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Fenugreek Microgreens (Trigonellafoenum-graecum L.) : comprehensive review of Cultivation, Growth and Nutritional Composition

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Abstract:
Fenugreek (Trigonellafoenum-graecum L.) is an important leguminous herb that belonging to family of Fabaceae and traditionally been valued as both a culinary ingredient and medicinal plant. In recent years, fenugreek microgreens have been attracted increasing scientific and commercial interest because they combine the characteristic nutritional and the phytochemical properties of the fenugreek with advantages associated with the microgreen production. Microgreens are young, edible seedlings- harvested at an early stage of the development, generally they consisting of fully developed cotyledons and emerging true leaves. Fenugreek microgreens are characterized by their rapid growth, relatively (simple) cultivation requirements, distinctive flavour, and considerable concentrations of the bioactive compounds.The available literature indicates that nutritional and phytochemical profile of the fenugreek microgreens is influenced by their genotype, seed quality, growing medium, light intensity and quality, temperature, nutrient availability, harvesting stage, and the postharvest storage. They Reported constituents include the protein, minerals, ascorbic acid, chlorophyll, carotenoids, phenolic compounds, flavonoids and the other specialized metabolites. Comparative research has been demonstrated that the fenugreek microgreens can possess particularly high levels of total ascorbic acid, total flavonoids and chlorophyll, together with the strong free-radical-scavenging activity. In one of the comparative investigation of fenugreek seed, stem, leaf and microgreens, microgreens demonstrated the highest total ascorbic acid, total flavonoid content and total chlorophyll, whereas seeds showed higher reducing sugars and total phenolic content.Cultivation conditions are the most important determinants of both yield and nutritional quality of the microgreens. Recent literature indicates that light intensity, wavelength, temperature, humidity and growth medium can modify the plant growth, sugar accumulation, antioxidant capacity and phytochemical production. Postharvest preservation is one of the another important consideration because fenugreek microgreens are highly perishable. Studies involving the refrigerated storage and the modified atmosphere packaging demonstrate that an appropriate packaging can substantially able to improve retention of the sensory, nutritional and their biochemical quality.Overall, fenugreek microgreens represent as a promising nutrient-dense functional food ingredient with the potential applications in a salads, beverages, bakery products, snacks, traditional foods and other value-added food products.

Keywords: Fenugreek microgreens, nutritional, phytochemicals, antioxidants, flavonoids, phenolics, cultivation, functional foods

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1. Introduction

Fenugreek (*Trigonellafoenum-graecum* L.) microgreen is an annual herbaceous plant belonging to Fabaceae family. It has long history of the use as a food, spice and a traditional medicinal plant, particularly in the places like South Asian, Middle Eastern and Mediterranean food cultures. The plant has been commonly cultivated for its seeds and leaves, although the other developmental stages are increasingly being investigated for their nutritional and their functional properties.Fenugreek contains a wide range of the primary and secondary metabolites. Traditional literature has associated fenugreek with the proteins, dietary fibre, minerals, vitamins, saponins, alkaloids, phenolic compounds, flavonoids and the other bioactive constituents. Earlier reviews have been highlighted its potential nutraceutical and their pfunctional-food applications (Srinivasan, 2006; Meghwal&Goswami, 2012; Wani& Kumar, 2018).

Microgreens have emerged as distinctive category of the plant-based foods. They are young edible seedlings that harvested before reaching maturity and generally consumed as whole aerial tissues. Their popularity has increased because of their colour, flavour, tender texture and nutrient density. The literature describes microgreens as young seedlings containing the concentrated nutrients and the health-promoting compounds and emphasizes their potential as functional-food ingredients.Fenugreek is particularly suitable for microgreen production because its seeds can germinate readily and the seedlings develop rapidly. Depending on their production system and definition adopted, fenugreek microgreens may be harvested approximately one to two weeks after the sowing. Ranjitha et al. (2023) describe fenugreek microgreens as young green herbs harvested with the developed cotyledons and the first pair of true leaves, commonly corresponding to an approximately 10–15 days after emergence.

The importance of studying a fenugreek at the microgreen stage arises from possibility that the biochemical composition changes substantially during germination and early seedling development. Germination activates metabolic processes that mobilize storage reserves and support seedling growth. At the same time, synthesis or accumulation of their certain vitamins, pigments, phenolics and other secondary metabolites may occur.

Ghoora and Srividya (2017) compared fenugreek microgreens with the mature leaves and they are demonstrated that microgreens had higher initial levels of the ascorbic acid, total polyphenols and antioxidant activity and retained these are characteristics better during storage. This finding provides an important basis for considering the fenugreek microgreens not simply as an immature leaves but as potentially valuable food material in their own right.Recent research has expanded beyond thr simple nutritional characterization to investigate the cultivation conditions, metabolomics, antioxidant potential, mineral bioavailability, storage, packaging and food-product development. Kumar and Singh (2026), for example, provided emphasized that light, temperature, substrate, nutrient management and cultivation systems can substantially influence nutritional and phytochemical composition.

