin health	Cracks in the lips, sore throat, skin disorders	Milk, eggs, green leafy vegetables, fortified cereals
Vitamin B_3 (Niacin)	Essential for energy production and DNA repair	Pellagra (dermatitis, diarrhoea, dementia)	Meat, poultry, fish, whole grains, fortified cereals
Vitamin B_5 (Pantothenic Acid)	Crucial for the metabolism of fats, proteins, and carbohydrates	Fatigue, irritability, digestive disorders	Chicken, beef, potatoes, oats, whole grains
Vitamin B_6 (Pyridoxine)	Important for protein metabolism and neurotransmitter synthesis	Anaemia, neuropathy, depression	Fish, beef liver, potatoes, non-citrus fruits
Vitamin B_7 (Biotin)	Plays a role in fatty acid synthesis and amino acid metabolism	Hair loss, skin rashes, neurological symptoms	Eggs, almonds, spinach, sweet potatoes
Vitamin B_9 (Folate)	Essential for DNA synthesis and red blood cell formation	Megaloblastic anaemia, neural tube defects in pregnancy	Leafy green vegetables, legumes, fortified grains
Vitamin B_{12} (Cobalamin)	Vital for red blood cell formation and neurological function	Anaemia, nerve damage, cognitive disturbances	Meat, fish, dairy products, fortified cereals
Vitamin C	An antioxidant; important for collagen	Scurvy (gum disease, fatigue,	Citrus fruits, strawberries, bell peppers,

(Ascorbic Acid)	synthesis and iron absorption	bruising)	broccoli
Vitamin D	Important for calcium absorption and bone health	Rickets in children, osteomalacia in adults	Sunlight exposure, fatty fish, fortified milk
Vitamin E	Acts as an antioxidant; protects cell membranes	Haemolytic anaemia, neurological problems	Nuts, seeds, vegetable oils, green leafy vegetables
Vitamin K	Essential for blood clotting and bone health	Increased bleeding, weakened bones	Leafy green vegetables, fermented foods, fish, liver

1. *Spinacia oleracea*

- Binomial Nomenclature: *Spinacia oleracea*.
- Vernacular Names: Spinach, palak, Espinaca
- **Synonyms:** *Spinacia oleracea* var. virdis, *Spinacia oleracea* var. spinacia

Fig 1: *Spinacia oleracea*

A very nutrient-dense leafy green food, spinach is categorized as an annual plant. Along with other vital vitamins including ascorbic acid (vitamin C), riboflavin (vitamin B2), and thiamine (vitamin B1), it is packed with vitamins, especially a high concentration of vitamin A. Spinach is also a good source of calcium and iron, among other minerals. This adaptable vegetable is an important part of our daily diet, supporting nutritional balance and general health [5]. Many colloquial names for spinach, technically known as *Spinacia oleracea*, exist in many languages and cultures. It is simply referred to as "spinach" in English and "palak" in Hindi. The Spanish word for it is "espinaca," and the French word for it is "épinard [6]."

Taxanomy: [7, 8]

- **Kingdom:** Plantae
- **Sub kingdom:** Viridiplantae
- **Super division:** Embryophyta
- **Division:** Angiosperms
- **Class:** Eudicots
- **Super order:** Rosidae
- **Order:** Caryophyllales
- **Sub family:** Chenopodioideae
- **Family:** Amaranthaceae
- **Genus:** Spinacia
- **Species:** *Spinacia oleracea*

Prelimanary phytochemical screening [9]:

Table 2: Phytochemical screening of *Spinacia oleracea* ethanol and water extract

Sr. No.	Compounds	Name of Test	Present/Absent	
			Ethanol	Water
1.	Alkaloids	Dragendroff Test	×	×
		Mayers Test	×	×
		Wagners Test	×	×
		Hager's Test	×	×
		Picrolonic Test	×	×
2.	Carbohydrates	1. General Test-Molish Test	✓	✓
		2. Test for reducing sugar -		
		Fehlings Test	✓	✓
		Benidicts Test	✓	✓
		3. Test for Monosaccharides -		
		Barfoeds Test	✓	✓
		4. Test for pentose sugar -	✓	✓
		5. Test for hexose sugar -		
		Selwinoff's Test	✓	✓
		Tollens pholoro glucinol Test	✓	✓
3.	Flavoniods	Shinoda test	✓	✓
4.	Glycosides	1. Cardiac glycoside -		
		Baljet's Test	✓	✓
		Legal's Test	✓	✓
		Keller killiani Test	✓	✓
		Liebermann's Test	✓	✓
		2. Antraquinone glycosides -		
		Borntrager's Test	✓	✓
		Modified Borntrager's Test	✓	✓
		3. Saponin glycoside -		
		Foam Test	✓	✓
		Hemolytic Test	✓	✓
5.	Phenolic compound	Ferric Chloride Test	✓	✓
		Test for chlorogenic acid	✓	✓
		Potassium dichromate	✓	✓
		Bromine water	✓	✓
6.	Proteins	Biuret Test	×	×

