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MICROGREENS: FUNCTIONAL POTENTIAL, CULTIVATION STRATEGIES, AND MARKET PROSPECTS

MICROVERDES: POTENCIAL FUNCIONAL, ESTRATÉGIAS DE CULTIVO E PERSPECTIVAS DE MERCADO

MICROGREENS: POTENCIAL FUNCIONAL, ESTRATEGIAS DE CULTIVO Y PERSPECTIVAS DE MERCADO

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ABSTRACT: This study reviewed the main aspects of microgreens production, addressing their nutritional benefits, cultivation techniques, functional importance, and market trends. The methodology consisted of a narrative review of national and international scientific literature, based on recent publications in indexed journals. The analyzed studies indicate that microgreens exhibit high concentrations of bioactive compounds, including vitamins, minerals, and antioxidants, often exceeding those found in mature vegetables. Cultivation is relatively simple and can be performed using different growing substrates, natural or artificial lighting, controlled irrigation, and short production cycles, enabling small-scale production and urban farming systems. Factors such as substrate type, light intensity, and cultivated species significantly influence plant growth, yield, and nutritional composition. The increasing demand for functional foods and sustainable agricultural practices, intensified after the COVID-19 pandemic, has driven the consumption of microgreens in gastronomic, household, and industrial markets. Microgreens are used in salads, soups, bakery products, beverages, and dietary supplements, adding value to food products. It is concluded that microgreens represent a promising alternative for agricultural diversification, health promotion, and innovation in the agri-food sector, requiring further research to optimize production techniques and expand commercial applications.

Keywords: Vertical farming. Urban agriculture. Environmental factors.

RESUMO: Esse artigo buscou Este trabalho revisou os principais aspectos da produção de microverdes, abordando benefícios nutricionais, técnicas de cultivo, importância funcional e tendências de mercado. A metodologia consistiu em revisão narrativa da literatura científica nacional e internacional, com base em publicações recentes de periódicos indexados. Os estudos indicam que microverdes apresentam elevadas concentrações de compostos bioativos, como vitaminas, minerais e antioxidantes, frequentemente superiores às de hortaliças adultas. O cultivo é simples e pode ser realizado com diferentes substratos, uso de luz natural ou artificial, irrigação controlada e ciclos curtos, permitindo produção em pequena escala e em ambientes urbanos. Fatores como tipo de substrato, intensidade luminosa e espécie cultivada influenciam significativamente crescimento, produtividade e composição nutricional. A crescente demanda por alimentos funcionais e práticas sustentáveis, intensificada após a pandemia de COVID-19, impulsionou o consumo desses produtos nos mercados gastronômico, doméstico e industrial. Os microverdes são utilizados em saladas, sopas, panificados, bebidas e suplementos, agregando valor aos alimentos. Conclui-se que representam alternativa promissora para diversificação agrícola, promoção da saúde e inovação no setor alimentício, demandando novos estudos para otimização produtiva e ampliação comercial.

Palavras-chave: Cultivos verticais. Agricultura urbana. Fatores ambientais.

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RESUMEN: Este trabajo revisó los principales aspectos de la producción de microvegetales (microgreens), abordando sus beneficios nutricionales, técnicas de cultivo, importancia funcional y tendencias de mercado. La metodología consistió en una revisión narrativa de la literatura científica nacional e internacional, basada en publicaciones recientes de revistas indexadas. Los estudios analizados indican que los microvegetales presentan elevadas concentraciones de compuestos bioactivos, tales como vitaminas, minerales y antioxidantes, frecuentemente superiores a las encontradas en hortalizas en estado adulto. El cultivo es relativamente simple y puede realizarse utilizando distintos sustratos de crecimiento, iluminación natural o artificial, riego controlado y ciclos productivos cortos, lo que permite la producción a pequeña escala y en sistemas de agricultura urbana. Factores como el tipo de sustrato, la intensidad lumínica y la especie cultivada influyen significativamente en el crecimiento, rendimiento y composición nutricional de las plantas. La creciente demanda de alimentos funcionales y prácticas agrícolas sostenibles, intensificada tras la pandemia de COVID-19, ha impulsado el consumo de estos productos en los mercados gastronómico, doméstico e industrial. Los microvegetales se emplean en ensaladas, sopas, productos panificados, bebidas y suplementos, agregando valor a los alimentos. Se concluye que representan una alternativa prometedora para la diversificación agrícola, la promoción de la salud y la innovación en el sector agroalimentario, siendo necesarios nuevos estudios para optimizar las técnicas de producción y ampliar sus aplicaciones comerciales.

