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Microgreens: Emerging functional food crop

Microgreens are a new class of specialty food products that are gaining increasing popularity. They are delicate, young, cotyledonary leafy greens characterized by a wide range of colours, textures, and flavours. Microgreens are harvested at an early stage, when the cotyledonary leaves are fully developed but before the emergence of true leaves. Due to their suitability for small-scale and indoor production, microgreens are widely cultivated under controlled environment agriculture. This indoor farming approach is particularly important for meeting the growing food demands of urban populations. Microgreens are gaining recognition as a novel culinary component and are commonly used in salads or as edible garnishes in a variety of dishes. They are valued for their higher concentrations of bioactive compounds, including vitamins, minerals, and antioxidants, compared to mature greens, making them beneficial for human health. Research on microgreens is still in its early stages; however, their popularity has increased significantly over the past decade.

Keywords: Microgreens, Novel culinary element, Indoor farming, Bioactive elements

MICROGREENS, young edible seedlings harvested at the cotyledon stage, are gaining popularity as nutrient-dense functional foods. They contain higher concentrations of vitamins, minerals, and bioactive compounds than their mature counterparts, making them valuable for enhancing dietary nutrition. Their rapid growth, minimal resource requirements, and adaptability make them ideal for urban and remote farming, thereby supporting food security and sustainability. Cultivated in trays using soilless media, microgreens can be grown year-round in limited spaces, reducing dependence on conventional farming systems.

Urban farming initiatives increasingly incorporate microgreens to combat malnutrition, improve local food production, and reduce environmental impact. Their cultivation aligns with Sustainable Development Goals such as Zero Hunger and Responsible Consumption. By integrating microgreens into modern food systems, individuals and communities can promote healthier diets while reducing pressure on agricultural land.

This article explores the nutritional benefits, cultivation techniques, market potential, and role of microgreens in sustainable horticulture. It also highlights their health and environmental advantages, business opportunities, and future trends in microgreens production.

Unique characteristics of microgreens

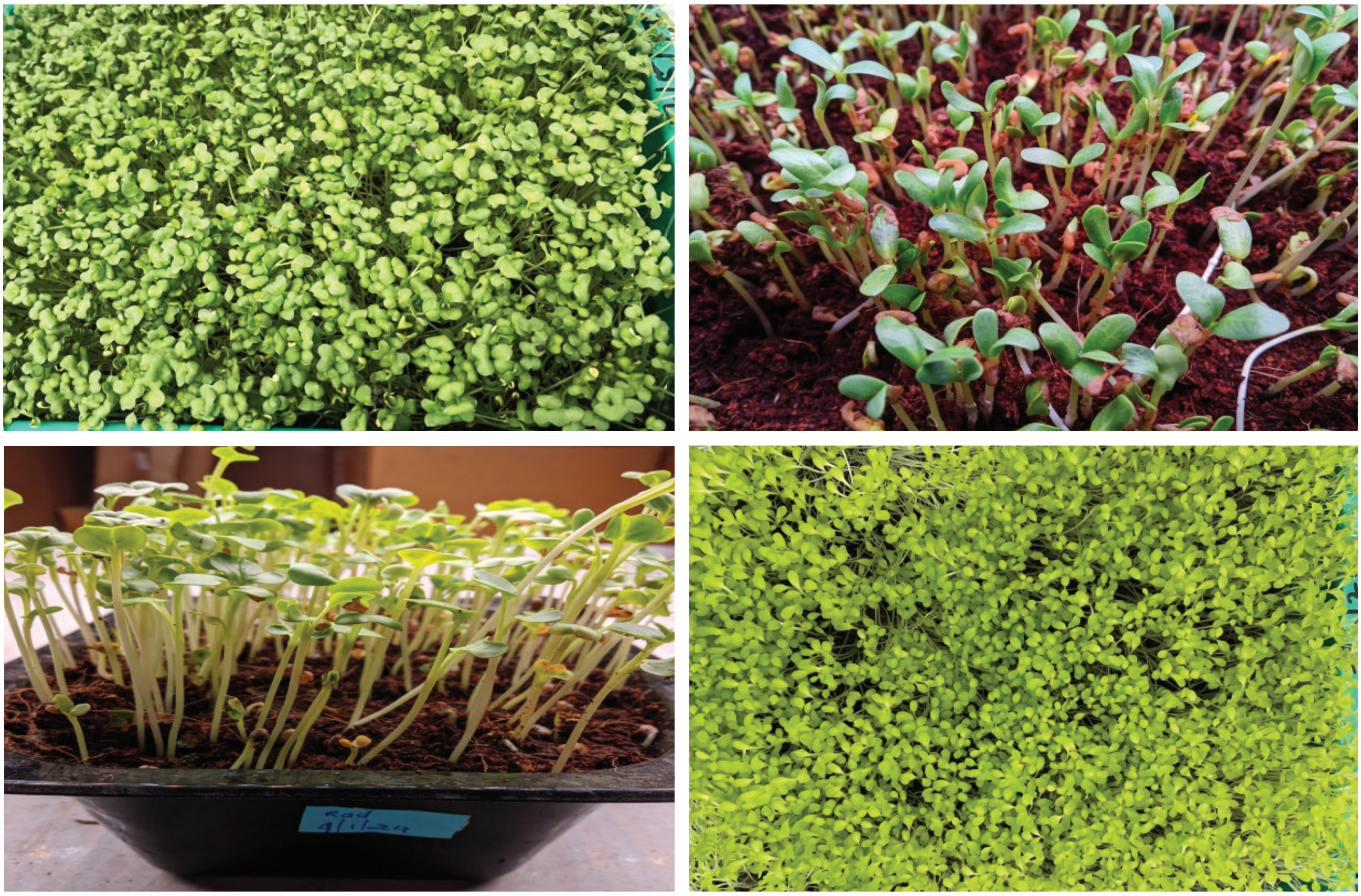
Tender, immature greens known as microgreens are larger than sprouts but smaller than baby greens or mature vegetables. They typically possess a primary stem bearing one pair of small true leaves and two fully developed, non-senescent cotyledonary leaves.