		Millions reagent Test Xantho protein Test	× ×	× ×
7.	Amino acid	Ninhydrin test Test for tyrosine Test for cysteine	× × ×	× × ×
8.	Steriods/Terpenoids	Salkowski Test Limbermann-buchard Test Sulphur powder Test	✓ ✓ ✓	✓ ✓ ✓

Physicochemical parameters [9]:
- **Loss on drying:** 0.96% w/w
- **Water soluble extractive value:** 11% w/w
- **Ethanol soluble extractive value:** 4% w/w

Chemical constituents:

1. Vitamin K

Vitamin K is crucial for the synthesis of specific proteins that mediate coagulation (blood clotting) and bone metabolism. It acts as a cofactor for the enzyme gamma-carboxylase, which modifies proteins, enabling them to bind calcium ions [10, 11].

Uses: Vitamin K is essential for maintaining healthy bones and preventing excessive bleeding. Its supplementation is often used in clinical settings to manage certain coagulation disorders [10].

2. Vitamin A [12]

Mode of Action: Vitamin A is involved in the formation of rhodopsin, a pigment in the retina that is vital for low-light vision. It also regulates gene expression through nuclear receptors that influence various cellular functions.

Uses: It is crucial for vision, immune function, skin health, and cellular communication. Vitamin A supplements are commonly recommended for individuals with deficiencies or conditions such as age-related macular degeneration.

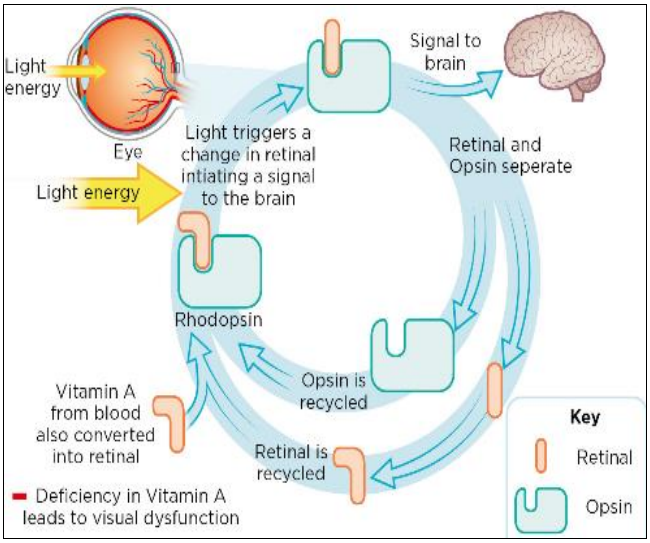

Fig 2: Mechanism of action of Vit A

3. Vitamin C [13]

Mode of Action: As an antioxidant, vitamin C protects against oxidative stress by scavenging free radicals. It also facilitates the conversion of non-hem iron into a more absorbable form in the gut.

Uses: Vitamin C enhances immune function, aids in collagen synthesis, and improves iron absorption, making it beneficial for conditions like anaemia caused by iron deficiency.

4. Carotenoids [14]

Mode of Action: Carotenoids, such as lutein and zeaxanthin, act as antioxidants and may protect against oxidative stress and inflammation. They are concentrated in the retina and contribute to visual health.

Uses: Lutein and zeaxanthin are associated with reduced risk of age-related macular degeneration and contribute to overall eye health.

2. *Moringa oleifera*
- **Binomial Nomenclature:** *Moringa oleifera*
- **Vernacular Names:** Drumstick tree, Horseradish tree, Saguna, Sainjna
- **Synonyms:** Moringa pterygosperma, Moringa malunggay, Moringa verniciflua

Fig 3: *Moringa oleifera*

Considering its many clinical and non-clinical applications *Moringa oleifera*, often recognized as the "tree of life" or "miracle tree," is acknowledged as an integral herbal plant. The herb has been utilized for years to treat inflammation, cancer, liver and heart disease, ulcers, wounds, and discomfort [15].