Therefore, an integrated review of the fenugreek microgreens is necessary to understand their cultivation requirements, nutritional composition, phytochemical characteristics, antioxidant potential, postharvest behaviour and the potential applications in functional foods.

2. Literature Review

Fenugreek as a Nutritional and Functional Plant

Fenugreek has extensively investigated because of their nutritional, functional and traditional medicinal importance. Srinivasan (2006) reviewed the health-beneficial physiological effects of fenugreek, while Wani and Kumar (2018) described its nutraceutical properties and applications. Meghwal and Goswami (2012) reviewed its functional properties, nutritional content, medicinal utilization and potential applications.Fenugreek seeds have a traditionally received greater research attention than their leaves or microgreens. Seeds contain protein, fibre, carbohydrates, minerals and variety of phytochemicals. However, germination and seedling development can alter their biochemical profile.

Studies on the germinated fenugreek have reported increases in the antioxidant activity compared with the ungerminated seeds. Dixit et al. (2005) investigated antioxidant properties of germinated fenugreek seeds, while Randhir et al. (2004) studied phenolics and antioxidant and antimicrobial activity in the dark-germinated fenugreek

sprouts. These studies provide antimicrobial for background to understand why early developmental stages of fenugreek may the possess substantial functional potential.

Pająk et al. (2019) further examined the antioxidant properties and phenolic and The mineral composition in a germinated seeds, including fenugreek. Such evidence supports the broader concept that germination is not merely a physical transformation but also biochemical transition associated with the changes in nutritional and phytochemical composition.

Fenugreek Microgreens: Cultivation, Growth and Development

Production Characteristics

Fenugreek microgreens can be produced using the relatively simple growing systems. The Soil-based cultivation, coco-peat and other soilless substrates can be used depending on intended production system.

Ghoora and Srividya (2017) produced fenugreek microgreens organically using the vermicompost-enriched soil under suitable ambient conditions. Seeds were soaked for the eight hours and sown in a trays. Initial germination occurred under when there is an high-moisture conditions, after which the seedlings were exposed to respective ambient light and the watered regularly. The microgreens were harvested for approximately 7–8 days when they reached approximately 2–3 inches in the height.

In contrast, Ranjitha et al. (2023) produced fenugreek microgreens using fermented with coco-peat and they harvested them around 14–15 days after sowing. Their study illustrates that the harvesting age varies according to each production system, target developmental stage and experimental objective.Thus, there is no specific or single universal harvest age for fenugreek microgreens. Factors such as the cultivar, growing medium, environmental conditions, light exposure and the intended use need to be considered.

Influence of Growing Conditions

The nutritional and their phytochemical quality of the fenugreek microgreens is strongly influenced by their growing conditions. Kumar and Singh (2026) emphasized that provided light, temperature, soil composition, growth medium and cultivation system can influence both the yield and biochemical composition.

Light

The Light is one of most important environmental factors that affect the microgreen development. It regulates their photosynthesis, pigment formation and secondary metabolism.

Recent evidence indicates that the different LED wavelengths can produce their different responses in fenugreek seedlings. Red light has been associated with the increased plant height and fresh weight, while blue light has been reported to enhance their photosynthetic pigments, growth, yield and trigonelline content in the fenugreek seedlings.

The effect of the light is therefore not limited to physical growth. It can also influence their accumulation of sugars, pigments and antioxidant-related metabolites.

Temperature

Temperature affects their germination, enzymatic activity, photosynthesis, growth rate and their secondary metabolism. Kumar and Singh (2026) identified that the temperature and light intensity as critical environmental factors controlling growth and their antioxidant capacity of the microgreens.

Excessive temperature may inducese the stress responses, whereas the inadequate temperature can slow the germination and development. Consequently, controlled environmental conditions may be useful when the objective is about to produce microgreens with consistent nutritional characteristics.

Growing Medium

The growth medium can influences water availability, nutrient supply, root development and the ultimately biomass production. Soil, coco-peat and other substrates can be used for fenugreek microgreen cultivation.

Differences in the cultivation substrate may contribute to variation in their nutritional composition between studies.

3. Nutritional Composition of Fenugreek Microgreens

Macronutrients

Fenugreek microgreens provide the protein, carbohydrates, fibre and minerals. Kumar and Singh (2026) reported on protein content of the approximately 3.33 g/100 g fresh weight and ash content of the approximately 0.48 g/100 g fresh weight in fenugreek microgreens under the cultivation conditions reviewed.

The nutritional composition of the microgreens can be differ according to the cultivation conditions, genotype, harvest stage and the analytical methodology. Consequently, reported values should be interpreted as a study-specific rather than the universal values.Fenugreek is also been recognized for its fibre and their gum components. These properties provide the opportunities for incorporating fenugreek-derived materials into bakery products, extruded foods and more other functional food formulations.

