

Comparative Assessment of Nutritional and Phytochemical Profiles of Selected Microgreens

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Abstract

Microgreens are nutrient-dense functional foods harvested at an early growth stage (7–14 days), valued for their rich composition of vitamins, minerals, and bioactive compounds. In this study, selected microgreen varieties were cultivated and evaluated for growth, nutritional quality and functional properties. Significant variation was observed among species, with green gram showing the highest shoot length (12.15 cm) and radish recording the greatest fresh weight (75 g). Phytochemical analysis indicated that fenugreek had the highest tannin content (69 mg), beetroot exhibited elevated polyphenols (576 mg) and fibre (32.7 mg), while amaranth showed the highest flavonoid content (68 mg). In terms of bioactive compounds, amaranth contained the highest iron (49 mg) and antioxidant activity (390 mg), beetroot was rich in vitamin C (520 mg), and radish had the highest β -carotene (520 mg). The microgreens also demonstrated low microbial load, indicating good quality and safety. A value-added microgreen-based product showed high sensory acceptability (scores >8.5). Overall, the results highlight the significant nutritional and functional potential of microgreens, supporting their role as sustainable, health-promoting foods.

Introduction

Microgreens are a novel category of edible plants harvested at an early developmental stage, typically after the emergence of cotyledons and the first true leaves. These tender greens,

consisting of stems, cotyledons, and young leaves, have gained increasing attention due to their vibrant sensory attributes and high nutritional density (Riggio *et al.*, 2019). Positioned between sprouts and mature

vegetables, microgreens are usually harvested within 7–14 days, whereas sprouts are consumed earlier, within 2–3 days of germination (Renna *et al.*, 2017).

Although sprouts are recognized for their higher levels of simple sugars, amino acids, and pectin, microgreens are comparatively richer in bioactive compounds such as carotenoids, chlorophyll, and organic acids, which contribute to their antioxidant, anti-inflammatory and potential anti-diabetic properties (Benincasa *et al.*, 2019). The enhanced nutritional profile of microgreens is largely attributed to enzymatic activities during early plant development, leading to the accumulation of essential nutrients and phytochemicals (Kyriacou *et al.*, 2019).

In recent years, microgreens have emerged as functional foods due to their high concentrations of vitamins, minerals, phenolic compounds, and carotenoids, including lutein, zeaxanthin, and β -carotene (Misawa *et al.*, 2010). These compounds play a crucial role in reducing oxidative stress and preventing chronic diseases. Studies have demonstrated that microgreens often contain higher levels of antioxidants and micronutrients compared to their mature counterparts, thereby enhancing their dietary significance (Xiao *et al.*, 2012).

The growing popularity of microgreens is also driven by their culinary versatility and aesthetic appeal. Since their introduction in Southern California during the 1980s, they have been widely utilized as garnishes and ingredients in

salads, soups, sandwiches, and gourmet dishes, particularly in high-end restaurants (Franks and Richardson, 2009). Their unique flavours, textures, and vibrant colours make them attractive to both consumers and chefs.

From a production perspective, microgreens are considered a sustainable food source due to their low resource requirements, including minimal land, water, and cultivation time. They can be grown under controlled indoor or outdoor conditions, making them suitable for urban agriculture and small-scale production systems (Di Gioia *et al.*, 2017). However, their delicate structure and high moisture content contribute to a relatively short shelf life, posing challenges in post-harvest handling and distribution (Puccinelli *et al.*, 2019).

To address these limitations, recent research has focused on optimizing pre- and post-harvest strategies to enhance nutritional quality and extend shelf life, including the use of controlled environments, innovative packaging, and natural preservation techniques (Allegretta *et al.*, 2019). Despite their growing popularity, comprehensive studies evaluating the physicochemical composition, bioactive properties, and storage stability of diverse microgreen species remain limited. Therefore, the present study aims to systematically investigate selected microgreens with respect to their growth performance, nutritional composition, bioactive compounds, and storage behaviour.

Materials and Methods

Seed Collection and Selection

Commonly consumed and commercially available seeds were selected for microgreen production based on their nutritional relevance and germination efficiency. A total of ten seed varieties were procured from the Agricultural College and Research Institute, Killikulam. The botanical classification of selected seeds is presented in Table 1.

