

Short Research Article

Protein and Crude Fibre Content of Various Millets: A Comparative Study

ABSTRACT

Aims: The study aimed to evaluate and compare the protein and crude fibre content of eight different millet species, emphasizing their potential in formulating nutritionally superior food products.

Study design: This was an experimental, laboratory-based study.

Place and Duration of Study: The study was conducted at the Department of Dairy Microbiology, Dairy Science College, Hebbal, Bengaluru, Karnataka, India, between January 2024 and October 2024.

Methodology: Eight millet species, including foxtail millet, bajra, sorghum, finger millet, little millet, kodo millet, barnyard millet, and proso millet, were analyzed for their protein and crude fibre content. The protein content was determined using the micro-Kjeldahl technique, while the crude fibre content was measured through a two-step acid and alkaline digestion process. Statistical analysis was performed using ANOVA, and the critical difference (CD) at a 5% significance level was calculated to determine significant variations in nutrient content.

Results: The protein content varied significantly among the millets, with foxtail millet showing the highest value at 10.50%, followed by proso millet at 9.94%. Finger millet had the lowest protein content at 7.24%. Crude fibre content was highest in finger millet (3.61%), while barnyard millet exhibited the lowest value (1.70%). Statistical analysis revealed a critical difference of 0.055 for protein content and 0.025 for crude fibre content at $P=0.05$, indicating significant differences between millet types.

Conclusion: The study highlighted the nutritional variability among different millet species, with foxtail millet standing out for its high protein and fibre content, making it suitable for high-protein, high-fibre food formulations. Finger millet's high fibre content makes it valuable for digestive health applications. These findings underscore the potential of millets as functional foods, contributing to better nutrition and sustainable agriculture.

Keywords: Millet, Protein, Crude fibre, Foxtail millet

1. INTRODUCTION

Grains are a fundamental component of most diets worldwide, serving either as staple foods or through a variety of processed products. For the 2023/24 season, global grain production is projected to reach 2,304 million tonnes, while consumption is expected to slightly surpass

this at 2,306 million tonnes, factoring in carryover stocks and international trade (IGC, 2023). In developing countries, cereal grains such as rice, wheat, maize, barley, oats, and rye play a critical role as primary sources of nutrition, unlike in developed nations where consumption patterns are more varied. However, the high water demands of these crops contribute significantly to issues like groundwater depletion and exacerbate the challenges posed by climate change. This highlights the urgent need for more sustainable alternatives to traditional cereal staples (Sruthi and Rao, 2021).

Millets, a group of small-seeded grasses, present a promising solution. Cultivated in semi-arid regions, these crops offer an alternative that is not only nutritionally rich but also environmentally sustainable (Sruthi and Rao, 2021). The term "millet" is derived from the French word "mille," meaning "thousand," referencing the high seed count in small millet portions. As members of the *Poaceae* family, millets have an annual growth cycle and trace their origins to Ethiopia, within the *Chloridoideae* subfamily (Abahet *et al.*, 2020).

According to FAOSTAT (2022), global millet production stood at 30.86 million tonnes, with India contributing the largest share at 11.85 million tonnes. Despite this, more than half of global millet production is used for non-food purposes. Nevertheless, millets hold significant potential in addressing malnutrition and mitigating agricultural challenges in regions with harsh climatic conditions. Their adaptability to less fertile soils, along with their tolerance for a wide pH range (4.5-8.0), makes them well-suited to diverse environments (Kumar *et al.*, 2018).

Millets are recognized for their resilience, requiring minimal water during their short growing period and demonstrating strong drought resistance. When stored as whole grains, they can be preserved for extended periods, making them critical for ensuring food security in challenging agro-climatic regions (Devi *et al.*, 2014). Nutritionally, millets are a rich source of protein (7-11%), carbohydrates (60-70%), and fibre (2-7%) (Mirzababaeet *et al.*, 2022).

Additionally, they contain bioactive compounds, including antioxidants, phytochemicals, and polyphenols, that offer notable health benefits (Muthamilarasan *et al.*, 2016). Millets are also packed with essential minerals and vitamins, providing calcium (10-348 mg/100 g), iron (2.2-17.7 mg/100 g), zinc (32.7-60.6 mg/100 g), phosphorus (200-339 mg/100 g), and vitamins such as thiamine (0.15-0.60 mg/100 g), niacin (0.09-1.11 mg/100 g), and riboflavin (0.28-1.65 mg/100 g), making them an excellent source of nutrition and energy (Kumar *et al.*, 2018).

In light of their impressive nutritional profile and environmental benefits, millets offer a sustainable alternative to conventional cereals, especially in regions facing water scarcity and adverse agro-climatic conditions. This study aims to examine and compare the protein and crude fibre content of various millet types, highlighting their potential in addressing both nutritional and environmental challenges.