Taxonomy [16]:
- **Kingdom:** Plantae
- **Sub kingdom:** Tracheobionta
- **Superdivision:** Spermatophyta
- **Division:** Angiosperms
- **Class:** Magnoliopsida
- **Super order:** Rosidae
- **Order:** Brassicales
- **Sub family:** Moringoideae
- **Family:** Moringaceae
- **Genus:** Moringa
- **Species:** *Moringa oleifera*

Phytochemical screening [17]

Table 3: Phytochemical screening of *Moringa oleifera*

Sr. No.	Compounds	Name of Test	Present/Absent Ethanolic extract
1.	Alkaloids	Mayers Test	✓
2.	Carbohydrates	1.General Test -Molish Test 2. Test for reducing sugar-Fehlings Test	× ✓
3.	Anthraquinones	Sulphuric acid	×
4.	Flavonoid's	Alkaline reagent test	✓
5.	Glycosides	Legal's Test	✓
6.	Proteins	Xantho protein Test	✓
7.	Amino acid	Ninhydrin test	✓
8.	Steroids	Sulfuric acid Test	✓
9.	Saponins	Foam test	✓
10.	Tannin	Gelatin test	×
11.	Phytosterols	Liebermann–Burchard's test	✓
12.	Triterpenoids	Salkowshis test	×
13.	Fats and oils	Filter paper press test	✓

Physicochemical parameters [18, 19, 20, 21]

- **Moisture content:** 0.5% - 7.23%
- **pH:** 5-7
- **Ash content:** 4% - 10%
- **Dietary fiber:** 11% - 25%

Chemical constituents

1. Vitamins A

- **Vision:** Retinol is crucial for the synthesis of rhodopsin, a pigment in the retina that plays a key role in night vision. It converts light into electrical signals, which are processed by the brain to create visual images [22].

- **Immune function:** Vitamin A enhances the immune system by promoting the differentiation and proliferation of lymphocytes, particularly T-cells, and by maintaining the integrity of epithelial cells, which act as a barrier against pathogens [23].

- **Cell growth and differentiation:** Retinoic acid, the active metabolite of Vitamin A, regulates gene expression and is involved in cell growth and differentiation, especially in organs and tissues like skin and mucous membranes, which are critical for preventing infections.

2. Flavonoids [23]

- **Quercetin:** Interacts with cellular signaling pathways to reduce oxidative stress and inflammation by scavenging free radicals and inhibiting pro-inflammatory mediators.

- **Kaempferol:** Exhibits anti-cancer effects by inducing apoptosis in tumor cells and suppressing cell proliferation via modulation of various apoptotic pathways.

- **Apigenin:** This flavonoid acts on multiple targets to exert anti-inflammatory and anti-cancer effects, particularly by inhibiting the activation of nuclear factor kappa B (NF-κB) and influencing apoptosis-related proteins.

3. Phenolic compounds [23]

- **Chlorogenic Acid:** Reduces glucose absorption in the intestine and mediates glucose utilization in tissues, contributing to its anti-diabetic effects.

- **Ferulic Acid:** Functions as a potent antioxidant, protecting cells from oxidative stress and enhancing endogenous antioxidant defences's.

4. Essential amino acids [23]

- Moringa leaves provide a complete profile of essential amino acids, vital for human health. Essential amino acids support protein synthesis and are necessary for various metabolic processes. They play critical roles in neurotransmission and immune function.

5. Vitamin C: Vitamin C scavenges free radicals and reactive oxygen species, reducing oxidative stress and protecting cells from damage, which is crucial in preventing chronic diseases such as cancer and cardiovascular diseases [24].

3. *Colocasia esculenta*

- **Binomial nomenclature:** *Colocasia esculenta*
- **Vernacular:** Taro, Kalo, Cocoyam, Dasheen
- **Synonyms:** Arum esculentum, Arum Colocasia, Arum esculentum, Caladium esculentum, Colocasia antiquorum, *Colocasia esculenta* var. antiquorum [25].

Fig 4: *Colocasia esculenta*

Taro, also known as *Colocasia esculenta* (*L*), is a tropical crop that is mostly grown for its tubers, or corms. The leaves and stems, on the other hand, are still underutilized and undeveloped by-products with promising prospective uses. In addition to being high in proteins, dietary fiber, and minerals, colocasia leaves are low in calories. Due to the

presence of antinutrients including tannins, phytates, and oxalates, as well as a lack of knowledge about its nutritional profile, its use as food is still restricted. By cooking and using different processing methods, the antinutritional components can be addressed and the nutritional benefits can be revealed [26].

