ORIGINAL RESEARCH PAPER

Pharmaceutical Science

MICROGREENS AND THEIR PHARMACOLOGICAL POTENTIAL: A COMPREHENSIVE REVIEW OF EMERGING NUTRACEUTICALS WITH BIOACTIVE PHYTOCHEMICALS

KEY WORDS: Microgreens, phytochemicals, pharmacology, nutraceuticals, antioxidants, functional foods

Madhu Harika Bonam*	Vikas Institute of Pharmaceutical sciences, Rajahmundry, India - 534315*Corresponding Author
Male Meghana	Vikas Institute of Pharmaceutical sciences, Rajahmundry, India - 534315
Malla Tejaswini	Vikas Institute of Pharmaceutical sciences, Rajahmundry, India - 534315
Malladi Mounika	Vikas Institute of Pharmaceutical sciences, Rajahmundry, India - 534315
Mane Leela Krishna Veni	Vikas Institute of Pharmaceutical sciences, Rajahmundry, India - 534315
Marnala V.V. Lakshmi	Vikas Institute of Pharmaceutical sciences, Rajahmundry, India - 534315

ABSTRACT

Microgreens are young edible seedlings of vegetables, herbs, and grains harvested at the early cotyledon stage, generally between 7 and 21 days after germination. In recent years, these nutrient-dense plants have gained considerable attention as functional foods due to their high concentrations of vitamins, minerals, antioxidants, and diverse phytochemicals. Microgreens are particularly rich in polyphenols, flavonoids, carotenoids, glucosinolates, and vitamins, which are associated with numerous pharmacological activities including antioxidant, anti-inflammatory, antidiabetic, antimicrobial, and anticancer effects. Compared with mature vegetables, microgreens often contain significantly higher levels of bioactive compounds, making them promising candidates for nutraceutical and pharmaceutical applications. Recent studies have highlighted their role in modulating metabolic pathways, regulating oxidative stress, and supporting immune responses. Furthermore, advances in controlled environment agriculture and metabolomics have enabled optimization of phytochemical production in microgreens. This review presents a comprehensive overview of microgreens from a pharmacological perspective, focusing on their nutritional composition, phytochemical profile, biological activities, therapeutic potential, and future prospects in functional food development and drug discovery.

INTRODUCTION

Microgreens are edible seedlings of vegetables and herbs harvested at an early developmental stage when the cotyledons are fully expanded and the first true leaves begin to emerge. These miniature plants are typically harvested within 7–21 days after germination and measure approximately 2–8 cm in height.

Interest in microgreens has grown rapidly in recent years due to their intense flavor, vibrant colors, and exceptionally high nutritional density. Unlike sprouts, which are consumed together with roots and seeds, microgreens are harvested above the soil surface and consist mainly of the hypocotyl, cotyledons, and emerging leaves.

Scientific investigations have demonstrated that microgreens may contain significantly higher concentrations of vitamins, minerals, and phytochemicals than their mature counterparts. This high nutritional density results from the intense metabolic activity occurring during early plant development, where nutrients are concentrated to support rapid growth.

Microgreens can be produced from a wide range of plant species including:
Brassicaceae (broccoli, kale, radish, mustard)
Amaranthaceae (amaranth, beet)
Apiaceae (carrot, fennel)
Asteraceae (lettuce, chicory)

Among these, Brassicaceae microgreens have received significant scientific attention because they contain glucosinolates and isothiocyanates with strong chemopreventive potential.

The increasing prevalence of chronic diseases such as diabetes, obesity, cardiovascular disorders, and cancer has stimulated research into natural products and functional foods capable of preventing or mitigating disease progression. In this context, microgreens represent a promising dietary intervention due to their high concentrations of bioactive compounds and potential pharmacological properties.

This review aims to summarize current knowledge regarding the phytochemical composition and pharmacological activities of microgreens and discuss their potential therapeutic applications.

Nutritional Composition of Microgreens

Microgreens possess remarkable nutritional value compared with mature vegetables. Studies indicate that these young plants contain elevated levels of vitamins, minerals, and secondary metabolites that contribute to human health. Several microgreens such as red cabbage, broccoli, and radish contain particularly high levels of vitamin C, carotenoids, and polyphenols. Furthermore, microgreens also contain dietary fiber and plant proteins that contribute to metabolic health.

Table 1. Nutritional Components of Microgreens

Nutrient	Biological Role
Vitamin C	Antioxidant, immune function
Vitamin E	Protection against oxidative stress
Vitamin K	Blood coagulation and bone metabolism
Beta-carotene	Vitamin A precursor
Iron	Hemoglobin synthesis
Calcium	Bone health
Magnesium	Enzyme activation
Potassium	Electrolyte balance

Phytochemical Profile of Microgreens

The pharmacological significance of microgreens arises from their rich phytochemical composition. These bioactive molecules play essential roles in plant defense and also provide health benefits when consumed.

