Characterization of Morphological, Physical and Functional Attributes of Microgreens and its Mature Greens

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Received : November 2024
Accepted : December 2024

Abstract

Microgreens, the young and nutrient-dense shoots of vegetables and herbs, represent a remarkable innovation in both agriculture and culinary arts. This study explores the morphological, physical and functional attributes of microgreens, specifically Red Amaranthus, Fenugreek and Spinach and compares them with their mature greens. Morphologically, Fenugreek microgreens exhibited the highest mean plant length of 10.3 cm, with each plant averaging 4.8 leaves and a leaf length of 0.6 cm. Red Amaranthus microgreens had a mean plant length of 5.5 cm and 2.2 leaves per plant, with a leaf length of 0.3 cm. Spinach microgreens demonstrated a mean plant length of 8.6 cm, averaging 4.0 leaves per plant and a leaf length of 0.3 cm. Functionally, Red Amaranthus microgreens showed a water absorption capacity (WAC) of 200 ± 3.2 per cent, oil absorption capacity (OAC) of 120 per cent and emulsifying capacity of 60 per cent, compared to 210, 130 and 65 per cent in mature greens, respectively. Fenugreek microgreens had a WAC of 210, OAC of 140 per cent and emulsifying capacity of 63 per cent, while Spinach microgreens exhibited a WAC of 205, OAC of 125 per cent and emulsifying capacity of 62 per cent. Red Amaranthus microgreens had a bulk density of 0.35 ± 0.02 g/cm³ and a dehydration ratio of 6.50 ± 0.15, while Fenugreek and Spinach microgreens showed bulk densities of 0.45 ± 0.02 g/cm³ and 0.40 ± 0.02 g/cm³ and dehydration ratios of 6.80 ± 0.18 and 6.75 ± 0.20, respectively. The study underscores the potential of microgreens and promotes their use as a sustainable and health-promoting food source and making them a valuable addition to the food industry.

Keywords : Microgreens, Morphological attributes, Functional properties, Nutritional benefits, Sustainable agriculture, Red amaranthus, Fenugreek, Spinach

Microgreens, a marketing term used to describe young and tender edible seedlings, are a remarkable innovation in the world of agriculture and culinary arts. These seedlings are produced using the seeds of various vegetables, herbaceous plants, aromatic herbs and wild edible plants. They are typically harvested within 7 to 21 days after germination, at the stage when the cotyledon leaves are fully developed and the first pair of true leaves had emerged. This timing is crucial because it is at this stage that microgreens are most nutrient dense, offering a significant nutritional punch despite their small size (Di Gioia, Mininni and Santamaria, 2015).

The concept of microgreens is relatively new in agricultural history. While sprouts, a similar but not identical product, had been utilised for thousands of years, microgreens as we know them today began gaining popularity in the 1980s in California. Initially, they were embraced by chefs looking to add color, texture and flavor to their dishes. Over the decades, microgreens had moved from being a niche product

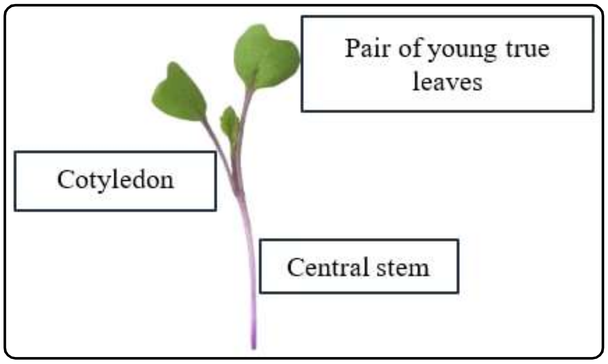

Plate 1 : Parts of Microgreen

to a main stream one, valued for both their nutritional benefits and ease of cultivation.

Microgreens are considered 'functional foods', often referred to as 'superfoods in miniature,' Despite their small size, they offer a concentrated source of essential nutrients and health-promoting compounds, making them a popular choice for families looking to improve their diet. These tiny greens can be grown from a variety of seeds, including herbs, vegetables, and legumes and they can be added to various meals for a nutritional boost. These include antioxidants, phenolics, vitamins and minerals, which can help in preventing diseases and promoting overall health (Renna *et al.*, 2017).

