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A Short Literature on Microgreens: Understanding their nature and Current Research

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ABSTRACT

Microgreens are immature greens that are harvested early which hold rewarding properties. They are considered to be rich in micronutrient composition and their phytochemical composition. A recent boom in the research on microgreens intrigued the need for research in their composition and the upcoming research. The review article was conducted with the help of literature sources – Google Scholar and PubMed. The article comprises of the comprehensive review of the ongoing and current research involved with regards to microgreens and their potential.

KEYWORDS:*Microgreens, nutrient composition, antioxidant, micronutrients*

INTRODUCTION:

Microgreens are vegetable greens and herbs harvested as soon as the first true leaves emerge on a plant. Microgreens are small, tender greens that are used to enhance colour, texture, and flavour to salads, as well as to garnish a variety of main dishes. Mustard, cabbage, radish, buckwheat, lettuce, spinach, and other traditional microgreens are produced. Microgreen consumption has risen in recent years as a result of higher concentrations of bioactive components such as vitamins, minerals, and antioxidants in microgreens than in mature greens, all of which are beneficial to human health. Thus a thorough review was directed in order to understand its benefits and also the current research undergoing regarding the same.

MATERIALS AND METHODS:

A detailed review was conducted with the help of the published English literature dating from 2010. The searched was carried out with the help of Google Scholar and PubMed with the words “microgreens” “current research in microgreens”and “nutritional composition”. Articles related to the search were reviewed and analysed with the focus on its recent research and its varied compositions.

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Primarily recent articles were chosen as a part of the review as there has been an escalation in the number of research in the recent times.

The review aimed to elaborate:

(a) The composition of the microgreens – its nutritional composition and functional capacities.
(b) The ongoing and current research on microgreens

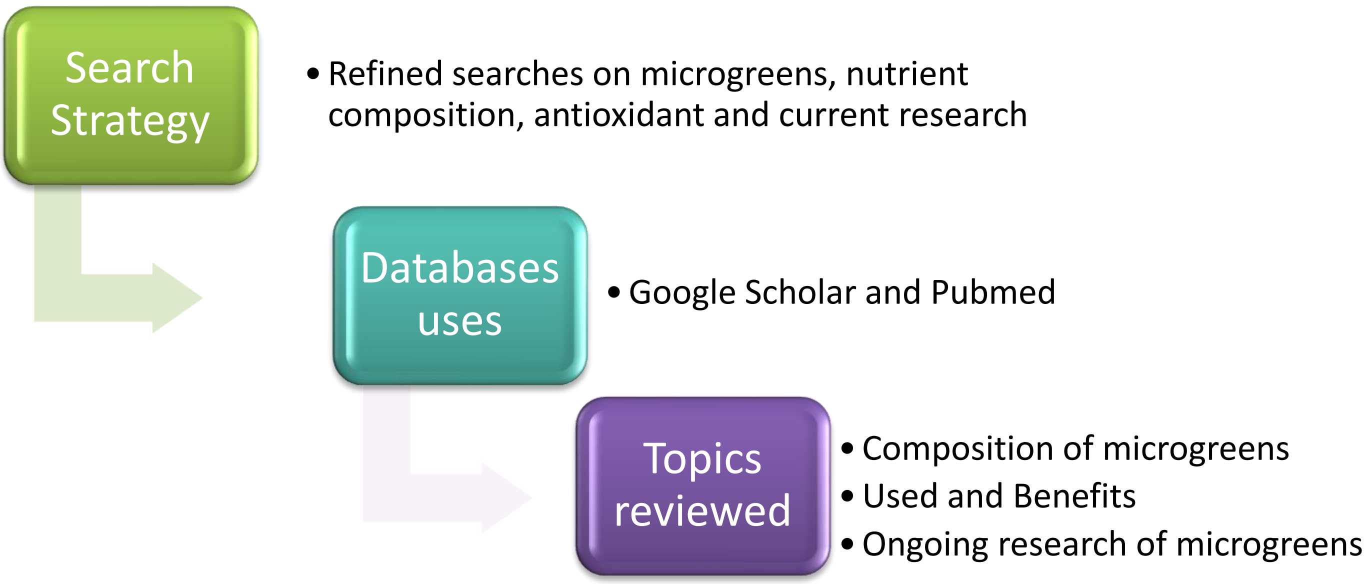

Figure 1.1 Methodology of the review

COMPOSITION OF MICROGREENS:

Micro-green families have distinct dietary values and individual characteristics based on the different families and species. Studies have been performed on the basis of the nutritional importance of various micro-greens. Although there are limited studies relating to the nutritional composition of micro-greens, each study investigated on different aspects of proximate analysis with different micro-greens that are discussed as follows.

NUTRITIONAL COMPOSITION:

General nutritional content analysis of microgreens were carried out among different types and species of microgreens where the early studies are as recent as 2013. One such study about the nutritional content of microgreens were studied by ***Xiao, 2013*** where the sensory characteristics, chemical composition and the nutrient quality of 6 microgreens were studied. The 6 microgreens were shortlisted from a list of 25 microgreens in a preliminary study. The findings from the study portrayed that the sensory characteristics of the six microgreens varied, with the consumer panel rating where bull's blood beet microgreen had the highest preference and peppercress had the lowest acceptance.

The flavour quality attribute predicted overall eating quality of microgreens, the highest of all the sensory quality attributes measured. Consumer acceptance was also influenced by visual and textural consistency attributes. The nutritional content of the 6 microgreens can be given as follows. ()

Table 1.Nutrient Composition of 6 microgreens given by Xiao, 2013.

MICROGREEN	TOTAL SUGAR (g/100g)	WATER CONTENT (%)	ASCORBATE (Total Ascorbic Acid) (mg/100g)	PHYLLOQU -INONE (mcg/g)	TOTAL PHENOLIC (mg GAE/100g)	TOCOPHE ROL γ-tocopherol (γ-T) (mg/100g)
Bull's blood beet	0.44± 0.03	95.1 ± 0.2	13.2 ± 1.9	2.1 ± 0.4	303.0 ± 9.8	0.1 ± 0.0
China rose radish	1.03± 0.17	92.1 ± 0.5	68.0 ± 3.6	3.2 ± 0.6	465.5 ± 15.9	0.5 ± 0.0
Dijon Mustard	0.77± 0.06	94.3 ± 0.0	58.9 ± 0.8	3.2 ± 0.7	149.5 ± 3.9	0.5 ± 0.0
Opal Basil	0.20± 0.02	94.3 ± 0.2	10.6 ± 0.5	4.0 ± 0.7	700.4 ± 9.7	0.2 ± 0.0
Peppercress	0.88± 0.11	93.8 ± 0.1	46.0 ± 2.1	2.9 ± 0.7	274.7 ± 20.1	0.3 ± 0.0
Red Amaranth	0.17± 0.00	93.5 ±0.2	35.8 ± 2.7 b	2.3 ± 0.4	256.5 ± 12.0	0.2 ± 0.0

A later study in by ***Paradiso et al., 2018*** investigated about another different range of microgreens for their proximate composition. The studied genotypes (Six genotypes of microgreens, belonging to three species and two families) of microgreens had some interesting properties when compared to their mature leaf counterparts, especially in terms of mineral nutrients (Calcium, Potassium, etc.) and the content of some bioactive compounds (such as carotenoids and tocopherol). The result of proximate analysis provided in the study can be tabulated as follows.

