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Small Seedlings, Big Impact: A Comprehensive Review of Microgreens

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ABSTRACT

Microgreens, also known as "vegetable confetti," are young, eatable sprouts of vegetables and herbs harvested approximately 7–20 days after germination, at the stage of completely developed cotyledons and emerging true leaves. Unlike sprouts, microgreens are collected without roots and have unique compositions and nutritional profiles. Because of their rapid growth cycle, low input requirements, and high nutrient density, microgreens have emerged as a sustainable and functional food source, particularly in Western diets. Their growth requires clean water, controlled moisture, and adequate light exposure, while fertilizers and pesticides are frequently unnecessary. Seed density, nutrient supplementation, and the quality and intensity of light significantly affect biomass yield and phyto-chemical accumulation. Microgreens are known for their rich phyto-composition, which includes essential minerals (Ca, Fe, Zn, Mg and Mn), vitamins (C, E and K), carotenoids, polyphenols and glucosinolates—all of which are frequently found in greater amounts than in mature plants. The regular consumption of microgreens has been linked to improved antioxidant capacity and anticancer, antidiabetic, anti-inflammatory and cardioprotective properties. Microgreens can be grown via hydroponic and aquaponic systems, as well as via substrate-based soilless techniques.

Keywords Microgreens, Cotyledons, Sprouts, Food, Health.

INTRODUCTION

Microgreens, frequently referred to as 'Vegetable confetti,' are vegetable or herb harvests that have emerged as novel dietary sources in Western nations (Kyriacou *et al.* 2020). Depending on the species, these are edible plant seedlings that are harvested 7–14 days after sowing (Turner *et al.* 2020) or 10–20 days after the sprout emerges. It consists of edible plant seedlings with fully developed cotyledons, the first true leaves, and established roots. Microgreens and sprouts differ significantly in their composition

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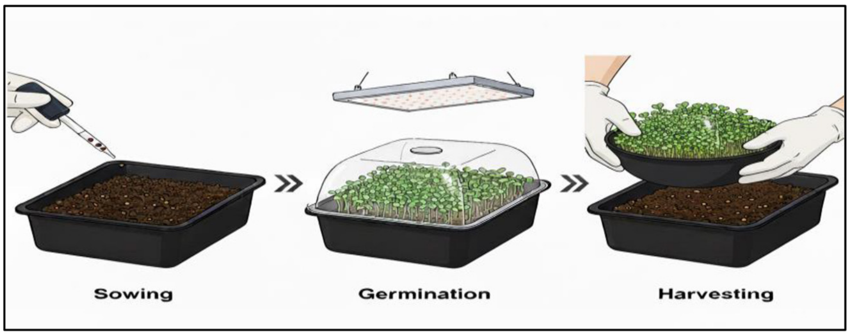

Fig. 1. Sequential stages of microgreen development under controlled conditions. (Left) Precise sowing of seeds onto a standardized growth medium ; (Center) Seedling germination and early vegetative growth under high-humidity covers ; (Right) Manual harvesting of mature microgreens at the first true leaf stage.

as well. A sprout has a seed, root and stem, whereas microgreens are harvested without the roots. The production of microgreens requires a substantial amount of clean, neutral water or water that is slightly acidic. Germination may be enhanced if seeds are submerged for the entire night at a steady temperature and in low light. After two or three days, the sprouts should be exposed to light, and the spreader should keep watering them until true leaves emerge (Turner *et al.* 2020). Sequential stages of microgreen development under controlled conditions are illustrated (Fig. 1). Microgreens typically have concentrated flavors, delicate textures, vivid colors, and many nutrients because of their immaturity. Microgreens have recently gained traction in the culinary industry, particularly among high-end establishments, where they are used as functional garnishes owing to their intense flavor profiles and desirable organoleptic properties. In addition to their aesthetic and sensory contributions to food presentation, these “Vegetable confetti” function as concentrated dietary supplements for health-conscious consumers (Teng *et al.* 2021).

