MIRCROGREENS AS A FUNCTIONAL COMPONENT OF THE HUMAN DIET: A REVIEW

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ABSTRACT

The alarming growth of chronic diseases is a major problem in Europe, and current data suggest an even greater burden in the future. Although genetic predispositions remain important determinants in the development of certain disorders, the appropriate diet can considerably minimize the risk of many diseases. Many plant species do, in fact, have health-promoting properties due to their high levels of physiologically active chemicals. Glucosinolates, vitamins, tocopherols, saponins, tannins, and other polyphenols have been shown to have beneficial impacts on human health, including cancer, diabetes, cardiovascular, kidney, and Alzheimer’s disease prevention. A new plant category known as microgreens has evolved as a rich source of vitamins, minerals, carotenoids, and physiologically active chemicals against these backdrops. Microgreens could have 10 to 100 times more effective phytochemical concentrations than adult equivalents. Furthermore, they are environmentally cultured in regulated environments with no dirt, harmful residues, or excessive water use. However, existing limitations include uncertain methods of action, varying bioaccessibility, and a paucity of published clinical research. Indeed, microgreens could be a viable new food source for people who are interested in consuming healthy diets.

Keywords: microgreens, phytochemicals, cancer, inflammatory

INTRODUCTION

Chronic diseases are becoming more common in Europe, and they are one of the primary causes of mortality and morbidity. Chronic diseases like heart attack, cancer, diabetes, osteoarthritis, Alzheimer’s, and Parkinson's were a primary concern of the elderly population. In the European Union (EU), life expectancy has increased dramatically in recent years, yet senescence is accompanied by at least two chronic disabilities. In addition, we know that middle-aged and young people are strongly affected by chronic conditions nowadays. This reflects a large extent of the cumulative effect of more difficult living or working conditions and greater exposure to various risk factors earlier in life. The EU approach to addressing the challenge of chronic diseases involves an integrated response focusing on prevention across sectors, combined with efforts to strengthen the health system to improve the management of chronic conditions. It is a public call and an important issue for policy-makers and researchers across the world. Many chronic diseases and conditions are linked to a genetic predisposition of individuals. Additionally, lifestyle choices such as smoking, alcohol drinking, fitness, or sexual behavior are significant factors determining the development of chronic disabilities (Busse et al., 2019). Human evolution and new advances are mirrored by the mutual injection of various conditions. It is a call to gather current experimental findings on the monitoring of chemical and nutrient compositions, biological efficacies, and health benefits of various microgreens regarding overall consequences on human health.

MIRCROGREENS

Microgreens have grown in popularity in recent years, and their popularity is growing due to a global increase in public awareness of healthy eating. Microgreens are young immature greens that are between the sprout and baby greens stages of growth. They're not as big as baby greens, and they're harvested later than sprouts. Microgreens are produced from the seeds of herbs, vegetables, and grains. It is the seedlings of edible plants with established roots and its first true leaves, the cotyledons, are fully developed. Additionally, microgreens consist of a central stem and a pair of young true leaves that start to emerge (Kyriacou et al., 2016; Choe et al., 2018). Di Gioia et al. (2017) declare that all tender young plant greens are considered microgreens. The size of them is approximately 1 to 3 inches tall, and they are harvested on average, between 7 - 14 to 21 days post-planting (species-dependent). Baby greens and sprouts, in addition to microgreens, are recognized, and the primary differences are provided in (Table 1).

Table 1 Cultured and morphological differences: sprouts, baby greens, microgreens

| GROWTH PHASE | HARVEST TIME (DAYS) | SIZE (INCHES) |
|--------------|---------------------|---------------|
| sprouts      | from 2 to 6         | from 0.8 to 1 |
| baby greens  | from 15 to 40       | from 2 to 4   |
| microgreens  | from 7 to 21        | from 1 to 3   |

