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Microgreens: Cultivation Practices and Health Benefits

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Abstract:

Microgreens are young, tender, edible seedlings harvested shortly after the development of cotyledons and the emergence of the first true leaves. They occupy an intermediate position between sprouts and baby-leaf vegetables and have emerged as an important specialty crop because of their short production cycle, attractive appearance, distinctive flavors, high nutritional density, and suitability for small-scale and controlled-environment production. Microgreens can be produced from a wide range of vegetable, herb, cereal, and legume species, including broccoli, radish, mustard, cabbage, kale, amaranth, pea, sunflower, coriander, fenugreek and beet. Their cultivation requires relatively little land and can be adapted to soil, soilless, hydroponic, vertical, greenhouse and indoor systems. Major production factors include seed quality, growing medium, seed density, irrigation, temperature, relative humidity, light intensity and spectrum, nutrient availability, and harvesting time. Research has demonstrated that microgreens can contain substantial amounts of vitamins, minerals, carotenoids, phenolic compounds, glucosinolates, anthocyanins and other bioactive constituents. However, nutrient concentration varies considerably with species, genotype and cultivation conditions.

Keywords: Microgreens, Cultivation, Nutrition, Antioxidants, Functional Food.

Introduction:

Increasing urbanization, limited agricultural land, changing food preferences and growing interest in nutritious foods have stimulated research into alternative forms of vegetable production. Microgreens have emerged as an attractive crop because they can be cultivated rapidly in small spaces and harvested within a short period. They are generally harvested when cotyledons are fully developed and the first true leaves are beginning to emerge. In comparison with sprouts, microgreens are grown under light and are harvested above the root system, whereas baby-leaf vegetables are generally harvested at a more advanced developmental stage (Kyriacou *et al.*, 2016; Verlinden, 2019). Microgreens have gained considerable attention not only as culinary ingredients but also as nutrient-dense foods. Their intense colors, textures, aromas and flavors make them useful in salads, sandwiches, soups and other dishes. More importantly, several studies have identified vitamins, minerals, carotenoids, phenolic compounds and other phytochemicals in different microgreen species. Xiao *et al*. (2012), for example, analyzed 25 commercially available microgreens and reported substantial variation in vitamin-C, carotenoids, vitamin-K and tocopherols among species. Microgreens can be cultivated in conventional soil as well as in soilless and hydroponic systems. Because their production cycle is short, they can be grown repeatedly throughout the year under suitable environmental conditions. This characteristic makes them particularly suitable for urban agriculture, household production and controlled-environment agriculture (Teng *et al*., 2023).

Concept and Classification of Microgreens:

Microgreens are edible young plants harvested at the seedling stage. They commonly consist of a short stem, cotyledons and one or two developing true leaves. Depending on species and environmental conditions, harvesting generally occurs approximately 7-21 days after germination, although the exact period varies considerably. Microgreens can be classified according to the plant species used for production. Common groups include Brassicaceae microgreens such as broccoli, cabbage, kale, mustard and radish; Amaranthaceae species such as amaranth and quinoa; Apiaceae species such as coriander, fennel and carrot; Fabaceae species such as pea and fenugreek; and Asteraceae species such as lettuce and sunflower-related crops. Cereal and pseudocereal species such as wheat, buckwheat and barley are also used. The diversity of species is important because nutritional composition and sensory characteristics differ among genotypes. Therefore, microgreens should not be considered nutritionally identical. Their concentrations of vitamins, minerals and phytochemicals depend on species, cultivar, developmental stage and growing conditions (Renna & Paradiso, 2020; Teng *et al*., 2021).

