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Bioactive Compound of Fenugreek Mustard Coriander Radish Broccoli Microgreens, and their Health Benefits and Growing Techniques

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Abstract: ***Microgreens, the young seedlings of many vegetables and herbs, have developed as a result of the growing interest in functional foods aimed at treating and preventing disease. This study investigates the levels of ascorbic acid, lutein, chlorophyll, phenolic, and flavonoids in fenugreek, mustard, coriander, radish, and broccoli microgreens. Microgreens' health-promoting benefits are attributed to these compounds, which have antioxidant and anti-inflammatory properties. Remarkably, microgreens can be cultivated within 7-21 days, requiring minimal water and space, thus offering sustainable and accessible options for urban and indoor farming. As a nutrient-dense food, microgreens hold potential for human health and sustainable agriculture, due to their nutritional composition. Researchers are investigating these facts and demonstrating their potential to improve nutrient density in diets.***

Keywords: Microgreens, fenugreek, mustard, coriander, radish, broccoli.

1. Introduction

As the population grows and the environment deteriorates, the importance of sustainable agriculture for human nutrition is highlighted. The increasing focus on promoting awareness of healthy lifestyle frameworks in recent years has spurred the exploration of novel food sources that are abundant in essential nutrients and show positive effects on human health.[1] The heavy reliance on fertilizers and pesticides in food production is significantly affecting biodiversity in ecosystems, causing adverse impacts. Mineral malnutrition is recognized as a crucial global challenge for humanity, yet it is a preventable issue. Current initiatives to address mineral malnutrition are concentrated on the advancement of biofortification methods. [2, 3]

In addressing the urgent demand for a sustainable, easily accessible, and highly nutritious food supply in the new century, microgreens appear as a dramatically potent solution.[2] Sprouts and microgreens are a novel approach to functional food, offering diverse advantages from a sustainability perspective, including the elimination of herbicides and pesticides and a reduction in the generation of food waste.[1]

It is a term used to describe early growth stages of pulses, herbs, and vegetables known as microgreens, or vegetable confetti. Microgreens are classified as superfoods owing to their elevated levels of bioactive compounds and rich nutrient content. [4] There are numerous flavours, textures, and vibrant colors to choose from when buying microgreens. Microgreens offer customized nutrition due to their variety and controlled growing conditions. As a result, microgreens appeal to consumers seeking nutrient-dense, unique foods, such as vegans or raw foodists. [5-8]

The first true leaves and horticultural and herbaceous plants juvenile shoots with developed cotyledons are microgreens. In order to make a unique and nutritious culinary addition, microgreens have their roots removed before consumption unlike sprouts. [5] At the first true leaves stage, fresh functional harvested foods are microgreens. Compared with mature plants, higher levels of phytochemicals seen in microgreens at this early stage. [6] A central stem and cotyledon leaf, typically 1 to 2.5 inches long are the three basic parts of microgreens. For urban cultivation, these greens are ideal, minimal inputs needed for the growth of home. For home microgreen farming, microgreens germinate quickly in 7-10 days to serve as excellent candidates. [7] In both Rabi and Kharif seasons, microgreens succeed as well shows adaptability to various environmental conditions. [6]

Ten times more phytochemicals seen in microgreens than seeds and mature plants of the same species. Manganese (Mn), molybdenum (Mo), iron (Fe), calcium (Ca), zinc (Zn), selenium (Se) and magnesium (Mg) are such essential minerals and rich amino acids and low anti-nutrients can be seen in microgreens. Ascorbic acid, polyphenols, carotenoids and anthocyanins are such secondary metabolites are rich in microgreens compared with mature plants. A microgreen, on the other hand, contains a lower level of nitrate than a mature leaf. [5]

The high moisture content of microgreens prevents them from retaining nutrients for long periods of time. Shelf stability is also reduced by their high respiration rate. [4]

Bioactive compounds make microgreens beneficial foods because of their high level of bioactivity. These are sources of protein, lipids, vitamins and carbohydrates. Compared to mature plants, young plants contain more polyphenols,

anthocyanins, carotenoids, and ascorbic acid. They also contain various anti-nutrients and are rich in amino acids and mineral salts (calcium, magnesium, iron, manganese, zinc, selenium and molybdenum) [9]. As standard medicine, light efficiency affects the body and layers of plants from different photoreceptors (phytochromes, cryptochromes, phototropins and UVR8) with sensitivity to different wavelengths. The choice of growing medium should be carefully considered, as it is one of the most important aspects of the production process that affects the results and quality of microgreens [11]. A microgreen's nutritional value must be determined in order to determine its role in our diet.

