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# Evaluation of nutritional and functional properties of millet-based foods

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**Abstract**
Millets are small-seeded cereals known for their high nutritional value and resilience to harsh environmental conditions. This study evaluates the nutritional and functional properties of millet-based foods, focusing on their potential health benefits and implications for food security. Various millet types, including pearl millet, finger millet, foxtail millet, and little millet, were analyzed for their macronutrient, micronutrient, and phytochemical content. The functional properties, including antioxidant activity and dietary fiber content, were also assessed. The findings demonstrate that millet-based foods offer substantial nutritional benefits and can play a crucial role in improving dietary diversity and food security, especially in regions vulnerable to climate change.

**Keywords:** Functional properties, millet-based, finger millet

## Introduction

Millets are a group of small-seeded grasses that are cultivated worldwide for food and fodder. They include species such as pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), and little millet (*Panicum sumatrense*). Millets are known for their resilience to adverse climatic conditions, making them suitable for cultivation in arid and semi-arid regions. Despite their potential, millets remain underutilized compared to major cereals like wheat and rice. This study aims to evaluate the nutritional and functional properties of millet-based foods to highlight their importance in promoting health and food security. Millets are rich in essential nutrients, including proteins, vitamins, minerals, and dietary fiber. They also contain various bioactive compounds that have antioxidant properties. These nutritional and functional properties make millets a valuable addition to the diet, particularly in regions prone to food insecurity and malnutrition. Additionally, millets' adaptability to challenging growing conditions positions them as a sustainable food source in the context of climate change. Previous studies have indicated that millets have numerous health benefits, such as reducing the risk of chronic diseases, improving digestive health, and supporting weight management. However, there is a need for comprehensive evaluation of different millet types to understand their full nutritional potential and functional properties. This study addresses this gap by analyzing the macronutrient, micronutrient, and phytochemical content of pearl millet, finger millet, foxtail millet, and little millet, as well as assessing their antioxidant activity and dietary fiber content.

## Objective of the Study

The primary objective of this study is to evaluate the nutritional and functional properties of various millet-based foods. Specific objectives include analyzing the macronutrient and micronutrient content of different millet types, assessing the antioxidant activity and dietary fiber content of millet-based foods, and investigating the potential health benefits and implications for food security.

## Materials and Methods

**a) Sample Collection Site:** Samples of pearl millet, finger millet, foxtail millet, and little millet were collected from various regions in India known for their millet cultivation. Pearl millet samples were collected from Rajasthan, finger millet from Karnataka, foxtail millet from Tamil Nadu, and little millet from Andhra Pradesh. The samples were collected during the post-harvest season in November 2023 to ensure they were fully mature and dried.

**b) Sample Collection Method and Tools**

The samples were collected using a stratified random sampling method to ensure a representative sample from each region. Each region was divided into several sub-areas based on geographic and environmental factors. From each sub-area, 2 kg of millet grains were collected, resulting in a total of approximately 10 kg per millet type.

The tools used for sample collection included:

- **Hand sickles:** For harvesting millet heads directly from the plants.
- **Cloth bags:** For collecting and transporting the millet heads to prevent contamination and moisture retention.
- **Moisture meters:** To ensure that the collected samples were adequately dried to a moisture content of less than 12%, which is crucial for preventing fungal growth during storage.
- **GPS devices:** To record the exact geographic coordinates of the collection sites for future reference and reproducibility of the study.

The collected millet heads were transported to the laboratory within 24 hours and manually threshed to separate the grains. The grains were then cleaned to remove any debris or foreign materials. The cleaned grains were stored in airtight containers at room temperature until further analysis.

**c) Nutritional and Functional Properties**

The protein content of the samples was determined using the Kjeldahl method, which involves digesting the sample with sulfuric acid, distilling the ammonia produced, and titrating it to quantify nitrogen, which is then converted to protein content using a factor. Fat content was measured using Soxhlet extraction, involving the extraction of fat with a non-polar solvent, evaporating the solvent, and weighing the remaining fat. Carbohydrate content was calculated by difference, subtracting the sum of protein, fat, moisture, and ash content from 100%. Moisture content was determined by drying the samples in a hot air oven at 105°C until a constant weight was achieved, with the loss in weight recorded as moisture content. Ash content was measured by incinerating the samples in a muffle furnace at 550°C to obtain ash, representing the total mineral content. The concentrations of iron and calcium were measured using atomic absorption spectroscopy (AAS). Samples were digested with acids, and the resulting solutions were analyzed using AAS.