These tiny plants are rich in flavour, colour, and nutrients, often representing a more concentrated form of their mature counterparts. Studies conducted both *in vivo* and *in vitro* have demonstrated that microgreens possess antibacterial, anti-inflammatory, anticancer, and antihyperglycaemic properties. These attributes enhance their appeal as a novel functional food beneficial for human health.

Research indicates that, compared to mature plants, microgreens may contain 4–40 times higher concentrations of vitamins and minerals. Additionally, microgreens have a short growth cycle of 7–9 days, requiring fewer resources while offering higher nutrient density.

Microgreen selection crops grown from seeds are used for microgreen production. Selection of suitable crops is based on seedling colour, texture, flavour, and market demand. The selected crops should exhibit rapid germination, ease of growth, and high nutritional value.

Most potential microgreens are derived from vegetable crops belonging to the families Amaranthaceae, Chenopodiaceae, Brassicaceae, and Apiaceae. A few crops from the family Fabaceae are also suitable. Commonly grown microgreens include broccoli, radish, mustard, sunflower, pea shoots, basil, cilantro, and amaranth. These



Different microgreens grown in our lab.

Key differences between microgreens and mature greens

Microgreens	Mature Greens	Reference
Young vegetable greens harvested just after the first true leaves develop.	Fully developed plants harvested at their mature stage.	Xiao Z. *et al.* 2012
Harvested within 7–21 days after germination.	Require 6–12 weeks, more space, agro-inputs, and environmental resources to reach harvest.	Ebert, 2022, Treadwell *et al.* 2020
Rich in glucosinolates, polyphenols, antioxidants—effective against inflammation and chronic diseases.	Lower per gram in bioactives; benefits still present but less concentrated as compared to microgreens.	Marchioni *et al.* 2021
Lower in nitrates, oxalates, and phytates; grown chemical-free and usually consumed raw.	Higher nitrate and anti-nutrient content; may contain pesticide residues if not properly handled.	Pinto *et al.* 2015
Contain 4–40x more vitamins (C, E, K), antioxidants, and minerals per gram than mature greens.	Lower nutrient concentration per gram due to dilution during plant growth.	Xiao Z. *et al.* 2012

are widely cultivated due to their high nutrient content, short growth cycle, and appealing flavours.

However, not all edible vegetable seeds are suitable for microgreen cultivation. It is important to note that crops from the family Solanaceae (e.g., tomato, pepper, potato, and eggplant) should not be used as microgreens due to the presence of potential anti-nutritional compounds during the seedling stage. It highlights the importance of chemical and biological safety considerations in microgreen production. Ensuring safe cultivation practices is essential not only for maintaining nutritional quality but also for avoiding harmful compounds that may be present in certain plant species at early growth stages.