Importance of Microgreen Cultivation:

Microgreen cultivation offers several advantages over conventional vegetable production. The crop requires limited growing space, has a short production cycle and can be cultivated close to consumers. These characteristics are valuable for urban and peri-urban food production. Microgreens can be produced on balconies, rooftops, shelves, greenhouses and indoor vertical farms. Controlled environments can allow growers to regulate temperature, light, humidity, irrigation and nutrient supply. Such systems can provide year-round production independent of some seasonal limitations. Weber (2017) demonstrated the potential of broccoli microgreens as a mineral-rich crop and reported that compost-grown broccoli microgreens contained greater concentrations of several minerals than mature broccoli. The study also highlighted the possibility of producing microgreens in urban settings with substantially lower water requirements than field-grown mature broccoli under the conditions evaluated.

Cultivation Practices:

Selection of Suitable Species: Successful microgreen production begins with selecting appropriate plant species and cultivars. Seeds should have high germination percentage, good vigor and freedom from visible contamination. Species should be selected according to market demand, nutritional characteristics, growth duration and environmental conditions. Broccoli, radish, mustard, cabbage, kale, amaranth, pea, sunflower, coriander, fenugreek and beet are among the commonly cultivated types. Brassicaceae microgreens are especially important because they provide glucosinolates and other phytochemicals (Dereje *et al*., 2023).

Seed Preparation: Seed quality is critical because microgreens are usually consumed fresh and production occurs under warm and humid conditions that can favor microbial growth. Seeds should be obtained from reliable sources and should be clean and suitable for edible production. Depending on species, seeds may require soaking before sowing. Larger seeds such as pea and sunflower can benefit from pre-soaking, whereas small seeds such as mustard and broccoli generally require less preparation. Excessive soaking should be avoided because it can promote fermentation or microbial growth.

Growing Medium: Microgreens can be cultivated in soil, compost-based media, cocopeat, peat-based substrates, vermiculite, perlite, jute or other specialized growing mats. A suitable medium should have good water-holding capacity, adequate aeration, drainage and structural stability. The growing medium can influence both yield and nutritional composition. Weber (2017) demonstrated that cultivation method affected mineral accumulation in broccoli microgreens, showing that production conditions should be considered when evaluating nutritional quality.

Seed Sowing: Seeds are distributed uniformly over the growing medium. Seed density should be adjusted according to seed size and species. Excessively high density can cause poor ventilation, elongated seedlings, competition and increased disease risk, whereas very low density can reduce productivity. After sowing, seeds are generally covered lightly when appropriate and irrigated carefully. Uniform moisture is required for rapid germination.

Germination: During germination, moisture and temperature are particularly important. Many species germinate effectively under warm conditions, but optimum temperature varies among crops. A humidity cover can be used during early germination to maintain moisture, but adequate ventilation becomes important after emergence. Once seedlings emerge, the cover should be removed or ventilation increased. Excess humidity and poor air circulation can encourage fungal growth and other microbial problems.

Light Management: Light is essential after germination because seedlings require photosynthesis for continued growth and pigment formation. Microgreens can be produced under natural sunlight, greenhouse light or artificial LED lighting. Light intensity, photoperiod and spectral composition can affect plant height, biomass, coloration, antioxidant compounds and other nutritional characteristics. Research summarized by Teng *et al.* (2021) indicates that pre-harvest factors such as illumination can influence the nutritional quality of microgreens.

Irrigation: Water should be supplied regularly but excessive irrigation should be avoided. Bottom irrigation can reduce disturbance of seedlings and may help maintain a relatively dry foliage surface. In hydroponic systems, nutrient solution management becomes an important component of production. Water quality should be suitable for edible crop production. Contaminated water can introduce microorganisms or undesirable chemical substances into the production system.

Nutrient Management: Microgreens have a short production period and generally rely substantially on seed reserves during early development. Nevertheless, nutrient availability can affect biomass and mineral composition. Depending on the species and production system, supplemental nutrients may be supplied through the growing medium or hydroponic solution.

Nutrient enrichment and biofortification have become important research areas. However, nutrient concentration should be carefully managed because excessive fertilizer application can negatively influence plant quality and environmental sustainability (Teng *et al.*, 2021).