Microgreens grown species

These young vegetables are nutritious, but not all species should be consumed because crops such as tomatoes, peppers, eggplants, potatoes, and possibly rhubarb have been shown to be toxic when consumed at an early stage (Jagatheeswari 2014). To determine the phyto-chemicals in microgreens that may trigger allergic reactions in certain consumers, this field of study should be taken into consideration. Fortunately, it has been determined that a number of species are safe to consume as microgreens, such as arugula (*Eruca sativa* Mill), celery (*Apium graveolens* L.), cilantro (*Coriandrum sativum* L.), red beet (*Beta vulgaris* L.), red cabbage (*Brassica oleracea* L. var. *capitata*,) purple mustard (*Brassica juncea* L.), spinach (*Spinacia oleracea* L.), amaranthus (*Amaranthus hypochondriacus* L.), golden pea tendril (*Pisum sativum* L.), green basil (*Ocimum basilicum* L.), green daikon radish (*Raphanus sativus* L. var. *longipinnatus*). The harvesting time and nutritional composition of different crops are present in Table 1. Days to harvest of the microgreens depends upon the crops. Harvesting is performed on the basis of the height and leaf area of the plant.

Factors affecting microgreen growth

Microgreens are easy to grow, environmentally friendly, and good sources of nutrients. The growth of the microgreens takes around 10–14 days. According to a recent study, broccoli microgreens need 158.236 times less water and 93.95% less time than mature broccoli to reach the same nutritious content. Fertilizers, herbicides, and energy-intensive transportation from farm to table are not necessary for microgreens (Weber 2017). The growth conditions significantly affect plant growth and phytonutrient levels. Numerous environmental and operational factors, such as seed rate, light, and nutrient input, can affect the growth and quality of microgreens.

Table 1. Harvesting time and nutritional components of microgreens.

Crop	Botanical name	Family	Nutritional components	Harvesting time (Days after sowing)	Source
Carrot	*Daucus carota* L.	Apiaceae	Anthocyanin, phenols	14-16 days	El-Nakhel *et al.* (2021a), Senevirathne *et al.* (2019)
Kale	*Brassica oleracea var. acephala* L.	Brassicaceae	Phenols, flavonoids, ascorbic acid, carotenoids	6-8 days	Vučetić *et al.* (2025), Senevirathne *et al.* (2019)
Fenugreek	*Trigonella foenum-graecum* L.	Fabaceae	Ascorbic acid, flavonoids, total chlorophyll	6-8 days	Ghevariya *et al.* (2023), Senevirathne *et al.* (2019)
Broccoli	*Brassica oleraceae var. italica* L.	Brassicaceae	Polyphenols, ascorbic acid	12-13 days	Ortiz *et al.* (2024), Di Bella *et al.* (2020)
Green peas	*Pisum sativum* L.	Fabaceae	Copper, phosphorus	6-8 days	Balik *et al.* (2025); Senevirathne *et al.* (2019)
Green radish	*Raphanus sativus* L.	Brassicaceae	Total amino acid, glucosinolates, phenols and flavonoids	6-8 days	Tilahun *et al.* (2023), Senevirathne *et al.* (2019)
Lettuce	*Lactuca sativa* L.	Asteraceae	Ascorbic acid, phenols	6-8 days	Martínez-Ispizua *et al.* (2022); Senevirathne *et al.* (2019)
Mustard	*Brassica juncea* L.	Brassicaceae	Calcium, ascorbic acid	6-8 days	Wardhana *et al.* (2025), Senevirathne *et al.* (2019)
Amaranthus	*Amaranthus sp.* L.	Amaranthaceae	Ca, Mg, K, Fe, polyphenols, flavonoids, antioxidant activity	14-16 days	Yadav *et al.* (2019), Senevirathne *et al.* (2019)
Sesame	*Sesamum indicum* L.	Pedaliaceae	Polyphenols, flavonoids, antioxidant activity	6-8 days	Senevirathne *et al.* (2019)

Plant growth is determined by seed sowing rate, since plants compete for limited resources like water and nutrients. Murphy and Pill (2010) examined four sowing rates for Arugula microgreens, ranging from 50.25 to 201 g/m², on the basis of a commercial sowing rate of 201 g/m². Researchers have reported a correlation among sowing rate, shoot number/m², and shoot fresh weight/m². Nevertheless, increasing the seeding rate led to a linear decrease in the individual fresh weight per shoot. This reflects competition for resources across microgreens.