Growing conditions

Successful cultivation of microgreens depends on maintaining optimal environmental and management conditions that support rapid growth and high-quality produce. The key growing conditions are outlined below:

• ***Containers:*** Microgreen containers should be shallow (1.5–2.5 inches deep) with proper drainage holes to prevent waterlogging. Common materials include BPA-free plastic, biodegradable fibre trays, or stainless steel. Standard sizes are 10″ × 20″ or 10″ × 10″, with smooth surfaces for easy cleaning and efficient stacking.

• ***Growing Medium:*** Use a sterile, soilless medium such as peat moss, coconut coir, or a specialized microgreen growing medium.

• ***Seeds:*** Select high-quality, untreated seeds specifically labelled for microgreen production.

• ***Light:*** Provide adequate light, preferably natural sunlight or artificial grow lights. Microgreens typically require 4–6 hours of direct light per day.

• ***Temperature:*** Maintain a moderate temperature range of 15–24°C for optimal growth.

• ***Watering:*** Mist seeds lightly after sowing and maintain consistent moisture without waterlogging. Bottom watering is recommended in tray systems to reduce the risk of mould development.

• ***Ventilation:*** Ensure proper air circulation to prevent disease and promote sturdy growth.

• ***Harvesting:*** Harvesting time varies depending on the crop and variety, generally ranging from 7 to 21 days after sowing. Fast-growing crops like radish may be ready within 6–10 days, whereas others like basil or beetroot may take up to 20 days. Harvesting is usually done when the first true leaves appear.

Comparative table showing the nutrient benefits of microgreens over its mature counterpart

Species	Effect	Reference
Lettuce (*Lactucasativa* L. var. capitata)	Compared to their fully developed counterpart, lettuce microgreens showed decreased NO_3^- level and greater concentrations of Ca, Mg, Fe, Mn, Zn, Se, and Mo. The concentration of NO_3^- in mature lettuce was four times greater than that in microgreens.	Pinto *et al.* 2015
Red Cabbage (*B. oleracea* var. capitata), Red and purple mustard (*B. juncea* L. czern.)	Compared to their fully developed counterparts, microgreens had a more complex polyphenol profile and a wider diversity of polyphenol components.	Sun *et al.* 2013
Fenugreek (*Trigonella foenum-graecum*)	Microgreens have higher quantities of ascorbic acid and α-tocopherol when compared to their mature state.	Ghoora *et al.* 2020
Cucumber (*Cucumis sativus*)	Greater amounts of ascorbic acid in comparison to their mature phases	Yadav *et al.* 2019
Mungbean *(Vigna radiata)*	Comparing mungbean microgreens to their mature counterparts, the former demonstrated stronger antioxidant activity (AA) and higher levels of total phenolic (TPC) and total flavonoid (TF).	Pajak *et al.* 2014
Arugula (*Eruca sativa*)	It has been found that arugula microgreens had lower nitrate content and higher levels of β-carotene, phylloquinone, and ascorbic acid than their fully developed counterparts.	Xiao *et al.* 2012
Cilantro (*Coriandrum sativum*)	The contents of lutein and zeaxanthin in cilantro microgreens are 11.2 times higher than in mature cilantro.	Xiao *et al.* 2012

Microgreen nutrient content

Microgreens, despite their small size, are highly nutritious. Their macronutrient composition–including carbohydrates, proteins, and lipids–varies among species. Carbohydrates are primarily present as soluble sugars and dietary fibre. Protein content typically ranges from 1.8 to 4.4 g/100 g of fresh weight, depending on the plant species and growing conditions.

Lipid content is generally low, similar to leafy vegetables, contributing to an energy value of approximately 70–100 kJ/100 g. The nutritional advantages of microgreens over their mature counterparts are summarized in the table.

Essential micronutrients further enhance the nutritional value of microgreens. Iron is the most abundant microelement, followed by zinc, manganese, and copper. Varietal differences result in diverse mineral compositions, with some species exhibiting higher potassium or calcium content. Microgreens are also rich in vitamins such as vitamin C, provitamin A, vitamin E, and vitamin K_1, all of which play vital roles in antioxidant activity and overall health. Notably, microgreens generally contain higher vitamin concentrations than their mature counterparts.

Pigments such as chlorophylls, anthocyanins, and carotenoids contribute not only to colour but also to health benefits. Chlorophylls are essential for photosynthesis and possess antioxidant properties, influenced by genetic and environmental factors such as light. Anthocyanins exhibit anti-inflammatory and antioxidant properties and vary widely among species, with broccoli microgreens showing particularly high levels. Carotenoid-rich microgreens, such as barley and wheat, often surpass common vegetables in carotenoid content and respond positively to varying light conditions.