Vitamins

Fenugreek microgreens contain the several vitamins and vitamin-related compounds. Ranjitha et al. (2023) describe fenugreek microgreens as a sources of vitamins, carotenoids and the antioxidants.Vitamin C or ascorbic acid is particularly relevant because of its contributes to the antioxidant activity. Ghoora and Srividya (2017) specifically measured the ascorbic acid in a fenugreek microgreens and the mature leaves and found the higher initial ascorbic acid levels in fenugreek microgreens.

Ranjitha et al. (2023) they additionally investigated B-group vitamins, vitamin E and vitamin K during storage. Their study showed that the B vitamins decreased during their refrigerated storage, although 40-µm polypropylene packaging is retained B vitamins better than the several other packaging materials. Vitamin E increased under low-temperature modified-atmosphere conditions used in the study.

Antioxidant Activity

Antioxidant capacity is one of most frequently investigated functional characteristics of the fenugreek microgreens.Common analytical approaches include the DPPH radical-scavenging activity and the ferric-reducing antioxidant power (FRAP). Ghoora and Srividya (2017) used both DPPH radical-scavenging activity and the FRAP to compare the fenugreek microgreens and mature leaves during their storage.

Ghevariya et al. (2023) reported highest DPPH scavenging activity in the fenugreek microgreens compared with Their seed, leaf and stem. The difference between plant parts was the statistically significant in their experiment ($p < 0.0001$).The antioxidant activity of the fenugreek microgreens is likely related to the combined content of their ascorbic acid, phenolics, flavonoids, carotenoids and other metabolites rather than a single constituent.

Postharvest Stability, Storage and Shelf Life

Fenugreek microgreens are the highly perishable because they are young, actively respiring plant tissues with the high moisture content.

Ghoora and Srividya (2017) stored fenugreek microgreens and mature leaves at the approximate temperature of 10 °C for 14 days and they are evaluated ascorbic acid, total polyphenols, lutein, DPPH antioxidant activity, FRAP and sensory characteristics. Microgreens had the higher initial values for the several phytochemical and the antioxidant parameters and demonstrated better retention during their storage than mature leaves. Also they maintained better sensory quality.

Sensory quality is the particularly important because fenugreek microgreens are often consumed as in form of fresh. such as freshness, colour, wilting, aroma and tenderness influence consumer acceptance.

Modified Atmosphere Packaging

Ranjitha et al. (2023) investigated passive modified of atmosphere packaging of the minimally processed fenugreek microgreens at temperature of 8 °C. The Several semi-permeable films were be compared, including the polypropylene, LDPE, PVC cling film and the Cryovac film.Among their tested systems, 40-µm polypropylene produced an equilibrium atmosphere of a approximate 10–14% oxygen and 5–8% carbon dioxide. Under these kind of conditions, fresh-like sensory, biochemical and nutritional quality was maintained for up to the 15 days.This study demonstrates that packaging is not merely a marketing component but an important technological to intervention capable of the influencing respiration, gas composition, vitamin retention and their shelf life.

4. Conclusion

Fenugreek microgreens represent a promising emerging functional food because of their combination of the rapid production, distinctive sensory characteristics, nutritional value and diverse phytochemical composition. Available evidence demonstrates that the microgreen stage can possess substantial concentrations of bioactive compounds, although the specific composition varies according to genotype, cultivation environment, developmental stage and analytical methodology.Comparative evidence is particularly encouraging. Fenugreek microgreens have demonstrated high total ascorbic acid, total flavonoid content and chlorophyll compared with other edible parts of the plant, while also showing strong DPPH radical-scavenging activity. At the same time, mature seeds may contain greater concentrations of particular constituents such as reducing sugars and total phenolics, illustrating the importance of considering the complete phytochemical profile rather than focusing on one parameter.Cultivation conditions play a central role in determining microgreen quality. Light, temperature, substrate, nutrient availability and harvesting stage can influence yield and phytochemical accumulation. Consequently, controlled cultivation may provide an opportunity to produce fenugreek microgreens with targeted nutritional characteristics.Postharvest management is equally important. Fenugreek microgreens are highly perishable, but refrigerated storage and appropriate packaging can preserve quality. In particular, passive modified atmosphere packaging using 40-µm polypropylene at 8 °C maintained fresh-like quality and nutritional characteristics for up to 15 days in the study by Ranjitha et al. (2023).Overall, fenugreek microgreens should be regarded as a promising functional-food resource rather than simply an immature form of fenugreek. Future research should focus on standardized cultivation, detailed metabolomic characterization, food-processing stability, bioaccessibility, food safety and human intervention studies. Such research could support the development of scientifically validated fenugreek microgreen-based functional foods and contribute to the wider utilization of this underexploited plant resource.

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