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Table 2. Proximate Composition of 6 different genotypes ofmicrogreens given by Paradiso et al., 2018 (Mean values)

MICROGREEN	DRY MATTER (g/100g)	LIPIDS (g/100g)	PROTEIN (g/100g)	FIBRE (g/100g)	GLUCOSE (g/100g)	FRUCTOSE (g/100g)	SUCROSE (g/100g)	ASH (g/100g)
Chicory-Molfetta	6.4	0.3	1.9	0.62	0.11	0.14	0.19	0.9
Chicory-Italico a costa rossa	6.3	0.3	2.4	0.70	0.26	0.22	0.32	1.1
Lettuce-Bionda da taglio	5.2	0.3	2.6	0.43	0.03	0.05	0.12	1.0
Lettuce-Trocadero	5.5	0.3	2.4	0.44	0.17	0.12	0.26	1.0
Broccoli-Mugnuli	6.8	0.4	3.0	0.36	0.17	0.03	0.38	1.2
Broccoli-Natalino	6.0	0.3	2.8	0.26	0.04	-	0.14	1.1

The mineral composition were also provided in a distinguished manner where the microgreens' mineral nutrient profile (P, K, Ca, Mg, Na, Fe, and Zn) was compared to the values recorded in the USDA's National Nutrient Database for Standard Reference for the corresponding grown up or fully developed plant. All the microgreens, except Lettuce *(Lactucasativa L.)* - Bionda da taglio, can be considered good sources of Calcium, whilst Lettuce *(Lactucasativa L.)* - Trocadero and Chicory *(Cichoriumintybus L)*- Molfetta also showed considerable amounts of Potassium. These findings point to the possibility of defining genotype-specific nutritional profiles and optimising the quality potential of microgreens. As specified in the study, biodiversity, in conjunction with effective growing techniques, may be a valuable resource for developing tailored microgreens with the desired nutritional characteristics.

A recent Indian study in by ***Ghoora et al., 2020*** elaborated about the compositional differences in macronutrient, micronutrient, and oxalate contents across 10 culinary microgreens were highlighted in this study. The nutritional profile of the 10 culinary microgreens can be given as follows.

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Table 3. Nutritional profile of 10 culinarymicrogreens given by Ghoora et al., 2020

MICROGREEN	TOTAL PROTEIN g/100g	TOTAL DIETARY FIBRE g/100g	TOTAL ASH g/100g	POTASSIUM mg/100g	IRON mg/100	ASCORBIC ACID (mg/100g)	BETA CAROTENE (mg/100g)
Carrot	2.42±0.03	2.46±0.19	1.42±0.01	314.5±3.0	0.44±0.01	65.6 ± 4.4	5.8 ± 0.6
Fennel	4.44±0.51	4.28±0.16	1.67±0.01	480.5±6.0	1.79±0.03	52.5 ± 2.7	9.1 ± 0.2
Fenugreek	3.33±0.06	1.48±0.04	0.48± 0.02	118.5±1.0	1.00± 0.01	92.7 ± 0.5	3.1 ± 0.0
French Basil	2.22±0.32	1.41±0.07	1.30±0.00	328.6±4.8	2.17± 0.09	96.3 ± 2.7	6.8 ± 0.2
Mustard	2.78±0.00	2.08±0.18	1.03±0.03	322.8±3.0	2.46± 0.01	57.1 ± 1.8	7.4 ± 0.2
Onion	2.58±0.14	1.93±0.11	0.67±0.05	273.9±1.9	0.99± 0.02	29.9±2.5	3.8±0.1
Radish	1.81±0.03	1.78±0.01	0.77±0.01	251.4±1.8	0.95± 0.15	88.5±2.2	7.6±0.1
Roselle	2.55± 0.10	2.40±0.14	1.03±0.01	214.6±5.8	1.62± 0.02	123.2±4.0	6.4±0.2
Spinach	2.32± 0.30	2.36±0.05	1.44±0.01	69.7±1.5	1.88± 0.03	71.2±1.8	6.1±0.4
Sunflower	3.93± 0.05	3.63± 0.04	0.81±0.00	331.1± 1.5	1.44± 0.01	86.2±3.0	4.5±0.2

Other nutritional compositions of the microgreens such as Magnesium, Phosphorous, Sodium, Tocopherol, Zinc, Selenium and Oxalic Acid were also investigated as a part of the study. The major macro-element in the microgreens was identified to be potassium and the micro-element was iron. The study concluded that radish, French basil and rosalle were the most nutrient-dense microgreens compared to the other species. This research was the first to publish a nutritional ranking of microgreens, which could be useful in directing consumers' dietary choices.