Murphy and Pill (2010) investigated the effects of several fertilizers on arugula microgreens. Ammonium nitrate, calcium nitrate, and urea all had an effect on fresh weight per plant (m²). Fertilizing the peat-lite mix with calcium nitrate at 2000 mg/L (150 mL/L of medium) before planting, followed by daily post-planting solution fertilization with 150 mg/L nitrogen, led to a considerable increase in beet microgreen yields (Murphy *et al.* 2010).

According to Sun *et al.* (2015), the levels of glucosinolate in *Broccoli* microgreens differed depending on whether they were treated with calcium chloride. Notably, those microgreens that received calcium treatment exhibited higher glucosinolate levels compared to those that did not, suggesting that modifying the growth conditions could enhance the nutritional content of microgreens. As a source of energy and environmental information, light is one of the primary external elements on which photosynthetic organisms depend (Murchie and Niyogi 2011, Fortunato *et al.* 2015). The impact of the light spectrum on yield, as well as on the composition and profiles of secondary metabolites like glucosinolates and phenolics, varies significantly among different species (Alrifai *et al.* 2020). Additionally, the photoperiod influences the production of secondary metabolites, regulates nutrient absorption and growth, and affects the circadian rhythm in plants (Liu *et al.* 2022). The ability of light to increase zeaxanthin concentrations in mustard microgreens was investigated by Kopsell *et* *al.* (2012). Photosynthesis is an essential mechanism for sustaining energy in plants. Photosynthesis is a process that involves carotenoids. Carotenoids are pigments found in chloroplasts that dissipate excess thermal energy and act as free radical quenchers. (Frank and Cogdell 1993). The contents of antheraxanthin and zeaxanthin from mustard microgreens increased by 50% and 133%, respectively, after brief exposure to 463 µmol photons/m²/s (Kopsell *et al.* 2012). In a study on broccoli microgreens, exposure to blue light increased carotenoids, total glucosinolates, and minerals. Microgreens' nutrient profiles are significantly influenced by light exposure, according to these findings.

Phytochemical composition of the microgreens

Microgreens now include a wide variety of vegetables and herbs. Commonly cultivated families are Brassicaceae, which includes broccoli, mizuna, cabbage and radishes; Fabaceae, which encompasses fenugreek, sweet pea, and alfalfa; and Apiaceae, which consists of carrot, parsley, and celery. Other families like Asteraceae and Amaranthaceae are also frequently grown. The chemical composition of microgreens is notably different from that of their fully grown counterparts. They are rich in numerous bioactive compounds, including carotenoids, vitamins, minerals, glucosinolates, and polyphenols (Turner *et al.* 2020, Marchioni *et al.* 2021, Kopsell *et al.* 2024).

Vitamins

Total ascorbic acid, commonly known as vitamin C, encompasses both free ascorbic acid and dehydroascorbic acid, which are notably concentrated in the Cucurbitaceae, Brassicaceae and Malvaceae plant families. As reported by Ghoora *et al.* (2020), ascorbic acid was the most abundant among the microgreens studied, including varieties like fenugreek, radish, and roselle, with levels ranging from 41.6 to almost 140 mg per hundred grams. Vitamin K_1 or phylloquinone, is found in high amounts in the Lamiaceae, Brassicaceae, and Amaranthaceae families. Red garnet amaranth had the highest concentration at 4.1 µg/g fresh weight, followed by magenta spinach at 0.9 µg/g, green basil at 3.2 µg/g, and red cabbage at 2.8 µg/g fresh weight. Detailed studies revealed that 18 out of 25 commercially cultivated microgreens contained more phylloquinone than their mature counterparts (Xiao *et al.* 2012, 2019). Alpha-tocopherol is recognized as the most effective form of vitamin E and it, along with other tocotrienols (β, γ and δ), constitutes the vitamin E group. In contrast, gamma-tocopherol is the most common form found in plants (Sadiq *et al*. 2019), with microgreens from the Brassicaceae and Apiaceae families being particularly rich sources.

