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Vegetable microgreens: A superfood with potential health benefits

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Abstract
In the culinary arts, microgreens are regarded as a novel specialty product. The stem, completely developed cotyledons, and occasionally the first two genuine leaves in the early stages of development make up this horticultural product. Microgreens can be cultivated using seeds from various vegetable species, fragrant herbs, and wild herbs, providing the culinary sector with new flavour, colour, and texture ingredients. When compared to fully grown environmentally friendly plants, microgreens appear to be more common because of their higher concentration of bioactive elements that are good for human health and wellness, such as minerals, antioxidants, anti-carcinogenic activity, anti-inflammatory, anti-diabetic, antimicrobial, anti-obesity, and vitamins. Microgreens can be generated in a range of conditions and are cultivated utilizing a variety of materials and techniques. Microgreens require a number of essential resources to flourish, including trays, growing media, light, water and seeds. There are soil-based and soilless production techniques, including as hydroponics. Lastly, microgreens are cultivated inside, in greenhouses and in urban agricultural settings such as shipping containers. Considering that microgreens are collected when their leaves are still fragile, their storage shelf life is a major concern. The rapid deterioration of product quality and short shelf life of microgreens provide challenges to their industrial processing and commercialization. Although harvested microgreens have a short shelf life due to various factors such temperature, relative humidity, kind of packaging film, and microbial load, the problem can be partially resolved. Microgreens can have their shelf life extended by a variety of methods. Storage temperature and storage atmospheric conditions are two crucial methods utilized to increase the shelf life of microgreens. The advantages of eating microgreens for your health are still up for dispute. The high productivity of microgreens can be leveraged to address the world's expanding food need. Because of their brief growing season, these greens can be an effective weapon in the fight against food insecurity.

Keywords: Microgreens, environmentally friendly, bioactive elements and hydroponics etc.

Introduction
During covid-19 world has realised the value of strong immunity and good health. People are now concerned about their food intake and health. Nowadays, chronic diseases such as heart attack, cancer, diabetes, osteoarthritis, Alzheimer's, and Parkinson's were a few decades ago thought to be primarily a concern of the elderly population. Microgreen farming is gaining popularity in recent years, it is due to increase in public awareness of healthy eating, numerous health-beneficial effects of Microgreens and disease preventing properties. Microgreens were first conceptualized in San Francisco, California, in the late 1980s. Since then, they have become a popular and innovative culinary component found in some of the best restaurants and high-end grocery shops worldwide (Treadwell, Hochmuth, Landrum and Laughlin, 2010) [41]. According to Global Opportunity Analysis and Industry Forecast, 2021-2028, the global microgreens market size was valued at $1.3 billion in 2019, and is projected to reach $2.2 billion by 2028. There is about 11.1% increase in Compound Annual Growth Rate from 2021 to 2028. The high productivity of microgreens can be leveraged to address the world's expanding food need. Because of their brief growing season, these greens can be an effective weapon in the fight against food insecurity.

What is microgreen?

