Microgreens: An Emerging and Sustainable Innovative Approach for Functional Properties

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Abstract

Microgreens are new specialty crops gaining popularity and increased attention nowadays. These are the juvenile and tender cotyledonary leafy greens having catchy appearance, tender texture, and strong flavor and provide full pack of healthful nutrients. They range in size from 1″ to 1 1/2″ including stem and leaves. Microgreens are considered to be beneficial for health and provide necessary nutrients to human body. Microgreens represent a new group of vegetables considered to be "functional foods" as they possess disease-preventing properties, in addition to their nutritional value. Microgreens have a short life cycle of 5–10 days which may go to few days more if they have not attained the desired height. Common examples of microgreens include red amaranth, green basil, cabbage, broccoli, cilantro, etc. Despite small size, microgreens have strong flavors including higher amounts of vitamins and minerals. Microgreens are rich in various phytochemicals as carotenoids, tocopherols, ascorbic acid, and phylloquinones. Microgreens are perishable and the problem results in case of their post-harvest storage and shelf life. The problems including rotting, foul odor, and premature degradation leads to shorter shelf life and hence, the spoilage of the product.

Keywords

Microgreens · Functional foods · Post-harvest storage

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28.1 Introduction

Microgreens are the latest rising food products, which are juvenile seedlings of vegetables and herbs, having two grown up cotyledons with the first duo of true leaves upcoming and uprising or moderately extended and up to inches tall. They range in size from 1″ to 1 1/2″ including the stem and leaves (Poorva and Aggarwal 2013). When the greens grow ahead of this size, it should no more be taken into account as a microgreen. The life cycle of microgreen takes only 14 days from seed to harvest. Some of the common microgreens that we have in our daily life includes basil, celery, broccoli, cabbage, mustard and cress, fennel, mint, etc. Microgreens need about 4 h every day of direct sunlight to bloom. Now, the growers after knowing the importance need vegetables that are even more babyish than babies—seedlings so small, and so young, are called microgreens; examples include baby-fication of our vegetables—baby spinach, baby lettuce, and baby squash valued for their tenderness and appealing size have attracted everyone.

In winter months, the microgreen production needs even more time. Depending upon the type of seed preferred, it will take about 2–3 weeks to harvest microgreens after planting. They are harvested at the first true leaf stage and sold with the stem, cotyledons, and first true leaves attached, though the post-harvest storage problems add in early dreadful conditions of the crops which results in little shelf life, tainted odor, and rotting. The commercial marketing of microgreens is principally under fire toward restaurant chefs or upscale grocery store. The product is packed in plastic clamshell containers or is sold in bunches.

Microgreens are well thought of as *functional foods* which are actually food product that possess specific health-promoting or disease-preventing properties that are additional to their normally nutritional value (Xiao et al. 2012). The epidemiological studies show that the everyday intake of microgreens especially broccoli and other cruciferous vegetables results in decreased cancer risk. Epidemiological studies on *Brassica* vegetables summarized the protective effect of *Brassica* against cancer due to hydrolysis product of glucosinolates (Verhoeven et al. 1996).

Verhoeven et al. (1996) conducted studies on consumption of cabbage, broccoli, cauliflower, and Brussels sprout (Table 28.1). They showed percentages of opposite involvement with cancer and were 70, 56, 67, and 29%, respectively. Verhoeven et al. (1997) certified the carcinogenic properties of cruciferous vegetables to their relatively high content of glucosinolates (Fig. 28.1).

Currently, the demand for these food products has been growing briskly, and consumption is increasing given their particular characteristics: exclusive color, prosper flavor, and considerable content of bioactive substances.

