Microgreens: A Comprehensive Review Emphasizing Urban Agriculture

Abstract:

In this comprehensive review, we delve into the multifaceted world of nutrient-rich microgreens, with a particular emphasis on their significance in urban agriculture. By exploring their nutritional composition, culinary applications and cultivation techniques, we aim to shed light on the transformative potential of microgreens in promoting sustainable urban food systems. Through an interdisciplinary lens encompassing agronomy, nutrition and urban planning, we uncover the myriad benefits of microgreens cultivation and highlight the critical role they play in shaping the future of urban agriculture.

Keywords: Microgreens, Urban agriculture, Sustainable food systems, Nutritional value, Culinary applications, Cultivation techniques, Food security, Bioactive compounds, Urban farming, Fresh produce

Introduction:

Microgreens, also known as "vegetable confetti" (Treadwell *et al*., 2010) or "micro herbs" in the case of aromatic herbs (Di Gioia & Santamaria, 2015), are tiny plants harvested at an early stage of growth. As per Commission Regulation (EU) 752/2014, "baby leaf" refers to the tender leaves and petioles of various crops, harvested before reaching the 8 true leaf stage. The term "Microgreen" was coined by Botanist John Naar in the early 1980s. "microgreens" is a marketing term used to categorize a type of product that currently lacks a legal definition, as noted by Treadwell *et al*. (2010). Traditionally considered as a specialty in high-end restaurant kitchens as they are gaining popularity and finding broader applications as a food ingredient for people everywhere. Within the dynamic realm of culinary arts, microgreens have become the newest culinary trends, capturing the interest of both culinary experts and health-conscious consumers. These miniature wonders, renowned for their potent combination of flavour and nutrition, represent a paradigm shift in the way we approach food cultivation and consumption. Microgreens are tiny, but they're mighty in terms of nutrition, with concentrated amounts of vitamins, minerals and antioxidants that considerably overshadow those of their mature counterparts (Nath *et al*., 2015). In complement to their nutritional advantages, microgreens are a visual and flavourful treat, adding a vibrant kaleidoscope of colour and a burst of powerful, fresh flavour to food.

Against the backdrop of urbanization and environmental challenges, innovative agricultural techniques have become imperative for sustainable food production. Among these techniques, soil-less farming methods such as hydroponics have garnered attention for their ability to maximize resource efficiency and minimize environmental impact (Gebreegziher, 2023). By cultivating microgreens through hydroponics and other urban cropping methods, urban farmers can optimize space, conserve water and reduce reliance on conventional agricultural inputs (Jayachandran *et al*., 2022; Bindu, 2018). In contrast to the frequent fusion of cooking styles (Renna *et al*., 2021), this example highlights the adaptability and resilience of urban farming in solving modern food security problems by combining state-of-the-art technology with traditional agricultural practices.

Moreover, the versatility of microgreens extends beyond their nutritional and culinary attributes to encompass their role in urban greening and community engagement. As cities grapple with issues of food deserts and limited access to fresh produce, microgreens offer a viable solution for localized food production and urban revitalization (Kumar *et al*., 2018). Through rooftop gardens, vertical farms and community-supported agriculture initiatives, microgreens cultivation not only provides fresh and nutritious produce to urban dwellers but also fosters a sense of connection to the food system and promotes attention towards environment.

However, space agencies are intrigued by microgreens for their potential to enhance astronaut's diets during space missions (Cahill & Hardiman, 2020). Additionally, cultivating microgreens holds promise for supporting the health of crew members during extended spaceflight missions. Moreover, organic farming concepts can be seamlessly integrated into urban cropping techniques, ensuring that microgreens are grown naturally and sustainably.

Sprouts vs Microgreens:

Microgreens and sprouts are both consumed in their early stages of growth, but they differ significantly. Sprouts are cultivated in damp, dark environments, whereas microgreens are grown in soil under light. This variance in cultivation methods results in microgreens having higher nutrient content and lower risk of microbial contamination compared to sprouts (Treadwell *et al*., 2010).