Palabras clave: Cultivos verticais. Agricultura urbana. Fatores ambientais.

INTRODUCTION

Food insecurity, exacerbated by climate change and accelerated population growth, stands as one of the greatest challenges of the 21st century. It is estimated that the global population will reach 8.6 billion people by 2050, with approximately 80% of this total concentrated in urban areas (DESPOMMIER, 2011; ISLAM e SIWAR, 2012; AL-CHALABI, 2015). This scenario imposes significant pressure on production systems, which face the continuous reduction in both the quantity and quality of arable land due to urbanization, environmental degradation, extreme climate events, intensive pesticide use, and inadequate soil management (FEDOROFF et al., 2010; LAKHIAR et al., 2024).

In this context, urban agriculture emerges as a promising alternative to ensure the local supply of fresh and high-quality food, taking advantage of available spaces in urban centers for plant cultivation and animal production (CFSC, 2003; MISRA e GIBSON, 2021). This approach aims not only to meet urban food demand but also to promote sustainability, reduce transportation costs, and contribute to food security.

Human nutrition relies heavily on the adequate supply of vegetables, which are important sources of phytonutrients and bioactive compounds that play an essential role in preventing chronic and age-related diseases (MARTIN e LI, 2017; LE et al., 2020). As a result of increased public awareness of the benefits of a healthy diet, interest has grown in functional foods—also called nutraceuticals—which combine high nutritional value with beneficial health properties (ALI et al., 2025).

Within this scenario, microgreens have gained prominence. These are small seedlings with two fully developed cotyledons, one pair of emerging true leaves, and an elongated stem, cultivated in specific substrates and harvested at early growth stages (ZHANG et al., 2020). Unlike sprouts, which are germinative structures harvested before the emergence of the first true leaf and consumed whole, microgreens are valued for their diversity of colors, flavors, and especially for their high concentration of essential nutrients (BENINCASA et al., 2019; WOJDYLO et al., 2020; KYRIACOU et al., 2016).

Studies indicate that microgreens contain higher levels of minerals, vitamins, and antioxidants compared to their mature counterparts, with concentrations of β-carotene and vitamins C, E, and K reaching up to 40 times greater (XIAO et al., 2012; DEREJE et al., 2023; GUNJAL et al., 2024). In particular, microgreens from the Brassicaceae family stand out due to the high bioaccessibility of bioactive compounds with significant functional potential (XIAO et al., 2012).