Temperature and Humidity: Temperature and relative humidity strongly influence germination, growth and microbial development. Excessively high temperatures may cause rapid water loss, poor growth or quality deterioration, whereas low temperatures can delay germination and development. High humidity combined with poor air circulation can increase the risk of fungal and bacterial contamination. Therefore, ventilation is particularly important in indoor and greenhouse systems.

Harvesting: Microgreens are usually harvested when cotyledons are fully expanded and the first true leaves have emerged. The exact harvest stage depends on species, market requirements and desired nutritional characteristics. Harvesting should be performed using clean and sanitized tools. Plants are generally cut above the substrate, leaving the roots behind. Harvesting during cooler periods can help maintain freshness and reduce post-harvest deterioration.

Nutritional Composition of Microgreens:

Microgreens are recognized as important sources of vitamins, minerals and phytochemicals. Their nutritional profile varies considerably among species. Major vitamins reported in microgreens include vitamin C, vitamin E and vitamin K, while carotenoids such as β-carotene, lutein and zeaxanthin are also found in many species. Xiao *et al*. (2012) reported considerable variation among 25 microgreen types. Total ascorbic acid ranged from 20.4 to 147.0 mg/100 g fresh weight, while concentrations of carotenoids and tocopherols also varied widely. The study found that some microgreens had higher nutrient densities than mature leaves, although nutritional superiority was not uniform across every nutrient or species. Minerals such as potassium, calcium, magnesium, iron, zinc, manganese and copper may occur in significant amounts. Weber (2017) found that compost-grown broccoli microgreens had higher concentrations of several minerals compared with mature broccoli, demonstrating the influence of production conditions on nutritional composition. Microgreens also contain secondary metabolites, including phenolic compounds, flavonoids, anthocyanins, carotenoids and glucosinolates. These compounds are associated with antioxidant and other biological activities (Dereje *et al*., 2023).

Antioxidant Properties: Oxidative stress occurs when the production of reactive oxygen species exceeds the body's antioxidant defense capacity. Diets containing vegetables and other plant foods provide antioxidant compounds that can contribute to the body's overall antioxidant system. Microgreens contain several antioxidant constituents, including vitamin C, tocopherols, carotenoids, phenolic compounds, flavonoids and anthocyanins. The composition varies according to plant species and growing conditions. Recent reviews have emphasized the abundance of antioxidant compounds in microgreens and their potential relevance to human health (Molecules review, 2023). De la Fuente *et al*. (2019) evaluated antioxidant bioactive compounds and minerals in Brassicaceae microgreens and demonstrated that these crops can provide bioactive compounds with potential nutritional significance. However, laboratory antioxidant activity should not automatically be interpreted as evidence that consuming a particular microgreen prevents or treats disease.

Potential Cardiovascular Benefits: A diet rich in vegetables is generally associated with cardiovascular health, and microgreens may contribute to such diets through their vitamins, minerals, carotenoids and polyphenolic compounds. Potassium, magnesium and antioxidant compounds have important physiological roles in maintaining normal cardiovascular function. The presence of phenolic compounds and carotenoids may help reduce oxidative processes, while the dietary fiber associated with whole plant foods can contribute to healthy dietary patterns. Reviews of microgreen research have identified cardiovascular protection as a potential health-related area, but human clinical evidence remains limited (Teng *et al*., 2021; 2023).

Anti-Inflammatory Potential: Chronic low-grade inflammation is associated with numerous non-communicable diseases. Plant-derived phytochemicals can interact with biological pathways involved in inflammation. Microgreens contain phenolic compounds, carotenoids and, particularly in Brassicaceae species, glucosinolates and their breakdown products. These compounds have been investigated for anti-inflammatory activities in experimental systems. However, most evidence for specific therapeutic effects comes from laboratory or preclinical studies rather than large human clinical trials (Teng *et al*., 2021; Dereje *et al.,* 2023).