The composition of sprouts and microgreens is also a significant difference. Microgreens are harvested without the roots, while a sprout includes seed, roots, and stem. An abundant supply of neutral clean water or slightly acidic water is
required for microgreens production. If seeds are immersed overnight at a constant temperature and under low light conditions, germination may be improved. The sprouts should be exposed to light after 2 or 3 days and watered continuously by the sprayer until real leaves emerge (Turner et al., 2020). Shrinking of agricultural field, soil deterioration, high application in the environment, radical population growth and needs to ensure the food security continually support indoor farming of microgreens. The attractivecality of the microgreens also comes from their short production cycle, acceptable cultivation conditions (e.g., less water usage), and loose or soilless germination media as well as their strong abilities to produce multiple crops of microgreens compared to mature vegetables. Controlled conditions such as climate, humidity, lighting, and irrigations with minimizing external environmental growth factors are other attributes, that markedly popularise the microgreen market (Goodman and Winner, 2019; Riggio et al., 2019). Despite much positive information regarding indoor farming, microgreens bring some challenges in contemporary days, such as the limitation on postharvest quality degradation and reduced shelf life. Due to their early senescence, microgreens are difficult to store. A high surface area to volume ratio, rapid postharvest degradation transpiration, a high respiration rate, and early tissue damage all have a negative impact on their quality (Renna et al., 2017). These microgreen are a special category of plants for their vibrant colors, freshness, flavor, aroma, cultivation conditions, and nutritional value. Owing to the enormous content of bioactive molecules they could be characterized as disease-preventing and health-promoting plants. Previous data suggest that microgreens are richer in polyphenols, glucosinolates, vitamins, minerals, or carotenoids. Saturated or unsaturated fatty acids are also more abundant compared to adult plants or seeds. It was demonstrated that microgreens contained a high content of some which are crucial in human cancer prevention. Likewise, broccoli microgreens exhibit a robust antioxidant, anti-inflammatory, anti-cancer, anti-diabetic, or anti-obesity potential compared to their corresponding adult plant (Xiao et al., 2019; Ghooara et al., 2021).

**PHYTO-COMPOSITION OF MICROGREENS**

Although a wide range of microgreens is currently being cultivated, scientific data about their direct potential to affect human physiological functions are not widely available. Nowadays, there are many herbs and vegetables grown as microgreens. Commonly cultivated taxonomic families include Brassicaceae (broccoli, mizuna, cabbages, radishes), Fabaceae (fenugreek, sweet pea, alfalfa), Apiaceae (carrot, parsley, celerely) Asteraceae, Amaranthaceae, and many others. It is also well documented that the chemical composition of microgreens differs considerably from that of mature plants. There is strong evidence about a huge abundance of bioactive compounds, including carotenoids, vitamins or minerals, glucosinolates, and polyphenols (Turner et al., 2020; Marchioni et al., 2021).

**Vitamins**

Phylloquinone known as vitamin K1 is highly presented in Amaranthaceae, Brassicaceae, and Lamiaceae families. The level of phylloquinone concentrations fluctuated between 0.6 to 4.1 µg/g fresh weight. Among the species, red garnet amaranth had the highest concentration (4.1 µg/g fresh weight), followed by green basil (3.2 µg/g), red cabbage (2.8 µg/g fresh weight), and magenta spinach (0.9 µg/g fresh weight). Compared to mature amaranth and cabbage, phylloquinone has been detected at a lower level (0.41 to 1 fresh weight 14 µg/g fresh weight) respectively. Detailed analyses also suggested that a total of 18 out of the 25 commercially grown microgreens contain a greater amount of phylloquinone compared to their adult form (Xia et al., 2012; 2019). Besides phylloquinone's role in blood coagulation and maintaining healthy bone tissue through the prevention of vascular calcification, it has been established that phylloquinone exerts immunosuppressive and anti-cancer effects (Halder et al., 2019). Vitamin C (total ascorbic acid) is considered as the sum of free ascorbic acid and dehydroascorbic acid, which are highly bounded in Malvaceae, Brassicaceae, or Cucurbitaceae families. Ghooara et al. (2020) declare that ascorbic acid was the most abundant at all evaluated microgreens (e.g., fenugreek, radish, roselle, etc.) with concentrations ranging from 41.6 to almost 140 mg/hundred grams. Roselle microgreens from the Malvaceae family have the highest value of ascorbic acids followed by basil and radish. In the previous study, Xiao et al. (2019) confirmed a higher level of total ascorbic acid in cauliflower and broccoli microgreens. Compared to accumulated data of the National Nutrient Database for Standard Reference Legacy Release (Haytowitz et al., 2018), the total ascorbic acid concentration of red cabbage, broccoli, and amaranth microgreens is 6 times greater than its mature counterpart. Ascorbic acid is a potent antioxidant, and it is also essential for a variety of human biological functions generally. In addition, it has a significant effect on collagen synthesis and immune system regulations. Serendipitous medical measurements could result in increased risk of many noncommunicable disease such as cancers, arthritis, or Alzheimer’s disease (Abyesuriya et al., 2020). The most active form of vitamin E is α-tocopherol. In addition to other tocotrienols (β, γ, and δ) belongs to the vitamin E family. On the other hand, γ-tocopherol is the most frequent in plants (Sadig et al., 2019). Especially, Brassicaceae and Apiaceae families of microgreens are considered the rich source of them. Xiao et al. (2019) confirmed green daikon radish has the greatest γ and δ-tocopherol levels (mg/100 g fresh weight). In addition, pepper cress and cilantro also showed high levels of both vitamin E isomers. According to a previous study, α-tocopherol was the most abundant in radish or sunflower (58.6 and 48.7 mg/100 g fresh weight), while mustard and spinach contain over 32 and 24 mg/100 g, respectively (Marchioni et al., 2020). Hence, it could be concluded that microgreens would be a potential health-promoting and anti-inflammatory activities are well documented. Recent research also explores their modulatory potential to cardiovascular, lung, and cancer diseases (Maina et al., 2020).