Table 1. Botanical Classification of the Selected Microgreens

S. No	Common name	Family	Botanical name
1	Green gram	Fabaceae	<i>Vigna radiate</i>
2	Beetroot	Amaranthaceae	<i>Beta vulgaris</i>
3	Fenugreek	Fabaceae	<i>Trigonella foenum-graecum</i>
4	Cumin	Apiaceae	<i>Cuminum cyminum</i>
5	Radish	Brassicaceae	<i>Raphanus sativus</i>
6	Coriander	Apiaceae	<i>Coriandrum sativum</i>
7	Mustard	Brassicaceae	<i>Brassica nigra</i>
8	Amaranth	Amaranthaceae	<i>Amaranthus viridis</i>
9	Cabbage	Brassicaceae	<i>Brassica oleracea</i>
10	Corn	Poaceae	<i>Zea mays</i>

Preparation of Growing Medium

The growing medium was prepared using garden soil enriched with vermicompost and cow dung in

a 1:1 ratio to ensure adequate nutrient availability and microbial activity. The medium depth was maintained between 0.5 and 2 inches, which is optimal for microgreen cultivation due to their shallow root systems. Previous studies have highlighted the importance of nutrient-rich substrates in enhancing microgreen yield and quality (Di Gioia *et al.*, 2017).

Cultivation of Microgreens

Microgreens were cultivated under controlled ambient conditions following standard agronomic practices. The cultivation process involved tray preparation, sowing, irrigation, and harvesting, as outlined below.

Tray Preparation

Shallow plastic trays with adequate drainage holes were used to facilitate proper aeration and prevent waterlogging. Trays with stackable design were selected to optimize space utilization during cultivation.

Filling of Growing Medium

The prepared growing medium was uniformly filled into trays, leaving a headspace of approximately 2–3 cm to facilitate watering and seed coverage. The medium depth was maintained at around 3–4 cm to support initial root establishment.

Seed Sowing

Seeds were densely broadcast over the surface of the growing medium without spacing, as microgreens require minimal growth area. A thin layer of soil was lightly applied to ensure seed-to-

soil contact and promote uniform germination.

Irrigation

Moisture levels were maintained by misting the trays once or twice daily. Bottom watering was adopted when necessary to enhance water uptake efficiency and minimize mechanical damage to delicate seedlings (Turner *et al.*, 2020).

Harvesting

Microgreens were harvested at the first true-leaf stage, typically 10–14 days after sowing, when seedlings reached approximately 5–7 cm in height. Harvesting was performed using sterile scissors to prevent contamination and mechanical damage. The harvested samples were handled carefully due to their high perishability.

Post-Harvest Handling and Storage

Harvested microgreens were gently washed with potable water and air-dried to remove excess moisture. Samples were stored in airtight containers and maintained under both ambient and refrigerated conditions to evaluate shelf life. Refrigeration was found to significantly reduce respiration rate and moisture loss, thereby extending storage stability (Mir *et al.*, 2017).

Analytical Evaluation of Microgreens

Physical Parameters

Growth and yield attributes were assessed through physical parameters including fresh weight, dry weight, moisture content, shoot height, and root length.

- **Fresh Weight:** Measured immediately after harvest using a digital balance (Kowitcharoen *et al.*, 2021).
- **Moisture Content:** Determined using oven drying method as per AOAC (2007):
$$\text{Moisture (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100$$
- **Shoot and Root Length:** Measured using a standard ruler following established protocols (Xu *et al.*, 2018).
- **Dry Weight:** Determined after complete drying of samples in a hot air oven (Gao *et al.*, 2017).

Chemical Composition

The biochemical constituents of microgreens were analyzed using standard procedures:

- **Tannins:** Estimated using the Folin–Denis method (Bensi *et al.*, 2024).
- **Total Polyphenols:** Determined using Folin–Ciocalteu reagent and expressed as gallic acid equivalents (Chandler and Dodds, 2004).
- **Flavonoids:** Quantified using aluminum chloride colorimetric method (Zhishen *et al.*, 2001).
- **Crude Fibre:** Assessed by acid-alkali digestion method (Sadasivam and Manickam, 2006).

Bioactive Compounds and Functional

Properties

Bioactive components were evaluated due to their role in health promotion and disease prevention.