Minerals

Macro-elements, including potassium, magnesium, calcium and phosphorus, as well as trace minerals like manganese, zinc, sodium and copper, are more concentrated in 90% of microgreen cultivars than in mature plants (Zhang *et al.* 2021, De la Fuente *et al.* 2019). Ghoora *et al.* (2020) found that spinach microgreens had a much greater concentration of Mg, while roselle had the greatest quantities of P, Zn and Se. Lettuce microgreens showed much higher amounts of most minerals, including Ca, Fe, Zn, Mg and Mn, than their mature counterparts, according to a prior study by Pinto *et al.* (2015).

Polyphenols and Glucosinolates

Kale and broccoli microgreens include polyphenols and glucosinolates (GSL), which have been associated with a lower risk of developing cancer (Odongo *et al.* 2017, Liu *et al.* 2021). Plant secondary metabolites require glucosinolates, which are nitrogen-sulfur derivatives (β-D-thioglucoside-n-hydroxysulfates). Huang *et al.* (2016) evaluated the quantity of glucosinolates in mature plants to microgreen red cabbage. Microgreens had a content of 17.1 µmol/g, which was twice that of mature plants (8.3 µmol/g). Several studies have found that microgreens contain more useful chemicals, including glucosinolates (Gan *et al.* 2017, Mir *et al.* 2017). Glucosinolates have been found to have bactericidal, nematocidal and fungicidal effects.

Health benefits of microgreens

Food is necessary for human growth, development, and survival since it supplies the body with vitamins and minerals required to fight illness (De Filippo *et al.*

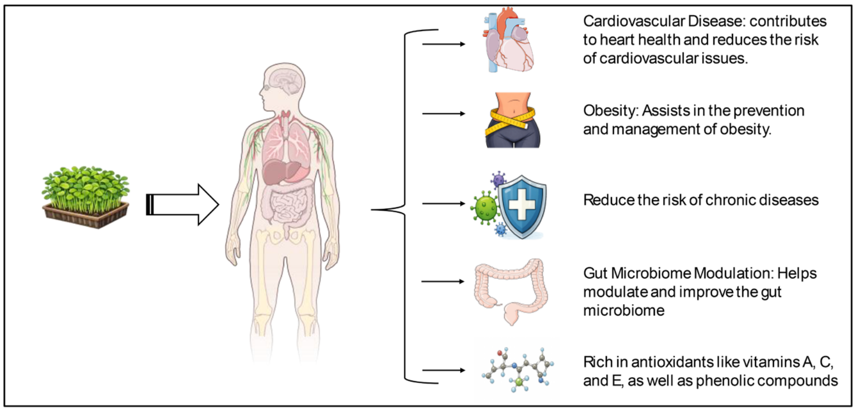

Fig. 2. Illustration depicting the potential health benefits of microgreens mediated through antioxidant activity, metabolic regulation, immune modulation, and chronic disease prevention.

2021). Numerous studies, including those by Choe *et al.* (2018) and Martinon *et al.* (2021), show that eating veggies can greatly reduce the risk of chronic disease. Many microgreens have a higher concentration of these nutrients and health-promoting micronutrients than their mature equivalents (Sies and Stahl 1995; Kyriacou *et al.* 2016, Choe *et al.* 2018, Johnson *et al.* 2021, Teng *et al.* 2021). Consuming microgreens can help prevent or manage health conditions (Fig. 2) such as immune system inflammation, obesity, cardiovascular disease, type 2 diabetes, cancer, and gut microbiota regulation (Castelão-Baptista *et al.* 2021, Machlin and Bendich 1987).