Microgreens are tender, fresh-cut product, immature miniature greens produced from vegetable seeds, herb seeds, grain seeds or the wild relatives (Kyriacou *et al.*, 2016[a]) [27]. Microgreens are new class of edible vegetable and are also called "Functional food" (Kyriacou *et al.*, 2017[b]) [26]. Microgreens are older than "sprouts" and younger than "baby greens" (Murphy *et al.*, 2010; Renna *et al.*, 2017) [32, 13]. Microgreens are different from sprouts; they are grown in water whereas microgreens require soil or other growing media. Sprouts are typically developed in dark, damp environments that are unlike micro- and baby-greens (Treadwell *et al.*, 2010) [41]. Microgreens have strong aromatic flavour, concentrated nutrient content and used for garnishing. Microgreens are grown under greenhouses, indoors, rooftops, balconies, windowsills or as urban farming in shipping containers with and without soil hydroponically or by the use of any other growing media (Enssle, 2020; Samuolien *et al.*, 2017) [18, 15]. Microgreens are harvested at the soil level when the seedlings attain height of 2-3 inches stem and have fully expanded cotyledons and first true leaves (Sun *et al.*, 2013) [40]. Microgreens generally takes 7-21 days from seed germination to harvesting depends upon the species. The major constraint with the microgreens is their short shelf life and quick deterioration of product quality which hampers marketing and processing of microgreens (Stoleru *et al.*, 2016) [39]. Families which are exploited as microgreens are Brassicaceae, Asteraceae, Chenopodiaceae, Lamiaceae, Apiaceae, Amarillydaceae, Amaranthceae, Cucurbitaceae, Linaceae, Fabaceae, Asteraceae, Pedaliaceae and Poaceae (Parida, 2020, Caracciolo *et al.*, 2020) [33, 6]. One can include microgreens in their diet by incorporating it into a range of foods, such as salads, wraps, and sandwiches or can be used as toppings for heated dishes like pizza, soups, omelets, curries, or blended into smoothies or juices.

Microgreens Market

Source: Global Opportunity Analysis and Industry Forecast, 2021-2028

Source: Parida, S. (2020) [33]

Why to grow microgreens?

People all over the world are gradually realizing the advantages of including leafy greens and microgreens in their diets, which will ensure that demand will

expand. Agriculture will likely move indoors in the future because we are witnessing an increasing number of issues and crop failures with vegetables cultivated outdoors. Some other benefits of growing microgreens are:

- **Low investment:** Since microgreens develop quickly and don't require many inputs, there is no need to invest in pesticides, fertilizers, insecticides, or other cultural activities.
- **Easily grown in urban and peri-urban locations**: Microgreen farming is a great option for those who live in urban areas where space constraints make gardening or farming difficult (Chandra, Kim and Kim, 2012; Kou *et al.*, 2013) [7, 24].
- **Fast turn-around time:** Microgreens grow quickly, usually taking only two or three weeks to mature and harvest.
- **Year-round growth:** Water, adequate lighting, trays, and tables for plant setup are the only necessities for microgreen farming. Because microgreens can be cultivated in controlled environments, all season crops can be produced year-round (Yadav K, 2021, Benke and Tomkins, 2017; Choe *et al.*, 2018; Mir *et al.*, 2017; Weber, 2017) [48, 3, 8, 31, 44].
- **Higher nutrition:** Microgreens contain a wide range of easily absorbed vitamins, minerals, and phytonutrients, making them a nutrient-rich diet. They have a nice flavor, color and texture in addition to nutrients and active enzymes (Ebert, 2012) [17].
- **Grown with or without soil:** Soil is not necessary for the cultivation of microgreens.
  The ideal growth conditions for microgreens include cocopeat-based growing media combined with compost, vermicompost, and peat moss, among other ingredients. Microgreens can be grown directly in water in hydroponic systems.
- **High-value crop:** Packed with vitamins, minerals, and antioxidants, microgreens are superfoods. They are believed to be healthier or to offer more health benefits, consumers frequently are willing to spend more. Because of their high vitamin content, microgreens are occasionally marketed as superfoods, which drives up their cost. (Chandra, Kim and Kim, 2012; Kou *et al.*, 2013) [7, 24].

Materials and Equipment required for large-scale microgreens farming

To ensure successful production, large-scale microgreen farming involves meticulous planning, as well as the appropriate supplies and tools. The following is a list of supplies and machinery needed for commercial microgreens farming: Growing trays, growing medium, seeds, watering system, greenhouse or growing space, lighting, ventilation system, temperature and humidity control, shelving or racks, pH testing kit, fertilizer, pest control supplies, harvesting tools, packaging materials, record-keeping system, workbench or potting bench, water storage and filtration, seed storage and waste disposal system.

How to grow microgreens?