28.2 Nutritional Value

Microgreens are gaining fame as a fresh culinary ingredient, giving intense flavors, bright colors, and crisp texture when supplemented to salads and other food preparations. Even though microgreens would intrinsically be regarded as a healthy

Table 28.1 Twenty-three commercially grown microgreens assayed in the nutrient study

S. no	Commercial name	Family	Scientific name	Plant color
1	Arugula	Brassicaceae	*Eruca sativa Mil*	Green
2	Celery	Apiaceae	*Apium graveolens* L.	Green
3	China rose radish	Brassicaceae	*Raphanus sativus* L	Purplish-green
4	Cilantro	Apiaceae	*Coriandrum sativum* L.	Green
5	Garnet amaranth	Amaranthaceae	*Amaranthus hypochondriacus* L.	Red
6	Golden pea tendrils	Fabaceae	*Pisum sativum* L.	Yellow
7	Green basil	Lamiaceae	*Ocimum basilicum* L.	Green
8	Green daikon radish	Brassicaceae	*Raphanus sativus* L. var. *longipinnatus*	Green
9	Magenta spinach	Chenopodiaceae	*Spinacia oleracea* L.	Red
10	Mizuna	Brassicaceae	*Brassica rapa* L. spp. *Nipposinica*	Green
11	Opal basil	Lamiaceae	*Ocimum basilicum* L.	Greenish-purple
12	Opal radish	Brassicaceae	*Raphanus sativus* L.	Greenish-purple
13	Pea tendrils	Fabaceae	*Pisum sativum* L.	Green
14	Peppercress	Brassicaceae	*Lepidium bonariense* L.	Green
15	Popcorn shoots	Poaceae	*Zea mays* L.	Yellow
16	Nutrient purple kohlrabi	Brassicaceae	*Brassica oleracea* L. var. *gongylodes*	Purplish-green
17	Purple mustard	Brassicaceae	*Brassica juncea* (L.) Czern.	Purplish-green
18	Red beet	Chenopodiaceae	*Beta vulgaris* L.	Reddish-green
19	Red cabbage	Brassicaceae	*Brassica oleracea* L. var. *capitata*	Purplish-green
20	Red mustard	Brassicaceae	*Brassica juncea* (L.) Czern.	Purplish-green
21	Red orach	Chenopodiaceae	*Atriplex hortensis* L.	Red
22	Red sorrel	Polygonaceae	*Rumex acetosa* L.	Reddish-green
23	Sorrel	Polygonaceae	*Rumex acetosa* L.	Green

addition to the diet, no information is accessible on their nutritional content. The present study conducted by Xiao et al. (2012) in the Department of Nutrition and Food Science, University of Maryland, USA, found out the concentrations of carotenoids, tocopherols, ascorbic acid, and phylloquinones in 25 commercially obtainable microgreens. Outcomes show that different microgreens supply tremendously varying amounts of vitamins and carotenoids. Total ascorbic acid ranged from 20.4 to 147.0 mg/100 g fresh weight, while beta carotene, lutein/

Fig. 28.1 Images of microgreens

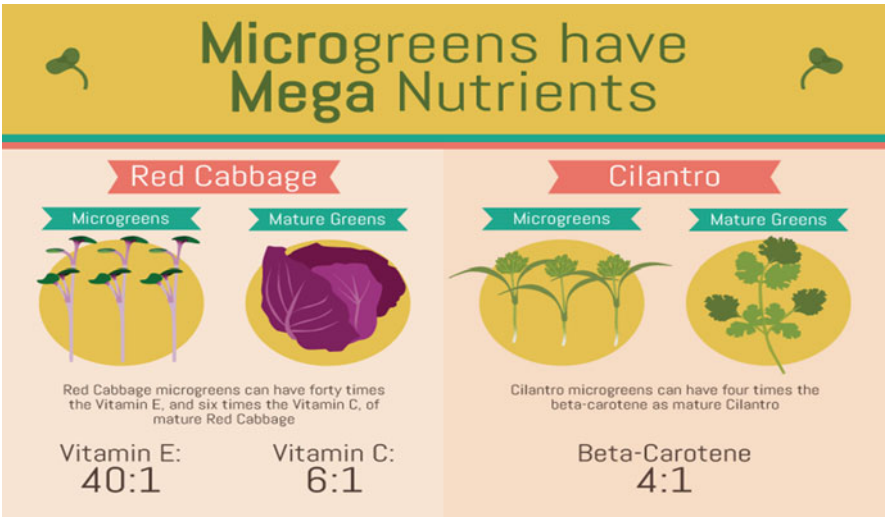

Fig. 28.2 Comparison of microgreen with mature green

zeaxanthin, and violaxanthin concentrations ranged from 0.6 to 12.1 μg/100 g, fresh weight, meanwhile α tocopherol and β tocopherol ranged from 4.9 to 87.4 and 3.0 to 39.4 mg/100 g fresh weight, respectively. Also, amid these microgram, red cabbage, cilantro, garnet amaranth, and green daikon radish had the maximum concentration of ascorbic acids, carotenoids, phylloquinones, and tocopherols, respectively (Fig. 28.2). It was observed that in contrast with mature leaves, microgreen cotyledon leaves possessed higher nutrition densities (Tables 28.2 and 28.3).