Polyphenols

Polyphenols are a large class of plant secondary metabolites known for their antioxidant properties. They neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is implicated in many chronic diseases.

Common phenolic compounds in microgreens include: Gallic acid, Chlorogenic acid, Ferulic acid, Caffeic acid. These compounds contribute to cardiovascular protection and anti-inflammatory activity.

Flavonoids

Flavonoids represent an important group of polyphenolic compounds present in microgreens.

Major flavonoids include: Quercetin, Kaempferol, Isorhamnetin etc. These molecules have been reported to inhibit inflammatory mediators such as cyclooxygenase-2 (COX-2) and nuclear factor- B (NF- B).

Carotenoids

Carotenoids are lipid-soluble pigments responsible for the yellow, orange, and red coloration of plants.

Key carotenoids found in microgreens include:Beta-carotene, Lutein and Zeaxanthin.

These compounds support vision health and immune function.

Glucosinolates

Glucosinolates are sulfur-containing phytochemicals found primarily in cruciferous plants such as broccoli and mustard microgreens. These compounds are hydrolyzed by the enzyme myrosinase to produce biologically active isothiocyanates such as sulforaphane, which possess anticancer properties.

Table2. Pharmacological activities of Micro greens

Pharmacological Activities of Microgreens

S.no	Variety	Source	Family	Nutritional reported	Pharmacological action
1	Fenugreek	Trigonella foenum graecum	Fabaceae	Alkaloid Saponins volatile oils	Gastroprotective Appetite stimulant Hypocholesterolemic Glactagogue
2	Chia	Salviahispanica	Lamiaceae	Macronutrients Vitamins Minerals	Antioxidant Hypolipidemi
3	Sun flower	Helianthus sannuus	Asteraceae	Phytochemicals Fatty acids vitamins	Emollent laxative Antimicrobial Anti-inflammatory
4	Spinach	Spinaciaoleracea	Amaranthaceae	Vitamins Macronutrients fiber	Hematinic Visionprotective Anti cancer
5	Mustard	Brassicanigra	Brassicaceae	Glucosinolates Fixed oils	Rubefacient Antimicrobial
6	Broccoli	Italica	Cruciferae	Vitamins Phytochemicals	Bone protective Antioxidant Antimicrobial
7	Flaxseeds	Linum UsitassimuLinn	Linaceae	Lignans Dietary fibers Protein	Antithromboticc Anticancer
8	Turnip	Brassicarapa Linn	Brassicaceae	Vitamins Minerals Macronutrients	Hypolipidemic Digestive aid Anticancer
9	Alfafa	Medicagosativa linn	Fabaceae	Phytochemicals Minerals Vitamins	Hypocholesterolemic Detoxifying Agent
10	Pea	Pisum sativum	Fabaceae	Polyphenols Saponins Tannins	Good for eye Diabetes management

Antioxidant Activity

Oxidative stress results from an imbalance between reactive oxygen species and antioxidant defenses in the body. Microgreens possess strong antioxidant activity due to their high content of Polyphenols, Vitamin C, Carotenoids. These compounds scavenge free radicals and prevent cellular damage.

Experimental studies have demonstrated that extracts from various microgreens exhibit high antioxidant capacity in vitro assays.

Anti-Inflammatory Activity

Inflammation plays a key role in the development of many chronic diseases including arthritis, cardiovascular disorders, and metabolic syndrome.

Flavonoids and glucosinolates present in microgreens inhibit inflammatory pathways by suppressing NF- B activation, COX-2 expression and Pro-inflammatory cytokines. These mechanisms contribute to reduced inflammatory responses.

Antidiabetic Activity

Microgreens have shown potential antidiabetic effects in experimental models.

Mechanisms include Enhanced insulin sensitivity, Reduced glucose absorption and Inhibition of carbohydrate-digesting enzymes. Animal studies have demonstrated that supplementation with broccoli microgreens improved glucose tolerance and reduced insulin resistance.

Anticancer Activity

Cruciferous microgreens are particularly rich in glucosinolates and isothiocyanates, compounds known for their chemopreventive properties. Sulforaphane, one of the most studied isothiocyanates, has been shown to Activate phase II detoxification enzymes, Induce apoptosis in cancer cells and Inhibit tumor proliferation. These effects suggest that microgreens may contribute to cancer prevention.

Antimicrobial Activity

Microgreens also exhibit antimicrobial properties due to the presence of phenolic compounds and essential oils. These compounds disrupt microbial cell membranes and inhibit pathogen growth. Studies have reported antimicrobial activity of microgreen extracts against bacteria such as Escherichia coli, Staphylococcus aureus and Salmonella species

Therapeutic Applications

Cardiovascular Protection

Dietary intake of microgreens may help reduce cardiovascular risk by lowering cholesterol levels and improving lipid metabolism. Research indicates that consumption of red cabbage microgreens can reduce LDL cholesterol and markers of liver inflammation.