2. Microgreens vs Sprouts [13,14]

Microgreens	Sprouts
Microgreens are harvested after the first true leaves have appeared.	Sprouts are smaller and grow faster than microgreens.
After a few weeks, microgreens can be harvested from soil or growing medium.	Sprouts are germinated seeds typically grown in water and harvested within a few days.
Upon the appearance of the first true leaves, only the aboveground part of microgreens can be harvested and consumed.	Sprouts are typically consumed whole, including the seed.
A microgreen is grown in sunlight and harvested when its baby leaves are just emerging, so it is as nutritious and flavourful as possible.	Sprouts are cultivated in conditions marked by higher moisture, greatest temperature, and limited light, creating an environment conducive to microbial growth, and raising the risk of contamination.

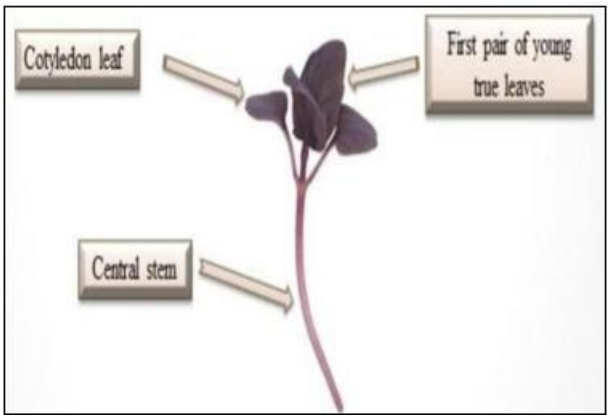


Figure 1: Diagrammatic representation of microgreens [14]

2.1 Microgreens

Commercial name	Coriender	Fenugreek	Mustard	Radish	Broccoli
Family	Apiaceae	Fabaceae	Brassicaceae	Brassicaceae	Brassicaceae
Genus and species	*Coriandrum sativum L*	*Trigonella foenum-graecum L*	*Brassica juncea(L.) Czern.*	*Raphanus sativus L*	Brassica oleracea

2.2 Coriander Microgreens

Often called the “happy herb,” coriander (Coriandrum sativum L.) is a world-famous culinary spice with deep roots in traditional medicine. Known for its diverse phytochemical composition, C. sativum appears to be a beneficial food in the prevention of many lifestyle-related diseases.

Coriander microgreens are immature green leaves that have higher bioactive content than mature leaves, making them a functional food. - tocopherol and phylloquinone. Coriander microgreens contain bioactive substances such as thienopyrimidines, phenylamides, imidazopyridazines, phenolic compounds and essential oils. In contrast to older leaves, cilantro microgreens contain a greater amount of total phenols, flavonoids, steroids, carbohydrates, and proteins. Compared to mature leaves, cilantro microgreens contain lower levels of nitrate.

Phytochemicals	Phenols GAE/g	Flavonoids, mgQE/g	Steroids, mgCE/g	Carbohydrates, mgGE/g	Proteins, mg/g
Aqueous extract	98.25 ± 0.27	119.43 ± 0.36	140.34 ± 0.57	457.65 ± 1.6	156.41 ± 0.38
Ethanol extract	116.78 ± 0.28	29.15 ± 0.26	50.41 ± 0.52	169.73 ± 1.50	101.40 ± 0.37