- **Calcium:** Estimated using o-cresolphthalein complexone method after acid digestion (kou *et al.*, 2014).
- **Iron:** Determined spectrophotometrically using ferrozine reagent (Smith *et al.*, 2021).
- **Vitamin C:** Estimated by 2,6-dichlorophenolindophenol titration method (Bensi *et al.*, 2026)
- **β-Carotene:** Measured spectrophotometrically at 450 nm (Srivastava and Kumar, 2013).
- **Total Plate Count (TPC):** Microbial load was assessed using standard plate count method on nutrient agar (Applegate, 2001).
- **Antioxidant Activity:** Evaluated using DPPH radical scavenging assay (Wong *et al.*, 2006).

Sensory Evaluation

Sensory analysis was conducted to evaluate the acceptability of developed microgreen-based products. A semi-trained panel of 20 members assessed attributes such as appearance, taste, texture, and overall acceptability using a 9-point hedonic scale. Sensory evaluation methodologies were adapted from standard food quality assessment protocols (Bhagavathi *et al.*, 2017).

Statistical Analysis

All experimental data were analysed using SPSS. One-way analysis of variance (ANOVA) was performed to determine significant differences among treatments, and results were expressed as mean $\pm$ standard deviation. Statistical significance was considered at $p < 0.05$.

Results and Discussion

Microgreen production and growth characteristics

Among the ten seed types selected for cultivation, eight microgreen varieties, namely green gram, beetroot, fenugreek, cumin, radish, coriander, mustard and amaranth, were successfully germinated and developed into microgreens. Cabbage and corn failed to develop under the experimental conditions, suggesting that environmental conditions may have influenced their establishment. Considerable variation was observed in both germination and harvesting periods among the successfully cultivated varieties. Green gram germinated within one day of sowing, followed by mustard, fenugreek and radish, whereas cumin required approximately four days. Beetroot, coriander and amaranth germinated within 2–3 days. Harvesting was achieved as early as the seventh day for green gram, while cumin, coriander and amaranth required approximately 14 days. These differences indicate that germination and harvest maturity are strongly influenced by species-specific growth characteristics.

The rapid germination observed for green gram

was comparable with the observations of Kowitcharoen *et al.*, (2021), who reported rapid emergence in mung bean and radish microgreens. Similarly, the harvesting period observed in the present investigation was broadly consistent with the findings of Phornvillay *et al.*, (2026), although minor differences were noted between the reported harvest dates. Such variation may be associated with differences in seed quality, environmental conditions, growing medium, and cultivation practices.

Table 2. Germination and Harvesting time of selected microgreens

S. No.	Microgreen Name	Germination Time	Harvesting Time
1	Green gram	Germinates within 1 day after sowing	Harvested on the 7th day after germination
2	Beetroot	Germinates within 2–3 days after sowing	Harvested on the 12th day after germination
3	Fenugreek	Germinates within 1–2 days after sowing	Harvested on the 12th day after germination
4	Cumin	Germinates within 4 days after sowing	Harvested on the 14th day after germination
5	Radish	Germinates within 1–2 days after	Harvested on the 13th day after

		sowing	germination
6	Coriander	Germinates within 3 days after sowing	Harvested on the 14th day after germination
7	Mustard	Germinates within 1 day after sowing	Harvested on the 12th day after germination
8	Amaranth	Germinates within 2 days after sowing	Harvested on the 14th day after germination

Physical Characteristics of Microgreens:

Physical characteristics differed significantly among the cultivated microgreens. Green gram exhibited the greatest shoot height (12.12 cm) and root height (4.38 cm), whereas amaranth recorded comparatively lower values of 4.74 and 1.63 cm, respectively. Significant differences among treatments were observed for both root and shoot height ($p < 0.001$). The root development observed in the present study was comparable with the approximately 4.5 cm root length reported by Briatia *et al.*, (2017) for microgreens belonging to the Polygonaceae family. Differences in shoot elongation from values reported by Li *et al.*, (2021) may be related to variations in growing medium and cultivation systems, particularly because hydroponic production can alter nutrient and water availability.