2. MATERIAL AND METHODS

2.1 Millet Samples

Eight different types of millets—Foxtail Millet (*Setaria italica*), Bajra (*Pennisetum glaucum*), Jowar/Sorghum (*Sorghum bicolor*), Finger Millet (*Eleusine coracana*), Little Millet (*Panicum sumatrense*), Kodo Millet (*Paspalum scrobiculatum*), Barnyard Millet (*Echinochloa frumentacea*), and Proso Millet (*Panicum miliaceum*)—were procured from a reputed local market in Bengaluru, Karnataka, India.

2.2 Estimation of Protein Content

The micro-Kjeldahl protein technique was used to determine the protein content. A Kjeldahl tube was filled with 0.5g of thoroughly mixed sample, 0.1ml of 5% copper sulphate solution, 1.5g of potassium sulphate and five to ten boiling aids. Next, 15ml of concentrated sulphuric acid were introduced via the tube's wall. After a gentle mixing process, the contents were digested until they were clear and devoid of any leftover substance. Then, the digest was let to cool to $25 \pm 2^\circ\text{C}$. After adding 100ml of distilled water, it was placed in an auto distillation unit and allowed to distill with 50% sodium hydroxide. The ammonia that was released was then trapped in 25ml of boric acid. 25ml of distillate were titrated with 0.02N hydrochloric acid until the colour turned pink. Then, same procedure was followed for blank by substituting the sample with 1ml of water and 0.17g of sucrose. The total nitrogen and crude protein percentages were then calculated using the formula provided below (FSSAI03.016:2022)

$$W_n = \frac{1.4007 \times (V_S - V_B) \times N}{W}$$

$$\text{Crude protein (\%)} = W_n \times 6.25$$

Where, W_n = Nitrogen content of sample, expressed as % by mass

V_S = Volume in ml of the standard HCl used for sample

V_B = Volume in ml of the standard HCl used for blank test

N = Normality of standard HCl

W = Mass of test portion in g

2.3 Estimation of Crude Fibre Content

A conical flask containing 2g of sample and 200ml of 0.128M sulphuric acid solution was boiled for 30 minutes on a hot plate. The boiled solution was filtered through the funnel, which was lined with cotton cloth. To remove acid residues completely, the filtrate was carefully rinsed with hot water. The sample procedure was repeated by adding 200ml of 0.313M sodium hydroxide solution to the filtrate. Subsequently, the filtrate was gathered into a crucible that had been cleaned and dried. It was then placed on a hot plate to remove any remaining water, and it was heated to 130°C for 2h. It was then cooled in a desiccator and weighed (W_1). The sample was then placed in a muffle furnace at 550°C for 2h, cooled in a desiccator for 20 minutes and weighed (W_2) (AOAC 978.10).

$$\text{Crude fibre \%} = \frac{W_1 - W_2}{W_s} \times 100$$

Where, W_s = Weight in g of sample

W_1 = Weight in g of crucible with fibre

W_2 = Weight in g of crucible with ash

2.4 Statistical Analysis

The data was analysed using R software [R. version 4.1.2 copyright] for statistical computing. Data on the response variables was collected for three replications of the trails and the ANOVA tables was prepared to analyse the data. The critical difference was calculated ($P=0.05$), where the F value was significant, and used to identify whether significant differences existed and indicated in the table using superscripts.

$$\text{Critical difference (CD)} = \frac{\sqrt{2} \times \text{MSS}(E)}{r} \times t_{\alpha}$$

Where, MSS (E) = Mean Sum of squares of the error

r = number of replications

t_{α} = table t value of the α level of significance

3. RESULTS AND DISCUSSION

3.1 Protein Content of Various Millets

The analysis of protein content across different millet types revealed considerable variability, emphasizing the nutritional distinctions among these grains. As presented in Table 1, foxtail millet (*Setaria italica*) emerged as the millet with the highest protein content, registering at 10.50%. This finding corroborates previous research, such as that of Sachdev *et al.* (2021), who reported a protein range of 10.3% to 13.6%, further highlighting foxtail millet's rich protein profile. The specific variety of foxtail millet analyzed by Brunda *et al.* (2019), known as DHF 22, exhibited a closely similar protein content of 10.49%, reinforcing the consistency of these results. The substantial protein content in foxtail millet makes it a nutritionally superior grain, particularly valuable in the formulation of high-protein food products, such as energy bars, health mixes, and functional flours targeted at health-conscious consumers.

Proso millet (*Panicum miliaceum*) exhibited the second-highest protein content, measuring 9.94%. This value is consistent with findings by Tyl *et al.* (2018), who documented a protein range of 9.82% to 12.98% across various proso millet varieties. The Snobird variety, grown in Minnesota, showed a similar protein content of 9.88%, which highlights the consistency of this millet species in terms of its protein yield across different geographical regions. Such robustness in protein content makes proso millet a versatile grain for use in both traditional diets and modern food products where protein enrichment is a key consideration.