3. Phytochemical content of coriander microgreens in aqueous and ethanol extract

It is believed that coriander microgreens offer a number of health benefits, including antioxidants, anticarcinogens, antidiabetics, neuroprotectives, anticonvulsants, migraine relievers, hypolipidemics, hypoglycemics, hypotensions, antimicrobials, anxiolytics, analgesics, and antiinflammatory properties. In addition to molybdenum, calcium, selenium, magnesium, manganese, iron, and zinc, microgreens also contain molybdenum (Mo), calcium, and selenium. Compared to mature leaves of coriander, microgreens have lower nitrate levels. This nutritional profile positions

coriander microgreens as a valuable source of health-promoting compounds and essential minerals.[15]

3.1 Fenugreek Microgreens

Microgreens of fenugreek are typically harvested within 5-7 days of seed germination, and they are suitable for raw consumption. [16] Microgreens of fenugreek were found to contain high amounts of AGM, PUT, CAD, SPD, and SPM. AGM (5392 mg/kg), PUT (1079 mg/kg), and CAD (3563 mg/kg) were found in the highest concentrations in sprouts. Also, fenugreek microgreens accumulated significantly SPM (922 mg/kg) and SPD (579 mg/kg). Notably, the polyamine content in fenugreek microgreens proved to be nutritionally helpful, featuring lower CAD levels compared to sprouts. At pH values above 5, fenugreek sprouts degraded exogenous PUT, CAD, and tyramine by enzymatic activity. In summary, fenugreek microgreens stand out as a robust source of bioactive compounds, particularly polyamines, with potential health benefits. [17]

Phytochemicals	Content
Ascorbic acid	67.7 ± 1.8
Lutein	12.6± 0.1
Chlorophyll	59.2±6.
Phenolics	23.5±0.5
Flavonoids	3.8±0.6

Figure 2: Phytochemical content of Fenugreek microgreens. [18]

Table 1: Fenugreek seed, leaf, stem, microgreens.[19]

Fenugreek	Ascorbic acid	Phenolic	Flavonoid	Tannin
Seed	0.14± 0.008	65.7±11.52	18.14±0.51	0.92±0.03
Leaf	0.13±0.007	38.1±1.98	17.13±0.58	0.6±0.008
Stem	0.20±0.003	53.94±11.03	18.27±0.40	0.77±0.03
Microgreen	0.33±0.039	63.91±4.55	19.07±0.20	0.83±0.03

The overall levels of ascorbic acid, phenolic content, flavonoid content, and tannin; content were measured in fenugreek (Trigonella foenum-graecum L.) seeds, stems, leaves, and microgreens [19]. According to the results, it was noted that fenugreek microgreens hold higher levels of total ascorbic acid, total flavonoids, and total chlorophyll compared to other components of fenugreek.[19]

3.2 Elements Present in Fenugreek Microgreens [20]

Growing on Water		Growing on soil	
Components	Quantity (%)	Molecules	Quantity (%)
Si	0.335	SiO_2	21.35
P	0.960	P_2O_5	17.15

Growing on Water	Components	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu	Zn	Br	Rb	Sr	Sm	Re	H2O
	Quantity (%)	0.335	0.96	0.68	0.76	3.798	1.41	0	0.01	0.069	0.003	0.009	6E-04	0.0016	0.001	0.009	3E-04	91.95
Growing on soil	Molecules	SiO2	P2O5	SO3	Cl	K2O	CaO	TiO2	MnO	Fe2O3	ZnO	Rb2O	Eu2O3	CO2	Re	0	0	0
	Quantity (%)	21.35	17.15	8.95	7.86	19.44	20	0.42	0.16	3.8	0.094	0.049	0.743	0	0.017	0	0	0

3.3 Mustard Microgreens

Mustard microgreens are rich in ascorbic acid, carotenoids, phylloquinone, and tocopherols, which contribute to their nutritional value. Consuming mustard microgreens can provide health benefits due to their bioactive compounds, which have protective benefits against chronic diseases such as cancer and cardiovascular disease.[21]

Microgreens	Total Phenolics	DPPH
Mustard	49.3	
Mustard red	208.6±3.8	233.1±16.4
Mustard Dijon	180.9±6.9	249.1±24.7

4. Total Phenolics and Antioxidant Content of Different Mustard Microgreens [22,23]

Mustard microgreens promote blood circulation and are beneficial for combating fever and colds. Microgreens boast higher nutrient levels and lower microbial contamination compared to sprouts.[24]