Table 28.2 Comparison of major nutrients in the following greens with their mature plants as per USDA National Nutrient Database

	Green daikon radish 		Red cabbage 		Garnet amaranth 		Cilantro 	
	Micro green	Mature	Micro green	Mature	Micro green	Mature	Micro green	Mature
Total ascorbic acid (mg/100 g)	70	14.8	130	43.3	40	27	140	57
Phylloquinone (μg/g)	1.75	1.3	4	1140	2.5	310	2.75	38.2
α-Tocopherol (mg/100)	90	0.0	15	–	50	2.5	25	0.11

Table 28.3 List of soil pathogens found on plant

S. no.	Pathogen	Plant
1	*Clostridium botulinum*	Cabbage
2	*Listeria monocytogenes*	Cabbage
3	*Shigella flexneri*	Scallions
4	*Campylobacter jejuni*	Lettuce, peppers, and spinach
5	*Salmonella* spp.	Cantaloupe, strawberries
6	*Escherichia coli*	Apple cider, lettuce, radish, alfalfa sprouts, and other mixed salads

28.3 Bioactive Components and Health Benefits of Microgreens

Due to changed lifestyle and increased health consciousness among people, the microgreen consumption has increased to a great extent. Microgreens contain more concentrated functional components than the mature leafy greens (Chandra et al. 2012; Xiao et al. 2012; Kou et al. 2013). There is an increase in demand for these products as people are paying more attention toward functional foods. Since microgreens are rich in amino acids, vitamins, antioxidants, and trace elements, therefore they are greatly valued for their health benefits (Finley et al. 2001; Han et al. 2006). Sun et al. (2003) used ultrahigh-performance chromatography photodiode array high-resolution multistage mass spectrometry to profile the five *Brassica* species microgreens. There were 164 polyphenols found in all, including 30 anthocyanins, 105 flavonol glycosides, and 29 hydroxycinnamic and hydroxybenzoic acids. When compared to mature plant equivalents, *Brassica* species microgreens had more complex polyphenol profiles and included more kinds of polyphenols, according to the findings.

28.3.1 Phytonutrients

1. Microgreens are the juvenile seedlings that contain large concentration of vitamins, minerals, and other health-giving phytonutrients than the mature leaves (Janovská et al. 2010).
2. The younger leaves of baby spinach (*Spinacia oleracea* L.) usually contain large amount of phytonutrients, vitamin C, Ba, and K1 and the carotenoids (lutein, violaxanthin, zeaxanthin, and β-carotene), than the mature leaves (Lester et al. 2010).
3. Oh et al. (2010) found that young lettuce (*Lactuca sativa*) seedlings, after 7 days of germination, contain the highest total phenolic concentration and antioxidant capacity in comparison to older leaves.

4. The red cabbage, garnet amaranth, and green daikon radish microgreens contain highest concentration of vitamin E, vitamin C, and vitamin K (Poorva and Aggarwal 2013).

28.3.2 Anticancerous

1. All the nutrients that are packed in microgreens are essential for the skin and eyes and also help fighting cancer. The number of studies has been done on cancer prevention by these microgreens (all *Brassica*: broccoli, cabbage, etc.).Various studies conducted on microgreens show that there have been a great reduction in the cases of lung, breast, colon, ovarian, and bladder cancer in people who eat diets high in these vegetables (Franks and Richardson 2009).
2. The balance that's being created by this compound results in better resistance to cancer plus the encouragement of overall hormone balance.
3. These microgreens contain crystalline compounds (indoles) having a wide range of health benefits. These contain an estrogen stabilizer, DIM (diindolylmethane), and are necessary for both men and women. DIM acts as an inhibitor of growth.