Microgreens generally contain lower levels of antinutritional factors compared to their mature counterparts. For example, oxalates, which hinder calcium absorption, are present in higher amounts in mature spinach than in spinach microgreens. Similarly, phytates, which reduce mineral bioavailability, are more concentrated in mature grains and legumes than in their microgreen forms. Lectins, commonly found in legumes, are significantly reduced in microgreens, making them easier to digest. Overall, microgreens provide a nutrient-dense food option with fewer antinutritional concerns.

Edible safety

Ensuring chemical safety is crucial in microgreen production. The quality of water used for cultivation must be carefully monitored to prevent contamination with harmful substances. Hydrogen peroxide, commonly used for disinfection, is considered safe at recommended concentrations for various microgreens. However, concerns remain regarding nitrate accumulation and the presence of certain metals. Although microgreens generally contain low nitrate levels, some wild species may accumulate higher levels and trace amounts of harmful metals, especially when grown on natural fibre substrates. Therefore, alternative substrates with lower nitrate accumulation are being explored.

Since microgreens are often consumed raw, there is a risk of contamination by pathogens such as *Escherichia coli*, *Salmonella*, *Listeria*, and norovirus. Contamination may arise from seeds, growth media, or irrigation water.

Studies have shown that *E. coli* present on seeds can proliferate during growth, although at reduced levels in harvested microgreens. Hydroponic systems have been reported to show higher contamination levels compared to soil-based systems. Waterborne contamination can lead to significant microbial colonization, highlighting the importance of maintaining water quality. The survival and growth of *Salmonella* are influenced by factors such as inoculum level, seed storage conditions, and irrigation practices. Similarly, murine norovirus has been detected in kale and mustard microgreens, persisting initially and declining over time after harvest.

Potential beneficial effects

Microgreens exhibit several health-promoting properties. Red cabbage microgreens have shown potential in reducing body weight gain and lowering LDL cholesterol and triglyceride levels in experimental studies. These effects are attributed to bioactive compounds such as polyphenols and glucosinolates, although further research is needed to identify the exact mechanisms.

Fenugreek microgreens, rich in polyphenols and antioxidants, have demonstrated potential antidiabetic effects by inhibiting α-amylase activity and enhancing glucose uptake in cells.

Microgreens from Brassicaceae crops, such as broccoli, have shown anti-proliferative effects against human colon cancer cells. Compounds like glucosinolates and polyphenols are believed to contribute to these anticancer properties.

Certain microgreens with lower potassium content may be beneficial for individuals with impaired kidney function. Hydroponically grown microgreens of chicory, lettuce, and Brassicaceae species have shown reduced potassium levels, making them suitable for specialized diets.

Watercress microgreens are rich in glucosinolates, polyphenols, vitamins, and bioelements, and exhibit antioxidant, anti-inflammatory, cardioprotective, and antibacterial properties. It may also help in reducing oxidative stress and liver damage, although further studies are required.

Microgreens are also recognized for their strong antioxidant potential, which helps combat oxidative stress associated with ageing and chronic diseases such as cardiovascular disorders, diabetes, and cancer. Species from the cruciferous and umbelliferous families, such as broccoli and soybean, exhibit high antioxidant capacity due to their phenolic compounds and isothiocyanates. Enhanced lighting and biofortification techniques can further improve their antioxidant potential.

How to use microgreens

Microgreens can be incorporated into a wide variety of dishes, including salads, wraps, and sandwiches. They can also be used in juices and smoothies, with wheatgrass being a commonly juiced microgreen. Additionally, they serve as attractive garnishes for hot dishes such as pizza, pasta, soups, omelettes, and curries, enhancing flavour, texture, and visual appeal.

In rice preparations, microgreens can be lightly cooked or used as a fresh garnish to retain their texture. They can also be added to raita, either whole or finely chopped, to enhance freshness and presentation. Incorporating microgreens into dal can improve its nutritional quality, making it a wholesome dish suitable for all age groups. Fenugreek microgreens are also used in traditional recipes such as methi thepla, offering a milder flavour compared to mature fenugreek while retaining its characteristic aroma.

Future trends

Microgreens hold significant potential in functional food development by enhancing the nutritional and bioactive profile of traditional foods. For example, incorporating legume-based microgreens into staple foods such as bread can improve their nutritional value without compromising quality.

They are also being explored as a viable food source for space missions due to their ease of cultivation, minimal resource requirements, and high nutritional value.

Utilization of surplus or unsold microgreens is another emerging area, with research focusing on developing value-added products to reduce waste. Additionally, microgreens show promise in bioenergy production and phytoremediation, including the removal of heavy metals from soil and water.

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