Table 2: Phytochemical content of mustard microgreens. [18]

Phytochemicals	Content
Ascorbic acid	50.0± 2.1
Lutein	18.3± 0.0
Chlorophyll	52.8±0.0
Phenolics	49.3±0.4
Flavonoids	1.1±0.2

4.1 Radish Microgreen

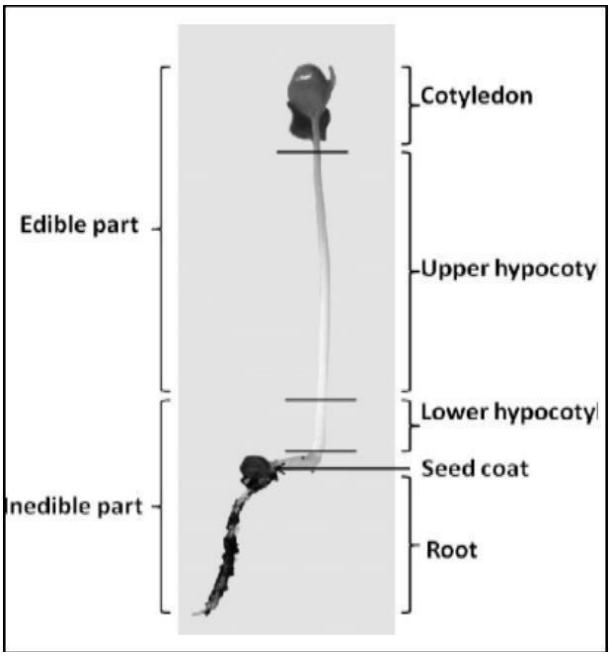
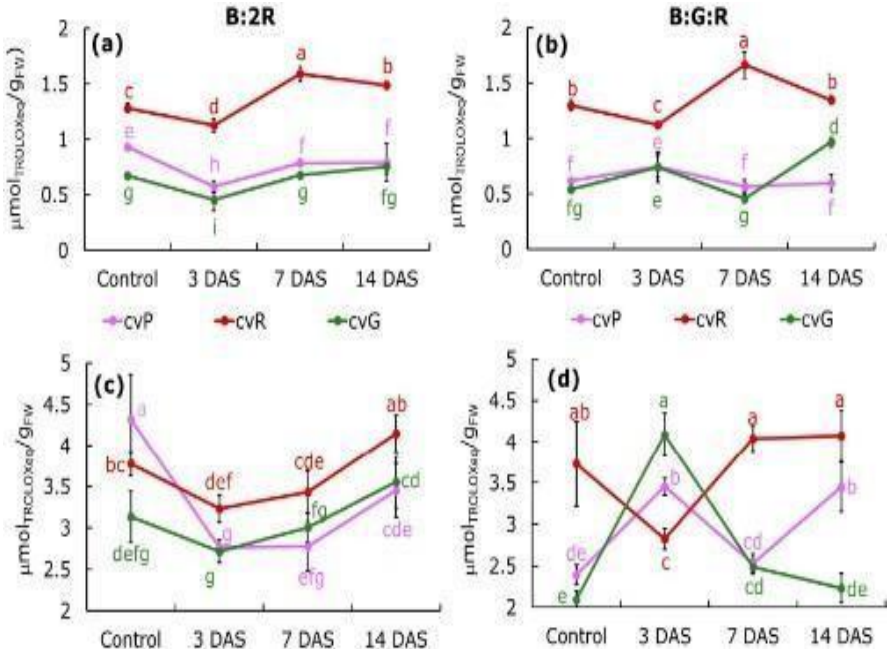


Figure 3: 7days old radish microgreens [2]

Anthocyanins, carotenoids, phenolic compounds, and antioxidants contribute significantly to the nutritional content of radish microgreens. Due to their high concentration of active compounds, such as antioxidants, microgreens from radishes are classified as functional foods. As a result of the type of LED lighting used during cultivation and the radish variety, radish microgreens differ in their antioxidant capability and phytochemical composition. The overall antioxidant potency and presence of bioactive compounds in radish microgreens are subject to measurement and analysis. [26]



The overall antioxidant activity of radish microgreens cultivated under blue/red light (B:2R; (a,c)) and white (B:G: R; (b,d)) light conditions, stored for 0 (control), 3, 7, and 14 days at +4 ◦C, was assessed using DPPH scavenging activity (µmolTROLOXeq/gFW; (a,b)) and FRAP assay (µmolTROLOXeq/gFW; (c,d)). [26].