Commercial microgreens farming requires careful planning as well as the appropriate supplies and tools. Seeds-Premium quality micro green seeds are fit for industrial cultivation (Di Gioia, Mininni and Santamaria, 2015) [12]. Precautionary sanitary treatments should be applied to seeds in order to eradicate pathogens. Preliminary germination test should be conducted for each seed lot in order to optimize the sowing rate. While some species grow slowly, many others germinate quickly (Di Gioia *et al.*, 2015) [12]. Pre-sowing treatments might be necessary to enhance, standardize, and reduce the duration of the production cycle (Lee, Pill, Cobb and Olszewski, 2004). Depending on the production scale, microgreens can be grown in a range of growth systems (soil, soilless), in open air, indoor, or in a protected environment. Containerized production adaptable both to small-scale urban and large-scale commercial operations allowing the product to be harvested directly by the end user (Di Gioia *et al.*, 2015) [12]. Shallow trays with drainage holes to hold the growing medium and microgreens. There are several ways to grow microgreens, including soil, tissue paper, cocopeat, peat moss, perlite, vermiculite, textile-fibre mat, biodegradable mat containing jute, rock, wools and hydroponics etc. (Isik *et al.*, 2020) [48]. However, in general, a mixture of perlite, vermiculite and coco-peat can be utilized in a 5:2:1 ratio to cultivate microgreens (Yadav K, 2021; Isik *et al.*, 2020) [48]. The ideal growing media should have good water holding capacity (55-

70% v/v), pH of 5.5-6.5, aeration (20-30% v/v), and low electrical conductivity (<500 mS/cm) (Abad, Noguera and Bures, 2001) [1]. In most cases, microgreens seed require ideal environmental conditions with the right amount of moisture and an appropriate temperature to germinate and grow up to the microgreen stage which makes the production of microgreens easy and cost-effective (Yadav K, 2021) [48]. Most of the species of microgreens are harvested when the first true leaves appear, the seedlings are 5 to 10 cm tall, and the cotyledons are fully extended but still turgid and keep their characteristic colour. Generally, harvesting in the morning time is advised as the crop seedlings during the morning hours have higher moisture content and respire more slowly in the morning (Saini *et al.*, 2017) [14]. Harvesting is carried out manually using sharp scissors or a harvesting knife for efficient and clean harvesting, or mechanically chopping the seedlings a few millimetres above the surface of the growth medium excluding growing media particles and seed integuments that remains attached to the cotyledons in some species (Di Gioia *et al.*, 2015) [12]. Microgreens are highly perishable, need to be handled carefully as soon as they are harvested. After harvesting, microgreens should be cleaned, dried, and stored in a cold, dark place. The ideal materials to keep harvested microgreens are those that are moisture-resistant and breathable. Popular choices for microgreens' packaging include: Microgreens clamshell containers, biodegradable microgreens packaging bags, resealable bags, vacuum-sealed bags, plastic trays with lids, paper cartons. Temperature has the most impact on rate of microgreens deterioration after harvest while it also interacts with the effects of ethylene and of reduced pO2 and elevated pCO_2 in the product environment (Kader, 2002; Kou, Luo, *et al.*, 2014) [23, 46]. Temperature directly affects the microgreens storage performance by regulating the rate of respiratory and metabolic activities related to the process of senescence (Xiao, Luo, *et al.*, 2014) [46]. The shelf-life of microgreens is about 2-4 days at room temperature and may reach 10-14 days at 5 °C (Chandra *et al.*, 2012; Kou *et al.*, 2013; Yang, *et al.*, 2015) [7, 24, 49]. Microgreens need better storage and transportation techniques because they have a short time span of usability. Microgreens for business purposes are usually stored in clamshell plastic containers. There are other biodegradable clamshell containers also available in market (Yadav K, 2021) [48].

