**Enhancing Food Diversity: Nutritional and Sensory Evaluation of Microgreens and Their Value-Added Product (Fryums)**

#### Abstract

**Aim:** This study aimed to assess the nutritional value of microgreens and their mature counterparts, focusing on red amaranthus, fenugreek, and spinach.

**Research design**: Comparative Nutritional Analysis- Proximate composition analysis of microgreens and mature greens. Creation of fryums incorporating microgreen powder.

**Methodology:** Proximate composition analysis was performed to measure protein, fat, ash. Fryums were formulated using dried microgreen powder for product development. Sensory evaluations rated fryums based on color, appearance, flavor, taste, texture, and overall acceptability. Additionally, the moisture content of fryums was measured periodically over 150 days to assess storage stability.

**Results:** The proximate composition analysis revealed that microgreens generally had higher protein, fat, and ash content but lower carbohydrate and energy levels compared to mature greens. Red amaranthus microgreens contained 4.5 g/100g of protein, significantly higher than 2.5 g/100g in mature greens, with similar trends observed for fenugreek and spinach. The fryums with 30% microgreens scored highest in various categories. Additionally, the moisture content of fryums reaching 4.53% for control fryums (CF), 5.90% for red amaranthus microgreens fryums (RAMF4), 6.30% for fenugreek microgreens fryums (FMF4), and 7.40% for spinach microgreens fryums (SMF3) by the end of the storage period (150Days).

**Conclusion:** The microgreens has increased protein, fat, and ash content when compare to its mature and have potential as value-added products, enhancing food diversity and providing economic benefits. It has the immense potential to enhance nutritional intake and creating innovative, health-focused food products.

**Keywords**: Microgreens, Nutritional composition, Red Amaranthus, Fenugreek, Spinach, Fryums,

**INTRODUCTION**

Microgreens, a commercially used term for young and soft edible seedlings, are a phenomenal discovery in agriculture and cooking. These seedlings are cultivated by using seeds of several vegetables, herbaceous plants, aromatic herbs, and wild edible plants. They are usually harvested between 7 to 21 days from germination, when the cotyledon leaves have fully developed and the first set of true leaves had appeared. This is important because microgreens are most nutrient-dense at this stage, providing a huge nutritional punch even though they are small in size (Di Gioia, Mininni, & Santamaria, 2015).

The term microgreen is fairly recent in the history of agriculture. Though sprouts, a close but not the same product, were used for millennia, microgreens as we have them today started to become popular in the 1980s in California. Chefs first adopted them to provide color, texture, and taste to dishes. Throughout the decades, microgreens have transitioned from a specialty item to a mass market one, appreciated for both their nutritional value and simplicity of growth

Microgreens are "functional foods, usually called "superfoods in small packages," though small in stature, they contain a dense dose of vital nutrients and health-building substances, thus making them a favorite among families trying to enhance the quality of their diet. The small greens are easy to produce from seeds, such as vegetables, herbs, and legumes, and may be incorporated into different meals as a nutritional enhancement. These compounds consist of antioxidants, phenolics, vitamins, and minerals, which are capable of preventing illness and fostering general health (Renna et al., 2017).

The objective of this study was to assess the nutritional value of microgreens and their mature counterparts. Additionally, it aimed to develop value-added products, such as fryums, from red amaranthus microgreens, fenugreek microgreens, and spinach microgreens. Value-added products are essential as they enhance the nutritional profile, diversify food choices, increase shelf life, and provide economic benefits to producers and consumers.

**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.

**Proximate analysis of fresh microgreens and their mature greens**

**Moisture Estimation**

A known quantity of the sample was taken in a Petri dish and weighed. The Petri dishes along with known weight of the sample were dried in a hot air oven at 105 °C until the weight of the Petri dish with its content attained a constant value. The Petri dish was cooled in a desiccator each time before weighing. Moisture content of the sample was calculated as follows.

|  |  |
| --- | --- |
| Moisture (g/100g) = | Initial weight (g) − Final weight (g) |
| ---------------------------------------------------ⅹ 100 |
| Weight of the sample (g) |

### Protein content estimation

The protein content of the samples was estimated as per cent total nitrogen by the Micro-Kjeldhal procedure. Protein per cent was calculated by multiplying the per cent nitrogen by the factor 6.25.

|  |  |
| --- | --- |
| Protein (g/100g) = | (Titre value − blank) × Normality of HCl × 14.001 × 6.25 |
| ----------------------------------------------------------------------ⅹ 100 |
| Weight of the sample (g) |