Table 3: Phytochemical content of Radish microgreens. [18]

Phytochemicals	Content
Ascorbic acid	114.4± 4.2
Lutein	10.7± 4.3
Chlorophyll	50.9±0.4
Phenolics	61.8±4.7
Flavonoids	2.1±0.2

4.2 Broccoli Microgreen

Microgreen broccoli contains soluble protein, soluble sugar, free amino acids, flavonoids, vitamin C, and glucosinolates, while progoitrin is excluded. As sulfur-containing compounds, glucosinolates, found in cruciferous vegetables like broccoli, may have anticancer properties. Moreover, broccoli microgreens contain flavonoids, which have anti-oxidant and anti-inflammatory properties. Ascorbic acid, an antioxidant nutrient that is abundant in broccoli microgreens, is also present. The presence of these active compounds in broccoli microgreens suggests potential health benefits, including antioxidant and anti-inflammatory effects, and protection against certain diseases. [27]

Table 4: Phytochemical content of Broccoli microgreens.[4]

Phytochemicals	Content
Carotene	554.95±6.30
Ascorbic acid	25.16±0.03
Chlorophyll	10.85±0.57
Total phenolic content	2346.46±0.36
Flavonoids	820.24±0.78

Figure 4: 5 Days old Broccoli microgreens [1]

Broccoli microgreens are delicate greens abundant in beneficial bioactive compounds, yet their marketability is compromised because of their brief shelf life and speedy metabolic activity. In order to improve the postharvest quality of broccoli microgreens, ascorbic and citric acids should be applied to them, then they should be stored in 15% CO2 and 5% O2. [28]

5. Health Benefits of Microgreens

Equalize Promising health advantages offered by microgreens due to rich in antioxidants, vitamins and minerals. In order to protect against oxidative stress and inflammation, beta-carotene, vitamin C and vitamin E, are such significant amounts of antioxidative properties given by them. Cancer and heart disease are such chronic ailments risks which can be reduced by microgreens rich in polyphenols. A study suggests microgreens may be nutrient-dense due to their higher nutrient content than mature plants. Microgreens may aid digestion, boost immunity and reduce disease risk. The specific health benefits and effects of microgreens on humans, however, need further study. [29]

In order to give great health advantages, rich antioxidants, vitamins, and minerals seen in microgreens. In order to protect against oxidative stress and inflammation, beta-carotene, vitamin C and vitamin E, are such significant amounts of antioxidative properties given by them. Cancer and heart disease are such chronic ailments risks which can be reduced by microgreens rich in polyphenols. To reduce disease risk, improve digestion and boost immunity, supports by microgreens. In addition to their nutritional value, microgreens may be easier to grow than mature plants. A microgreen's higher nutrient concentration compared to its mature counterpart makes it an ideal dietary choice for those seeking nutrients. In order to determine microgreens' exact effects on well-being and health, more research must be conducted. [2]

As a result of their bioactive compounds, microgreens have a number of health benefits, such as glucosinolates, phenolics, vitamins, and minerals. Oxidative stress is reduced and chronic diseases are protected by their antioxidants. Inflammation may also be reduced by microgreens' anti-inflammatory properties. Infections and harmful bacteria can be prevented by their antimicrobial properties. Obesity-related diseases can be reduced with microgreens. Additionally, they contribute to blood sugar regulation and insulin sensitivity improvement. With antioxidants, high levels of polyphenols, carotenoids, folate, and glucosinolates in microgreens, they support cardiovascular, digestion, and immune health. They hold promise in combating malnutrition, inflammation, and chronic conditions. Recognized as sources of nutritional and bioactive compounds, microgreens can be incorporated into a health-conscious diet.[30]

6. The Impact of Light on the Physiology of Microgreens and their Nutraceutical Quality is Significant [31]

Light is one of the most vital external elements that photosynthetic organisms unquestionably need because it provides them with energy and environmental information. All species that rely on oxygenic photosynthesis need strategies for striking a balance between efficient light collection, photochemistry, and UV protection from intense light. Light intensity and quality influence the face at which photosynthesis occurs in plants and the amount and quality of other organic molecules created, including secondary plant chemicals.