Hence, the previous studies thus shows that microgreens are highly nutrient-dense compared to their mature counterparts.

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ANTIOXIDANT CAPACITY AND PHYTOCHEMICAL COMPOSITION:

From preceding studies on the nutritional content of microgreens it was evident that microgreens were nutrient dense food commodities that contained high macro and micro nutrients.

Further investigations were performed by researchers on the antioxidant and phytochemical potential of microgreens that have been discussed based on different species of microgreens and their different antioxidant potential.

Senevirathne et al., 2019 studied the germination, harvesting stage and antioxidant capacity of 10 different microgreens. The microgreens were analysed for antioxidant activity in the seeds, sprouts as well as the microgreens.DPPH (Diphenylpycrylhydrazil) radical scavenging antioxidant activity was observed for understanding the antioxidant activity in the study. The microgreens shortlisted in the study were green pea, finger millet and sesame based on the consumer acceptance.Finger millet seeds and sesame microgreens had higher antioxidant activities than the other species when seeds, sprouts, and microgreens were compared, with the latter having a high total phenol content. The overall phenol content of green pea microgreens was higher than that of the seeds and sprouts.

The phytochemical concentration and antioxidant capacity of the microgreens of Brassicaceae family were studied by ***Xiao et al., 2019*** where diverse genotypic variations were identified and observed for ascorbic acid, α-tocopherol, phylloquinone, β-carotene, lutein/zeaxanthin, total glucosinolates, total phenols and 1,1-diphenyl-2-picrylhydrazile (DPPH) radical scavenging activity. Findings showed that microgreens of Brassicaceae are great sources of antioxidant phytochemicals, although there are significant variations within and between species.

The difference of antioxidant potentials among microgreens were studied between microgreens grown from local and commercial farms by ***Tan et al., 2020.*** The article aimed to assess the nutritional and sensory qualities of broccoli microgreens grown using various methods (hydroponically and soil grown) and from various sources.In all broccoli microgreens, there was no significant difference in total phenolic concentration or antioxidant capacity, but farm microgreens had a significantly higher chlorophyll concentration than commercial microgreens. Furthermore, the vitamin C concentration of the soil-grown farm microgreens was significantly greater than that of the hydroponically-grown farm sample and the commercial sample.

Another study conducted by ***Ghoora et al., 2020*** provided a comparative analysis of the phytochemical content and antioxidant potential of ten selective culinary microgreens. The antioxidant assays such as DPPH, FRAP, TEAC, ABTS and ILAP were a part of the analysis.

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Phytochemical parameters such as ascorbic acid, lutein, chlorophyll, total phenolics and total flavonoids were also observed as a part of the study. The results of the study exhibited the following findings:

The highest levels of ascorbic acid, total phenolics, and total flavanoids, as well as DPPH and ILAP activity, were found in Roselle microgreens.

- The OPCI and APCI of roselle and fennel microgreens were both high.
- The highest lutein content was found in carrot microgreens, while the highest chlorophyll content was found in fennel microgreens, according to FRAP and TEAC.

These values were considered to be higher than that of the mature leaves of any spinach variety, and it was also suggested by the researchers that complementing microgreens in the diet against their mature counterparts can help in achieving a healthier inclusion of antioxidant rich food in their diet.

USES AND BENEFITS OF MICROGREENS

Due to their extraordinary nutrition profile with high antioxidant potential, it is believed that they possess several health benefits. Research studies on specific microgreens have also shown the following potential effects on human health.