Fresh weight also varied considerably among the varieties. Amaranth recorded the highest fresh

weight (75.30 g), followed by mustard (72.79 g) and radish (66.90 g), whereas green gram recorded the lowest value (10.30 g). Moisture content ranged from 86.94% in green gram to 97.73% in coriander. Amaranth recorded the highest dry weight (2.49 g), while green gram had a comparatively lower value of 0.71 g. Analysis of variance confirmed significant differences among treatments for moisture, fresh weight and dry weight ($p < 0.001$ for moisture and fresh weight; $p = 0.002$ for dry weight).

The fresh weight obtained for radish in the present study was higher than the value of 63.2 g reported by Li *et al.*, (2021). Differences in fresh biomass may be attributed to seed characteristics, growing medium, environmental conditions and harvesting stage. The moisture content of radish was comparable with the value reported by Kowitcharoen *et al.*, (2021), further demonstrating that freshly harvested microgreens generally contain a high proportion of water. The differences in dry matter among the varieties reflect variation in the accumulation of structural and non-water-soluble components during early plant development.

Table 3. Physical Attributes of the Selected Microgreens

Treat ment	Root height (cm)	Shoot height (cm)	Moisture (%)	Fresh weight (g)	Dry weight (g)
T1	12.1200 ^e ± 0.46953	4.3775 ^c ±0.61345	86.9350 ^a ± 1.15425	10.3000 ^a ±0.41650	0.7050 ^a ± 0.16606
T2	5.2625 ^b ± 0.43159	2.1400 ^a ± 0.42863	92.2025 ^c ± 0.82553	14.1750 ^b ± 0.69493	1.5525 ^a ± 0.29313
T3	8.4600 ^d ± 0.59479	4.1550 ^b ± 0.53296	92.5000 ^c ± 0.89536	30.6400 ^c ± 0.38808	1.0125 ^a ± 0.28200
T4	3.5575 ^a ± 0.39869	2.6075 ^a ± 0.42845	90.1750 ^b ± 0.24958	34.9175 ^d ±0.27114	1.0775 ^a ± 0.32923
T5	6.6775 ^c ± 0.32569	4.3850 ^b ± 0.39422	92.2375 ^c ± 0.35318	66.9000 ^e ± 0.55396	1.0475 ^a ± 0.23081
T ⁶	7.7675 ^c ± 0.39712	3.6975 ^b ± 0.55207	97.7250 ^d ± 0.20156	55.3050 ^f ± 0.67102	1.0275 ^a ± 0.18953
T ⁷	8.4875 ^d ± 0.48635	3.4925 ^b ± 0.30780	92.7250 ^c ± 0.22867	72.7925 ^g ±0.56618	0.8750 ^a ± 0.25329
T ⁸	4.7375 ^a ± 0.35227	1.6250 ^a ± 0.39913	89.8625 ^b ± 0.40793	75.2975 ^h ± 0.45559	2.4850 ^b ± 0.31117
CD Value	< 0.001	< 0.001	0.016	< 0.001	0.002

a,b,c Means with the difference letter within the column are significantly different ($p < 0.05$)

Values are mean ± S.D (from 3 determinations)

whereas, T1- Green gram microgreen, T2- Beetroot microgreen, T3- Fenugreek microgreen T4- Cumin microgreen T5- radish microgreen T6- Coriander microgreen T7- Mustard microgreen T8- Amaranth microgreen

Phytochemical composition

The selected microgreens exhibited

substantial variation in their phytochemical composition. Tannin concentration ranged from 0.53 mg in amaranth to 68.95 mg in fenugreek. Polyphenol concentration was highest in beetroot (562.03 mg), whereas cumin exhibited the lowest concentration (10.88 mg). Amaranth recorded the highest flavonoid concentration (68.44 mg), while beetroot had the lowest value (10.77 mg). The differences among treatments were statistically significant for tannins, polyphenols and flavonoids ($p < 0.001$), indicating pronounced species-dependent variation in the accumulation of these compounds.