**Minerals**

Some previous studies suggest that microgreens are excellent sources of minerals. Some of them are important but the majority are considered essential nutrients. In general, the concentrations of macro-minerals (e.g., potassium, magnesium, calcium, phosphorus) and trace minerals (e.g., manganese, zinc, copper, and cobalt) is greater in 90% of microgreens cultivars compared to mature plant (De la Fuente et al., 2019; Zhang et al., 2021). The results of the recent study suggest that a valuable source with the highest concentrations of Ca, K, and Mg could be the Fennel microgreen. Spinach microgreens had a significantly richest content of Mg, while roselle had a maximum source of P, Zn, and Se (Ghooara et al., 2020). Pinto et al. (2015) previously showed that lettuce microgreen had significantly higher concentrations of most minerals such as Ca, Fe, Zn, Mg, or Mn compared to mature counterparts. Webster (2017) declare that mustard microgreen contains a higher concentration of Ca and Mg but, at the same time, the other two mustard genotypes have a lower level in both. It could be affected by varietal differences and the composition of growth substrate or culture conditions. A lack of experimental data on the essential mineral content was published so far. Therefore, a concrete conclusion is not fully created.

**Polyphenols**

As we discussed previously, the nutritive and functional value of microgreens rest in their rich in vitamin, minerals, sugar, and also carotenoid content. However, the most important molecules essential for human health are phytochemicals that include phenolic compounds subdivided into classes such as flavonoids, phenolic acids, tannins, stilbenes, or lignans. As relatively unknown plant materials with limited scientific knowledge, the overall phenolic content, antioxidant potential, and nutritional profile of microgreens have yet to be fully examined (Bella et al., 2020). Currently, common commercial microgreens families such as Brassicaceae, Apiaceae, Lamiaceae, or Malvaceae exhibited enormous antioxidant activity with a wide variation ranging from 303.3 mmol/kg in jute to 878.3 mmol/kg in cress. Overall, the highest antioxidant capacity was confirmed in species of the Brassicaceae followed by the Lamiaceae family. If we look at the evidence in detail, coriander had the highest level of total polyphenol content (5920 mg/g dry weight) followed by green basil and tassoi (3506 and 2645 mg/g dry weight). Compared to the data from mature plants (database on polyphenol content in foods) coriander has reached a level of only around 2260 mg/g in dry weight (Kyriacon et al., 2019). If we look in deep, kaempferol, quercetin, isorhamnetin, and hydroxycinnamic acids with derivatives are the most potent health-promoting phytoconstituents commonly found in mature brassicaeous vegetables. Experimental data showed that the level of isorhamnetin and quercetin-3-O-glucoside is 80 - 80% 3-fold lower in mature pakchoi than in microgreen counterparts. Similarly, comparing the level of caffec and ferulic acid were significantly lower values detected in mature plants. More than a 100-fold higher level of quercetin-3-O-glucoside was measured in cress, while the content of ferulic acid has been estimated at the same level, respectively. According to current evidence, microgreens have more diverse polyphenol profiles, strong antioxidant potential, and could be favored in the human diet due to their bioavailability (Li et al., 2018; Kyriacon et al., 2019).