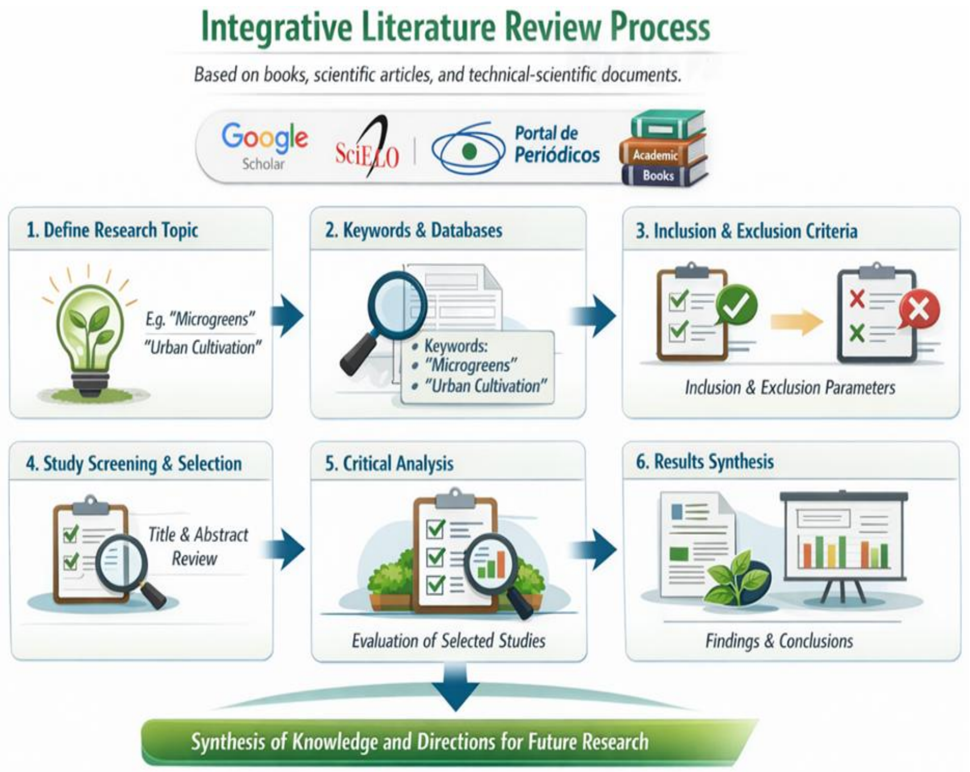
Therefore, the present study aims to compile and critically discuss the available scientific knowledge on production, nutritional and functional benefits, species used, cultivation methods, and potential challenges associated with the use of microgreens in human nutrition, highlighting their role as a strategic tool in addressing urban food insecurity.

METHODS

This study is an integrative literature review, developed based on previously published materials such as books, scientific articles, and technical-scientific documents. The purpose of the integrative review is to gather and synthesize the knowledge produced on a specific topic, allowing for a comprehensive understanding of the current state of research, as well as supporting future investigations (SOUZA et al., 2010).

The construction of the review was carried out systematically, encompassing the following stages: a) definition of the research topic; b) selection of keywords and databases; c) establishment of inclusion and exclusion criteria; d) screening and selection of studies; e) critical analysis of the selected works; and f) organization and presentation of the results obtained. The methodological flow adopted in this integrative review is illustrated in Figure 1.

Figure 1 – Systematic flowchart of the integrative literature review process adopted in this study, including topic definition, keyword and database selection, inclusion and exclusion criteria, study screening, critical analysis, and synthesis of results.



The databases consulted included Google Scholar, Scientific Electronic Library Online (SciELO), the journal portal of the Coordination for the Improvement of Higher Education Personnel (CAPES), and digital archives of academic books. The keywords used in the search were: "Microverdes," "Microgreens," and "Urban Cultivation."

The initial selection of materials was carried out through the reading of titles and abstracts, with duplicate studies and those not directly related to the proposed theme being excluded. Studies were included if they contained the keywords in the title, objectives, or within the body of the text and abstract, contributing in a relevant way to the scientific approach to the subject.

Technical and Environmental Aspects of Microgreen Cultivation

The efficient cultivation of microgreens depends on a series of agronomic and environmental factors that directly influence their productivity, phytosanitary quality, and nutritional value. Among the main elements to be considered are the appropriate selection of species, cultivation methods, type and quality of substrate, seed purity and germination capacity, sowing and germination techniques, irrigation and fertilization practices, harvesting procedures, as well as postharvest storage conditions (EBERT, 2022).

Microgreens are easily cultivated in small spaces and require minimal resources, making them an attractive option for home production. Despite morphological distinctions between microgreens and sprouts—particularly with regard to harvest stage—both offer similar nutritional benefits and broad culinary applications (ALI et al., 2025). However, for commercial or large-scale production, the use of controlled environments such as greenhouses or urban farming facilities is recommended. Estimates suggest that three to four workers can efficiently produce up to 90 kg of microgreens in a 400 m^2 area, with an average yield of 300 g per square meter per week. Depending on the species and cultivation conditions, the cycle may range from 10 to 14 days (LONE et al., 2024).

The growth medium is a critical factor, influencing not only yield but also the sensory and microbiological quality of the product. Microgreens can be grown in soil or in alternative substrates such as expanded clay, coconut fiber, agricultural felt, glass wool, grape pomace, gravel, hemp, jute, recycled paper, perlite, rice husks, rock wool, sand, sawdust, sugarcane fiber, tree bark, vermiculite, and zeolite (DI GIOIA et al., 2017; SALEH et al., 2022; GUNJAL et al., 2024).