Source: homemicrogreens.com

Health-beneficial effects of microgreens

Microgreens are packed with nutrients, antioxidants, minerals, and vitamins. When compared antioxidants are abundant in several microgreens, including kale, broccoli, and radish. By assisting the body in combating free radicals, antioxidants help lower inflammation and oxidative stress (De La Fuente *et al.*, 2020) [10]. Microgreens also promote heart health, possess anti-carcinogenic, anti-inflammatory, antidiabetic and anti-obesity properties (Xiao *et al.*, 2019) [47]. Certain microgreens, such as broccoli and red cabbage, have ingredients that may help decrease cholesterol, which is good for the heart. Broccoli, cauliflower, and Lepidium are high in glucoraphanin, a chemical that has anticarcinogenic properties when converted into sulforaphane. Microgreens are a great way to get important vitamins and minerals like beta-carotene, folate, vitamin C, vitamin K, and vitamin E. Dietary fibre, which is present in microgreens, can facilitate better digestion and support gut health. In order to sustain regular bowel motions and promote overall digestive health, fibre is crucial. Research indicates that certain microgreens, such as radish and broccoli, may contain substances that have the ability to fight cancer. These substances might aid in preventing the spread of cancer cells. Microgreens are full of low-calorie supplement to meals. They can be added to many different recipes without drastically increasing calorie intake. Certain microgreens, like cilantro and fenugreek, may have qualities that assist control blood sugar levels, which is advantageous for those who have diabetes. Microgreens of kale and red spinach exhibit slightly greater antimicrobial activity than mature plants against specific pathogenic microorganisms (Huang, 2016) [22]. Thus, strengthen immune system. Jiang, *et*

al., (2016) [22] further demonstrated that consumption of red cabbage micro green decreases blood lipid levels. Huang *et al*., (2016) [22] examined the glucosinolate content of mature red cabbage and microgreen cabbage. The findings showed that the content in microgreens was two times greater (17.1 µmol/g) than their mature counterparts' 8.3 µmol/g. The highest total phenolics content (TPC) was found in pearl millet microgreens. The ascorbic acid content was highest in red cabbage. The total anthocyanin content was estimated in all six selected microgreens, and observed the highest content in red radish. Phytic acid contents were reduced in the microgreens as compared to the content in their seeds (Dhaka *et al.*, 2023) [11].

Commercially grown microgreens with their nutritional and phytochemical importance