The high tannin concentration observed in fenugreek may contribute to its characteristic astringent and bitter sensory properties. Butkutė *et al.*, (2019) reported approximately 2 mg of tannins in amaranth microgreens, whereas the concentration observed in the present investigation was considerably lower at 0.53 mg. Variation in tannin accumulation may arise from differences in genotype, cultivation environment, and harvest maturity. Beetroot exhibited a particularly high polyphenol concentration of 562.03 mg, which was greater than the 313.8 mg reported by Bhaswant *et al.*, (2023). The higher concentration observed in the present study may be associated with differences in nutrient availability and cultivation

conditions. Flavonoid accumulation also differed considerably among the species. The radish Fibre content ranged from 3.88% in coriander to 32.80% in beetroot. Fenugreek contained 18.03% fibre, which was higher than the approximately 3% reported by Kumar *et al.*, reported by Bhaswant *et al.*, (2023). Variations in the composition of the growing medium and microgreens contained 27.94 mg of flavonoids, which was lower than the value of 39.8 mg nutrient availability may influence the biosynthesis of secondary metabolites.

Table 4. Phytochemical Characteristics of the Selected Microgreens

Treatm ent	Tannin (mg)	Polyphenol (mg)	Flavonoids (mg)	Fibre (%)	Total sugars (g)
T1	1.1000a± 0.07483	127.9500e± 0.22546	43.1675e± 0.26781	11.7700c± 0.15160	5.9050e± 0.14500
T2	11.4675c± 0.50222	562.0250f± 13.90889	10.7700a± 0.18344	32.8025f± 0.12717	6.3375f± 0.29817
T3	68.9500e± 0.7000	14.3200c± 0.32017	14.3200c± 0.25288	18.0275d± 0.18006	1.2825c± 0.04768
T4	5.3000b± 0.33665	10.8750a± 0.18484	10.8750a± 0.28687	7.1725b± 0.23293	6.9800g± 0.08602
T5	11.3775c± 0.40302	27.9350d± 0.18708	27.9350d± 0.32387	4.3275a± 2.43052	0.5225a± 0.13769
T6	0.6900a± 0.26771	48.4750f± 0.31652	48.4750f± 0.36372	3.8750a± 0.20156	0.9275b± 0.03838
T7	26.0000d± 0.73643	125.9500b± 0.24199	12.7975b± 0.341133	5.1000a± 0.43780	0.5225a± 0.09313
T8	0.5300a± 0.14136	87.0500c± 0.11902	68.4350g± 0.18998	23.9250e± 0.69086	0.9275b± 0.15049
CD Value	0.063	<0.01	0.778±	<0.01	<0.001

Fibre content ranged from 3.88% in coriander to 32.80% in beetroot. Fenugreek contained 18.03% fibre, which was higher than the approximately 3% reported by Kumar *et al.*, (2021). Total sugar concentration ranged from 0.52 g in radish and mustard to 6.98 g in cumin. Significant differences were observed among the treatments for both fibre and total sugar content ($p < 0.001$). The relatively low sugar concentration observed in most varieties, together with their appreciable fibre content, supports the nutritional potential of microgreens as components of a diversified diet.

Nutritional and bioactive constituents

Marked differences were observed in the concentrations of selected nutritional and bioactive constituents. Mustard recorded the highest calcium concentration (279mg), whereas green gram contained the lowest concentration (4.34 mg). Amaranth exhibited the highest iron concentration (47 mg), while green gram recorded the lowest value (0.6 mg). These findings demonstrate substantial variation in mineral accumulation among microgreen species. The calcium concentration observed in fenugreek was comparable with the value reported by Kumar *et al.*, (2021), although differences in mineral composition between studies may be related to the growing medium and nutrient availability.

Vitamin C concentration also varied considerably among the varieties. Beetroot exhibited the highest concentration (520 mg), whereas

coriander recorded the lowest value (26.8 mg). Radish contained 69.3 mg/100 g of vitamin C, which was slightly higher than the 52.31 mg/100 g reported by Bhaswant *et al.*, (2023). Differences in vitamin C accumulation may be associated with genotype, environmental conditions, nutrient availability and harvesting stage.

β -Carotene concentration showed pronounced inter-varietal variation. Radish recorded the highest value (502 mg), whereas amaranth exhibited the lowest concentration (2.43 mg). The β -carotene concentration of coriander was approximately 6 mg, compared with 3.56 reported by Tan *et al.*, (2020). Differences between the two studies may be related to climatic conditions, growing substrate and other cultivation factors that influence carotenoid biosynthesis.