Microgreens contain antioxidants such as vitamins A, C and E, as well as phenolic chemicals. Compounds that scavenge reactive oxygen species (ROS) and maintain normal signaling can help to avoid cancer cell damage (Carmo *et al.* 2018). Polyphenols like epigallocatechin-3-gallate (EGCG), trans-resveratrol, quercetin, and curcumin may increase oxidation. These chemicals generate hydrogen peroxide, which kills cancer cells while sparing normal tissues (D'Angelo *et al.* 2017, León-González *et al*. 2015). Recent research has demonstrated that barley (Mohamed *et al.* 2022) and broccoli (Ma *et al.* 2022) microgreens have considerable antidiabetic properties.

Microgreens are regarded to be promising in cancer prevention because of their high content of polyphenols, vitamins, carotenoids, and minerals, as well as their controlled ability to alter certain metabolic processes and mechanisms within cancer cells. Only lately has convincing evidence been provided (De La Fuente *et al.* 2020). The Scientists demonstrated that bio-accessible fractions from four Brassicaceae microgreens (broccoli, radish) had an anti-proliferative effect on human colorectal cancer cells.

Cultivation system of microgreens

The most practical growth technique for non-commercial settings, such as home gardens, is soilless substrate-based farming. These systems distribute water using soilless substrates such as rockwool, hemp mats, coconut coir, peat moss, or other inert porous materials (Di Gioia *et al.* 2017, Thuong and Minh 2020), as well as bottom-up wicking or top-down dripping/spraying. This method is frequently contrasted to the hydroponically grown mature produce. Microgreen culture differs in that the nutrient solution is discretionary rather than required (El-Nakhel *et al.* 2021 a, b). As a result, the substrates may act as a nutrient source rather than simply a support (Thuong and Minh 2020).

Hydroponic techniques, which include deep-water culture (DWC) and nutrient film technology (NFT), are more water efficient but require more equipment, energy, and space. Seeds are sown on an inert substrate suspended in a deep reservoir of circulating water or nutrient solution in deep water culture systems. The roots expand to seek sustenance. Grishin *et al.* (2021) found that appropriate aeration boosts the productivity of lentil and wheat microgreens, whereas insufficient aeration promotes root hypoxia and poor development. NFT systems employ an angled growing tray to continually provide a shallow, recurring stream of nutrient solution. NFT lowers root submersion, which promotes root zone aeration and plant growth. However, it is sensitive to pump failure, which causes fast root dehydration. Murphy *et al.* (2010) found that, when compared to substrate-based approaches, NFT considerably boosted table beet microgreen yields.

Aquaponic systems allow plants (hydroponics) and fish (aquaculture) to be grown simultaneously. They use naturally occurring microbes to convert fish waste into plant nutrition (Yep and Zheng 2019) and then purify and recycle the water used by the plants. According to Nicoletto *et al.* (2018), this system's distinct dissolved organic matter and microbiota enhance plant growth and make it extremely water and nutrient efficient. There is currently only one scholarly article about growing arugula microgreens through an aquaponic system (Kizak and Kapaligoz 2019).

CONCLUSION

Microgreens are a promising type of functional food that combines rapid growth, sustainability, and high nutritional value. They are harvested at an early developmental stage and differ from sprouts and mature vegetables in terms of morphology, cultivation practices, and phyto-chemical composition, with significantly higher levels of vitamins, minerals, antioxidants, polyphenols, and glucosinolates. Numerous edible plants, particularly those from the Brassicaceae, Fabaceae, Apiaceae and Amaranthaceae families, have been demonstrated to have health-promoting qualities, including antioxidant, anti-inflammatory, antidiabetic, cardioprotective, and anticancer properties. Microgreens' development and nutritional quality are significantly impacted by parameters such as seed density, light intensity and spectrum, photoperiod, and nutrient availability, allowing for precise adjustment of growing conditions to boost yield and bioactive compound concentrations. Furthermore, microgreens can be efficiently grown via substrate-based, hydroponic or aquaponic systems, which provide flexibility, water efficiency, and lower resource inputs. Collectively, these characteristics distinguish microgreens as an innovative and sustainable dietary component with significant potential to improve human health and resilience in future food systems.

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