Huang et al., 2016 studied the effect of Red Cabbage microgreens on the lipid and cholesterol levels of mice that were fed with a high fat diet. Microgreen supplementation was found to be attenuated by high fat diet induced weight gain. In addition, supplementation with microgreens significantly lowered circulating LDL levels in animals fed high fat diets, reduced hepatic cholesterol ester and triacylglycerol levels and expressed inflammatory cytokines in the liver.These data suggest that **microgreens can modulate weight gain and cholesterol**.

The anti-proliferative effects of BrassicaceaeMicrogreens on human colon cancer cells were studied by ***Fuente et al., 2020***. The cell viability assays and mechanisms related to anti-proliferative activity were studied as a part of the research. As a result, the antioxidant bioactive compounds in these **microgreens blocked tumour cell proliferation**. Thus, the study concluded that eating microgreens on a daily basis as part of a well-balanced diet may be a dietary approach for avoiding chronic degenerative diseases like colon cancer.

Other review articles studied about the multiple potentials of microgreens that showed to have an **anti-carcinogenic activity, anti-inflammatory effect, anti-diabetic effect, antimicrobial activity, anti-obesity effect** of select microgreens especially *Brassica oleracea L. var. Italica.*(13) It was also claimed by a different that microgreens have the ability to increase the immunity and its benefits against chronic diseases. (14) A very recent review article in 2021 elaborated that microgreens have an increasingly critical part to play in health-promoting diets. They can be considered as **good sources of nutritional and bioactive compounds and have potential to prevent malnutrition and chronic diseases.**This study offered helpful nutritional proof and health information for micro-greens, as well as a scientific foundation for people to eat micro-greens more carefully. It also highlighted the relevance of micro-green functional products manufacturing..(15)

CURRENT RESEARCH ON MICROGREENS

There have been huge numbers of studies conducted on microgreens based on the shelf-life, consumer acceptability, production, nutritional composition, types and several other proximal compositions. They can be elaborated as follows.

Stoleru et al., 2016conducted a study on microgreens about its novelty and extensive expectations from the upcoming food product. The study has explained about growing micro-greens, including substrate aspects, seeds aspects and grow light conditions along with the nutritive value of the product. Disadvantages of microgreens are also explained in the study where the limited storage duration and shelf life of the product are noticed. Microgreens' industrial processing and marketing are hampered by their short shelf life and quick deterioration of product quality.Although, it has been stated that several post-harvest and pre-harvest techniques are used to extend the shelf-life of the microgreens. Conclusions in the study state that there is still a lot of discussion about the health benefits that come from consumption of microgreens. Growing microgreens can be very efficient and can be used to satisfy the growing demand for food as suggested by the author.

An article by ***Kyriacou et al., 2016***elaborated on the rise of the microgreens and its potential up scaling as vegetables. This review article focused on the recent advances on microgreens, particularly on the impact of pre-harvest factors (species selection, fertilization, bio fortification, lighting and harvest stage) on their physiology and quality, as well as of postharvest factors (handling and applications, temperature, atmospheric composition, lighting and packaging technology) on their quality, postharvest performance and microbial safety. It concludes by presenting crucial opportunities for future research aimed at enhancing production performance, product quality and the shelf-life of microgreens. Progress in understanding the pre-harvest factors influencing their development and quality and the post-harvest factors regulating their shelf-life was discussed in the current analysis along with the challenges ahead.