28.3.3 Prevention of Inflammation

C-reactive protein (CRP) and tumor necrosis factor alpha (TNF-α) levels in the liver were reduced by eating red cabbage microgreens. This impact could be owing to the microgreen's capacity to reduce liver lipids, which have been linked to inflammatory reactions in the past (Huang et al. 2016). Other potential effects generated by microgreens can also be deduced by looking at some of the most well-known inflammation-related pathways.

28.4 Pathogen Risk

Pathogens may be defined as the organisms flourishing on plants and causing disease in their host. Since microgreens are lucky plants that are harvested at early stages of their growth, therefore pathogen risk is low (Table 28.3). However, if not handled properly may get prone to occurrence of soilborne pathogens resulting in health hazards.

28.5 Marketing

The interest toward microgreens has expanded. Since their introduction in high-end culinary establishments (Kaiser and Ernst 2012) in the late 1990s, the main market continues to be restaurant chefs. Further direct market opportunity may include upscale or gourmet grocery stores, as well as health food stores (Table 28.4).

Table 28.4 Few functional microgreens with their flavors and food uses

S. no.	Microgreens	Flavor	Food use
1	*Arugula*	Rich peppery taste with strong distinct flavor	Use it in foods with olives, garlic, tomatoes, peppers
2	*Red amaranth*	Mild beet root	Fries, salads, egg dishes, garnish
3	*Green basil*	Spicy, peppery	Tomatoes, soft cheeses, salads, pasta, pizza
4	*Lemon balm*	Lemon sherbet	Fish, chicken, leafy salad, fruit salad, iced tea
5	*Broccoli*	Mild broccoli	Eggs, sandwiches, cheeses, smoked fish
6	*Celery leaf*	Celery, lemony	Salads, soups, garnish
7	*Coriander*	Aromatic	Curries, salads, soups, salsa
8	*Pea shoots*	Freshly podded peas	Seafoods, salads, stir fries, sandwiches, cheeses
9	*Thyme*	Spicy	Chicken, meat, fish, vegetables, pizza
10	*Garlic chive*	Mild onion garlic	Seafood, eggs, sour cream, cheese, garnish
11	*Purple shiso*	Cumin, cinnamon, anise	East Asian cuisine, sushi, salads, soups
12	*Wasabi*	Spicy	Japanese cuisines
13	*Mizuna*	Mild peppery, slightly spicy	Stir fries, soups, nabemono
14	*Opal basil*	Slightly stronger anise flavor, mild ginger tinge	Garnish for desserts, salads, pizza, and pastas

Microgreens are the food commodities requiring very little initial investment with more varieties in less amount of space. Once sown, they start generating income in just 2 to 3 weeks.

28.5.1 Market Outlet

Microgreens one of the most recent cooking trends are gaining popularity. Microgreens are being promoted as an extremely nutritious food product. The demand for these juvenile plants has increased since being recognized as a national trend in haute cuisine around 2006. Microgreens are added as garnishes or flavoring substances by many white tablecloth restaurants. Microgreens have gained attention particularly among health-conscious consumers; the primary market is still fine dining establishments. Some specialty grocers and health food stores are interested in supplying microgreens to consumers, but the highly perishable nature of the crop can create substantial marketing challenges, particularly for inexperienced growers. The most excepted flourishing marketing strategy for the producers who are interested in growing microgreens is to work directly with a restaurant or chef, growing and delivering microgreens at the requests and preferences of the restaurateur. The

rapid growing and harvest time of microgreens make it most interesting crop for small growers paying attention in developing nearby, high-end specialty markets for fresh produce.

28.5.2 Microgreen Production

Microgreens may be developed by persons for home use. Growing miniature amount at home is comparatively simple; however, growing and marketing high-quality microgreens commercially is much hard. Having the right blend at the perfect stage for harvest is one of the most decisive production tactics for success. The time from seeding to harvest fluctuates significantly from crop to crop. When seeding a blend of crops in a single planting flat, growers should choose crops that have a comparable growth rate so the whole flat can be harvested at once. On the other hand, growers can seed the various crops singularly and blend them after harvest.