Powerhouses of Flavour and Nutrition:

Microgreens are the miniature yet mighty members of the vegetable and herb kingdom. These tender greens are harvested from the seeds of various plants, typically just 7 to 14 days after germination. (Lester *et al.,* 2013) They feature two fully developed cotyledon leaves and may sometimes exhibit the first signs of true leaves emerging (Choe *et al*., 2018). Despite their small size, microgreens pack a punch in both flavour and nutritional value.

Microgreens, with their high moisture content and low carbohydrates and fat, may potentially aid in preventing weight gain and type 2 diabetes (Seidelmann *et al.,* 2018). A protein-rich diet not only assists in weight maintenance and loss but also stabilizes blood sugar, increases energy levels, and enhances nutrient absorption (Westerterp-Plantenga *et al.,* 2009). Fiber is essential for digestive, heart, and skin health, and can contribute to lowering blood cholesterol and glucose levels (Anderson *et al*., 2009).

These miniature greens, measuring between 2.5 to 7.6 centimetres (1 to 3 inches) in height, offer an explosion of intense flavours, vibrant colours and tender textures. They provide a feast for the senses, enhancing the visual appeal, taste and mouthfeel of any dish they adorn.

Versatility is the name of the game when it comes to microgreens. Whether sprinkled atop salads, stirred into soups, or layered into sandwiches, these tiny greens elevate culinary creations to new heights. Their addition brings not only a burst of fresh flavour but also a pop of colour and a satisfying crunch.

A Holistic Approach to Health and Wellness:

Microgreens, a plant-based functional food that consists of the seedlings of the edible plants harvested after 7–14 days of the germination process, are the stellar source of phytochemicals, such as essential minerals, polyphenols, carotenoids, chlorophyll, anthocyanins, glucosinolates, etc., which imparts high antioxidant, anti-inflammatory, anti-diabetic effects due to which it is considered as a practical food that might improve or attenuate chronic diseases.

Moreover, emerging research suggests that integrating microgreens into one's diet could potentially mitigate the risk factors associated with a variety of chronic ailments. Conditions like cardiovascular disease, chronic kidney disorders and diabetes may benefit from the nutrient-rich profile of microgreens, which can aid in maintaining healthy blood pressure, cholesterol levels and blood sugar regulation. Additionally, microgreens' abundance of iron makes them particularly valuable in combating iron deficiencies, a prevalent concern globally. Their low-calorie content and high nutrient density also position them as allies in the battle against obesity, offering satiety and nourishment without excess calories It has also been found to be effective in combating the common cold and treating skin infections, as demonstrated by research conducted by Hodges *et al*. (1969) and Heimer *et al*. (2009).

1,1-diphenyl-2-picrylhydrazil (DPPH) acts as a radical scavenger, binding with other free radicals in the body and facilitating their removal, thereby promoting overall health and longevity, as highlighted by Sharma and Bhat (2009). DPPH radical scavenging activity with less IC_{50} (Inhibitory substance dosage metric) leads to better antioxidant capacity like vitamin C aids in shielding the body from carcinogenic free radicals, as noted by Stratton and Godwin (2011). Furthermore, the presence of bioactive compounds in microgreens holds promise in combating carcinogenic processes and tumour growth. These compounds, including glucosinolates found in cruciferous microgreens like broccoli and kale, exhibit potential anti-cancer properties by interfering with tumour initiation, progression, and metastasis. Incorporating microgreens into daily meals could thus serve as a proactive measure in promoting overall health and reducing the risk of various chronic diseases.

Commonly Used species: Microgreen farming has proven successful with a variety of vegetables including white radish, pink radish, cabbage, red cabbage, leafy cabbage, mustard, broccoli, and bunching fenugreek. Additionally, plants such as peas, beans, mung beans, and cucumbers, known for their rich phytonutrient content, have been evaluated and cultivated with positive results (Rani *et al*., 2019).