Potential Antidiabetic and Metabolic Benefits: Microgreens may have potential relevance to metabolic health because of their phytochemical composition. Some experimental studies have investigated antioxidant, anti-inflammatory and antihyperglycemic activities of microgreen extracts. Phenolics, flavonoids and other bioactive compounds may influence oxidative stress and metabolic pathways. Nevertheless, microgreens should be considered a nutritious component of a balanced diet rather than a treatment for diabetes. Evidence summarized by Teng et al. (2021) indicates promising anti-hyperglycemic activity, but further human studies are needed to establish dose-response relationships and clinical effectiveness.

Potential Anticancer Properties: Brassicaceae microgreens have attracted particular research attention because of their glucosinolate content. During plant tissue disruption and digestion, glucosinolates can produce biologically active compounds such as isothiocyanates. These compounds have been studied for their potential roles in cellular antioxidant defense and mechanisms relevant to cancer biology. Dereje *et al.* (2023) reviewed phytochemicals and health-related properties of Brassicaceae microgreens, highlighting antioxidant, anticancer, antidiabetic and anti-inflammatory potential. However, the presence of bioactive compounds does not mean that microgreens can prevent or cure cancer. Human dietary intervention studies are required to determine the actual contribution of microgreens to cancer risk reduction.

Role in Dietary Diversity and Functional Foods:

Microgreens can increase dietary diversity because many species offer different colors, textures, flavors and nutritional profiles. Their compact production system allows households to grow several species simultaneously. Teng *et al.* (2021) described microgreens as emerging functional foods because of their combination of nutrients, phytochemicals and sensory characteristics. They can be incorporated into salads, sandwiches, soups, smoothies and other food products. The growing interest in functional foods has also encouraged research into microgreen powders, extracts and value-added products. However, processing can alter heat-sensitive compounds such as vitamin-C, so fresh consumption may preserve some nutrients more effectively.

Food Safety Considerations:

Despite their nutritional advantages, microgreens require careful attention to food safety. Their production involves high moisture and relatively warm conditions, which can favor microbial growth if hygiene is inadequate. Potential contamination may originate from seeds, growing media, irrigation water, equipment, workers or handling surfaces. Therefore, growers should use clean water, safe growing media, hygienic containers and sanitized tools. Good personal hygiene and prevention of crosscontamination during harvesting and packaging are essential. Renna and Paradiso (2020) identified food safety, shelf life, nutritional retention and sustainable production as important research areas.

Sustainable Production and Urban Agriculture:

Microgreens are particularly promising for urban agriculture because they can be grown in small spaces. Vertical shelves and controlled-environment systems can increase production per unit of floor area. Their short growth cycle also permits multiple production cycles. Teng *et al*. (2023) reviewed microgreen production for home, commercial and space-farming systems and highlighted the crop's suitability for controlled environments, automated irrigation, nutrient delivery and lighting systems. Microgreens may therefore contribute to localized food production, although claims of sustainability must consider electricity consumption, lighting requirements, substrate use, packaging and transportation. Production methods that use natural light, renewable energy, reusable equipment and locally available substrates may improve environmental performance.

Microgreens represent an innovative category of young edible vegetables with considerable potential for modern food systems. Their short production cycle, low space requirement, diverse crop choices and compatibility with indoor and vertical farming make them suitable for household, commercial and urban production. Scientific evidence indicates that microgreens can provide vitamins, minerals, carotenoids, phenolic compounds, glucosinolates and other bioactive constituents. Nutritional concentration, however, varies considerably with species, genotype, growing medium, nutrient supply, light, temperature, harvest stage and other production factors. Consequently, the term "microgreen" should not be interpreted as guaranteeing a uniform nutritional profile. Overall, microgreens can be considered a promising component of sustainable horticulture and functional-food systems. Future research should integrate crop science, nutrition, food safety, environmental assessment and human health research to develop standardized, safe, nutritionally optimized and economically viable microgreen production systems.

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