The objective of this study was to assess the functional properties such as water-holding capacity, emulsion activity and stability, which are important for food processing and culinary applications.

Material and Methods

The present research was carried out in the Department of Food Science and Nutrition, University of Agricultural Sciences, GKVK, Bengaluru, India. The study was conducted during the academic year 2023-2024.

Procurement of Raw Materials

Microgreens such as red amaranthus, fenugreek and spinach were grown in University of Agricultural sciences, GKVK, Bangalore. The mature greens are procured from the Bangalore local market.

Preparation of Sample

The three microgreens and their respective mature greens were subjected to tray drying at 40°C. Drying was carried out until the samples were completely dry, crisp and achieved a constant weight. The dried materials were subsequently ground into a fine powder using a mixer grinder and sieved through a 75 µm mesh sieve. The resulting powders were stored in airtight containers for future analysis.

Bulk Density (Tahmaz *et al.*, 2020)

A known mass (M) of powder was weighed and its volume (V) in a container was measured without tapping or compressing. The bulk density, depending on particle density and arrangement, was calculated in g/ml. This procedure was repeated three times to ensure accuracy.

The bulk density was calculated using the formula:

$$\text{Bulk density } (\rho b) = \frac{M}{V}$$

Where, ρb - Bulk density, M - Weight of the powder and V - Volume occupied by the powder

Functional Parameters of Microgreens Powders and its Mature Greens

The functional parameters, including water absorption capacity, oil absorption capacity, emulsifying activity, emulsifying stability, foaming capacity, foaming stability, solubility, water activity and pH, were systematically studied for both microgreens and mature green powders.

Water Absorption Capacity (Onwuka, 2005)

One gram of the sample was taken and mixed with 10 ml of distilled water, then allowed to stand at ambient temperature (30 ± 2 °C) for 30 minutes in a pre-weighed centrifuge tube. The mixture was centrifuged for 30 minutes at 3000 rpm. After the complete removal of the supernatant, the sediments were weighed. Water absorption was measured as the percentage of water bound per gram of powder. The following equation was used to calculate the water holding capacity.

$$\text{Water holding capacity (\%)} = \frac{W2 - W1}{W} \times 100$$

Where, W = Weight of the sample

W1 = Weight of the centrifuge + sample

W2 = Weight of the centrifuge + sediments

Oil Absorption Capacity (Onwuka, 2005)

One gram of the sample was mixed with 10 ml of cooking oil in a centrifuge tube and left to stand for 30 minutes at room temperature (30 ± 2 °C). After centrifuging for 20-30 minutes at 3000 rpm, the supernatant volume was recorded to determine the oil absorption capacity, expressed as ml of oil absorbed per gram of the sample

$$\text{Oil absorption capacity (\%)} = \frac{\text{Final weight of the sample - initial weight of the sample}}{\text{Weight of the sample}} \times 100$$

Emulsifying Activity and Stability (Yasumatsu *et al.*, 1972)

To determine emulsifying activity, a mixture of 1g of sample, 10ml of distilled water and 10ml of sunflower oil was centrifuged at 2000 rpm for 5 minutes. The emulsifying activity was calculated as the height of the emulsion layer divided by the total height of the mixture, expressed as a percentage.

$$\text{Emulsifying activity (\%)} = \frac{\text{Height of the emulsion layer}}{\text{Total height of the mixture}} \times 100$$

Emulsifying stability was assessed by heating the emulsion at 80 °C for 30 minutes, cooling it for 15 minutes and then centrifuging at 2000 rpm for 15 minutes. The stability was calculated as the height of the emulsified layer to the total height of the mixture, expressed as a percentage.

$$\text{Emulsifying stability (\%)} = \frac{\text{Height of the emulsion layer}}{\text{Total height of the mixture}} \times 100$$

Foaming Capacity and Stability (Onwuka, 2005)

Two grams of powdered sample was weighed and added to 50 ml distilled water in a 100 ml measuring cylinder. The suspension was mixed and properly shaken to foam and the total volume after 30 seconds was recorded. The percentage change in volume after 30 mins was expressed as foaming stability.