**Fat content**

Fat content was estimated in the samples by determining the crude ether extract of the moisture-free sample. A moisture-free sample weighing 5 grams was carefully placed into a thimble and sealed with cotton to prevent any sample loss. The thimble, was then positioned within a Soxhlet apparatus and over a period of 3 hours, the sample was subjected to extraction using anhydrous ether as the solvent. Following this, the solvent was evaporated, leaving a residue in the flask. This flask was subsequently dried in a hot air oven maintained at a temperature ranging from 80 to 100 °C. After complete evaporation of the solvent, the flask, now with the dried residue, was allowed to cool within a desiccator and weighed.

Initial weight (g) – Weight after extraction (g)

Fat (g/100g) = **---------------------------------------------------------------×** 100

Sample weight (g)

**Ash content**

Total ash was estimated in the sample by weighing about 2 g of dried sample into a crucible. The crucible was placed on a wire gauze and heated over a low flame till the material was completely charred. Further, it was ignited in a muffle furnace for about 4 hours at 600 ˚C, cooled in desiccators and weighed soon after room temperature was reached. The obtained ash weight was divided by the original sample weight and expressed in per cent. The ash content was calculated using the following formula:

Weight of the ash

Ash content (g/100g) = **----------------------------------×** 100

Weight of the sample

### Computation of carbohydrate

Carbohydrate content was determined using a differential method, which involved subtracting the combined values of moisture, crude protein, crude fat, and total minerals

**Formulation and standardization of value-added products**

**Fryums incorporated with dried microgreens powder**

The control instant fryums were prepared using sago (*sabudana*). The microgreen fryums was prepared by incorporating 8.5-34g of each microgreen powder. The five formulations of fryums were prepared by substituting the sago with the microgreen powder where it was replaced by 10, 20, 30, and 40 per cent proportions.

**Sensory evaluation of developed product**

The sensory attributes of the formulated microgreens-based sago was analysed by 30 semi-trained panel members using a 9-point hedonic scale at food science and nutrition department, UAS, GKVK, Bangalore. The products were scored for colour, appearance, flavour, taste, texture, and overall acceptability. Scores were based on a hedonic scale of 1-9. Where 9- I like extremely, 8- I like very much, 7- I like moderately, 6- I like slightly, 5- I neither like nor dislike, 4- I dislike slightly, 3-I dislike moderately, 2- I dislike very much, 1- I dislike extremely.

**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

Compared the nutritional composition of fresh microgreens with their mature greens explained in Table 1, Table 2 and Table 3. Microgreens consistently showed higher protein levels compared to their mature greens. For red amaranthus microgreens contained 4.5g of protein, whereas mature greens had 2.5g. In fenugreek, microgreens had a higher protein content of 5.5g, compared to 3.4g in mature greens. Similarly, spinach microgreens contained 3.6g of protein, whereas mature greens had 2.9g. These findings suggested that microgreens had a more nutrient-dense profile with respect to protein.

The protein content of microgreens in this study was consistent with previous research on culinary microgreens, which ranged from 1.8 to 4.4 g/100g. High concentrations were found in fennel (4.4 g/100g) and sunflower (3.9 g/100g) microgreens, as reported by Ghoora *et al.* (2020b). Additionally, Ebert *et al*. (2015) noted a protein content of 1.3 to 1.6 g/100g in amaranth microgreens.

The observed variations in protein content among different microgreens can be attributed to factors such as the type of fertilizer used and soil composition, as suggested by Dubey *et al*. (2024). These environmental and agronomic factors play a crucial role in determining the nutritional profile of microgreens. This variability underscored the importance of optimizing growing conditions to enhance the nutritional quality of microgreens.

In the present study, Microgreens exhibited higher ash content compared to mature greens, indicating a greater mineral presence. For instance, Red Amaranthus microgreens had an ash content of 2.5g, while mature greens had 1.2g. Fenugreek microgreens showed 3.5g of ash content, compared to 2.7g in mature greens. Similarly, Spinach microgreens contained 2.2g of ash, whereas mature greens had 1.7g. This highlights the superior mineral content in microgreens.

The findings of this study on the ash content of microgreens align with previous research. Ghoora *et al.* (2020) reported that the total ash content of microgreens ranged from 0.48 g/100g in fenugreek to 1.67 g/100g in fennel.