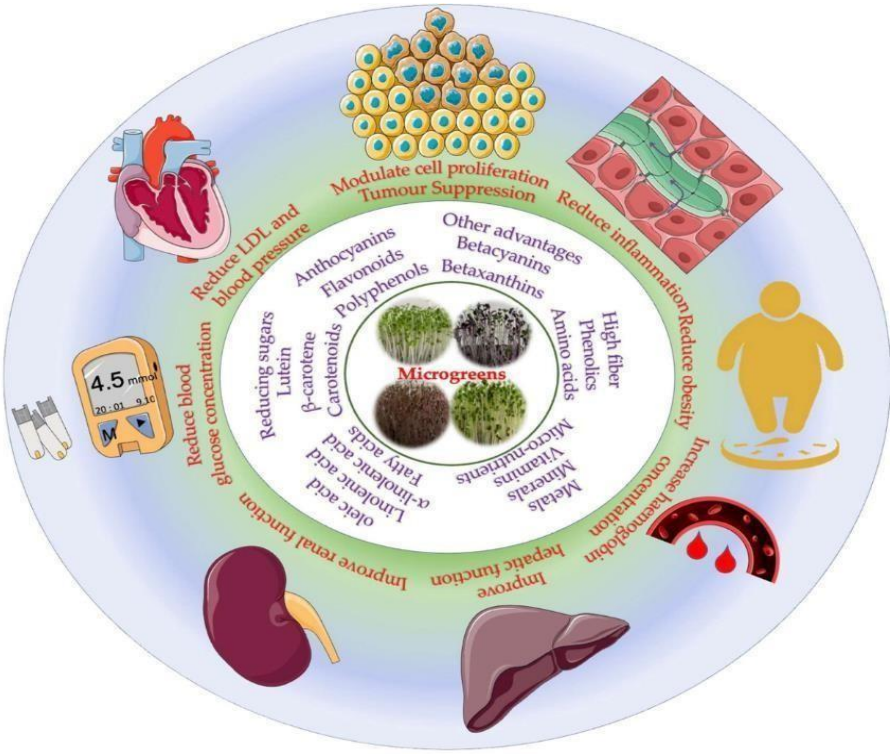


Figure 5: Overview of health benefits of microgreens [30]

Harvesting of Microgreens

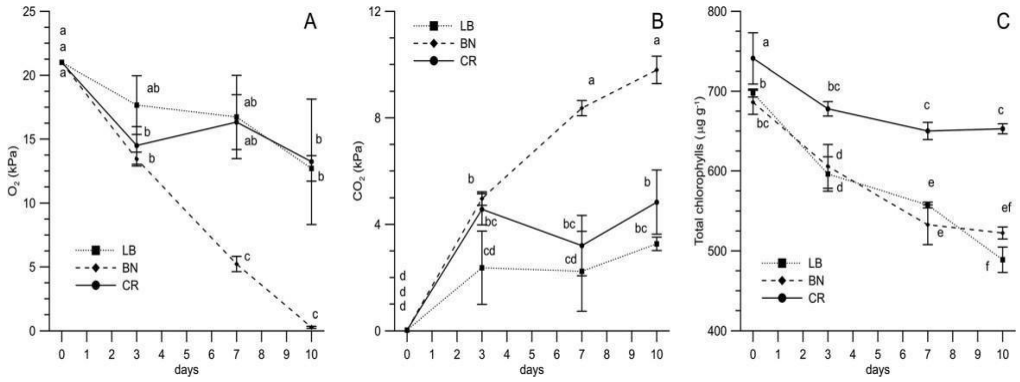
Microgreens cotyledons with stems were taken slightly above the ground following the illumination experiment [32]. The true leaves and cotyledons of microgreens are harvested once they have developed. The first genuine leaf of the crop will be ready for harvesting around 5 cm after it reaches its first stage of growth. In general, crops were harvested between one and three weeks after they were sown. For food safety, microgreens must be handled carefully, including washing and cooling immediately after harvesting [33]. Microgreens' short lifespan does not diminish the importance of their growing medium. The growing medium is one of the primary production expenses and has a significant impact on the quantity and Caliber of microgreens produced as well as the process's environmental sustainability. [34]