Taxonomy [27, 28]

- **Kingdom:** Plantae
- **Sub kingdom:** Tracheobionta
- **Super division:** Embryophyta
- **Division:** Angiosperms
- **Class:** Monocots
- **Superorder:** Alismatidae
- **Order:** Alismatales
- **Sub family:** Aroideae
- **Family:** Araceae
- **Genus:** Colocasia
- **Species:** *Colocasia esculenta*

Preliminary phytochemical screening [29]**:**

Table 4: Preliminary phytochemical screening of *Colocasia esculenta*

Sr. No.	Compounds	Name of Test	Leaves Methanol	Water
1.	Alkaloids	Dragendroff's Test	✓	✓
		Mayers Test	✓	✓
		Wagners Test	✓	✓
		Hager's Test	✓	✓
2.	Carbohydrates	1.General Test- Molish Test	✓	✓
		2. Test for reducing sugar- Fehlings Test	×	✓
3.	Flavonoids	With sodium hydroxide	✓	✓
		With con. Sulphuric acid	✓	✓
		Shinoda test	✓	✓
4.	Tannins	FeCl3	×	×
		Lead acetate	×	×
5.	Phenolic compound	Lead acetate	✓	✓
		Gelatin test	×	✓
6.	Terpenoids	Salkowski	✓	✓
8.	Saponins	Foam test	✓	✓

Physicochemical parameters [29]**:**

- **Loss on drying:** 4.50%
- **Water soluble extractive value:** 11.2%
- **Alcohol soluble extractive value:** 12.0%
- **Ether soluble extractive value:** 14.4%
- **Total ash:** 9%
- **Acid insoluble ash:** 1%
- **Water soluble ash:** 6.5%
- **pH:** 6.8

Chemical constituents:

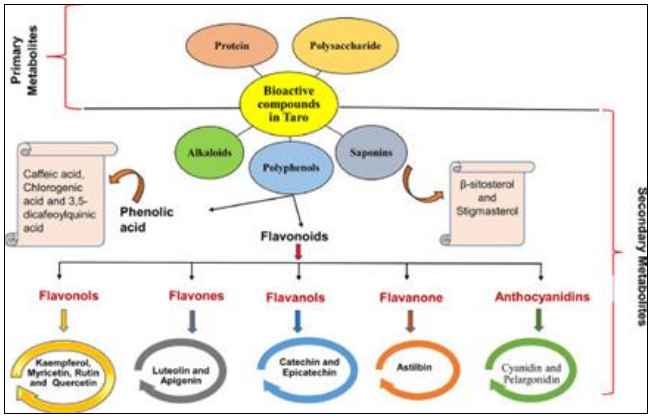

Fig 5: Bioactive compounds in *Colocasia esculenta*

1. Vitamins:
Description: Taro leaves are rich in vitamins A, C, and several B vitamins.
MOA: These vitamins play vital roles in various metabolic pathways, support immune function, and contribute to skin health and cellular repair [30].

2. Flavonoids:
Description: Flavonoids are a subclass of polyphenols that have anti-inflammatory and antioxidant effects.
MOA: They modulate various cell signaling pathways and possess the ability to inhibit enzymes involved in inflammation, thereby contributing to their anti-inflammatory effects [26].

3. Polyphenols:
Description: These are a group of naturally occurring compounds known for their antioxidant properties.
MOA: Polyphenols can scavenge free radicals and reduce oxidative stress, which is implicated in aging and many chronic diseases [26].

4. Tannins:
Description: Tannins are polyphenolic compounds that can bind and precipitate proteins.
MOA: Their astringent properties may reduce digestive issues by inhibiting the activity of digestive enzymes and may also contribute to the prevention of certain diseases through their antioxidant activity [30].

5. Essential fatty acids:
Description: Taro contains omega-3 and omega-6 fatty acids, crucial for numerous bodily functions.
MOA: These essential fatty acids are beneficial for cardiovascular health, reducing inflammation, and supporting brain health [31].