$$\text{Foaming capacity (\%)} = \frac{\text{Volume after whipping - volume before whipping}}{\text{Volume before whipping}} \times 100$$

$$\text{Foaming stability (\%)} = \frac{\text{Foam volume after 30 mins}}{\text{Initial foam volume}} \times 100$$

Solubility (Subramanian *et al.*, 1986)

A 0.5 g powder sample was mixed with 20 ml distilled water and heated at 90 °C for 1 hour, with periodic shaking. After cooling, the mixture was centrifuged at 5000 rpm for 10 minutes. A 10 ml aliquot was then pipetted into a pre-weighed moisture dish and evaporated to dryness at 110 °C. The weight difference before and after drying was used to calculate the percent solubility.

$$\text{Solubility (\%)} = \frac{(W1 - W2) \times VE}{VA \times 0.5\ g}$$

Measurement of pH (Mashau *et al.*, 2020)

The pH of microgreens and their mature counterparts was determined using a pH 700 Digital meter at 25 ± 1 °C. The meter was standardized with pH buffers of 4.0, 7.0 and 9.2. One gram of powdered sample was mixed with distilled water in a 100 mL volumetric flask, shaken and centrifuged. The pH was measured from 25 mL of the supernatant.

Water Activity (Abbey *et al.*, 2017)

The water activity of microgreens and its respective mature counterpart powder were measured at an ambient temperature (25±1 °C) using a Rotronic Hygro Lab water activity meter. Around 2 g of powdered sample was taken in the sample chamber and the measuring head was placed on it. The instrument was run and the obtained constant reading was noted.

Statistical Analysis

All the results were presented as mean ± standard deviation (SD). Independent samples t-tests were used for two-group comparisons. Statistical analyses were performed using SPSS 20.0 (IBM, USA).

Results and Discussion

Morphological Parameters of Fresh Microgreens

Table 1 and plate 1 Depicts the morphological parameters of fresh microgreens grown in cocopeat + vermicompost demonstrate notable variations across different microgreens.

Red Amaranthus : Exhibited a mean plant length of 5.5 cm, with an average of 2.2 leaves per plant. The leaves were relatively short (0.3cm) and displayed a dark red-green color with a soft texture.

Fenugreek : Showed the highest mean plant length among the studied microgreens at 10.3cm. Each plant averaged 4.8 leaves and the leaves had a length of 0.6cm. The color was light green and the texture was slightly rough.

Spinach : Had a mean plant length of 8.6cm with an average of 4.0 leaves per plant. The leaf length was 0.3, with the color being dark green and the texture smooth.

These morphological observations suggest that the growth medium significantly impacts the physical characteristics of the microgreens. The addition of vermicompost to cocopeat appears to enhance the growth metrics, potentially due to the improved nutrient availability and soil structure provided by vermicompost.

This result was supported by the study conducted by Gunjal *et al.* (2024) where the beetroot microgreens showed a leaf length (0.77 ± 0.15 cm), leaf width (0.16 ± 0.08 cm), and total leaf area (0.10 ± 0.06 cm), while red amaranthus microgreens had a shorter leaf length (0.44 ± 0.05 cm), a similar leaf width (0.15 ± 0.02cm) and a smaller total leaf area (0.05 ± 0.01 cm) were observed.

Physical Parameters of Microgreens and Microgreen Powders

The physical parameters of microgreens and mature greens powders are represented in Table 2 and Fig. 1. The physical parameters of microgreens and mature greens revealed notable differences in bulk density, dehydration ratio and rehydration ratio.

For Red Amaranthus, microgreens exhibited a lower bulk density (0.35 ± 0.02 g/cmł) compared to mature greens (0.42 ± 0.03 g/cmł). Additionally, the dehydration ratio was lower for microgreens (6.50 ± 0.15%) than for mature greens (7.20 ± 0.20%). The rehydration ratios were not significantly different.