Table 1 : Common Vegetables/Plants Used for Microgreens

Botanical Family	**Common Vegetables/Plants Used for Microgreens**
Brassicaceae	Cauliflower (*Brassica oleracea* var. *botrytis*), Broccoli (*Brassica oleracea* var. *italica*), Cabbage (*Brassica oleracea* var. *capitata*), Chinese Cabbage (*Brassica rapa* subsp. *pekinensis*), Kale (*Brassica oleracea* var. *acephala*), Savoy Cabbage (*Brassica oleracea* var. *sabauda*), Rappini or Brassica raab (*Brassica rapa*), Watercress (*Nasturtium officinale*), Mizuna (*Brassica rapa* var. *nipposinica*), Radish (*Raphanus sativus*), Arugula (*Eruca vesicaria*), Mustard (*Brassica juncea*), Tatsoi (*Brassica rapa* var. *rosularis*), Wild Radish (*Raphanus raphanistrum*), White Mustard (*Sinapis alba*), Mediterranean Mustard (*B. tournefortii*).
Asteraceae	Lettuce (*Lactuca sativa*), Endive (*Cichorium endivia*), Escarole (*Cichorium endivia* var. *latifolium*), Chicory (*Cichorium intybus*), Radicchio (*Cichorium intybus* var. *radicchio*), Sunflower (*Helianthus annuus*), Common Dandelion (*Taraxacum officinale*)

Apiaceae	Dill (*Anethum graveolens*), Carrot (*Daucus carota*), Fennel (*Foeniculum vulgare*), Celery (*Apium graveolens*), Wild Fennel (*Foeniculum vulgare*)
Amaryllidaceae	Garlic (*Allium sativum*), Onion (*Allium cepa*), Leek (*Allium ampeloprasum* var. *porrum*), Sea Fennel (*Crithmum maritimum*)
Amaranthaceae	Amaranth (*Amaranthus* spp.), Red Orach (*Atriplex hortensis*), Swiss Chard (*Beta vulgaris* var. *cicla*), Beet (*Beta vulgaris*), Spinach (*Spinacia oleracea*), Quinoa (*Chenopodium quinoa*), Pigweed (*Amaranthus* spp.)
Cucurbitaceae	Melon (*Cucumis melo*), cucumber (*Cucumis sativus*), squash (*Cucurbita pepo*)
Poaceae	Oat (Avena sativa), soft wheat (*Triticum aestivum*), durum wheat (*Triticum durum*), corn (*Zea mays*), barley (*Hordeum vulgare*), rice (*Oryza sativa*)
Fabaceae	Chickpea (*Cicer arietinum*), alfalfa (Medicago sativa), Green bean (*Phaseolus vulgaris*), Fenugreek (*Trigonella foenum-graecum*), Fava bean (*Vicia faba*), Lentil (Lens culinaris), pea (Pisum sativum), clover (*Trifolium repens*)
Linaceae	Flax (*Linum usitatissimum*)
Boraginaceae	Borage (*Borago officinalis*)
Asteraceae	Sea beet (*Beta vulgaris* subsp. *Maritima*), smooth golden fleece (*Urospermum dalechampii*), prickly golden fleece (*Urospermum picroides*), sea rocket (*Cakile edentula*), wild chicory (*Cichorium intybus*), common purslane (*Portulaca oleracea*), Goats beard (*Aruncus dioicus*)
Brassicaceae	White wall rocket (*Diplotaxis erucoides*), wild rocket (*Diplotaxis tenufolia*)
Brassicaceae	Watercress (*Nasturtium officinale*)
Amaranthaceae	*Salicornia*

Source: Di Gioia *et al.* 2015

Urban environment:

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Microgreens are a promising solution for urban agriculture, addressing the unique challenges of urban environments through their space efficiency, rapid growth, water efficiency and contribution to reducing transportation emissions (Bhaswanth *et al*., 2023). Their ability to thrive in compact spaces makes them an ideal choice for city dwellers with limited land, while their quick turnaround time allows for multiple harvests within a short period, maximizing productivity and ensuring a steady supply of fresh greens throughout the year (Franks and Richardson, 2009). Additionally, microgreens require significantly less water to thrive compared to traditional crops, making them a sustainable choice for urban agriculture that promotes water conservation and responsible resource management. In recent years, the adoption of modern high-tech growing methods, like indoor soilless cultivation, has led to enhanced water use efficiency (WUE) (Pignata *et al.*, 2017). Soilless agriculture involves growing plants without soil, where nutrients are supplied through irrigation water or a nutrient solution (NS) (Olympios, 1999). Presently, indoor soilless cultivation systems are a significant contributor to vegetable production in Europe, Canada, and the United States (O'Sullivan *et al.*, 2019). It's estimated that producing 1 kg of lettuce in an indoor soilless farm requires only 3% of the water needed for field-grown lettuce (O'Sullivan *et al*., 2019). Furthermore, the cultivation of microgreens in urban settings contributes to a reduction in transportation emissions, thereby mitigating the environmental impact associated with food production and distribution (Despommier, 2013). This localized approach not only reduces carbon emissions from transportation but also supports the development of resilient and self-sufficient food systems within urban communities. By adopting microgreens in urban agriculture, cities can create greener, healthier and more sustainable urban environments, aligning with global efforts to combat climate change and promote sustainability (Armanda *et al*., 2019)

Microgreens Vs Mature plants

Microgreens contain better nutrient composition compared to the mature plants but this is not always true. Microgreens have a lower NO_{3-} concentration than mature lettuces and a greater amount of most minerals (Ca, Mg, Fe, Mn, Zn, Se, and Mo), according to Pinto *et al.* (2015). Microgreens of celery were found to contain higher amounts of macro elements (e.g., calcium and potassium) and microelements (e.g., iron and zinc), suggesting their potential to contribute significantly to fulfilling daily nutrient requirements and emphasizing the importance of identifying and developing celery cultivars with enhanced nutritional profiles (Singh *et al*., 2023). Based on the dry weight analysis, microgreens were found to contain higher concentrations of minerals compared to other developmental stages of kale, but based on fresh weight the mature stages are better (Waterland *et al*., 2017). In a study, the USDA-

ARS researchers from the Food Quality Laboratory and Crop Systems and Global Change Laboratory examined the concentrations of microelements (copper, iron, manganese, and zinc) and macro elements (calcium, magnesium, phosphorus, sodium, and potassium) in 30 species of microgreens from 10 genera. The findings showed that microgreens of the Brassicaceae family are an excellent source of both macro and microelements, including potassium and calcium (e.g., iron and zinc). It appears that this study (Xiao *et al*., 2016) is the first to record the mineral content of microgreens of the Brassicaceae family that are sold commercially.

Whereas, Yadav *et al*. (2019) conducted the first study comparing antioxidants and mineral profiles of summer leafy vegetables at both microgreen and mature stages. They found that mature stages had higher antioxidant content and activity compared to microgreen stages. However, microgreens were identified as richer sources of potassium (K) and zinc (Zn). No specific trend was observed for copper (Cu), iron (Fe) and manganese (Mn) content. Consequently, the experiment concluded that for dietary antioxidants, leafy vegetables at mature stages should be consumed for better health, while microgreens should be preferred for mineral intake.

So not all studies agree on the extent of the difference in nutrient content. Some research suggests that mature crops may sometimes contain similar or even higher levels of certain nutrients Microgreens often have a stronger flavour compared to mature plants, which can be a positive or negative aspect depending on individual preferences.

Balancing Organoleptic and Nutritional Factors

Harvesting microgreens requires a keen eye and attention to detail, as there isn't a specific stage akin to traditional crop harvesting (Franks and Richardson, 2009.). Instead, the decision to harvest microgreens hinges on assessing both organoleptic (sensory) and nutritional components to pinpoint the optimal stage.