Cleaning Microgreens [35]

A clean product can be produced after harvesting microgreens by removing soil particles. The initial bacteria count will be lower after washing greens, but moisture will encourage microbial growth. It is therefore necessary to eliminate extra water in order to stop this growth. Many producers choose not to wash their greens since it involves more handling that could damage them and make them more vulnerable to microbial development. This is because washing and dewatering them involves touching them more. The fabric might be damaged if moisture is left on it after washing. Maintaining a balanced temperature, moisture, and atmosphere is essential to preventing spoilage and disease.

Storage of Microgreens

Humidity, temperature, treatment, packaging, and microbial load can all affect microgreens' shelf life. Microgreens should be produced, handled, and conserved according to safe and suitable protocols to extend their shelf life. A relative humidity of 95% is ideal for storing at 1°C to 5°C. Maintaining the freshness of microgreens can be helped by packaging them in permeable materials like clamshell containers or perforated plastic bags. To avoid microgreens from becoming contaminated while being stored, it's also critical to keep workers safe and away from polluted water, wild animal faces, and seeds [36].



The storage conditions for freshly cut microgreens packed in polypropylene bags were assessed. On the basis of multiple comparisons (n = 3), distinctive letters show a notable contrast at $p < 0.05$. Parameters examined include: (A)

Oxygen concentration in the headspace; (B) Carbon dioxide concentration in the headspace; and (C) Total chlorophyll content.[37]

7. Problems with Strong Microgreens [38]

The respiration rate of microgreens is higher when they are harvested. A microgreen's shelf life at room temperature is 3 - 5 days. When microgreens are sold while rooted in the growing medium, their shelf life is extended. Microgreens should be stored in the refrigerator for best results. A variety's quality may last longer than 14 days depending on storage and variety. In spite of Codex Alimentarius not requiring this, studies have indicated a 5°C storage temperature for microgreens. MAPs are required in order to ensure a suitable cold chain. Breathing is reduced, moisture is prevented, environmental pollution is reduced, spoilage is prevented, and bacterial growth is prevented.

Relative Humidity

Fresh produce's quality and safety are also affected by the relative humidity (RH). Excessive moisture, however, is more harmful to the quality and safety of products than dehydration. Prolonged condensation of moisture (sweat") on the crop promotes microbial growth and decay more than the corresponding soil environment [39].

8. Biological Impact of Light on Microgreens Plants and their Nutritional Quality [35]

One of the most important external factors needed by photosynthetic organisms is light because it is energy and environmental information. All species that require oxygen for photosynthesis must have a physical balance of light, photochemistry and UV protection to prevent excess. During photosynthesis, light intensity and quality play an important role in determining the amount and type of organic compounds produced.