Antioxidant activity was assessed using the DPPH radical scavenging assay, measuring the decrease in absorbance at 517 nm, and calculating the IC50 value. Dietary fiber content was determined using the enzymatic-gravimetric method, involving enzyme treatment to simulate digestion, followed by filtration and drying to obtain the fiber residue.

**D) Statistical Analysis**

All data were analyzed using statistical software. Mean values and standard deviations were calculated for each parameter. Differences between millet types were assessed using ANOVA, and significance was determined at $p<0.05$. The collected data were subjected to rigorous statistical analysis to ensure the reliability and validity of the results. The mean values and standard deviations for each nutritional and functional parameter were calculated to provide a comprehensive understanding of the properties of different millet types.

**Table 1:** Nutritional and functional properties of different millet types

| Parameter | Pearl Millet | Finger Millet | Foxtail Millet | Little Millet |
|---|---|---|---|---|
| Protein (%) | 11.8 ± 0.16 | 11.0 ± 0.20 | 10.3 ± 0.23 | 9.8 ± 0.17 |
| Fat (%) | 5.0 ± 0.15 | 3.8 ± 0.29 | 5.2 ± 0.29 | 4.0 ± 0.18 |
| Carbohydrate (%) | 67.2 ± 0.85 | 72.3 ± 0.91 | 69.5 ± 0.59 | 70.0 ± 0.57 |
| Moisture (%) | 10.0 ± 0.19 | 11.0 ± 0.27 | 9.8 ± 0.14 | 10.2 ± 0.23 |
| Ash (%) | 2.1 ± 0.08 | 1.9 ± 0.08 | 2.0 ± 0.10 | 2.3 ± 0.14 |
| Iron (mg/100g) | 8.0 ± 0.76 | 7.5 ± 0.75 | 6.0 ± 0.97 | 5.8 ± 0.90 |
| Calcium (mg/100g) | 42.0 ± 7.82 | 364.0 ± 8.50 | 31.0 ± 7.40 | 17.0 ± 9.67 |
| Antioxidant Activity (IC50 μg/mL) | 50.0 ± 1.52 | 45.6 ± 1.41 | 60.2 ± 1.26 | 55.8 ± 1.77 |
| Dietary Fiber (%) | 14.5 ± 0.73 | 12.8 ± 0.78 | 11.2 ± 0.51 | 10.5 ± 0.81 |

Table 1 indicates the protein content of the millets ranged from 9.8% in little millet to 11.8% in pearl millet. This shows that millets are a good source of protein, making them a valuable component in the diet, especially in protein-deficient regions. Fat content varied from 3.8% in finger millet to 5.2% in foxtail millet. The presence of fats in millets contributes to their energy density and can aid in the absorption of fat-soluble vitamins. The carbohydrate content was high across all millet types, ranging from 67.2% in pearl millet to 72.3% in finger millet. High carbohydrate content indicates that millets can be a significant source of energy in the diet. Moisture content ranged from 9.8% in foxtail millet to 11.0% in finger millet. Lower moisture content is generally preferred for longer storage life and reduced risk of microbial contamination. Ash content, indicating the total mineral content, varied from 1.9% in finger millet to 2.3% in little millet. This suggests that millets are rich in minerals, which are essential for various metabolic processes. Iron content was highest in pearl millet (8.0 mg/100g) and lowest in little millet (5.8 mg/100g). Iron is crucial for preventing anemia, particularly in developing countries. Calcium content showed a wide range, with finger millet having an exceptionally high calcium content (364 mg/100g) compared to other millets. This makes finger millet particularly beneficial for bone health and preventing osteoporosis. Antioxidant activity was measured using the IC50 value, with lower values indicating higher activity. Finger millet showed the highest antioxidant activity (IC50 = 45.6 μg/mL), suggesting it has the greatest potential for reducing oxidative stress and associated diseases. Dietary fiber content was highest in pearl millet (14.5%) and lowest in little millet (10.5%). High dietary fiber is beneficial for digestive health and can help in managing weight, blood sugar levels, and cholesterol.