**Glucosinolates**

The last group of phytochemicals strongly abundant in microgreens is glucosinolates. Glucosinolates are essential to plant secondary metabolites recognized as nitrogen-sulfur derivatives (β-D-thioglucoside-n-hydroxysulfate). The major group of glucosinolates is aliphatic derivates (derived from valine, isoleucine, etc.) followed by aromatic (derived from phenylalanine) and indole (derived from tryptophan) derivates (Le et al., 2016). The results revealed a 2-fold higher concentration in microgreens (17.1 µmol/g) compared to 8.3 µmol/g in mature counterparts. Similar reports demonstrated that microgreens contain more functional substances including glucosinolates (Gan et al., 2017; Mir et al., 2017). Evidence about glucosinolates and their biological effects is currently recognized bactericidal, nematocidal, and fungicidal properties. In addition, glucosinolate-related antimicrobial and anti-inflammatory activities are well documented. Recent research also explores their modulatory potential to cardiovascular, lung, and cancer diseases (Maina et al., 2020).
HEALTH-BENEFICIAL EFFECTS OF MICROGREENS

As we have already outlined in the previous sections, microgreens are becoming recognized as a novel source of physiologically active substances, and their popularity is skyrocketing due to a variety of nutritional and chemical factors. Current research has been expanding gradually while the pilot study confirmed effectiveness in the reduction of blood glucose, weight control, and cardiovascular diseases prevention. The high bioaccessibility of phytochemicals after digestion can provide the antimicrobial, anti-inflammatory, antioxidant, or anti-diabetic potential of microgreens (De La Fuente et al., 2020; Le et al., 2020). Overleaf, the rich content of ascorbic acid, carotenoids, and isothiocyanates are responsible for a strong anti-proliferative effect. Additionally, Huang et al. (2016) describe inhibition of cholesterol and triglycerides synthesis, together with regulation of plasma and liver lipid metabolism.

Anti-cancer potential of microgreens

Malignant tumors are the second leading cause of death globally and there is a prediction of increasing incidence during the next few years. Therefore, there is an urgent requirement for cost-effective cancer prevention through the boost of plant bioactive phytochemicals intake (Koh et al., 2020). Microgreens, with a variety of polyphenols, vitamins, carotenoids, and minerals, are considered promising in cancer prevention and have the regulated ability to affect specific metabolic processes and mechanisms within cancer cells. Overleaf, clear evidence was first reported only recently (De La Fuente et al., 2020). Those authors reported the anti-proliferative effect of the bio-accessible fractions extracted from four Brassicaceae microgreens (broccoli, radish, etc.) on human colorectal adenocarcinoma cells. Cell cycle arrest in G2/M, immediate reactive oxygen species generation, and apoptotic cell death were reported. It is well recognized that the exact mechanism underlying cancer development is unknown, however, inflammation plays a crucial part in carcinogenesis. This pathway is related to the Kelch-like ECH-associated protein (Keap1)-nuclear factor erythroid 2-related factor 2 (Nrf2), AhR (aryl hydrocarbon receptor), and nuclear factor kappa B (NF-kB). Simultaneously, all of them could be affected by diet-derived compounds (indole-3-carbinol, diindolylmethane, glucoraphanin, or oxazolidinones) involved in microgreens (Choe et al., 2018). Especially, the Brassicaceae family is a significant source of glucosinolates metabolites. Their effect starts with the activation of Phase I and II in xenobiotic-metabolizing enzymes that could be effective in cancer protection. They can activate specific enzymes involved in cancer metabolism and allow cells to start defending against potential carcinogens (Singh et al., 2019). In general, glucosinolates are not functional phytochemicals, but their hydrolysis products have a strong potential to affect molecular and signaling pathways in organisms. It detailed, glucosinolates could be hydrolyzed by the enzyme myrosinase into several functional substances such as isothiocyanates, oxazolidinones, or epipithionitiles. Notably, isothiocyanates have been proven to present excellent anti-carcinogenic potential. Enzymatic conversion of them is responsible for sulforaphane, iberin, and erucin production in broccoli microgreens. It was confirmed that all of them could significantly reduce the risk of colon and bladder malignant growth (Baenas et al., 2017; Le et al., 2020). In current days, breast and prostate cancer are common diseases, and malignant growth is promoted by the hormone-mediated route. It suggests that inhibiting or regulating estrogen and androgen receptor binding activity could have a significant impact on the development of hormone-dependent cancers. A previous study confirmed that plant-derived phytochemicals such as indoles or flavonoids, which are primarily represented in microgreens, act an effective role in prostate and breast protection at earlier stages. Indole-3-carbinol significantly repressed estrogen receptor alpha (ER-α) signaling in MCF-7 breast cancer cells. In addition, downregulated expression of the estrogen-responsive genes, repression of trefoil factor 1 (TEF1), and cathepsin-D, followed by upregulation of the tumor suppressor gene was also reported (Baenas et al., 2017; Tomas et al., 2021).