Antioxidant activity ranged from approximately 240 to 350 $\mu\text{g/g}$, with mustard exhibiting the highest activity and green gram the lowest. The findings were broadly comparable with those of Tan *et al.*, (2020), who reported relatively limited differences in total antioxidant capacity among microgreens cultivated under different conditions. However, variations in extraction procedures and the units used for expressing antioxidant activity should be considered when comparing values among studies.

Microbiological analysis revealed variation in total plate counts among the microgreens. Green gram recorded the highest count (250×10^1),

followed by amaranth (230×10^1), whereas fenugreek exhibited the lowest count (70×10^1). The differences in microbial load highlight the importance of hygienic production, handling and storage practices, particularly because microgreens have a high moisture content and are commonly consumed fresh.

Table 5. Nutritional and Bioactive Constituents in Selected Microgreens

Treatment	Calcium	Iron	Vitamin C	Beta carotene	Antioxidant activity
T1	4.3450a $\pm$ 0.37686	0.6925a $\pm$ 0.8882	51.5750a $\pm$ 0.43851	241.5000c $\pm$ 0.64550	239.0000a $\pm$ 1.47196
T2	75.2000c $\pm$ 0.32404	1.9725b $\pm$ 0.20353	520.0000c $\pm$ 0.70711	311.5250f $\pm$ 0.62633	309.2500b $\pm$ 0.37969
T3	279.0250b $\pm$ 0.39025	4.1775c $\pm$ 0.05893	71.6000a $\pm$ 0.31091	18.8500d $\pm$ 0.15546	265.8750c $\pm$ 0.82601
T4	85.9750d $\pm$ 0.17970	1.3300a $\pm$ 0.06245	43.4250a $\pm$ 0.45346	13.1075c $\pm$ 0.04110	247.2250b $\pm$ 0.50724
T5	34.1000b $\pm$ 0.34881	1.3225a $\pm$ 0.05573	69.3000b $\pm$ 0.30015	502.9500b $\pm$ 0.39686	274.9500d $\pm$ 0.10408
T6	181.9875f $\pm$ 0.81659	16.0900e $\pm$ 0.57657	25.7525a $\pm$ 0.54153	6.1675b $\pm$ 0.04535	280.8750c $\pm$ 0.42696
T7	03.3450b $\pm$ 0.44575	5.2900d $\pm$ 0.10661	59.7000 $\pm$ 0.21213a	5.6250b $\pm$ 0.12500	348.2500b $\pm$ 0.85391
T8	89.1500c $\pm$ 0.23274	47.8000f $\pm$ 0.45451	38.1500a $\pm$ 0.18484	2.4100b $\pm$ 0.10669	289.5000f $\pm$ 0.64550
CD Value	0.008	0.002	<0.001	<0.001	0.185

Storage stability

Storage temperature had a pronounced effect on the post-harvest stability of the microgreens. Samples stored under refrigerated conditions remained fresh and suitable for consumption for approximately 14 days, whereas those maintained at ambient temperature began to wilt by the fourth day and showed substantial deterioration by the

end of the first week. Moisture loss was also considerably greater under ambient conditions. For example, green gram retained approximately 70.3% moisture under refrigeration compared with 40.7% under ambient storage.

The faster decline in moisture under ambient storage is likely associated with increased water loss and progressive physiological deterioration. The extended maintenance of freshness under refrigeration indicates that temperature control is an important post-harvest strategy for preserving microgreen quality. Considering their high moisture content and short shelf life, appropriate packaging and refrigerated storage may be important for maintaining quality during distribution and marketing.

Conclusion

The present study confirms that microgreens are nutritionally rich, functionally significant, and highly acceptable food products. Considerable variations were observed among species in growth performance, physicochemical characteristics, and bioactive composition, highlighting the importance of species selection. The evaluated microgreens exhibited appreciable levels of essential nutrients, including vitamin C, β -carotene, iron, calcium, and dietary fibre, along with bioactive compounds such as polyphenols and flavonoids that contributed to their antioxidant potential. Differences in root and shoot length, fresh biomass, and dry biomass further demonstrated species-specific growth patterns, while the low total plate counts

indicated satisfactory microbiological quality.

The findings support the potential of microgreens as sustainable and health-promoting food sources due to their short growth cycle, minimal resource requirements, and high nutritional value. Their antioxidant capacity, mineral richness, and favourable sensory acceptability further indicate their suitability for functional food applications and sustainable nutrition.

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