Fenugreek microgreens also showed a lower bulk density (0.45 ± 0.02 g/cmł) compared to mature greens (0.52 ± 0.03 g/cmł), although this difference was not statistically significant. The dehydration ratio for Fenugreek microgreens (6.80 ± 0.18%) was significantly lower than that for mature greens

Table 1

Morphological parameters of fresh microgreens

Morphological Parameters	Red Amaranthus (Mean ± SD)	Fenugreek (Mean ± SD)	Spinach (Mean ± SD)
Length of the plant (cm)	5.5 ± 0.8	10.3 ± 1.1	8.6 ± 0.7
Number of leaves per plant	2.2 ± 0.5	4.8 ± 0.4	4.0 ± 0.6
Length of leaves (cm)	0.3 ± 0.3	0.6 ± 0.4	0.3 ± 0.3
Colour of microgreens	Dark Red-Green	Light Green	Dark Green
Texture of microgreens	Soft	Slightly Rough	Smooth

Plate 2 : Microgreens of Red Amaranthus, Fenugreek and Spinach

TABLE 2
Physical parameters of microgreens and mature greens powders

Samples	Bulk density (g/cmł)	Dehydration ratio	Rehydration ratio
Red Amaranthus			
Microgreens	0.35 ± 0.02	6.50 ± 0.15	3.40 ± 0.12
Mature greens	0.42 ± 0.03	7.20 ± 0.20	3.90 ± 0.14
t-value	4.15 *	3.75 *	2.89 NS
Fenugreek			
Microgreens	0.45 ± 0.02	6.80 ± 0.18	3.50 ± 0.14
Mature greens	0.52 ± 0.03	7.30 ± 0.22	3.95 ± 0.17
t-value	1.68 NS	3.90 *	1.50 NS
Spinach			
Microgreens	0.40 ± 0.02	6.75 ± 0.20	3.45 ± 0.15
Mature greens	0.48 ± 0.03	7.40 ± 0.25	3.95 ± 0.18
t-value	4.50 *	4.12 *	3.05 *

Note : * Significant at (p d≤0.05). NS : Not Significant

(7.30 ± 0.22%). No significant differences were observed in the rehydration ratios (t-value 1.50 NS).

Similarly, Spinach microgreens demonstrated a significantly lower bulk density (0.40 ± 0.02 g/cmł) than mature greens (0.48 ± 0.03 g/cmł). The dehydration ratio was also significantly lower for microgreens (6.75 ± 0.20%) compared to mature greens (7.40 ± 0.25%), the rehydration ratio for Spinach microgreens (3.45 ± 0.15%) was significantly lower than that of mature greens (3.95 ± 0.18%).

These findings suggested that microgreens generally had lower bulk densities and dehydration ratios than