Common name	Nutritional components	Phytochemical components
Basil	Vitamin K, Ca	Total ascorbic acid, phylloquinone, carotenoid, tocopherol, total phenols
Radish	Vitamin (E), carbohydrates, protein and minerals (Ca, K and P, Mg, Se and omega-3 fatty acids than mature vegetable	Carotenoid, ascorbic acid, amino acid content, total phenols, flavonoid and anthocyanins, tocopherol (Xiao *et al.*, 2019; Xiao *et al.*, 2014) [47, 46]
Lettuce	Minerals (Ca, Mg, Fe, Mn, Zn, Se and Mo)	Polyphenols, carotenoids and chlorophyll (Pinto *et al.*, 2015) [34]
Carrot	Vitamin A, Beta-carotene	Anthocyanin and carotenoids, lutein and zeaxanthin.
Cauliflower	Fe, Vitamin C, K and E.	Polyphenols, anthocyanin, flavanol, glycosides, hydroxybenzoic acid, Ascorbic acid (Xiao *et al.*, 2019) [47]
Celery	Vitamin A, E and K, and Ca, Mg and Fe	phytochemical content, antioxidant activity
Chickpea	Carbohydrates, proteins, fat, fiber, pantothenic acid (B_5) and pyridoxine (B_6)	Carotenoids, lutein, isoflavones
Fenugreek	Potassium, and minerals (K, Ca, Na, Fe and Cu)	Phytochemical content, antioxidant activity (Turner *et al.*, 2020; Marchioni *et al.*, 2021) [42, 30]
Arugula	Phylloquinone, and β-carotene, linolenic acid Calcium, Potassium, Folate, Vitamin C, Vitamin K, Vitamin A	Glucosinolates, ascorbic acid and total carotenoids (De La Fuente *et al.*, 2019) [10]
Broccoli, daikon, mustard and watercress	Vitamins (E, A, K), minerals (N, K, Ca, Fe) and chlorophyll contents	Carotenoid, Isothiocyanates polyphenols, anthocyanin, monoterpene hydrocarbons, phytol and ascorbic acid, indole-3-carbinol, diindolylmethane, glucoraphanin, or oxazolidines (Choe *et al.*, 2018; Sun *et al.*, 2013) [8, 40]
Chicory	Minerals (Mg, Zn), protein, vitamins (A) and minerals (K, Ca and P)	Total flavonoids, total phenolic, Ascorbic acid
Coriander	Vitamins A and minerals	Carotenoids, phenols, vitamin C and flavonoids
Lettuce	Minerals (Ca, Mg, Fe, Mn, Zn, Se and Mo)	Polyphenols, carotenoids and chlorophyll (Pinto *et al.*, 2015) [34]
Amaranthus, Bottle gourd, cucumber, palak, poi, pumpkin, radish and water spinach	Minerals (K, Fe, Mn, Zn and Cu)	Phenolics, flavonoids and ascorbic acid (Turner *et al.*, 2020; Marchioni *et al.*, 2021; Bergquist, Gertsson, & Olsson, 2006; Kou *et al.*, 2014[a]) [42, 30, 5, 46].
Purple kohlrabi	Ferulic acid, Kaempferol, Quercetin (Hedges & Lister 2009) [21]	
Sunflower	Rich in fibers, protein, ascorbic acid,	α-tocopherol, β-carotene, lutein and chlorophyll (Dalal *et al.*, 2020; Ghoora *et al.*, 2020[a]; Ghoora *et al.*, 2020[b]) [9, 19, 20]
Red Cabbage	Ascorbic acid, Phylloquinone, β-carotene, Tocopherol, Glucoraphanin, lutein/ zeaxanthin (Huang *et al.*, 2016; Xiao *et al.*, 2012; USDA, 2011; Berba, and Uchanski, 2012; Podsedek *et al.*, 2006; Singh *et al.*, 2006) [22, 45, 43, 4, 35, 38].	

Future prospects of microgreen farming

Understanding market integrity is crucial to growing microgreens as a major gardening crop, further integrating them into the world food chain, and evaluating and disseminating their health benefits. Taste and preference are significant factors influencing customers' food purchases (Drewnowski and Gomez Carneros, 2000) [16]. In addition to giving more details about their nutritional characteristics might provide health-conscious consumers with more purchasing ideas (Asioli *et al.*, 2017) [2]. It is anticipated that in the near future demand for natural foods like microgreens is expected to increase. Thus, crop breeders and food technologists shall collaborate to enhance the nutritional, functional, and shelf-life qualities of the current crops and provide the health-conscious customer with the highest quality microgreens.

Conclusion

Small-scale and urban farmers are increasingly turning to microgreen production. Microgreens may be cultivated year-round utilizing a variety of techniques, have a low initial cost, consume little space and resources, have a rapid turnover rate, and are typically very profitable. Microgreens could be a great, cost-effective method to supply city families with seasonal, fresh, local, leafy vegetables that are friendly to the environment. Antioxidants, vitamins, minerals, glucosinolates, polyphenols, and other nutrients that are vital for optimal health can be found in abundance in microgreens. Apart from these, microgreens also possess anti-cancer, anti-inflammatory, anti-fungal, anti-microbial, anti-diabetic, reduction of blood glucose, weight control, cardiovascular diseases prevention and antioxidant properties. In addition to helping to prevent nutritional deficiencies, microgreen farming helps protect farmers' livelihoods during non-cropping seasons. When it comes to fresh and nutritious microgreens, minimal processing and other innovative technical tools can guarantee that the most of the nutrients remains present in the seedlings when the microgreens are consumed. Breeding initiatives should focus on genetic enhancement or utilize native and wild germplasm to choose genotypes with enhanced nutritional and sensory qualities with a long shelf life that can improve the product's

overall quality and prolong its marketing period.

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