**Table 1: Proximate composition comparison of red amaranthus microgreens and its mature greens**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Red Amaranthus** | | **t- value** |
| **Nutrients** | **Microgreens** | **Mature greens** |
| Moisture (%) | 87 ± 3.0 | 86 ± 2.5 | 0.24NS |
| Carbohydrates (g/100g) | 3.2 ± 0.5 | 5.8 ± 0.7 | 5.19\*\* |
| Protein (g/100) | 4.5 ± 0.3 | 2.5 ± 0.2 | 9.23\*\* |
| Fat (g/100g) | 0.4 ± 0.05 | 0.3 ± 0.02 | 4.08\* |
| Ash (g) | 2.5 ± 0.1 | 1.2 ± 0.1 | 13.80\*\* |
| Crude fibre (g/100) | 2.4 ± 0.15 | 4.2 ± 0.25 | 9.11\*\* |
| Energy (kcal/100g) | 30 ± 1.5 | 36 ± 2.0 | 3.84\* |

**Table 2: Proximate composition comparison of fenugreek microgreens and its mature greens**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Fenugreek** | | **t- value** |
| **Nutrients** | **Microgreens** | **Mature greens** |
| Moisture (%) | 82 ± 3.0 | 86 ± 2.5 | 0.97NS |
| Carbohydrates (g/100g) | 5.2 ± 0.4 | 2.7 ± 0.3 | 12.50\*\* |
| Protein (g/100) | 5.5 ± 0.3 | 3.4 ± 0.2 | 13.07\*\* |
| Fat (g/100g) | 1.0 ± 0.1 | 0.9 ± 0.05 | 2.58\* |
| Ash (g) | 3.5 ± 0.2 | 2.7 ± 0.1 | 7.65\*\* |
| Crude fibre (g/100) | 2.8 ± 0.15 | 5.4 ± 0.4 | 11.65\*\* |
| Energy (kcal/100g) | 51 ± 2.5 | 35.7 ± 1.5 | 4.96\*\* |

**Table 3: Proximate composition comparison of spinach microgreens and its mature greens**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Spinach** | | **t- value** |
| **Nutrients** | **Microgreens** | **Mature greens** |
| Moisture (%) | 88 ± 2.0 | 88.4 ± 1.5 | 0.45NS |
| Carbohydrates(g/100g) | 4.4 ± 0.3 | 2.97 ± 0.2 | 8.15\*\* |
| Protein (g/100) | 3.6 ± 0.2 | 2.9 ± 0.15 | 5.23\*\* |
| Fat (g/100g) | 0.6 ± 0.05 | 0.4 ± 0.02 | 6.32\*\* |
| Ash (g) | 2.2 ± 0.1 | 1.7 ± 0.1 | 7.46\*\* |
| Crude fibre (g/100) | 1.2 ± 0.05 | 3.63 ± 0.3 | 11.01\*\* |
| Energy (kcal/100g) | 37 ± 1.5 | 27 ± 1.0 | 15.38\*\* |

Note: Values were expressed as mean ± standard deviation of three determinations, \*\*Significant at (p ≤ 0.01), \* Significant at (p ≤ 0.05). NS: Not significant

In the study conducted by Khatoon *et al.* (2022), ash content in radish microgreens in the range of 2.16 to 2.41 g/100 g, dry weight basis was observed in different formulated growing mediums.

Similarly, Kowitcharoen *et al.* (2021) found ash content values between 0.34 to 0.65 g/100g, which were lower than those reported in this study.

The variations in the ash content of microgreens could be attributed to genotypic differences (Ghoora *et al.,* 2020). These comparisons reinforce the variability and potential nutrient richness of microgreens, highlighting their importance in diet and nutrition research.

Crude fiber, microgreens typically had lower content than mature greens. Red Amaranthus microgreens had 2.4g of crude fiber compared to 4.2g in mature greens. In fenugreek, microgreens contained 2.8g of crude fiber, while mature greens had 5.4g. Spinach microgreens had 1.2g of crude fiber, whereas mature greens had 3.63g.

Carbohydrate content in microgreens varies but they were generally higher in some cases compared to mature greens. Red Amaranthus microgreens contained 3.2g of carbohydrates, while mature greens had 5.8g. In contrast, fenugreek microgreens had a higher carbohydrate content (5.2g) compared to 2.7g in mature greens. Spinach microgreens contained 4.4g of carbohydrates, whereas mature greens had 2.97g.