Microbial Safety of Microgreens

Various factors occurring after harvesting can contribute to the buildup of microbes in microgreens, such as their closeness to soil during harvest (like plant height), leftover moisture post-application cleanup, and notably, the temperature. Ensuring cleanliness is vital in preparing packaged microgreens for consumption and facilitating their commercial cultivation. [40]. Rinse microgreens, particularly with chlorinated water, prior to packaging, has the potential to decrease the presence of AMB (Aerobic Mesophilic Bacteria) [41]. Initially, the count of AMB in buckwheat microgreens before storage decreased by 0.3, 0.9, and 1.3 log CFU/g following washing treatments with water, 50 mg/L, and 100 mg/L chlorine solutions, respectively. [42], Similarly, radish microgreens showed negative results when exposed to the same chlorine treatment [43]. Additionally, the efficacy of cleaning is restricted to the initial 7-day storage period at 5°C, beyond which the bacterial count rebounds to 10.3 log CFU/g after 21 days in buckwheat microgreens [42]. Packaging microgreens and running microgreen businesses require meticulous sanitation. In order to evaluate how different cleaning solutions affect shelf life, as well as how drying techniques affect the shelf life, further study is required. Considering the risks to human health and the environment associated with sodium hypochlorite, currently under examination within the framework of the European Biocidal Products Directive 98/8/EC, there is an urgent need for alternative disinfectants that are equally effective [44, 45, 46]. Toward a comprehensive understanding of microbial growth dynamics, further research should include mesophilic bacteria that thrive between 20 and 45 degrees Celsius, along with psychotropic bacteria, which prefer temperatures below 7°C. Heat exposure of microgreens should also be investigated [42,47].

9. Challenges and Opportunities of Microgreens

Vitamins, minerals, and antioxidants are concentrated in microgreens, making them one of the most nutritionally dense foods available. They offer health-conscious consumers wholesome food options with high nutritional density. Quick harvest offered by microgreens within 1-2 weeks growth cycles. Timely market availability and efficient production offered through this rapid growth.

Various colours, textures and flavours provided by microgreens, enhancing culinary creations with their vibrant presence. Both the taste and look enhances through their versatility.

Market stability and consumer satisfaction are supported by this steady supply. A microgreen garden promotes local, sustainable farming in cities and small-scale settings. Their impact on the environment and community resilience is reduced.

The safety of microgreens is crucial, despite their nutritional value. When raw food is grown, handled, and packaged with strict hygiene, raw consumption risks are reduced. The changing environment makes it difficult to maintain consistent quality and flavor in microgreens. Customer satisfaction and consistency can only be achieved through careful monitoring and management.

For microgreens to stay fresh and reduce waste, handling, packaging, and distribution are crucial. The shelf life of these products can be extended sustainably through innovative preservation methods. Investments in seeds, equipment, and infrastructure are necessary for starting microgreen production. Long-term benefits outweigh the initial costs associated with sustainable practices. Creating customer loyalty requires standing out through quality, variety, and sustainability. Strategic branding and marketing initiatives can elevate market presence and drive growth.

The growing demand for "superfoods" such as microgreens could be a huge opportunity for the Indian food industry. Many people have become familiar with microgreens by creating a special category for green vegetables. Microgreens has a high market share and a loyal customer base (restaurants and fine dining). Thanks to today's technology, pollution is no longer a problem; but it also comes with its own costs. On the other hand, microgreens have low yield, rapid aging and short lifespan, limiting the expansion of their products [48, 49, 50].

10. Conclusion

Increasingly, microgreens are being accepted as food products or nutraceuticals due to their significant health benefits in recent years. It is known that microorganisms contain a greater number of nutrients and highly active compounds compared to their macro-organisms' counterparts. There is many health benefits associated with microgreens, including antioxidants, anti-diabetics, anti-inflammatory, anti-inflammatory, anti-obesity, and anti-cancer properties. In addition to antioxidants, these fruits contain carotenoids and flavonoids that reduce oxidative stress and help prevent chronic disease.

Furthermore, microgreens increase insulin sensitivity, which prevents diabetes. In addition to its antibacterial properties, it promotes the health of the gut by containing glucosinolates and sulfur compounds. Arthritis, asthma, and inflammatory bowel disease can all be relieved by microgreens' strong anti-inflammatory properties. By reducing obesity and inflammation, it contributes to a healthy lifestyle and may help prevent cancer as well. There is many health benefits associated with microgreens, as well as their delicious flavor. Many dishes can be enhanced by using microgreens due to their unique taste and visual appeal. Microgreens are rich in vitamins, minerals, and phytonutrients compared to mature plants. Healthy diets should include microgreens since they are packed with nutrients. In addition to boosting health and preventing disease, microgreens can help improve quality of life. A microgreen diet is an easy way to increase well-being, especially with health growing in popularity.

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