Seed quality is decisive for obtaining healthy and uniform seedlings. It is recommended to use seeds with high germination capacity (above 95%), free from impurities and microbial contaminants such as fungi and bacteria (STOLERU et al., 2016). Due to the short cultivation cycle, fertilizer use is limited. Many producers use nutrient-rich commercial peat-based substrates and, occasionally, unconventional organic fertilizers such as reused brewer's yeast (LOBIUC et al., 2017).

Irrigation is a key factor for both product quality and food safety. Methods such as drip irrigation, combined with soil moisture sensors, contribute to efficient water use and reduced risk of microbial contamination (RAJAN et al., 2019; EREKATH et al., 2024). In contrast, systems such as sprinkler irrigation or hydroponics may be more susceptible to pathogen introduction (XIAO et al., 2015).

Among environmental factors, temperature and light are decisive elements for the agronomic performance of microgreens. Studies indicate that temperatures between 17 and 20 °C (night/day) are ideal for growth and postharvest quality (SAMUOLIENE et al., 2017; PALMITESSA et al., 2022). Temperature exerts differentiated influence on plant phenological stages, with the vegetative stage generally requiring higher temperatures than the reproductive stage (HATFIELD et al., 2015).

Light intensity, duration, and spectrum directly affect attributes such as color, aroma, flavor, nutritional quality, and phytochemical content of microgreens (KYRIACOU et al., 2016). During germination, it is recommended to maintain trays in well-lit environments with a photoperiod of 12 to 16 hours per day. Relative humidity (RH) is also an essential factor during both cultivation and postharvest. Low humidity levels can lead to dehydration and quality loss, while excessive humidity favors microbial proliferation and hinders proper plant development (WARRINER et al., 2003).

Microgreens are highly perishable after harvest, with a shelf life of only 2 to 3 days at room temperature. To extend preservation, immediate storage at 4 °C is recommended, which can prolong their durability to up to 14 days (SHARMA et al., 2022).

Due to high planting density, humid microclimate, and the early developmental stage of the plants, microgreens are susceptible to diseases such as seed, root, and seedling rot, particularly caused by the pathogen Pythium (PILL et al., 2011). However, the extremely short cultivation cycle (6 to 20 days), combined with the presence of natural bioactive compounds in the cultivated species, tends to significantly minimize the impacts of these diseases (LONE et al., 2021; XIAO et al., 2016).

Variety of Species, Nutritional Value, and Functional Properties of Microgreens

Microgreens encompass a wide variety of plant species, including leafy vegetables, legumes, and grasses, selected based on their agronomic potential, nutritional composition, and applicability for human consumption. Among the most commonly cultivated species are amaranth, radish, parsley, mustard, chard, celery, cabbage, coriander, chervil, kale, fennel, watercress, basil, beet, arugula, and sorrel. Some of these, such as radish and amaranth, are recognized for exhibiting vibrant leaf coloration, ranging from shades of green, red, purple, and pink (XIAO et al., 2012).

In addition to traditional vegetables, legumes such as beans, chickpeas, and lentils, as well as cereals such as oats, wheat, rice, barley, and corn, can also be used for microgreen production (PARASCHIVU et al., 2021). However, certain species are not suitable for this purpose. Crops belonging to the Solanaceae family, such as tomato, eggplant, and pepper, contain antinutritional factors that discourage their use as microgreens (DI GIOIA et al., 2017).

Regarding nutritional value, microgreens are concentrated sources of essential macro- and micronutrients, such as iron (Fe), zinc (Zn), potassium (K), calcium (Ca), nitrogen (N), phosphorus (P), sulfur (S), manganese (Mn), selenium (Se), and molybdenum (Mo), among others. Beyond minerals, these vegetables are rich in phytochemicals with recognized bioactive potential, including ascorbic acid (vitamin C), phylloquinones (vitamin K), α-tocopherol (vitamin E), β-carotene (provitamin A), phenolic antioxidants, carotenoids, anthocyanins, glucosinolates, and soluble sugars (BHASWANT et al., 2023).