Organoleptic factors such as colour, flavour, aroma and texture play a crucial role in determining readiness for harvest (Adewoyin, 2023). Microgreens should exhibit vibrant hues indicative of their specific plant variety, along with a fresh and appealing aroma (Partap *et al.*, 2023). The leaves should be tender yet crisp, providing a satisfying texture when consumed.

Nutritional considerations are equally important. Microgreens reach their peak nutritional potency at different stages of growth, depending on the plant variety. The ontogenetic stages for harvesting microgreens range from the cotyledonary stage to the emergence of the second true leaf (Kyriacou *et al*., 2021). Typically, microgreens are harvested when they have developed their first true leaves, which are the second set of leaves to emerge after the cotyledons (Wikipedia). At this stage, they typically contain higher concentrations of vitamins, minerals and phytochemicals, making them nutritionally dense (Paradiso and Renna, 2021)

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Harvesting at the optimal stage ensures the microgreens offer the best combination of flavour and nutritional value (Hendriks, 2021) It's a delicate balance that requires careful observation and timing to achieve the desired outcome.

Home gardening: From a home gardening perspective, microgreen farming not only provides consumers with essential nutritious foods but also offers an excellent hobby and healthy activity for people of all ages during their leisure time. It serves as an excellent means of recreation and exercise for family members. Vegetables grown at home with one's own labor have a special appeal to the palate, and the pleasure and satisfaction derived from this activity are priceless. Additionally, home gardening is an ideal way to teach children responsibility and organization.

Commercial Microgreen Farming:

The rich flavour and nutrient density of these miniature plants have propelled their popularity, becoming sought-after additions to salads, sandwiches and garnishes in upscale restaurants and health-conscious markets (Ebert *et al.*, 2022). This demand has created a substantial market for growers, particularly in tier-1 cities, where the trend toward healthier eating and gourmet culinary experiences is most pronounced (Paraschivu, 2022)

In developing countries like India, where the majority of microgreens are imported, they often come at a higher price and incur a significant 40% loss when supplied to hotels. However, an article from the Economic Times highlights how First Agro, a Bangalore-based company, has addressed this challenge. They have ventured into producing exotic greens and have successfully established partnerships with prestigious hotels such as Ritz Carlton, JW Marriott, Hyatt, Oberoi, and Taj.

Recognizing the increasing demand for fresh produce in the hospitality sector, First Agro launched Chef Garden, a dedicated business unit targeting large hotel chains. By locally sourcing their produce, they not only ensure freshness but also gain better control over wastage. This strategic approach is in line with the trend among five-star hotels to either cultivate their own vegetables or procure them from local growers as a cost-saving measure.

Cultivation: In urban environments where resources are limited, special attention is given to cost-effective methods for producing microgreens.

Selection of Crops: All Crops are not economical for commercial microgreen production. Some commercial microgreens are Arugula, Radish, Cilantro, Peas, Broccoli, Basil etc. which are commonly used by chefs (EUTM Organics).

Growing Environment: Microgreens are commonly cultivated for commercial purposes using soil-less farming systems or mist chambers in trays (Bhaswanth *et al*., 2023).

Commercial microgreen farming in soil-less systems involves selecting a suitable growing method like hydroponics or aeroponics, setting up a growing area with appropriate lighting and racks and choosing inert mediums such as coco coir or rockwool. Nutrient solutions are prepared and delivered to the plants, ensuring optimal growth conditions. Germination, seeding and maintenance are closely monitored to promote healthy growth and prevent nutrient imbalances and pests (Ampim *et al*., 2022). Harvested microgreens are packaged and distributed to various markets. As demand increases, growers can scale up their operations by investing in additional equipment and space. This approach allows for efficient, year-round production of high-quality microgreens while minimizing resource use and environmental impact.