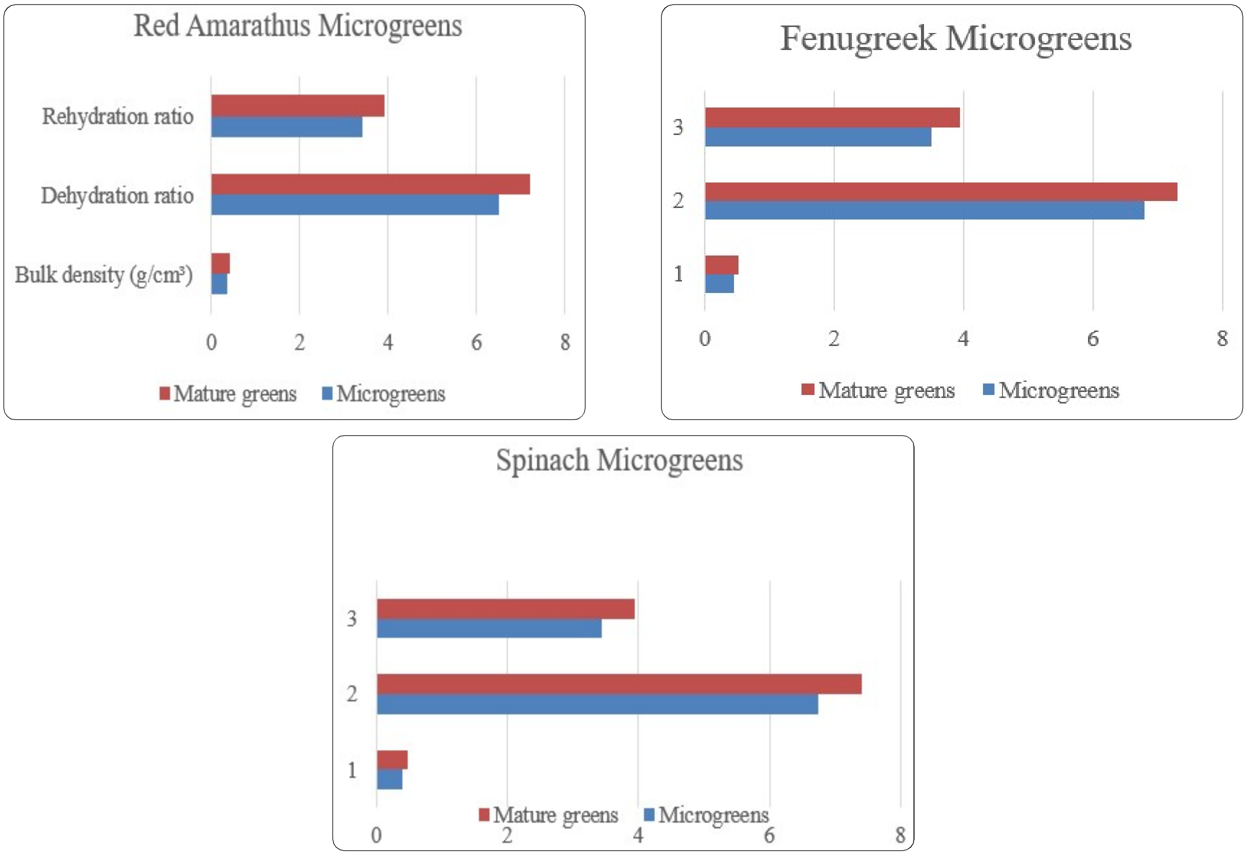

Fig. 1 : Physical parameters of microgreens and microgreen powders

mature greens, which can affect their drying and rehydration properties. The significant differences in these parameters highlighted the advantages of microgreens in terms of processing and rehydration efficiency.

The results were on par with the result of Devi *et al.* (2023) where bulk density was analyzed for tray-dried samples, the bulk density for the microgreens of mustard was 0.16 ± 0.01 g/cmł, spinach was 0.18 ± 0.02 g/cmł, safflower was 0.22 ± 0.05 g/cmł, fenugreek was 0.17 ± 0.04 g/cmł and amaranth was 0.12 ± 0.02 g/cmł.

Sneha *et al.* (2018) found the similar trend in rehydration ratio of dehydrated ivy guard which was in the range of 2.44 to 3.63.

Microgreens showed a lower bulk density than mature greens, meaning they occupy less space for the same weight. This characteristic allows for easier incorporation into dishes without overwhelming other flavors or textures. Their light weight nature makes them ideal for garnishing, enhancing visual appeal without adding excessive volume.

Microgreens showed higher dehydration rate which is due to their smaller size and higher surface area-to-volume ratio. This rapid dehydration can intensify their flavors, making them more concentrated when dried. Chefs can utilize this concentrated flavor in various culinary applications, such as seasoning blends or as toppings.

Microgreens had lower rehydration ratio compared to mature greens, meaning they absorb water more efficiently when rehydrated. This property allows them to regain their texture and flavor quickly, making them convenient for use in dishes that require quick preparation, such as salads or soups.

TABLE 3
Functional parameters of red amaranthus microgreens and its mature greens

Samples	Microgreens	Mature greens	t-value
Water Absorption Capacity (%)	200 ± 3.2	210 ± 3.5	2.85 *
Oil Absorption Capacity (%)	120 ± 2.8	130 ± 2.9	3.20 *
Emulsifying Capacity (%)	60 ± 1.5	65 ± 1.7	3.35 **
Emulsifying Stability (%)	50 ± 2.0	55 ± 2.1	2.75 *
Foaming Capacity (%)	40 ± 1.2	42 ± 1.3	1.95 NS
Foaming Stability (%)	35 ± 1.1	36 ± 1.2	1.88 NS
Water Activity (aw)	0.95 ± 0.02	0.96 ± 0.02	1.60 NS
pH	6.5 ± 0.1	6.7 ± 0.1	2.15 *
Solubility (%)	75 ± 2.5	78 ± 2.7	3.10 *