Comparative studies have demonstrated that nutrient content in microgreens can be 30 to 40 times higher than in their mature forms (CHOE et al., 2018). For example, flaxseed microgreens exhibited higher levels of chlorophyll, carotenoids, and phenolic compounds compared to sprouts, while broccoli microgreens stood out for their greater antioxidant content (PUCCINELLI et al., 2022). Table 1 demonstrates a comparison between microgreens and mature plants of broccoli, coriander, radish, and arugula with respect to nutritional composition.

Table 1 – Comparative Analysis of the Nutritional Composition of Microgreens and Adult Plants

Species	Nutritional components	Microgreens	Mature plant	References
Broccoli	Glucoraphanin (μmol g^{-1} DW)	0.67–0.85	7,1 ± 2,5	Choe et al. (2018); K. Khoja et al. (2020)
	Glucobrassicin (μmol g^{-1} DW)	10.13–10.81	1,1 ± 0,4	
	Minerals (Fe, Ca, Cu, Mg, Mn, Mo, Zn; μg g^{-1} DW)	55.90, 25601.7, 6.40, 3702.53, 115.0, 2.76, 39.65	54,37, 3911,91, 8,26, 1752,92, 25,67, 1,67 e 52,22	
Arugula	Total ascorbic acid (mg 100 g^{-1} FW)	45.8	15.0	Choe et al. (2018) Rizvi et al. (2022)
	Phylloquinone (μg g^{-1} FW)	1.6	1.1	
	β-carotene (mg 100 g^{-1} FW)	7.5	1.4	
	Tocopherol (mg 100 g^{-1} FW)	19.1	0,4	
	Lutein/zeaxanthin (mg 100 g^{-1} FW)	5.4	3.6	

Species	Nutritional components	Microgreens	Mature plant	References
Coriander	Phylloquinone ($\mu g\ g^{-1}$ FW)	250	310	Rizvi et al. (2022)
	Ascorbic acid (mg 100 g^{-1} FW)	40.6	27.0	
	Tocopherol (mg 100 g^{-1} FW)	53	2,5	
	β-carotene (mg 100 g^{-1} FW)	11.7	0,3	
	Lutein/zeaxanthin (mg 100 g^{-1} FW)	10.1	0,9	
Radish	Minerals (F^{-}, Mg, Na, K, Se, Ca, P; mg 100 g^{-1} FW)	181, 75, 192, 990, 0.05, 81, 193	88, 22,13, 222, 394, 0,03, 44 e 49	Rani et al. (2018); Yadav et al. (2018); Rizvi et al. (2022)
	Vitamin B9 (mg 100 g^{-1} FW)	34.5	18h20	
	Vitamin C (mg 100 g^{-1} FW)	4.78–95.8	14,8–18,74	
	Phylloquinone (mg 100 g^{-1} FW)	180	2	
	Tocopherol (mg 100 g^{-1} FW)	19.7	0	
	β-carotene (mg 100 g^{-1} FW)	5.4	4.0	
	Omega-3 fatty acid (mg 100 g^{-1} FW)	15.65	9,38	
	Total phenolics (mg GAE 100 g^{-1})	135.74	225	
	Total flavonoids (mg CE 100 g^{-1})	39.83	42,2	