Microgreens can be grown up in a normal, disinfected, slack, soilless germinating media. Many blends have been used effectively with peat, vermiculite, perlite, coconut fiber, and others. Moderately fill up tray with the media selected to a depth of 1/2 in. to 1 or 2 in., depending on irrigation programs. Overhead mist irrigation is normally used only through the germination period in these media systems. After germination, trays should be subirrigated to shun excess moisture in the plant canopy.

A substitute production system uses one of several materials as a mat or lining to be placed in the bottom of a tray or longer trough. These materials are normally fiber-like and give a brilliant seeding bed. Materials may consist of burlap or a food-grade plastic particularly designed for microgreens. These mat systems are frequently used in a commercially available production system using wide NFT-type troughs. The burlap mat may be enough alone for certain crops or may necessitate a light topping with a media after seeding. Seeding may be ended as a broadcast or in rows. Seeding density is complicated to suggest. The majority of the growers state that they want to seed as densely as possible to maximize production, but not too densely because crowding encourages elongated stems and increases the risk of disease. Most crops necessitate slight or no fertilizer, as the seed provides adequate nutrition for the young crop. Long growing microgreens, such as micro carrot, celery, and dill, may perhaps benefit from a light fertilization applied to the tray bottom. Some of the rapid growing greens, the same as mustard cress and chard, may also benefit from a light fertilization because they germinate quickly and exhaust their self-contained nutrient supply speedily. Light fertilization is mostly achieved by allowing each tray of microgreens to float for 30 s in a prepared nutrient solution of approximately 80 ppm nitrogen.

Microgreens are ready for harvest when they attain the first true leaf stage, usually at about 2 in. tall. Seeding to harvest time vary greatly by crop from 7 to 21 days. Production in small trays will likely require harvesting with cutters. This is a very time-consuming part of the production cycle and is frequently mentioned by growers as a major disadvantage. The seeding mat type of production system has gained fame

with many growers because it facilitates faster harvesting. The mats are usually picked up by the hands and are held vertically. An electric knife or trimmer may be used for harvesting and permitting cut microgreens to drop from the mat into a clean harvest container. Harvested microgreens are highly perishable and should be washed and cooled as quickly as possible. Some chefs request growers to deliver microgreens in the trays or mats as such so that they will incise these as needed to improve quality. Microgreens are washed using good handling practices for food safety reasons. Microgreens are mostly packed in a small, plastic clamshell packages and are then cooled to recommended temperatures for the crops in the mix. Growers must be aware that marketing agreement such as the National Leafy Green Marketing Agreement (NLGMA) has been proposed so as to reduce the risk of microbial contamination of mature and immature leafy greens.

28.6 Microgreen Vs. Sprouts

When anyone says the word "Microgreen," the things that strike our mind are:

1. It's the kid version of the mature vegetables.
2. It's a sprout.
3. It's an appealing and decorative plant.

But among the three, only first the option is the most accurate. Microgreens, divergent to accepted belief, are not the same things as sprouts. Indeed, not only they appear and taste poles apart, but even the way in which they are grown is different. One more difference between the two is that both are technically different at different parts of the cycle (Fig. 28.3).

Fig. 28.3 Sprouts vs. microgreens

Table 28.5 Various dissimilarities between microgreens and sprouts

S. no.	Microgreens	Sprouts
1	Microgreens are grown in soil	Sprouts grow in water
2	Leaves and stems of microgreens are eaten	Seeds of sprouts are eaten as such
3	It takes 1 to 3 weeks for microgreens to grow	Sprouts grow in a week
4	Microgreens are filled with flavor and are frequently used as garnishes	Sprouts are frequently great for crunch

Since all plants begin their journey as a seed. Seeds are embryos that come with a defensive shell particularly termed as the seed coat and inside it are present all essential nutrients and vitamins that are required by plant to burst out of that coating.

Sandwiched between the protective coating and the embryo is that endosperm, which hushes up the embryo and gives the baby nutrition. Now comes sprouts which are germinated seeds. By utilizing the nutrients present in the seed, the embryo develops its stem. Most of the times, people germinate sprouts in water. To make sure that they do not mold, the seeds are bathed once or twice a day. Sprouts grow fast and are harvested just in 4 to 6 days. Since only little amount of light and nutrition is need by sprouts to grow. In addition, they are embedded in fiber, protein, essential nutrients, and enzymes. A considerable amount of humidity is required so that a condition is created in which bacteria thrive in.