Values are expressed as mean ± standard deviation of three determinations, **Significant at ($p \leq 0.01$), * Significant at ($p \leq 0.05$)

Functional Parameters of Red Amaranthus Microgreens and Mature Greens

The functional parameters of Red Amaranthus microgreens and mature greens (Table 3) exhibited notable differences. For water absorption capacity (WAC), microgreens showed a value of 200 ± 3.2%, slightly lower than the 210 ± 3.5% observed in mature greens. Similarly, oil absorption capacity (OAC) for microgreens is 120 ± 2.8%, compared to 130 ± 2.9% in mature greens. Emulsifying capacity and stability were marginally lower in microgreens, with values of 60 ± 1.5% and 50 ± 2.0% respectively, versus 65 ± 1.7% and 55 ± 2.1% in mature greens. Emulsifying capacity and stability were both significantly higher in mature greens, indicating better emulsifying properties as plants age.

Although the differences in foaming capacity (40 ± 1.2% for microgreens and 42 ± 1.3% for mature greens) and foaming stability (35 ± 1.1% for microgreens and 36 ± 1.2% for mature greens) were not significant, the pH and solubility percentages do highlight significant contrasts. Microgreens had a slightly lower pH of 6.5 ± 0.1 compared to 6.7 ± 0.1 in mature greens and solubility of 75 ± 2.5% versus 78 ± 2.7%. These findings suggested that while both microgreens and mature greens had their unique functional properties, microgreens may offer distinct advantages in specific applications and nutritional benefits.

A similar study by Gupta *et al.* (2023) supports these findings, indicating that microgreens often had higher concentrations of bioactive compounds compared to mature plants, which may enhance their functional properties despite lower values in certain parameters like emulsifying capacity.

Functional Parameters of Fenugreek Microgreens and Mature Greens

The functional parameters of Fenugreek microgreens compared to their mature greens displayed some significant differences (Table 4). Microgreens showed a slightly lower water absorption capacity (WAC) of 210 ± 2.5 compared to 225 ± 3.0% in mature greens. Similarly, oil absorption capacity (OAC) in microgreens was 140 ± 3.2%, while mature greens had 150 ± 2.9%. Emulsifying capacity and stability are also lower in microgreens, with values of 63 ± 1.5 and 54 ± 1.8%, respectively, versus 68 ± 1.7 and 59 ± 1.9% in mature greens.

Foaming capacity and stability showed no significant differences, with microgreens at 38 ± 1.4 and 34 ± 1.2%, compared to 42 ± 1.3 and 37 ± 1.1% in mature greens. The pH and solubility percentages highlighted

TABLE 4

Functional parameters of fenugreek microgreens and its mature greens

Samples	Microgreens	Mature greens	t-value
Water Absorption Capacity (%)	210 ± 2.5	225 ± 3.0	4.10 *
Oil Absorption Capacity (%)	140 ± 3.2	150 ± 2.9	3.65 *
Emulsifying Capacity (%)	63 ± 1.5	68 ± 1.7	2.89 *
Emulsifying Stability (%)	54 ± 1.8	59 ± 1.9	3.21 **
Foaming Capacity (%)	38 ± 1.4	42 ± 1.3	1.55 NS
Foaming Stability (%)	34 ± 1.2	37 ± 1.1	1.60 NS
WaterActivity (aw)	0.92 ± 0.02	0.93 ± 0.02	1.85 NS
pH	6.4 ± 0.1	6.6 ± 0.1	2.35 *
Solubility (%)	70 ± 2.1	74 ± 2.4	3.45 *

Values are expressed as mean ± standard deviation of three determinations, **Significant at ($p \leq 0.01$), * Significant at ($p \leq 0.05$)

significant contrasts, with microgreens had a slightly lower pH of 6.4 ± 0.1 and solubility of 70 ± 2.1%, versus 6.6 ± 0.1 and 74 ± 2.4% in mature greens.