Growing microgreens in trays within a mist chamber cooled with a fan and pad system, with trays arranged in racks, is a sophisticated method that optimizes growing conditions (Robert and Elsa) The mist chamber maintains high humidity levels essential for germination and growth, while the fan and pad system regulate temperature, creating an ideal microclimate (Shamsheri, 2007). Trays are organized in racks, maximizing space utilization and facilitating efficient airflow around the plants. This setup ensures consistent moisture levels, proper airflow and temperature control, promoting healthy and uniform growth of microgreens.

In this setup, inert growing media like coco coir, rockwool, or peat moss are commonly used. These media offer a stable base for the roots of microgreens and facilitate efficient nutrient absorption. Moreover, they have excellent moisture retention properties, ensuring consistent hydration for the growing plants. Additionally, these media are sterile and devoid of pests and diseases, promoting a clean and healthy growth environment.

However, according to Arif Sadik *et al*. (2019), the optimal medium for microgreen farming in trays or beds is a mixture of cow dung and soil. This combination offers advantages such as high-water retention capacity, improved root penetration and increased nutrient availability.

Vertical Stacking:

Many microgreen farmers enhance space efficiency by stacking trays vertically. Typically, microgreen trays are arranged on 4 to 6-shelf racks made of metal or plastic, with lighting strips mounted under each shelf. Vertical stacking can be utilized in both soil-based and soilless growing systems, optimizing the use of available space. However, it is crucial to evaluate the growing environment to ensure it is practical and safe for farmers to access higher shelves multiple times throughout the day.

Deep Water Culture:

An alternative to vertical stacking is the deep-water culture (DWC) method, suitable for both hydroponic and aquaponic systems. In this approach, small net pots or trays containing the growing medium and seeds are placed directly into a large tank, giving plants direct access to a water source. This method is often more cost-effective due to its simplicity, requiring minimal maintenance once established and involving fewer components. However, regulating water temperature and pH levels can be challenging, potentially affecting plant growth.

Irrigation: In commercial Farming instead of direct watering Misting is done to the trays @ 50 ml water per tray (Rani *et al*., 2019) which increases the water use efficiency and reduce cultivation cost.

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Manuring and Fertilization: Unlike mature crops, microgreens require minimal fertilizers since most essential nutrients are already present in the seeds themselves. Therefore, sustainable agricultural practices like organic farming can be effectively implemented without concern for yield loss.

In soilless farming, nutrient solutions are frequently incorporated into the water utilized for misting or irrigation in microgreen cultivation. These solutions are carefully formulated to encompass crucial macro and micronutrients necessary for strong plant growth, including nitrogen, phosphorus, potassium, calcium, magnesium and trace elements. They are customized to suit the unique needs of the microgreens being grown. Through vigilant monitoring of pH levels and nutrient concentrations, growers maintain proper nutrient uptake and prevent any imbalances. This approach affords precise control over nutrient delivery, thereby promoting robust growth and optimizing nutrient absorption by the plants.

Bulk ordering of seeds and seed multiplication are indeed positive approaches to reduce the cost of cultivation in commercial microgreen farming

Bulk Ordering of Seeds:

By purchasing seeds in bulk quantities, growers can often negotiate lower prices per seed, reducing the overall cost of production. This approach is especially beneficial for popular microgreen varieties that are frequently used in commercial cultivation. Additionally, bulk ordering allows growers to plan their seed supply for multiple growing cycles, ensuring continuity of production and minimizing the risk of running out of seeds during peak demand periods. Moreover, bulk ordering may also provide access to discounts, promotions, or special deals offered by seed suppliers for large-volume purchases, further enhancing cost savings.

Seed Multiplication:

Seed multiplication involves producing your own seeds from the initial seed stock, either through traditional seed saving methods or through controlled breeding and selection processes. This approach offers several advantages for commercial microgreen farming. Firstly, it reduces reliance on external seed suppliers, providing greater control over seed quality, availability, and pricing. Secondly, seed multiplication allows growers to adapt and tailor their seed varieties to specific growing conditions, customer preferences, and market demands. Additionally, by selecting and propagating seeds from the best-performing plants in each growing cycle, growers can gradually improve the genetic traits and performance of their microgreen varieties over time, enhancing overall crop yield, quality, and profitability.