The carbohydrate content of microgreens, as reported by Kowitcharoen *et al.* (2021) ranged between 1.88 to 6.47 g/100g for various types including Brassicaceae, Fabaceae, and others.

In terms of moisture content, there was no significant difference between microgreens and mature greens across all three types. However, microgreens showed significant variations in their nutritional profile, particularly with higher protein and ash content, and lower crude fiber. This highlights their potential as nutrient-dense food sources.

The moisture content of fresh microgreens was reported by Kowitcharoen *et al.* (2021) which was in the range of 86.57 to 94.67 per cent which was similar to the results of present study.

The effect of cultivation substrate on different sprouts of sorghum, wheat, horse gram, cowpea, mungbean, and fenugreek the moisture content similar ranged (90.28–90.74 g/100 g, FW), was observed (Eswaranpillai *et al*., 2023). Radish sango microgreens, the moisture content was 90.84 to 92.20%, containing soil, vermicompost, and cocopeat growing medium. The findings closely aligned with the present study.

**Development of fryums from the dried microgreens powder and their sensory evaluation**

**Soak the sago**

Rinse the **sago** well and soak it in water for about 4-6 hours or overnight until it softens. Drain excess water after soaking.

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**Prepare the dough**

* Once the **sago** is cooked and the mixture is thick, gradually add **microgreen powder**, green chilly paste, cumin seeds and salt.
* Keep stirring until the mixture forms a thick, pliable dough.

**Shape the fryums**

* On a plastic sheet or clean kitchen towel, spread small portions of the dough. It can be shaped into small discs or long strips using spoon or piping bag
* Allow the shaped fryums to sun-dry for 1-2 days or tray dry for 5hr until they become completely dry and crisp.

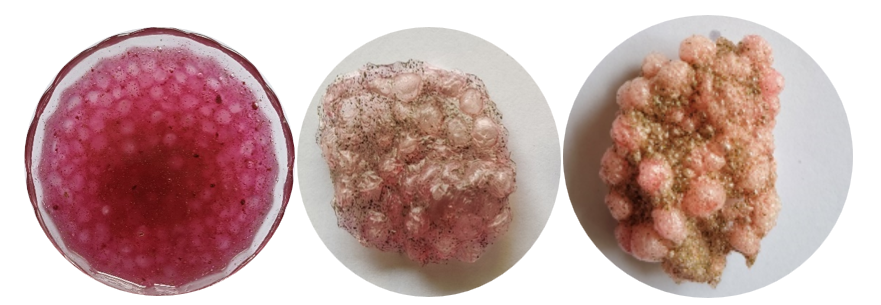
**Cook the sago**

* In a pan, bring about 1 to 1.5 cups of water to a boil.
* Add the soaked **sago** and cook on low heat until it becomes translucent and the water turns starchy. Stir continuously to prevent sticking.

**Fry the fryums**:

* Once the fryums are completely dried, heat **oil** in a pan for deep frying.
* Deep fry the fryums in batches until they puff up and turn golden.
* Drain on paper towels to remove excess oil.

**Fig 1 : Flow chart showing the preparation of fryums**



Picture 3 Fried fryums

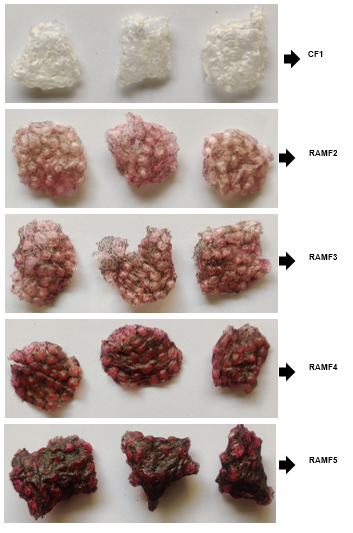
Picture 2 Raw fryums

Picture 1 Batter

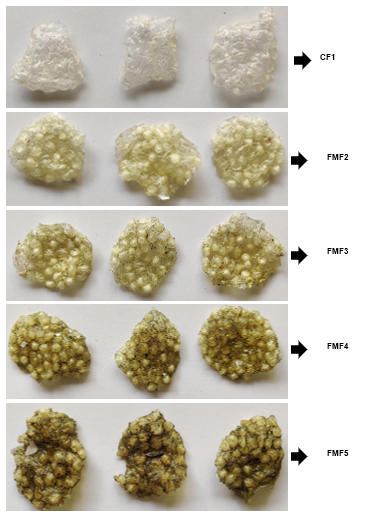
The sensory evaluation of fryums incorporating red amaranthus microgreens (Table 4a) revealed interesting trends. RAMF4 (20% incorporation) achieved the highest scores for color (8.70 ± 0.31), appearance (8.85 ± 0.37), flavor (8.08 ± 0.34), and overall acceptability (8.75 ± 0.37). These results indicate that the 20% incorporation level provides the best balance of sensory attributes, enhancing the visual appeal, taste, and overall enjoyment of the fryums. In RAMF5 the colour was too much that sensory panel members openioned that it was not that appealing so resulting in getting less score.