Functional Parameters of Fenugreek Microgreens and Mature Greens

The functional parameters of Spinach microgreens and mature greens revealed significant differences in various attributes (Table 5). Microgreens had a slightly lower water absorption capacity (WAC) of 205 ± 2.8 compared to 220 ± 3.1% in mature greens. Similarly, oil absorption capacity (OAC) in microgreens is 125 ± 3.0%, while mature greens had 135 ± 2.8%. Emulsifying capacity and stability are also lower in microgreens, with values of 62 ± 1.6 and 52 ± 1.9%, respectively, versus 67 ± 1.8 and 57 ± 2.0% in mature greens.

Foaming capacity and stability showed no significant differences, with microgreens at 39 ± 1.3 and 34 ± 1.1%, compared to 41 ± 1.4 and 36 ± 1.2% in mature greens. The water activity (aw) levels were similar, with microgreens at 0.91 ± 0.02 and mature greens at 0.93 ± 0.02. The pH and solubility percentages highlight significant contrasts, with

TABLE 5

Functional parameters of spinach microgreens and its mature greens

Samples	Microgreens	Mature greens	t-value
Water Absorption Capacity (%)	205 ± 2.8	220 ± 3.1	3.92 *
Oil Absorption Capacity(%)	125 ± 3.0	135 ± 2.8	3.47 *
Emulsifying Capacity (%)	62 ± 1.6	67 ± 1.8	2.98 *
Emulsifying Stability (%)	52 ± 1.9	57 ± 2.0	3.15 **
Foaming Capacity (%)	39 ± 1.3	41 ± 1.4	NS
Foaming Stability (%)	34 ± 1.1	36 ± 1.2	NS
Water Activity (aw)	0.91 ± 0.02	0.93 ± 0.02	NS
pH	6.3 ± 0.1	6.5 ± 0.1	2.25 *
Solubility (%)	72 ± 2.2	76 ± 2.5	3.32 *

Values are expressed as mean ± standard deviation of three determinations, **Significant at (pŁ0.01), * Significant at (pŁ0.05) microgreens having a slightly lower pH of 6.3 ± 0.1 and solubility of 72 ± 2.2%, versus 6.5 ± 0.1 and 76 ± 2.5% in mature greens.

Similar observation was found in Veena *et al.* (2011) whereat pH 6, the solubility of SPI (soy protein isolate) is 80 per cent, while the solubility of hydrolyzed SPI is 80 per cent.

These results indicated that the functional parameters of microgreens, such as WAC, OAC and emulsifying properties, tend to be lower than those of mature greens, highlighting the impact of growth stage on these properties. Additionally, this study emphasized the importance of selecting the appropriate growth stage and drying method to optimize the functional benefits of microgreens.

These observations are consistent with the findings of Shin *et al*. (2015) who highlighted that the functional properties of underutilized green leafy vegetables observed that the water activity of dried ranged from 0.52 to 0.57, which was significantly lower compared to the fresh samples that had a water activity of 0.84.

The finding aligns with another study by Sanyukta *et al.* (2023) who studied the four botanical varieties of microgreens studied, bathua microgreens demonstrated the water holding capacity (1.58 g/g), emulsion activity (56.37%) and emulsion stability (53.72%).

Dried microgreens have a lower water absorption capacity than mature greens. This characteristic allows them to maintain their texture and flavor integrity when rehydrated or incorporated into dishes. In culinary applications, this means that dried microgreens can enhance the flavor profile without becoming overly soggy.

The microgreen powder had less values for oil absorption capacity when compare to their mature plants.This characteristic suggested that microgreen powder is less prone to absorbing excess oil during food processing, making it a healthier ingredient for developing low-fat products. The reduced oil absorption also contributes to an extended shelf life by minimizing the risk of lipid oxidation, which can cause rancidity (Mansouri *et al.,* 2024).

Determining these physical and functional parameters is essential to understand the behavior of powders in various applications, such as food formulations, ensuring their suitability and effectiveness in the desired processes. This ensured the maximum exploration of unconventional greens like red amaranthus, fenugreek and spinach in the sustainable and health promoting food source and making then a valuable addition to the food basket.

REFERENCES

ABBEY, L., AMENGOR, M. G., ATIKPO, M. O., ATTER, A. AND TOPPE, J., 2017, Nutrient content of fish powder from low value fish and fish byproducts. *Food Sci. Nutr.,* **5** (3) : 374 - 379.