In contrast, bajra (pearl millet, *Pennisetum glaucum*) and barnyard millet (*Echinochloa frumentacea*) demonstrated moderate protein levels, with values of 8.82% and 8.26%, respectively. The protein content of pearl millet, however, is highly variable, as evidenced by Tomar *et al.* (2021), who recorded a wide protein range of 8.07% to 18.15%, depending on the cultivar. Such variability makes it crucial to consider specific cultivars when selecting bajra for nutritional purposes. Barnyard millet, on the other hand, has a more stable protein content, aligning with findings by Vimalaraniet *et al.* (2023), who reported a range between 8.09% and 10.5%. Despite its moderate protein levels, barnyard millet offers other nutritional advantages, such as low glycemic index and high dietary fibre, making it a valuable addition to healthy diets.

At the lower end of the spectrum, finger millet (*Eleusine coracana*) exhibited the lowest protein content among the millets tested, with a value of 7.24%. This result falls within the protein content range of 4.63% to 10.6% reported by Abioye *et al.* (2022) for various finger millet varieties. While finger millet is not as rich in protein as other millet species, it is renowned for its high calcium content, which contributes to bone health and makes it an important dietary component, especially for populations at risk of calcium deficiency.

Similarly, little millet (*Panicum sumatrense*) and kodo millet (*Paspalumscrobiculatum*) exhibited protein contents of 7.66% and 7.84%, respectively. These values are consistent with the findings of Karuppasamy and Veena (2019) and Louis *et al.* (2023), who documented similar protein ranges in these millet species. While lower in protein, little millet and kodo millet are still valuable grains, particularly in traditional dishes where their unique taste and texture are appreciated. Additionally, their rich content of phytochemicals and antioxidants adds to their nutritional value, making them ideal for inclusion in diets that prioritize overall health benefits.

The statistical analysis of protein content revealed a critical difference (CD) at the 5% significance level of 0.055, indicating significant variability in protein content across most of the tested millet types. However, the protein contents of sorghum (8.28%) and barnyard millet (8.26%) did not differ significantly, as the difference fell below the critical threshold. This statistical similarity suggests that, nutritionally, both sorghum and barnyard millet can be considered comparable in terms of protein content, allowing for flexibility in selecting either grain depending on other dietary or sensory preferences.

3.2 Crude Fibre Content of Various Millets

The results from the analysis of crude fibre content across various millet species demonstrated notable variations, highlighting the nutritional diversity within the group. Finger millet (*Eleusine coracana*) emerged as the richest source of crude fibre among the tested millets, recording a fibre content of 3.61%. This value significantly exceeded that of other millet species, emphasizing finger millet's potential role as a primary source of dietary fibre in functional foods. The observed fibre content is consistent with prior studies, including those by Abioye *et al.* (2022), who reported a crude fibre range of 3.10% to 4.50% in finger millet. Such data further solidify finger millet's reputation as a fibre-rich grain, positioning it favorably for the development of health-promoting food products designed to enhance digestive health and promote satiety.

Foxtail millet (*Setariaitalica*) also demonstrated a relatively high crude fibre content, measured at 3.22%. This value, while slightly lower than that of finger millet, is still significant, especially when compared to other millet species. The result is in line with earlier findings by Brunda *et al.* (2019), who documented a crude fibre range between 1.89% and 3.75% for foxtail millet, reinforcing its potential as a high-fibre ingredient. Given its dual advantage of high protein and fibre content, foxtail millet stands out as a particularly promising candidate for inclusion in formulations aimed at enhancing both fibre and protein intake, such as in functional foods targeted at health-conscious consumers.

On the lower end of the spectrum, barnyard millet (*Echinochloafrumentacea*) and kodo millet (*Paspalumscrobiculatum*) exhibited the lowest crude fibre contents among the millets studied, with values of 1.70% and 1.81%, respectively. These findings are consistent with those reported by Hymavathi *et al.* (2020), who found similarly low fibre contents in these species. While these values are lower compared to the other millets, barnyard and kodo millet are still valuable components of the diet, particularly for those seeking low-fibre alternatives or those focusing on other health benefits such as their low glycemic index.

Little millet (*Panicum sumatrense*) and jowar (*Sorghum bicolor*), or sorghum, had slightly higher crude fibre contents than barnyard and kodo millet, with values of 1.96% and 2.05%, respectively. These values align well with those reported in previous studies, such as those by Tasia and Gabreyes (2020) and Hymavathi *et al.* (2020). The moderate fibre content of these grains still makes them suitable for dietary inclusion, particularly in balanced formulations where the fibre content is a concern but not the primary focus.