Bulk ordering of seeds enables growers to capitalize on economies of scale, leveraging their purchasing power to negotiate lower prices and secure a steady supply of seeds for their commercial microgreen operations. By buying seeds in larger quantities, growers can benefit from reduced per-seed costs, making cultivation more cost-effective and financially sustainable in the long run (Jones *et al., 2001*). Furthermore, seed multiplication empowers growers to become more self-sufficient and independent in their seed sourcing, reducing their reliance on external suppliers and mitigating the risks associated with fluctuations in seed availability and prices. Through careful selection, propagation, and improvement of their own seed stocks, growers can optimize the performance, resilience, and profitability of their microgreen crops, reinforcing the economic viability and competitiveness of their commercial farming ventures. Overall, both bulk ordering and seed multiplication strategies contribute to cost reduction, supply chain resilience, and long-term success in commercial microgreen cultivation.

In addition to bulk ordering and seed multiplication, commercial microgreen farmers can employ various strategies to enhance cost-effectiveness and profitability. These include efficient resource utilization through techniques like vertical farming and automation, implementing integrated pest management practices, leveraging cooperative purchasing arrangements, diversifying product offerings, exploring value-added products, utilizing direct marketing channels, and continuously improving production practices and business operations (Hati and Singh 2021). By combining these strategies, growers can optimize resource use, minimize costs, and maximize revenue, thereby strengthening the economic viability and competitiveness of their commercial microgreen farming operations.

Limitations of Microgreens:

Producing microgreens demands significant quantities of seeds, leading to higher costs. Moreover, they should exhibit high purity levels and be free from pathogenic bacteria or moulds to ensure optimal growth and food safety (Stoleru *et al*., 2016). Also, according to Warriner *et al*. (2003) found that microgreens are more susceptible to bacterial infiltration than mature plants. Bacteria from seeds can integrate into the plant's internal microbial community during germination (Acuña *et al.,* 2023). Despite protective border cells, bacteria can enter through germinating radicals or secondary roots, persisting locally. Unlike mature plants with a Casparian strip barrier, immature plants lack full protection, allowing bacterial penetration into the xylem (Calvo-Polanco *et al.,* 2021).

Microgreens have a very limited shelf life, typically lasting only 3-5 days under optimal conditions (Mir Shah & Mir, 2017). To extend their freshness, it's recommended to keep them with their roots intact in their growth medium and refrigerate them. Depending on the variety and storage conditions, microgreens can maintain their quality for over 14 days. However, exposure to temperatures below freezing can cause damage, and high humidity levels promote microbial growth and decay (Zagory & Kader, 1988). Therefore, it's essential to use a combination of proper refrigeration and modified atmosphere packaging (MAP) to minimize respiration rates, moisture loss and microbial contamination (Berba & Uchanski, 2012; Zagory & Kader, 1988). Moreover, research suggests that cultivating microgreens under specific light conditions, such as a blue/red light combination (B:2R), enhances the synthesis of beneficial compounds. Immediate consumption after harvest is also recommended to retain the highest quantity and quality of microgreens, especially in household farming settings (Mlinarić *et al.*, 2023).

Promoting the benefits of microgreens and urban agriculture is the need for comprehensive education and awareness campaigns (Enssle, 2020). Without widespread dissemination of information regarding the nutritional value, sustainability and accessibility of microgreens, individuals may lack awareness of their potential benefits. Additionally, limited understanding of urban agriculture initiatives could hinder community engagement and participation in local food production efforts. Overcoming this limitation requires dedicated resources and efforts to develop and implement effective educational programs and outreach strategies, thereby empowering individuals to make informed choices and actively support urban agriculture endeavours (Baudoin and Drescher, 2008)

Common Pests and Diseases: Common pests that can affect microgreen farming include aphids, thrips, fungus gnats, spider mites and whiteflies (Rao *et al.*, 2023). Aphids are small insects that feed on plant sap and can spread diseases, while thrips leave silver streaks on leaves and can transmit diseases. Fungus gnats lay larvae that feed on plant roots, weakening the plants, and spider mites suck sap from leaves, causing yellowing. Whiteflies also feed on plant juices and can transmit diseases.