According to Foodsafety.gov, there have been at least 30 reported outbreaks of foodborne illness allied with sprouts since 1996 caused by *Salmonella* and *E. coli* (https://www.foodsafety.gov/keep/types/fruits/sprouts.html). The best and simple way to lessen the risk of illness is to cook the sprouts, which, optimistically, will kill all of the bacteria.

Sprouts are nutritional powerhouses that hold a high concentrate of antioxidant nutrients. Microgreens are the outcome of the cotyledon growth stage, becoming the plant's initial set of leaves. These are shaped in the seed and function in similar way as leaves do when it comes to photosynthesis—both change light energy into chemical energy that the plant uses to grow. The leaves and stem can usually be eaten, and the seeds are started in soils or peat moss, as opposed to in water like sprouts.

Microgreens take around 1 to 3 weeks, depending on the plant. They require a plenty of light and good air ventilation. Many studies have also shown that, depending on the variety, microgreens are more concentrated in nutritional value than their mature counter parts (Table 28.5).

28.7 Post-Harvest Storage of Microgreens

Microgreens senesce fast after harvest and have usually a very small shelf life (1–2 days) at ambient temperature, due to the abrupt disruption of plant growth at a very early stage (Guo and Gan 2012; Xiao et al. 2015).

Microgreens that are produced conventionally are highly perishable and are fragile having shelf life of only about 5 to 10 days. This short shelf life of these microgreens is considered to be a major limitation and detriment in the use and marketing of microgreens. So these should be consumed within few days after receiving or have to be discarded resulting in more waste because of loss in color and flavor and begin to rot. On the other hand, regular sized greens such as lettuce have a shelf life of about 14 days. Currently, the blends of microgreens such as beets, broccoli, kale, and radish are sold and used and the most common mixture is known as "Micro Rainbow Mix," and it consists of four to six varieties. The shelf life of the blend depends on the components of blend; in simple words, the component that will rot first will cause whole blend to be unusable even if other components are not rotted. By knowing the shelf life of specific varieties, it is easy to make the blend of these microgreens resulting in longer shelf life and hence profit to the growers, distributors, retailers, and consumers.

28.8 Conclusion

The study done on new specialty crops: Microgreens show that they are juvenile version of green leafy vegetables ranging in size from 1″ to 1 1/2″ including stem and leaves. Microgreens can be eaten as whole and waste is very minute. They have catchy appearance, tender texture, and strong flavor and provide full pack of healthful nutrients. Microgreens are usually more nutrient-dense than their mature counterparts, compared with the records in the USDA National Nutrient Database. They have good consumer acceptability correlated with flavor acceptability. These are perishable and the problem results in case of their post-harvest storage and shelf life. The problems including rotting, foul odor, and premature degradation leads to shorter shelf life and hence, the spoilage of the product. The quality can be maintained by exposing them to low temperature with modified atmosphere packaging. Compared to sprouts, microgreens bear relatively low safety risk.

28.9 Future Work

As the conservative produce lacks the trace minerals our body needs to function, people will start to make links between poor health and lack of nutrient-based foods in their diet. Microgreens are in demand not because of appealing appearance but they have appealing taste as well as have complete pack of nutrients embedded in them. Yet, there is no ready-to-eat microgreens available in the market, therefore it's necessary to develop the ready-to-eat microgreens with best quality, long shelf stability, and ensured safety. Based on the research results on the comparison of *E. coli* growth on sprouts and microgreens, it can be seen that microgreens seem to present a lower food safety risk. As a result, the mechanism of bacterial distribution, attachment, and interaction with the microgreen plants could be further investigated.

Moreover, there will be great demand in the coming years for establishment of such techniques that will keep these products shelf stable. The microgreens need

more attention as various physiological and biochemical changes occur during storage. Post-harvest processing and packaging technology advancements will help to keep quality for extended periods of time and improve shelf life. In addition to quality parameters, functional information about microgreens will aid in the selection of the right crop and harvesting at the right time.

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