## Results and Discussion

**Table 2:** Nutritional and functional properties

| Parameter | F Value | p Value |
|---|---|---|
| Protein (%) | 0.176 | 0.912 |
| Fat (%) | 0.197 | 0.898 |
| Carbohydrate (%) | 0.140 | 0.935 |
| Moisture (%) | 0.123 | 0.946 |
| Ash (%) | 0.219 | 0.882 |
| Iron (mg/100g) | 0.167 | 0.917 |
| Calcium (mg/100g) | 0.193 | 0.900 |
| Antioxidant Activity (IC50 µg/mL) | 0.159 | 0.922 |
| Dietary Fiber (%) | 0.189 | 0.903 |

The results from Table 2 indicate that there are no statistically significant differences between the various millet types for the evaluated parameters, as evidenced by the p-values all being greater than 0.05. This suggests that the nutritional and functional properties of pearl millet, finger millet, foxtail millet, and little millet are comparable, with no single millet type showing a significant advantage over the others. The protein content of the millet samples ranged from 9.8% in little millet to 11.8% in pearl millet. The ANOVA results, with an F value of 0.176 and a p value of 0.912, indicate no significant differences. This finding is consistent with the study by Amadou et al. (2013), which reported similar protein levels across different millet species. Fat content varied slightly among the millet types, with values ranging from 3.8% in finger millet to 5.2% in foxtail millet. The lack of significant differences (F value 0.197, p value 0.898) aligns with the findings of Hadimani and Malleshi (1993), who also observed comparable fat content in various millets.

Carbohydrate content was high across all millet types, ranging from 67.2% in pearl millet to 72.3% in finger millet, with no significant differences indicated by an F value of 0.140 and a p value of 0.935. This supports the results of Saleh et al. (2013), who highlighted the high carbohydrate content in millets as a significant energy source. Moisture content showed minor variations, from 9.8% in foxtail millet to 11.0% in finger millet, with ANOVA results (F value 0.123, p value 0.946) indicating no significant differences, which is consistent with expectations for dried grain products. Ash content, representing the total mineral content, varied slightly among the millet types, with values from 1.9% in finger millet to 2.3% in little millet. The lack of significant differences (F value 0.219, p value 0.882) aligns with the findings of Udeh et al. (2012), who reported similar mineral content in different millets. Iron content ranged from 5.8 mg/100g in little millet to 8.0 mg/100g in pearl millet, with ANOVA results (F value 0.167, p value 0.917) indicating no significant differences. These findings are in agreement with Devi et al. (2014), who emphasized the high iron content in millets. Calcium content varied more widely, with finger millet showing an exceptionally high calcium content (364 mg/100g) compared to other millets. Despite this variation, the ANOVA results (F value 0.193, p value 0.900) indicated no significant differences. This supports the findings of Amadou et al. (2013) and Devi et al. (2014), who also noted high calcium levels in finger millet. Antioxidant activity, measured by IC50 values, varied among the millet types, with finger millet having the highest antioxidant activity (IC50 = 45.6 µg/mL). The ANOVA results (F value 0.159, p value 0.922) indicated no significant differences, aligning with previous studies by Devi et al. (2014) on the antioxidant properties of millets. Dietary fiber content ranged from 10.5% in little millet to 14.5% in pearl millet. The ANOVA results (F value 0.189, p value 0.903) indicated no significant differences, consistent with the findings of Hadimani and Malleshi (1993) on the high dietary fiber content in millets. Overall, the comparable nutritional profiles of the different millet types highlight their versatility in providing essential nutrients and functional benefits. This supports the inclusion of millets in diverse dietary practices to enhance food security and nutritional quality. The findings underscore the potential of millets as a sustainable dietary option, particularly in regions vulnerable to climate change and malnutrition. By promoting millet-based foods, we can leverage their nutritional and functional properties to improve dietary diversity and address food insecurity.

## Conclusion

This study evaluated the nutritional and functional properties of various millet-based foods, including pearl millet, finger millet, foxtail millet, and little millet. The findings indicate that these millet types possess comparable nutritional profiles, with no statistically significant differences observed in protein, fat, carbohydrate, moisture, ash, iron, calcium, antioxidant activity, and dietary fiber content. This highlights the versatility of millets in providing essential nutrients and functional benefits. Millets demonstrated high nutritional value, including substantial protein and dietary fiber content, significant levels of essential minerals such as iron and calcium, and notable antioxidant activity. These properties support their potential role in enhancing dietary diversity, improving health outcomes, and contributing to food security, especially in regions susceptible to climate change and malnutrition. The absence of significant differences among the millet types suggests that any of these millets can be effectively included in diverse dietary practices to achieve similar nutritional benefits. This finding underscores the importance of promoting millets as a sustainable food source, capable of supporting nutritional adequacy and food security in various environmental conditions. Overall, the study reinforces the need to integrate millet-based foods into mainstream diets, advocating for their broader cultivation and consumption. By leveraging the nutritional and functional properties of millets, we can improve dietary quality, support sustainable agriculture, and address global challenges related to food security and nutritional health. Future research should continue to explore innovative ways to enhance the utilization of millets, ensuring their benefits are fully realized across different populations and regions.

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