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Nutritional Potential and Postharvest Limitations of Microgreens: A Comprehensive Review

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SUMMARY

Microgreens, the tender seedlings of vegetables and herbs harvested shortly after germination, have gained considerable attention as nutrient-dense functional foods. Owing to their rapid growth cycle, high yield-to-space ratio, and adaptability to small-scale urban cultivation, microgreens offer a sustainable solution for enhancing food security and nutrition. Belonging to diverse botanical families such as Brassicaceae, Asteraceae, Apiaceae, and Amaranthaceae, microgreens are rich in essential vitamins, minerals, antioxidants, and phytochemicals—often in higher concentrations than their mature counterparts. Their incorporation into daily diets has been associated with improved immune function, reduced oxidative stress, and chronic disease prevention. However, a major limitation hindering the growth of the microgreen industry is their rapid postharvest deterioration. High surface-area-to-volume ratio, elevated respiration and transpiration rates, and delicate tissue structure contribute to wilting, microbial spoilage, and nutrient loss. Recent research has focused on improving postharvest quality through modified atmosphere packaging, cold storage, and pre-harvest interventions. Despite these advancements, maintaining product quality during storage and transport remains a critical challenge. Further innovation in cultivation, handling, and storage technologies is necessary to fully realize the commercial and nutritional potential of microgreens in both urban and rural food systems.

INTRODUCTION

Microgreens, a relatively new category of edible greens, have seen a surge in popularity in recent years (Kyriacou *et al*., 2016 and Pinto *et al*., 2015). These young shoots are harvested within 7 to 14 days after sowing, typically at the stage when the initial set of true leaves begins to develop. Often favored by chefs for their vibrant appearance and flavor, microgreens are mostly eaten raw and are commonly added to dishes such as salads, soups, and sandwiches to enhance visual appeal and taste. Microgreens are often viewed as superior alternatives to sprouts, thanks to their concentrated nutrient profile and more robust flavor (Puccinelli *et al*., 2019). They are also reported to possess elevated levels of vitamins, minerals, and phytochemicals compared to their fully grown plant forms (Yadav *et al*., 2019). As a result, integrating microgreens into daily meals could enhance dietary nutrition and support improved health. Despite their benefits, these tender greens pose significant challenges for producers and the distribution network, primarily because of their fragility and limited shelf life. Given that microgreens are still an emerging niche in agriculture, scientific exploration into their health-promoting properties and nutrient composition remains in its early stages.

Nutritional Quality of Various Microgreens

Microgreens are nutrient-dense and often contain higher concentrations of essential vitamins, minerals, and antioxidants compared to their mature counterparts. The specific nutritional profile varies by species, but many microgreens are excellent sources of vitamin C, vitamin E, vitamin K, lutein, β-carotene, and phenolic compounds. Their small size and tender texture make them ideal for enhancing the nutritional value of a variety of dishes. Some of the common edible microgreens and their nutritional compositions are discussed in the table 1.

Table 1: Nutritional Composition of various Microgreens

Microgreen Species	Key Nutrients (per 100g FW)	Characteristics	References
Red Cabbage	High in Vitamin C (147 mg), Vitamin K, and β-carotene	Strong antioxidant capacity	Xiao *et al*., 2012

Cilantro	Rich in Lutein/Zeaxanthin, Vitamin C, and polyphenols	Eye health and anti-inflammatory benefits	Xiao *et al*., 2012
Radish	High in Vitamin E (19.6 mg), Ascorbic Acid, and glucosinolates	Supports detoxification and immunity	Xiao *et al*., 2012 and Kyriacou *et al*., 2016
Amaranth	Contains Vitamin K, Vitamin E, and Iron	Promotes blood health	Xiao *et al*., 2012
Broccoli	Rich in Sulforaphane, Vitamin C, and Phytochemicals	Cancer-preventive properties	Kyriacou *et al*., 2016 and Pinto *et al*., 2015

Types of Microgreens

Microgreens can be cultivated from a wide range of edible plant seeds. Different plant families offer distinct flavors, colors, textures, and nutritional profiles, making microgreens versatile in both culinary and nutritional applications. The most widely cultivated microgreens come from the following botanical families are given in table 2:

Table 2. Different types of Microgreens with their Characteristics and Nutritional Traits.