Kyriacou et al., 2017presented his extensive article on the superlative ability of the microgreens to be presented as potential space foods. The study commented thatspace farming is an upcoming field of research where it has been observed that plant development under space conditions is faced with major restrictions unfamiliar to Earth-based farming processes and beyond our existing knowledge of plant physiological responses in terrestrial environments. It is also conspicuous that astronauts have a need to consume functional food in order to sustain an optimal nutritional status in space. Thus, it is unusually critical to maintain the individual's nutritional status because of various reasons such as mitigating stress effects from long-duration space travel, including weight loss, hematological changes. This also includes oxidative cytotoxic stress caused by spatial radiation, protein oxidation, increased muscle proteolysis, compromised eye health, and changes in the central nervous system. The review claimed on how microgreens can be produced on static, shallow substrates with little to no nutrient supplementation, thus alleviating the problems of poor crop production associated with low oxygen in microgravity hydroponic systems. They also include a relatively high phytochemical as well as carotenoid content which helps in maintaining optimal health status of the space travellers. Microgreens were termed as "Ideal Candidates for the Astronaut's Functional Salad" also provide an easy platform for widening space crop genetic diversity since the diverse cultural needs of long-cycle crops are avoided.

A study by ***Choe et al.,2018***explains the chemical compositions, growing conditions, and biological efficacies of microgreens. The main aim of this study was to analyze the benefits of microgreens with regard to several chronic diseases such as prevention of inflammation, obesity, cardiovascular diseases, diabetes mellitus and even cancer. All these aspects were discussed in this review along with understanding the proximate composition of microgreens such as their micronutrient content (ascorbic acid, carotenoids, minerals), phytochemical composition, polyphenols as well as bioactive compounds in them. It is also understood that in general, microgreens contain greater amounts of nutrients and health-promoting micronutrients than their mature counterparts. Hence it is concluded that based on their chemical compositions, these nutrient-rich plants may provide health-promoting effects related to abilities to prevent the development of the vast array of inflammatory-related chronic diseases. The author also termed microgreens as "Exciting New Food for the 21st Century"

The sensory attributes and their acceptability by consumers was studied by ***Caracciolo et al., 2020***of 12 different microgreen species. This research examines whether sensory characteristics and visual presentation influence customer appetite for microgreens and their ability to consume them. By way of a market evaluation, the sensory attributes of 12 microgreen species were tested, in which a partial least square structural equation model was built to relate sensory attributes to the willingness to eat the food. The findings revealed that while the external quality of the microgreens was highly admired, the general reception of the customer was primarily dictated by taste and texture. In fact, the lower the astringency, sourness and bitterness, the greater the market acceptability of micro-greens. Of the 12 species studied, mibuna and cress had the lowest market approval, while Swiss chard and coriander were the most valued which identified as antioxidants.

A similar study on the consumers sensory perception was reviewed by ***Michell et al., 2020***. Microgreens are ultimately a functional food, which includes several benefits and potential used. But, it is necessary to understand that research is needed to elucidate consumer acceptance of various micro-greens species, including factors contributing to their acceptance. The study included n=99 participants who measured the sensory experience of the user and the acceptability, barriers of acceptance of six microgreen species - arugula, broccoli, bull's blood beet, red cabbage, red garnet amaranth, and tendril pea. It demonstrated that all microgreens had high-likability scores from the consumers. Participants suggested that factors such as awareness and familiarity of microgreens, quality, access/availability, freshness/shelf life, among other factors affect their intention to purchase microgreens.

As a result of the continuing studies alluded to above, it is known that a variety of studies are just underway and the importance of microgreens is just emerging. These studies allow one to consider the acceptability of consumers, the versatility to manufacture, the outstanding nutritional profile, their ability to act as space food, and their ability to avoid a variety of chronic diseases. Considering the recent studies on lifestyle changes, poor lifestyle habits and changes in dietary habits that lead to a variety of chronic diseases, as was emphasized by ***Ramya, Subasshini and Aruna, 2021*** in a study on the lifestyle, nutritional status and dietary pattern among IT employees, measures can be taken with the help of microgreens which act as a simplistic way of including antioxidants and functional foods in the diet that can potentially help in improving the dietary habits of the individuals as well.

CONCLUSION

The review in detail discussed about the potential benefits, the easy accessibility and the wide range of nutrients available in microgreens. Thus it can be concluded that microgreenshold exponential potential and there is furthermore research to be done on the complete efficiency of them with respect to their cooking aspects, different growing environements and various food processing techniques.

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