This optimal incorporation level demonstrated the potential of red amaranthus microgreens to improve the quality and sensory attributes of fryums product, making them a valuable addition to food formulations. The consistent high scores across different attributes at the 20% level suggested that this was an effective way to integrate the nutritional benefits of microgreens without compromising on taste or texture.

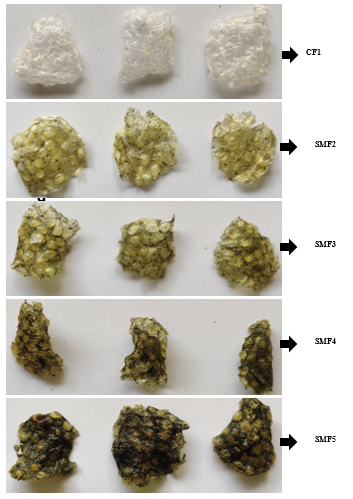
The sensory evaluation of fryums incorporating fenugreek microgreens represented in the Table 4b. The highest score for color was achieved by FMF5 (40% incorporation) with 8.31 ± 0.27, indicating that this level of microgreen content significantly enhanced the visual appeal of the fryums. For appearance, FMF5 also led with a score of 8.40 ± 0.30, suggested that the fryums look most attractive at this incorporation level.



**Plate 1: Dried red Amaranthus microgreens fryums**



**Plate 2: Dried Fenugreek microgreens fryums**



**Plate 3: Dried spinach microgreens fryums**

Flavor scores peaked with FMF4 (30% incorporation) at 8.59 ± 0.36, showing that this level provides the best flavor profile. Taste scores followed a similar trend, with FMF4 scoring 8.73 ± 0.40, indicating the most pleasant taste experience at this incorporation level.

However, texture scores were slightly varied, with the control (CF1) achieving the highest score of 8.20 ± 0.28. This suggested that while microgreens improve other sensory attributes, they might slightly alter the texture.

Overall acceptability was highest for FMF4 (30% incorporation) at 8.70 ± 0.37, indicating that this level provides the best balance of sensory attributes, making the fryums more appealing and enjoyable.

The sensory evaluation of fryums incorporating spinach microgreens showed in Table 4c. The highest scores for color were observed in SMF3 (20% incorporation), which scored 8.50 ± 0.28. This indicates that this incorporation level significantly enhanced the visual appeal of the fryums. For appearance, SMF3 also led with a score of 7.98 ± 0.31, suggested that this level makes the fryums look most attractive.

Flavor scores peaked with SMF3, achieving 8.78 ± 0.30, indicating the best flavor profile at this level. Taste followed a similar trend, with SMF3 scoring the highest at 8.75 ± 0.32, indicating a more pleasant taste experience. However, texture scores varied slightly, with the control (CF1) achieving the highest texture score (8.20 ± 0.27), indicating that while microgreens improve other sensory attributes, they might slightly alter the texture.

Overall acceptability was also highest for SMF3 (20%), with a score of 8.59 ± 0.33, suggested that this incorporation level provides the best balance of sensory attributes

Shetty *et al.,* 2024 conducted a study on soilless grown microgreens and their sensory acceptability of raw red amaranthus, Fenugreek and spinach. Red amaranthus scored maximum in overallacceptability followed by spinach and fenugreek. This result may directly influence for the product developed form the following microgreens.

The study conducted by Joshi *et al*., 2015 on value added products from the leaf powders of dehydrated less utilized green leafy vegetables found that the integration of these leaf powders not only boosts the nutritional value of fryums but also enhanced their sensory attributes, making them more appealing to consumers.

The incorporation of leaf powders, such as Moringa and fenugreek, enhanced the color of fryums, making them visually appealing. For instance, Moringa leaf powder can impart a vibrant green hue, which was often associated with freshness and healthiness (Jakobson e*t al*., 2023) explains the increased colour of the microgreens fryums in present study.