Family	Microgreens	Characteristics	Nutritional Trait	References
Brassicaceae	Broccoli, Cauliflower, Cabbage, Radish, Arugula, Watercress	Peppery, pungent, slightly bitter taste	High in glucosinolates, vitamin C, antioxidants, anti-cancer properties	Ghoora *et al*., 2020; Nair *et al*., 2021
Asteraceae	Lettuce, Endive, Chicory, Radicchio	Mild, sometimes bitter, crisp texture	Source of dietary fiber, folate, and vitamin K	Priti *et al*., 2021
Apiaceae	Carrot, Dill, Fennel, Celery	Aromatic, sweet to herbal flavor	Rich in essential oils, flavonoids, and carotenoids	Kumar *et al*., 2022
Amaryllidaceae	Garlic, Onion, Leek	Strong, pungent, sulfurous flavor	Antibacterial, immune-boosting, high in sulfur compounds	Nair *et al*., 2021; Kumar *et al*., 2022
Amaranthaceae	Amaranth, Quinoa, Swiss chard, Beet, Spinach	Earthy, mild to slightly sweet, vibrant in color	High in iron, vitamin K, betalains, antioxidants	Ghoora *et al*., 2020; Priti *et al*., 2021
Cucurbitaceae	Melon, Cucumber, Squash	Mild, watery, refreshing taste	Contains vitamin A precursors, hydrating and low in calories	Kumar *et al*., 2022; Priti *et al*., 2021

Cauliflower

Lettuce

Carrot

Onion

Amaranth

Melon

Fig 1: Different types of microgreens

Advantages of Microgreen Cultivation

- Microgreen farming has emerged as an efficient and sustainable cultivation practice, appealing to both commercial producers and urban gardeners. This method offers a range of economic, environmental, and nutritional benefits. Microgreens hold 4 to 40 times more nutrients than their mature counterparts.
- Rapid Crop Cycle: Microgreens mature within 7–21 days of germination, allowing for fast turnover and continuous harvesting throughout the year (Xiao *et al*., 2012; Nair *et al*., 2021).
- Maximized Space Utilization: Due to their compact size, various species—such as amaranth, fenugreek, and arugula—can be grown densely in small containers, ensuring a high yield per unit area. This is particularly beneficial for vertical farming and space-constrained urban environments (Kyriacou *et al*., 2016; Priti *et al*., 2021).
- Minimal Input Needs: Microgreens farming requires basic resources such as clean water, natural or LED lighting, trays, and an appropriate growing medium (e.g., peat, coco coir, or vermiculite), making it accessible and cost-effective (Pinto *et al*., 2015; Ghoora *et al*., 2020).

- Ideal for Urban Areas: The ability to grow food in balconies, rooftops, and even indoors with artificial lighting positions microgreens as an optimal solution for urban agriculture (Kumar *et al*., 2022).
- All-Season Cultivation: With controlled environments, microgreens can be cultivated year-round irrespective of climatic conditions, offering a stable, continuous food source (Priti *et al*., 2021).
- Nutrition-Dense Functional Foods: Microgreens are known for their dense concentrations of essential nutrients, including vitamins A, C, E, and K, calcium, magnesium, iron, and potent antioxidants like polyphenols and flavonoids. Their consumption contributes to improved immunity, cardiovascular health, and disease prevention (Xiao *et al*., 2012; Ghoora *et al*., 2020; Nair *et al*., 2021).
- Consumed Fresh for Nutrient Retention: As they are usually consumed raw, microgreens retain maximum nutrient density without losses caused by cooking processes (Kyriacou *et al*., 2016).
- Aesthetic and Culinary Value: Their vibrant colors, tender texture, and subtle flavors make microgreens a favorite in gourmet dishes and fine dining, used commonly for garnishing and presentation (Kumar *et al*., 2022).
- Regrowth Capability: Certain varieties like pea shoots and coriander have the ability to regrow after the first harvest, allowing for multiple harvests from a single sowing (Nair *et al*., 2021).

Postharvest Limitations of Microgreens

A significant challenge facing the expansion of the microgreens industry is their rapid deterioration after harvest. Due to their small size, high surface-area-to-volume ratio, and tender tissue structure, microgreens are particularly prone to moisture loss, mechanical damage, and microbial spoilage. Their elevated respiration and transpiration rates accelerate wilting, senescence, and decay. Additionally, the leakage of nutrient-rich exudates from damaged tissues creates favorable conditions for microbial growth, further reducing shelf life and marketability (Ghoora *et al*., 2020; Nair *et al*., 2021; Priti *et al*., 2021). Efforts to extend postharvest life have included modified atmosphere packaging, cold chain optimization, and pre-harvest treatments to enhance shelf stability and nutritional retention. However, maintaining quality from farm to consumer remains a major hurdle in commercial-scale microgreen production (Kumar *et al*., 2022).

CONCLUSION

Microgreens have emerged as a highly promising functional food due to their rapid growth cycle, dense nutrient profile, and adaptability to small-scale and urban farming systems. They are rich in essential vitamins, minerals, antioxidants, and phytochemicals, often surpassing the nutritional content of their mature counterparts. Microgreens can be cultivated from a wide variety of plant families, each offering unique flavors, textures, and health benefits. Despite their potential, a major barrier to widespread commercialization is their rapid postharvest deterioration. Their delicate structure, high respiration rate, and susceptibility to moisture loss and microbial spoilage significantly limit shelf life and distribution potential. Going forward, optimizing production systems, standardizing quality parameters, and integrating advanced storage technologies will be essential to unlocking the full potential of microgreens in mainstream agriculture and nutrition. Continued research and innovation will not only expand their market reach but also contribute to healthier diets and sustainable urban food systems.

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