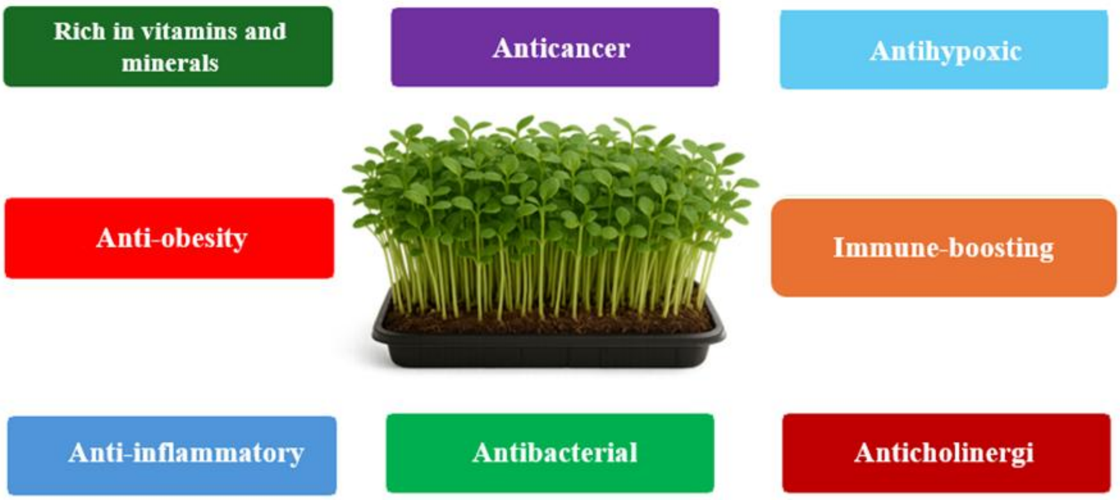
DW = Dry weight; FW = Fresh weight; GAE = Gallic acid equivalents; CE = Catechin equivalents. Source: adapted from Gunjal et al. (2024)

Quantitative studies indicate that microgreens can supply 2% to 12% of the recommended daily intake (RDI) of iron, 2% to 13% of zinc, 1% to 6% of selenium, 28% to 116% of vitamin C, 28% to 332% of vitamin E, and 24% to 72% of vitamin A, depending on the species (GHOORA et al., 2020). With respect to ascorbic acid, microgreens present significantly higher concentrations compared to sprouts, leafy greens, or mature-stage plants (DI BELLA et al., 2020).

Specific species exhibit distinct nutritional profiles. For instance, mustard, basil, beet, red amaranth, watercress, and radish microgreens contain between 2.1 and 4.0 g of vitamin K per kilogram of fresh mass (XIAO et al., 2015). Coriander microgreens, in turn, stand out for their high levels of lutein/zeaxanthin (10.1 mg/100 g) and violaxanthin (7.7 mg/100 g), values superior to those observed in microgreens produced from popcorn maize, which contain approximately 1.3 mg and 0.9 mg, respectively (XIAO et al., 2012).

From a functional perspective, microgreens have been the subject of several in vitro and in vivo studies demonstrating anti-inflammatory, antibacterial, anticancer, antidiabetic, antihypoxic, anti-obesity, anticholinergic, and antihyperglycemic properties (Figure 2). These therapeutic effects, combined with their high nutritional value, reinforce the classification of microgreens as promising functional foods in the context of preventive nutrition and the promotion of human health (ZHANG et al., 2021).

Image 2 – Beneficial properties conferred by microgreens



Source: The authors (2025).

Market Trends and Future Perspectives in the Microgreens Sector

The microgreens market is segmented according to different criteria, such as the predominant crop type, cultivation methods, growing media used, geographical area of commerce, and final applications of the products, which include the food, cosmetic, and other sectors (PARASCHIVU et al., 2021).

In recent decades, microgreens have gained notable prominence in the gastronomic scene, especially due to their high nutritional value and sensory characteristics. They are now widely used as ingredients in starters (salads, soups, and sandwiches) and for finishing main courses, adding aesthetic and functional value to culinary preparations (CIUTA et al., 2020). This versatility positions microgreens as strategic ingredients in the formulation of functional and high-value-added foods.

In addition to fresh consumption, microgreens have been incorporated into the development of innovative food products, such as beverages, spices, baby food, probiotic-added foods, yogurts, flours enriched with microgreen powder, bakery products, and infusions (GUNJAL et al., 2024). These applications expand the market potential and stimulate product diversification.

FINAL CONSIDERATIONS

Growing microgreens represents an innovative, sustainable, and highly promising agricultural practice, both from a nutritional and commercial standpoint. The adoption of different production methods, combined with the use of sustainable technologies and efficient management strategies, makes it possible to optimize crop quality and yield. Furthermore, the growing interest from the food industry and consumers, driven by factors such as the demand for functional foods and the post-pandemic context, strengthens the expansion of the microgreens market across different segments. Thus, microgreens are emerging as a viable alternative for diversifying agricultural production, promoting food security, and developing value-added products.

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