Marketed formulations:

Table 5: Marketed products of *Spinacia oleracea*, *Moringa oleifera*, *Colocasia esculenta*

Name	Type of formulation	Brand name	Ingredients	Price/ Quantity	Benefits
1. Fresh Spinach	Fresh Spinach leaves	Fresh India Organics	Spinach leaves	Approx.60 Rs. for 200 grams.	Rich in vitamins A, C, and K, iron, and folate; contributes to overall health, digestion, and immunity.
2. Spinach Capsules	Capsules	TeraVetaa	Fresh leaves of spinach	Approx. 50 Rs. for 100 Capsules.	Capsules can serve as a convenient supplement to support overall health, boost antioxidant intake, aid in weight management, and promote better eye and cognitive health.
3. Spinach Powder	Powder	Holy natural	Pure spinach (100%)	Approx. 200 Rs. for 200 grams.	Holy Naturals Spinach Powder is a versatile and beneficial dietary supplement rich in vitamins and minerals.
4. Frozen Spinach	Frozen vegetable product	Vegi Naturale	Fresh spinach leaves	Approx. 60 Rs. for 250 grams	It serves as an excellent choice for enhancing overall well-being, whether used in cooked dishes, smoothies, or as a side vegetable.
5. Spinach Chips	Fried/Baked	Aggarwal chips	Spinach, Urad dal flour, Tapioca starch, Rice flour, Salt, Spices, Palm oil.	Approx. 75 Rs. 75 grams.	Aggarwal's spinach chips are a nutritious and delicious option for health-conscious snackers, combining the benefits of spinach with various flavour profiles
6. Moringa Powder	Powder	Organic India	Organic moringa leaf	Approx. 227 grams for 226.8 grams	Rich in proteins, vitamins, calcium; boosts nutrition.
7. Moringa Capsules	Capsules	Organic India	Organic moringa leaves in HPMC capsules.	Approx. 250 Rs for 100 grams	Convenient source of nutrients; supports overall wellness.
8. Moringa Powder Canister	Powder	Pure Indian Foods	100 % pure organic moringa powder	Approx. 749 Rs. for 227 grams.	Packed with antioxidants; enhances energy and immune support.
9. Moringa Leaf Extract	Liquid Extract	Herbal Hills	Moringa leaf extract	Approx. 16.50 Rs. for each tablet	Antioxidant benefits; potential blood sugar regulation
10. Moringa Oil	Oil	Soothe Naturals	Cold- Pressed Moringa oil	Approx. 14 Rs for ml	Nourishes skin and hair; anti-inflammatory properties.
11. Moringa Tea	Tea	Organic India	Dried Moringa leaves and hibiscus.	Approx. 494 for 25 bags	Supports digestion and immune health.
12. Moringa Protein Powder	Powder	Zen Professional	Moringa leaf powder	Approx. 5.80 Rs. for 1 lb	High protein content; aids in muscle recovery and growth.
13. Fresh Taro Leaves	Fresh/ Whole Leaves	Big Basket	*Colocasia esculenta* leaves	Approx. 1 kg at ₹210.3	Nutrient-rich; provides dietary fibre and vitamins.
14. Dried Taro Leaves	Dried Leaves	India MART	Dried *Colocasia esculenta* leaves	₹250 per kg	High in fibre; versatile for cooking in various cuisines.
15. Organic Taro Leaves	Fresh Organic Leaves	Green DNA	Organic colocasia leaves	Approx. 500 grams	Rich in vitamins A, C, and calcium; supports immune health.
16. Frozen Taro Leaves	Frozen Leaves	Vinay's	Frozen *Colocasia esculenta* leaves	Approx. 500 grams	Convenient storage; quick-cook options for recipes.
17. Taro Leaf Mix	Instant Mix	Dhanashree Gruha Udyog	Taro leaves mix with spices	50 grams (Pack of 2)	Quick preparation option; enhanced flavor for curries and stews
18. Taro Chips (Red Chilli)	Chips	Rivera Foods	Taro root, rice bran oil, red chilli seasoning	Approx. ₹150 for 150 grams	Crispy texture; made from real vegetables; vegan and gluten-free.
19.Taro Pakoras	Taro Pakora	Local Vendors	Taro, chickpea flour, turmeric, spices, oil	₹80 for 200 grams	Crispy and spicy, excellent as appetizers; packed with flavor.

Conclusion

Spinach (*Spinacia oleracea*), moringa (*Moringa oleifera*), and taro leaves (*Colocasia esculenta*) offer immense potential as natural multivitamin sources due to their exceptional nutrient profiles and bioactive compounds. These leafy greens can effectively combat micronutrient deficiencies while promoting overall health and well-being. Their rich content of vitamins, minerals, antioxidants, and dietary fiber highlights their value as sustainable and eco-friendly nutritional supplements. By incorporating these plants into multivitamin formulations, it is possible to develop accessible and affordable solutions to address global nutritional challenges. In the future, the focus should be on formulating these greens into tablet forms, with an emphasis on optimizing processing, preserving bioactive compounds, and enhancing bioavailability. Further research should explore methods to improve consumer acceptance and ensure the stability and efficacy of these tablets for widespread use.

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