Bandral *et al*. (2023) studied on effect of incorporation of fenugreek and coriander leaves on nutritional quality of broken basmati rice far-far and found out leaf powders contributed for distinct flavors and aroma to fryums. Fenugreek leaves can add a slightly bitter and nutty flavor, while coriander leaves provide a fresh, citrusy taste. These studies explained the increased flavour, colour and aroma of the developed microgreens fryums in the present study.

**Table 4: Mean sensory evaluation scores of fryums from dried microgreens powder**

1. **Red Amaranthus**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variations** | **Colour** | **Appearance** | **Flavour** | **Taste** | **Texture** | **Overall**  **Acceptability** |
| CF1 | 4.50 ± 0.25a | 5.00 ± 0.30a | 6.40 ± 0.28a | 7.50 ± 0.35a | 8.20 ± 0.32a | 7.10 ± 0.36a |
| RAF2 | 6.70 ± 0.28b | 7.90 ± 0.33b | 7.25 ± 0.30b | 8.14 ± 0.34b | 8.38 ± 0.31b | 7.80 ± 0.35b |
| RAF3 | 7.95 ± 0.29c | 8.28 ± 0.35c | 7.82 ± 0.32b | 8.36 ± 0.36b | 7.98 ± 0.30a | 8.26 ± 0.34b |
| RAF4 | 8.70 ± 0.31c | 8.85 ± 0.37c | 8.08 ± 0.34c | 8.65 ± 0.38b | 7.94 ± 0.29a | 8.75 ± 0.37c |
| RAF5 | 8.50 ± 0.30c | 8.40 ± 0.34c | 7.85 ± 0.31b | 7.01 ± 0.29a | 7.02 ± 0.28b | 8.20 ± 0.32b |
| F-value | \* | \* | \* | \* | \* | \*\* |
| SEm± | 0.20 | 0.22 | 0.21 | 0.23 | 0.21 | 0.26 |
| CD @ 5% | 0.28 | 0.30 | 0.29 | 0.31 | 0.29 | 0.34 |

**Note:** \*\*Significant at (p ≤ 0.01), \* Significant at (p ≤ 0.05).

CF1- Control fryums; RAMF2- 10 % incorporated Red Amaranthus microgreen fryums; RAMF3- 20 % incorporated Red Amaranthus microgreen fryums; RAMF4- 30 % incorporated Red Amaranthus microgreen fryums; RAMF5- 40 % incorporated Red Amaranthus microgreen fryums;

1. **Fenugreek**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variations** | **Colour** | **Appearance** | **Flavour** | **Taste** | **Texture** | **Overall**  **Acceptability** |
| CF1 | 4.50 ± 0.22a | 5.00 ± 0.25a | 6.40 ± 0.30a | 7.50 ± 0.35a | 8.20 ± 0.28a | 7.10 ± 0.32a |
| FMF2 | 7.48 ± 0.24b | 7.50 ± 0.28a | 7.22 ± 0.34b | 8.13 ± 0.38b | 8.37 ± 0.31b | 7.50 ± 0.34b |
| FMF3 | 7.50 ± 0.25b | 8.15 ± 0.29b | 8.39 ± 0.31c | 8.27 ± 0.32b | 8.05 ± 0.30a | 8.28 ± 0.36b |
| FMF4 | 8.00 ± 0.26c | 8.30 ± 0.32b | 8.59 ± 0.36c | 8.73 ± 0.40b | 7.90 ± 0.29a | 8.70 ± 0.37c |
| FMF5 | 8.31 ± 0.27c | 8.40 ± 0.30c | 7.89 ± 0.29b | 7.55 ± 0.28a | 7.50 ± 0.26a | 8.12 ± 0.33b |
| F-value | \*\* | \* | \* | \* | \* | \*\* |
| SEm± | 0.18 | 0.22 | 0.21 | 0.24 | 0.20 | 0.27 |
| CD @ 5% | 0.25 | 0.30 | 0.28 | 0.32 | 0.27 | 0.35 |

**Note:** \*\*Significant at (p ≤ 0.01), \* Significant at (p ≤ 0.05).

CF1- Control fryums; FMF2- 10 % incorporated fenugreek microgreen fryums; FMF3- 20 % incorporated fenugreek microgreen fryums; FMF4- 30 % incorporated fenugreek microgreen fryums; FMF5- 40 % incorporated fenugreek microgreen fryums.