Common diseases in microgreen farming include damping-off, powdery mildew, and root rot. Damping-off is a fungal disease that affects seedlings, causing wilting and collapse. Powdery mildew manifests as white spots on leaves and reduces photosynthesis. Root rot, another fungal disease, decays the plant's root system, leading to poor nutrient uptake and wilting (Vertical Farm Daily)

Preventive Measures: Maintaining sanitation is crucial in microgreen farming to minimize the risk of disease transmission. Keep growing trays, equipment and growing media clean and sterile. Ensure proper ventilation to reduce humidity and prevent fungal diseases like damping-off and powdery mildew. Regularly monitor microgreens for signs of pests or diseases and take prompt action if needed. Consider using biological controls such as ladybugs or predatory mites to manage pest populations naturally. Utilize organic pest control methods like neem oil, insecticidal soaps, or diatomaceous earth (Sprout small farms). Opting for well-draining soil or growing media to prevent waterlogged conditions and root rot (Sharma and Gaurav, 2022). Implement crop rotation to disrupt pest and disease cycles. By adhering to these practices and remaining vigilant, you can effectively prevent and manage common pests and diseases in microgreen farming.

Market Analysis: In their 2020 study, Michell et al. evaluated consumer acceptance and sensory perceptions of six microgreens species, finding high overall acceptability. The mean liking scores ranged from 6.0 (slightly acceptable) to 7.9 (acceptable). Red-coloured species such as bull's blood beet, red cabbage, and red garnet amaranth received the highest appearance ratings, while tendril pea scored the highest for flavour (7.8). Arugula had the lowest flavour acceptability (5.8) and the highest ratings for astringency, bitterness, sourness, and heat. Females generally rated appearance and texture higher than males, especially for arugula and broccoli. Participants' familiarity with microgreens was moderate, with most encountering them in markets, restaurants, or through media. Food neophobia negatively impacted acceptability, indicating that openness to new foods enhances the acceptance of microgreens. Principal component analysis showed that overall acceptability was positively associated with favourable sensory attributes like sweetness and texture and negatively with bitterness and sourness. These findings underscore the need for consumer education on the benefits and uses of microgreens to enhance their market appeal. Future research should investigate the bioactive compounds in microgreens and their sensory perceptions across diverse populations, considering factors such as cost, availability, and sustainability to promote wider consumption, particularly in urban areas where finding nutritious food is increasingly challenging due to the prevalence of adulterated foods.

Conclusion:

In conclusion, this article highlights the pivotal role that microgreens play in urban agriculture and the advancement of sustainable food systems. These tiny, nutrient-dense plants offer exceptional nutritional value, providing concentrated amounts of vitamins, minerals and antioxidants that surpass those of their mature counterparts. Their culinary versatility makes them a valuable addition to a wide range of dishes, enhancing both flavour and visual appeal.

Microgreens' efficient cultivation methods, such as hydroponics and vertical farming, are particularly well-suited for urban environments where space and resources are limited. These methods maximize resource efficiency, conserve water, and reduce the reliance on conventional agricultural inputs, making microgreens an ideal solution for addressing food security challenges in densely populated areas.

By harnessing the potential of microgreens, we can significantly improve the nutritional quality of our diets and contribute to the development of innovative, sustainable agricultural practices. Furthermore, the integration of microgreens into urban agriculture can foster community engagement, promote local food production, and reduce the environmental impact associated with long-distance food transportation.

Embracing microgreens in urban agriculture represents a significant step towards creating a healthier, more resilient food system that benefits both people and the planet. As we continue to face global challenges related to food security and sustainability, the adoption of microgreens can play a crucial role in building a sustainable future for urban communities.

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