Metabolic Health

Due to their high antioxidant content and ability to regulate glucose metabolism, microgreens may help prevent metabolic disorders such as obesity and type 2 diabetes.

Immune System Support

Microgreens contain vitamins C and E along with various polyphenols that support immune responses and reduce oxidative stress.

Nutraceutical Applications

Microgreens are increasingly being incorporated into Functional beverages, Nutraceutical supplements and Herbal formulations. These applications highlight their potential as natural health products.

Advances in Microgreen Cultivation

Modern agricultural technologies have enabled improved microgreen production and phytochemical enrichment.

Key innovations include:

- Hydroponic cultivation
- Vertical farming
- Controlled LED lighting systems

These technologies allow manipulation of environmental conditions to enhance phytochemical synthesis. For example, light spectrum modifications can increase phenolic and carotenoid accumulation in microgreens.

Safety and Toxicological Considerations

Although microgreens are generally considered safe for consumption, certain factors must be addressed to ensure food safety.

Potential concerns include Microbial contamination, Pesticide residues and Poor cultivation practices. Proper hygiene and controlled cultivation conditions are essential to minimize these risks.

Future Perspectives

The growing interest in microgreens provides several opportunities for future research.

Key research directions include:

- Clinical trials to validate health benefits
- Metabolomic profiling of bioactive compounds
- Development of microgreen-based nutraceuticals
- Integration into personalized nutrition programs

Advances in biotechnology and analytical chemistry will facilitate the identification of novel pharmacologically active compounds from microgreens.

CONCLUSION

Microgreens represent a promising category of functional foods with significant pharmacological potential. Their high concentrations of vitamins, minerals, and bioactive phytochemicals contribute to multiple therapeutic activities including antioxidant, anti-inflammatory, antidiabetic, antimicrobial, and anticancer effects. The growing interest in plant-based health products highlights the importance of microgreens as a valuable source of nutraceutical compounds. Continued research focusing on clinical validation, bioavailability studies, and phytochemical profiling will further enhance our understanding of their therapeutic potential and support their integration into preventive medicine and pharmaceutical development.

REFERENCES

1. Bhaswant M, Shanmugam DK, Miyazawa T. Microgreens: a comprehensive review of bioactive molecules and health benefits. Molecules. 2023.
2. Zeng W, Yang J, Zhu Z. Bioactive compounds in cruciferous sprouts and microgreens. J Sci Food Agric. 2023.
3. García-Pérez P, Tomas M. Bioaccessibility of polyphenols from microgreens. Food Chem. 2024.
4. Amil M, Hazwani H. Microgreens and biological activities. Int J Biotechnol Biomed. 2024.
5. Kapoor J, Krupa K. Enzymes and inhibitors in microgreens. J Innov Pharm Biol Sci. 2024.
6. Kyriacou MC, Rouphael Y. Microgreens as functional foods. Trends Food Sci Technol. 2021.
7. Xiao Z, Lester GE. Nutritional composition of microgreens. J Agric Food Chem. 2019.
8. Turner ER, Luo Y. Microgreen nutrition and shelf life. J Food Sci. 2020.
9. Kim HJ, et al. Antioxidant properties of microgreens. Antioxidants. 2021.
10. Nascimento M, et al. Functional food applications of microgreens. Foods. 2022.
11. Alloggia M, et al. Bioactive compounds in Brassicaceae microgreens. Food Chem. 2023.
12. Li Q, et al. Polyphenol bioaccessibility from microgreens. Food Chem. 2024.
13. Huang H, et al. Microgreens and metabolic disorders. Nutr Res. 2022.
14. Gupta S, et al. Nutritional importance of microgreens. Foods. 2021.
15. Barut Gök S, et al. Nutritional enhancement of microgreens. Food Chem. 2024.
16. Rouphael Y, et al. Controlled environment microgreen production. Agronomy. 2022.
17. Di Gioia F, Santamaria P. Microgreens functional food research. 2020.
18. Soteriou GA, et al. Phytochemical variability in microgreens. Molecules. 2022.
19. Truzzi F, et al. Antiproliferative activity of microgreens. Nutrients. 2021.
20. Liu Y, et al. Glucosinolates and health benefits. J Nutr Biochem. 2023.
21. Kyriacou MC, et al. Ontogenetic variation in microgreens. Molecules. 2021.
22. Xiao Z, et al. Sensory attributes of microgreens. Postharvest Biol Technol. 2020.
23. Li M, et al. Polyphenols and chronic disease prevention. Nutrients. 2022.
24. Kim S, et al. Phytochemical profiles of microgreens. Foods. 2023.
25. Truzzi F, et al. Light spectrum effects on microgreens. Food Res Int. 2021.