Figure 1 Another biological activity of microgreens. Abbreviations: ROS – reactive oxygen species, XO – xanthine oxidase, LOX – lipooxygenase, POD – peroxidase, CAT – catalase, SOD – superoxide dismutase, GPX – glutathione peroxidase, G – Gram-negative bacteria G+ -Gram-positive bacteria, Nrf2 - nuclear factor erythroid 2-related factor 2

Anti-inflammatory potential of microgreens

In general, inflammation plays a critical role in the progression of several diseases, including cancer, cardiovascular diseases, and obesity. Higher quantities of phytochemicals, which are prevalent in microgreens, are thought to regulate the immune system and prevent the diseases and health issues stated above. It is well known that the NF-kB pathway has a major role in many inflammatory stimuli. NF-kB induces transcription of pro-inflammatory genes and lymphs the synthesis of pro-inflammatory cytokines, concretely tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin 6 or 8 (IL-6, IL-8). A high level of polyphenols and glucosinolates presented in microgreens could inhibit phosphorylation or ubiquitination of kinases, essential in the NF-kB signaling pathway. Overleaf, glucosinolates may potentially inhibit catabolism of nuclear factor kappa light polypeptide gene enhance in B-cells inhibitor alpha and subsequently interfere with NF-kB (Lopez-Chillon et al., 2019; Subedi et al., 2019). An important enzyme involved in inflammation is cyclooxygenase-2 (COX-2). Its upregulation can lead to the destabilization of an inflammatory process through prostaglandin production. However, various polyphenols (kaempferol, quercetin, etc.) presented in microgreens could suppress COX-2 activity (Subedi et al., 2019). Previous reports suggest, that AhR also plays an important role in the regulation of the immune system. It has been shown to affect the transcription of interleukin-17 (IL-17). AhR also participates in the differentiation of FoxP3-IL-10- producing type 1 regulatory T-cells induced by interleukin-27 (IL-27). Microgreens have a high concentration of AhR ligands in their phytochemical composition. This suggests that indole-3-carbinol, as well as other polyphenols and glucosinolates, can influence AhR-mediated immunological responses and T-cell regulation (Wheeler et al., 2017, Subedi et al., 2019). In addition, Huang et al. (2016) confirmed, that the consumption of red cabbage microgreen inhibits TNF-α due to the ability to reduce liver lipids, an excess of which has been known to induce inflammatory responses. Marotti et al. (2021)
found that Glycyrrhiza glabra L., also known as licorice, has anti-inflammatory properties that are mediated through suppression of the proinflammatory cascade. Subedi et al. (2019) revealed evidence of immune system modification through ingestion of broccoli microgreens. Sulfophorpeptide-enriched broccoli microgreens inhibited the NF-κB signaling pathway as well as inflammatory proteins such as TNF-α, IL-1β, and prostaglandin E2 (PGE2). Microgreens have a variety of health-promoting properties in addition to anti-carcinogenic and anti-inflammatory properties, as shown in Figure 1.

CONCLUSION

Microgreens are still a relatively new subject, thus research into their nutritional content and evaluation of health-promoting characteristics is at the beginning. Microgreens have a more powerful overall profile (amounts of carotenoids, glucosinolates, polyphenols, and vitamins) than their mature counterparts, and thus there is a presumption of more significant health advantages, including the ability to prevent the development of a wide range of chronic diseases. To this date, anti-cancer, anti-inflammatory, anti-diabetic, anti-fungal, anti-microbial, anti-diabetic, and antioxidant properties have been identified. Current evaluations highlight a range of constraints in the microgreens research area of leaf, External factors, for instance, can have an impact on nutritional and phytochemical compositions. Therefore, there is essential to comply with the proper cultivation, harvesting, and processing approach of microgreens. Other critical points, which could be addressed are: identifying the mechanism of cellular action, determining bioaccessibility, and validation of health-promoting effect in human studies. Indeed, microgreens could be a promising new source for people who are interested in consuming healthy diets. As a result, more research is required to properly comprehend the importance of microgreens in human health.

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