1. **Spinach**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variations** | **Colour** | **Appearance** | **Flavour** | **Taste** | **Texture** | **Overall**  **Acceptability** |
| CF1 | 4.50 ± 0.22a | 5.00 ± 0.30a | 6.40 ± 0.28a | 7.50 ± 0.35a | 8.20 ± 0.27a | 7.10 ± 0.34a |
| SMF2 | 7.89 ± 0.26b | 7.50 ± 0.32a | 8.64 ± 0.31b | 8.05 ± 0.34b | 8.45 ± 0.30b | 8.21 ± 0.32b |
| SMF3 | 8.50 ± 0.28c | 7.98 ± 0.31b | 8.78 ± 0.30c | 8.75 ± 0.32c | 8.50 ± 0.29b | 8.59 ± 0.33b |
| SMF4 | 8.40 ± 0.30c | 7.75 ± 0.28b | 8.30 ± 0.33b | 8.58 ± 0.31c | 8.30 ± 0.27b | 8.30 ± 0.35b |
| SMF5 | 8.38 ± 0.29c | 7.45 ± 0.27b | 7.39 ± 0.32a | 8.16 ± 0.30b | 7.52 ± 0.26a | 7.83 ± 0.34a |
| F-value | \*\* | \* | \* | \* | \* | \*\* |
| SEm± | 0.24 | 0.19 | 0.22 | 0.21 | 0.23 | 0.20 |
| CD @ 5% | 0.32 | 0.27 | 0.30 | 0.29 | 0.31 | 0.28 |

**Note:** \*\*Significant at (p ≤ 0.01), \* Significant at (p ≤ 0.05).

CF1- Control fryums; SMF2- 10 % incorporated spinach microgreen fryums; SMF3- 20 % incorporated spinach microgreen fryums; SMF4- 30 % incorporated spinach microgreen fryums; SMF5- 40 % incorporated spinach microgreen fryums.

**Proximate analysis of best accepted microgreens fryums**

Table 5 shows the proximate composition analysis of fryums with microgreens reveals significant nutritional enhancements compared to the control fryums. Notably, protein content increased in SMF3 (4.45 g) and FMF4 (4.4 g) compared to the control (1.03 g). Ash content significantly increased in SMF3 (7.98 g), compared to the control (0.69 g). Crude fiber was highest in FMF4 (3.96 g), compared to the control (0.84 g).

Among the variations, RAMF4 (30% Red Amaranthus) and SMF3 (20% Spinach) stand out with the highest nutritional values, making them highly suitable for fryums due to their enhanced nutrient profiles.

The fortification of fryums with GLV not only enhanced their micronutrient density but also contributed to better health outcomes by addressing common deficiencies in populations. For instance, iron and vitamin A deficiencies were prevalent, and incorporating GLV can help mitigate these issues (Subbulaxmi *et al*., 2024)

Vanishree *et al.,* 2021 study indicates that using high-quality protein sources, such as maize or soy flour, can significantly increase the protein content of fryums. Fryums made with 100% maize flour exhibited excellent organoleptic properties and higher protein levels compared to traditional recipes.

Fryums can be enriched with proteins and other nutrients depending on the ingredients used. They often contained carbohydrates, proteins, and fats, with variations based on the formulation. The nutritional composition can be enhanced through the addition of legumes or fortified grains, which can improve their overall health benefits (Vanishree *et al.,* 2021).

**Table 5: Proximate composition of control and microgreens fryums**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Nutritional Component (g/100g)** | **CF** | **RAMF4** | **FMF4** | **SMF3** |
| Moisture | 4.03 ± 0.10a | 5.40 ± 0.12b | 5.80 ± 0.13c | 6.90 ± 0.14d |
| Protein | -1.03 ± 0.05a | 3.49 ± 0.10b | 4.4 ± 0.15c | 4.45 ± 0.16c |
| Fat | 3.5 ± 0.15a | 1.6 ± 0.05b | 3.4 ± 0.12c | 1.86 ± 0.06b |
| Ash | 0.69 ± 0.02a | 7.36 ± 0.25b | 7.02 ± 0.20b | 7.98 ± 0.30c |
| Crude Fibre | 0.84 ± 0.05a | 2.47 ± 0.10b | 3.96 ± 0.15c | 3.17 ± 0.12c |
| CHO# | 72.63 ± 0.50a | 79.75 ± 0.60b | 75.42 ± 0.55c | 75.64 ± 0.60c |
| Energy# | 372.63 ± 2.50a | 347.36 ± 2.75b | 349.88 ± 2.60b | 337.1 ± 2.65c |