Bajra (*Pennisetum glaucum*) and proso millet (*Panicum miliaceum*) exhibited moderate crude fibre levels as well, with values of 2.36% and 2.12%, respectively. These findings are consistent with earlier work by Kultheet *al.* (2016) and Karkannavaret *al.* (2021), who reported similar crude fibre values for these species. The moderate fibre content of bajra and proso millet makes them versatile options in food formulations where balanced fibre content is needed without compromising other nutritional or sensory attributes.

The statistical analysis revealed that the critical difference (CD) at a 5% significance level for crude fibre content was 0.025, indicating that the differences observed in fibre content among the various millet species were statistically significant. This level of significance underscores the diversity within millet species in terms of fibre content and highlights the importance of selecting the appropriate millet variety based on specific nutritional goals.

Table 1. Protein and crude fibre content of various millets

Type of Millet	Protein content	Crude Fibre content
	Percentage (%)	
Foxtail Millet	10.50 ^a	3.22 ^b
Bajra	8.82 ^c	2.36 ^c
Jowar/Sorghum	8.28 ^d	2.05 ^e
Finger Millet	7.24 ^g	3.61 ^a
Little Millet	7.66 ^f	1.96 ^f
Kodo Millet	7.84 ^e	1.81 ^g
Barnyard Millet	8.26 ^d	1.70 ^h
Proso Millet	9.94 ^b	2.12 ^d
CD ($P=0.05$)	0.055	0.025

Note: CD = Critical Difference, all the values are average of three trials (n=3) and same superscript indicate non-significance while different, indicate statistically significant difference at $P=0.05$

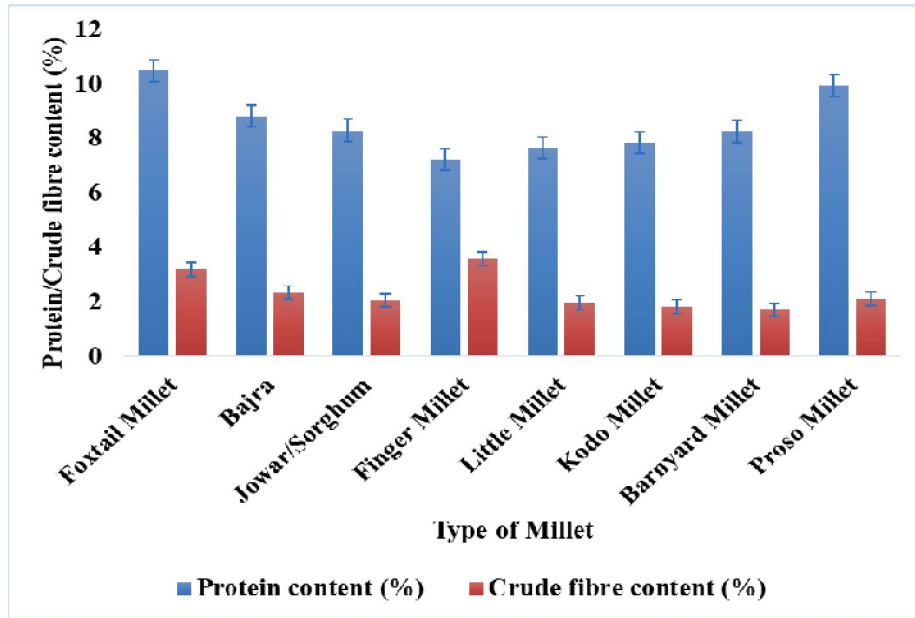


Fig. 1. Protein and crude fibre content of various millets



Plate 1. Different types of millets

4. CONCLUSION

In conclusion, the comparative analysis of protein and fibre content across various millet species highlights the substantial nutritional variability within these grains. When considering

both protein and fibre content, foxtail millet emerges as the superior choice. Its high levels of both nutrients make it an optimal candidate for the development of high-protein, high-fibre food products, catering to consumers seeking health benefits such as improved digestive health and enhanced satiety. This dual advantage aligns with the increasing interest in using millets as functional foods for reducing the risk of chronic diseases, including diabetes and cardiovascular disorders.

While other millets, such as proso millet and pearl millet, offer substantial protein content, and finger millet stands out for its exceptional fibre content, foxtail millet provides the best balance of both protein and fibre. This makes it a valuable ingredient for addressing multiple dietary needs simultaneously. The results underscore the importance of selecting the appropriate millet based on specific nutritional goals, and they emphasize the potential of foxtail millet as a key component in food formulations aimed at improving overall nutritional intake.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ABBREVIATIONS

IGC: International Grains Council

FAOSTAT: Food and Agriculture Organization Corporate Statistical Database

FSSAI: Food Safety and Standards Authority of India

AOAC: Association of Official Analytical Chemists

UNDER PEER REVIEW