DEVI, R., DEVI, T. S., KUN, A., REDDY, M. V., CHARY, D. S. AND BABU, K. M., 2023, Formulation and sensory evaluation of fenugreek microgreens incorporated instant chutney powders. *Environment and Ecology*, **41** (1B) : 486 - 491.

DI GIOIA, F., PETROPOULOS, S. A., OZORES-HAMPTON, M., MORGAN, K. AND ROSSKOPF, E. N., 2019, Zinc and iron agronomic biofortification of Brassicaceae microgreens. *Agronomy*, **9** (11) : 677.

GUNJAL, M., SINGH, J., KAUR, S., NANDA, V., ULLAH, R., IQBAL, Z., ERCISLI, S. AND RASANE, P., 2024, Assessment of bioactive compounds, antioxidant properties and morphological parameters in selected microgreens cultivated in soilless media. *Sci. Rep.*, **14** (1) : 23605.

GUPTA, A., SHARMA, T., SINGH, S. P., BHARDWAJ, A., SRIVASTAVA, D. AND KUMAR, R., 2023, Prospects of microgreens as budding living functional food: Breeding and biofortification through OMICS and other approaches for nutritional security. *Frontiers in genetics*, **14** : 1053810.

MANSOURI, M., NOSHAD, M., AMIN MEHRNIA, M. AND HOJJATI, M., 2024, Sunflower microgreen powder as functional component to enhance the quality of gluten-free cakes. *LWT*, **198** : 116049.

MASHAU, M. E., JIDEANI, A. I. O. AND MALIWICHI, L. L., 2020, Evaluation of the shelf-life extension and sensory properties of mahewu - a non-alcoholic fermented beverage by adding aloe vera (*Aloe barbadensis*) powder. *Br. Food, J.*, **122** (11) : 3419 - 3432.

ONWUKA, G. I., 2005, Food analysis and instrumentation: Theory and practice. Lagos, Nigeria: *Naphtali Prints* : 129.

RENNA, M., DI GIOIA, F., LEONI, B., MININNI, C. AND SANTAMARIA, P., 2017. Culinary assessment of self-produced microgreens as basic ingredients in sweet and savory dishes. *J. Culin. Sci. Technol,* **15** (2) : 126 - 142.

SANYUKTA, BRAR, D. S., PANT, K., KAUR, S., NANDA, V., NAYIK, G. A., RAMNIWAS, S., RASANE, P. AND ERCISLI, S., 2023, Comprehensive analysis of physicochemical, functional, thermal and morphological properties of microgreens from different botanical sources. *ACS omega*, **8** (32) : 29558 - 29567.

SHIN, L. E., ZZAMAN, W., KUANG, Y. T. AND BHAT, R. 2015, Influence of dehydration techniques on physico chemical, antioxidant and microbial qualities of I pomoeaa quatica Forsk: an underutilized green leafy vegetable. *JFPP*., **39** (6) : 1118 - 1124.

SNEHA SHIGIHALLI, S. S. AND VIJAYALAKSHMI, K. G., 2018, Effect of pretreatments on dehydration of ivy gourd. *Mysore J. Agric. Sc*i., **52** (3).

SUBRAMANIAN, V., JAMBUNATHAN, R. AND RAMAIAH, C. D., 1986, Physical and chemical characteristics of pearl millet grains and their relationship to roti quality. *J. Food Sci.,* **5** (4) : 1005 - 1008.

TAHMAZ, J., BEGIĆ, M., ORUČEVIĆ ŽULJEVIĆ, S., MEHMEDOVIĆ, V., ALKIĆ-SUBAŠIĆ, M., JURKOVIĆ, J. AND DJULANĆIĆ, N., 2020, Physical properties of vegetable food seasoning powders. *CEFood*., 14 - 32.

VEENA, R., KEMPANNA, C. AND NARASIMHA MURTHY, N. M., 2011, Functional properties of soy protein isolate hydrolysed with neutrase enzyme. *Mysore J. Agric, Sci*., **45** (1) : 11 - 15.

YASUMATSU, K., SAWADA, K., MARITAKA, S., TODA, J., WADA, T. AND ISHI, K., 1972, Whipping and emulsifying properties of soy bean products. *Agri. Biol. Chem.,* **36** : 719 - 727.