**Note:** CHO- Carbohydrates; #- Computed values

**Moisture content of *fryums* on storage**

The effect of storage on the moisture content of fryums over 150 days (Table 6) showed a gradual increase across all samples, including the control (CF) and those with microgreens. On the 0th day, moisture content was 4.03% for CF, 5.40% for RAMF4, 5.80% for FMF4, and 6.90% for SMF3. By the 30th day, slight increases were observed with CF at 4.00%, RAMF4 at 5.42%, FMF4 at 5.83%, and SMF3 at 6.99%.

As storage continued, moisture content rose further. By the 60th day, CF reached 4.16%, RAMF4 was at 5.53%, FMF4 at 5.93%, and SMF3 at 7.03%. On the 90th day, these values increased to 4.28%, 5.65%, 6.05%, and 7.15% respectively. By the 120th day, moisture content was 4.41% for CF, 5.78% for RAMF4, 6.18% for FMF4, and 7.28% for SMF3. Finally, by the 150th day, the moisture content peaked at 4.53% for CF, 5.90% for RAMF4, 6.30% for FMF4, and 7.40% for SMF3.

**Table 6. Effect of storage on the moisture content of fryums**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Storage period** | **Moisture content (%)** | | | |
| **CF** | **RAMF4** | **FMF4** | **SMF3** |
| 0th day | 4.03 | 5.40 | 5.80 | 6.90 |
| 30th day | 4.00 | 5.42 | 5.83 | 6.99 |
| 60th day | 4.16 | 5.53 | 5.93 | 7.03 |
| 90th day | 4.28 | 5.65 | 6.05 | 7.15 |
| 120th day | 4.41 | 5.78 | 6.18 | 7.28 |
| 150th day | 4.53 | 5.90 | 6.30 | 7.40 |
| F-value | \* | \* | \* | \* |
| SEm± | 0.19 | 0.20 | 0.21 | 0.22 |
| CD @ 5% | 0.27 | 0.28 | 0.29 | 0.30 |

\* Significant at (p ≤ 0.05), CF: Control fryums; RAMF4- 30 % incorporated Red Amaranthus microgreen fryums; FMF3- 20 % incorporated fenugreek microgreen fryums; SMF3- 20 % incorporated spinach microgreen fryums.

Despite these increases, the overall rise in moisture content was minimal. RAMF4 (30% Red Amaranthus) and SMF3 (20% Spinach) exhibited the highest moisture content by the end of the storage period. However, the incremental increase was so slight that it indicates fryums incorporating microgreens can be kept for extended periods without significant degradation, thus maintaining their quality and shelf life effectively.

**Effect of storage on microbial population in fryums**

The effect of storage on the microbial population in microgreens fryums that both total bacteria and mould counts remained undetected (ND) throughout the 150-day period across all samples, including the control (CF), RAMF4 (30% Red Amaranthus), FMF4 (20% Fenugreek), and SMF3 (20% Spinach). This absence of microbial growth can be attributed to the low moisture content in the fryums, which inhibits the growth of microorganisms. This stability highlights that microgreens fryums can be stored for long periods without compromising safety or quality.

Microgreens, known for their high nutritional value, also possess antimicrobial properties. Studies indicate that extracts from microgreens can be effective against various pathogens, potentially serving as natural preservatives in food (Xiao *et al*., 2015) explains the results of present study.

Dry foods were generally considered microbiologically safe and clean for consumers (Alp and Bulantekin, 2021). This was because low water activity levels inhibit the growth of most bacteria, yeasts, and molds, which cannot thrive below the thresholds of 0.87, 0.88, and 0.80 respectively (Beuchat *et al*., 2013) and fryums will come in the category of dry food.

**Conclusion:** This research indicates the remarkable nutritional benefits of microgreens compared to their mature form, especially regarding increased protein, fat, and ash content. Creation of value-added products like fryums from red amaranthus, fenugreek, and spinach microgreens not only enriches the nutrition but also boosts sensory acceptability.

The encouraging findings suggest that microgreens have the potential to be a key player in food diversification, providing economic advantage, as well as overcoming nutritional shortages. By integrating microgreens in value-added products, we can make available healthier and more desirable alternatives to consumers, in turn contributing to enhanced public health and sustainable agriculture.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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