

## International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693  
ISSN Online: 2617-4707  
IJABR 2025; 9(1): 276-281  
[www.biochemjournal.com](http://www.biochemjournal.com)  
Received: 11-10-2024  
Accepted: 13-11-2024

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## Millets: The wholesome supplement of contemporary times

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**DOI:** <https://doi.org/10.33545/26174693.2025.v9.i1d.3473>

### Abstract

Millets are a group of small-seeded, hardy cereals cultivated widely in semi-arid regions, known for their resilience to harsh climates and low water requirements. Millets have gained widespread recognition as a valuable dietary supplement due to their exceptional health benefits and ability to meet the nutritional demands of contemporary diets. These ancient grains, cultivated for millennia, are rich in protein, fiber, vitamins, and essential minerals. Additionally, millets are an outstanding source of phytochemicals, which possess detoxifying and antioxidant properties. Millet based food and beverages have been shown to provide health-promoting benefits, including anti-diabetes, anti-obesity, cardiovascular disease prevention, and immune system booster. The nutritional profile and possible health advantages of millets are explored in this study, emphasizing their potential as a sustainable and health-promoting dietary source.

**Keywords:** Millets, nutritional profile, health benefits, phytochemicals, antioxidant properties

### Introduction

With the increase in global population, food security has become a growing concern. Ensuring adequate nutrition for everyone requires not only improved cultivation practices and genetic advancements but also a focus on crop diversification. In this context, millets emerge as a wholesome and sustainable choice. These nutrient-rich crops are not only vital for addressing food and nutritional security but are also hardy and resilient, capable of thriving in harsh environmental conditions. Despite their exceptional climate resilience and nutritional benefits, research on millets has fallen behind compared to major cereals (Ajeesh Krishna *et al.*, 2022) [2]. Millets were staple crops in India for millennia, but they were gradually supplanted by high-yielding wheat and rice cultivars, resulting in their marginalization (Harish *et al.*, 2024) [21]. Millets garnered significant global attention in 2023, designated as the "International Year of Millets." This initiative aimed to raise awareness and promote both the consumption and production of these nutrient-rich grains. Millet can serve both nutritional and medicinal purposes, is rich in health-enhancing phytochemicals, and is regarded as a functional food. Millets are rich in carbohydrates, proteins, dietary fiber, healthy fats, minerals (such as calcium, potassium, magnesium, iron, manganese, and zinc), and B vitamins. They also contain bioactive phytochemicals, including feraxans, lignans, beta-glucan, inulin, resistant starch, sterols, and phenolic compounds (BAJPAI *et al.*, 2023) [7]. Millets offer numerous health benefits, as supported by epidemiological studies, which show that their consumption can lower the risk of heart disease, help manage diabetes, enhance digestion, reduce cancer risk, detoxify the body, boost respiratory health and immunity, increase energy levels, support muscular and neural health, and protect against degenerative conditions such as metabolic syndrome and Parkinson's disease (Chandrasekara and Shahidi, 2011) [14]. Millets are more nutritious than rice and wheat, providing affordable sources of minerals, protein, and vitamins, making them a valuable dietary option for improving the well-being of poor communities in the Asia-Pacific region (Huang *et al.*, 2023) [23]. With their unexploited grain yield potential and nutritional advantages, millets are poised to become essential food crops of the future, particularly in challenging rainfed regions (Yang *et al.*, 2012) [61].

Promoting millet consumption is crucial to boosting their demand as food, animal feed, and industrial raw materials, which can be achieved through targeted policies and awareness campaigns.

### Classification of millets

Generally, millets can be classified in two major classes (Table: 1) basically based on their grain size, e.g., Major millets and minor millets.

**Table 1:** List of major and minor millets

| Major Millets        | Minor Millets          |
|----------------------|------------------------|
| Sorghum (Jowar)      | Foxtail millet (Kakum) |
| Pearl millet (Bajra) | Proso millet (Cheena)  |
| Finger millet (Ragi) | Kodo millet (Kodo)     |
|                      | Barnyard millet (Sawa) |
|                      | Little millet (Kutki)  |

### Nutritional and health benefits of millets

**Pearl millet:** Pearl millet (*Pennisetum glaucum*) offers a rich nutritional profile comparable to other cereals, with certain superior attributes. It provides substantial energy value of approximately 17 MJ/kg and contains high-quality proteins ranging from 9.5 to 14.41 g/100 g. The lipid content is moderate, varying between 4.8 and 7.1 g/100 g. Pearl millet is also a significant source of minerals, including calcium (16-46 mg/100 g), iron (4-11.2 mg/100 g) and zinc (2.95-7.1 mg/100 g) (Hassan *et al.*, 2021; Pei *et al.*, 2022) [22, 42]. In addition to these macronutrients, it is rich in dietary fiber, ranging between 8 and 11.3 g/100 g and includes vital micronutrients such as vitamins and trace minerals, which play a critical role in enhancing gut health and metabolism. Among all millet varieties, pearl millet is distinguished by its high protein content, surpassed only by foxtail and proso millet. It also has the highest fat content, dietary fiber and energy value, making it a valuable food source for malnourished populations in Africa and Asia (Hassan *et al.*, 2021; Satyavathi *et al.*, 2021) [22, 51]. Despite its numerous benefits, pearl millet contains antinutritional factors like polyphenols, tannins and phytic acid, which range from 354 to 796 mg/g. These compounds can limit nutrient bioavailability. Additionally, goitrogenic polyphenols, such as C-glycosylflavones (C-GFs) like glucosyl orientin, glucosyl vitexin and vitexin, are also present and have been associated with iodine deficiency and goiter (Boncompagni *et al.*, 2018) [9]. On the positive side, pearl millet is a rich source of bioactive compounds that exhibit antioxidant, antidiabetic, antimicrobial, hypocholesterolemic and hypoglycemic properties. However, the flour of pearl millet (PMF) is prone to rancidity due to the presence of an active lipase enzyme, which hydrolyzes glycerides into free fatty acids, especially under moist and oxidative conditions (Pawase *et al.*, 2019) [41]. To enhance the shelf life and stability of pearl millet flour, various processing methods such as roasting, fermentation, germination, microwaving and hydrothermal treatments have been developed. These methods also improve the flour's functionality and nutritional profile. Pearl millet is widely used in both traditional products (e.g., raabadi, chapatti and fura) and modern innovations such as bakery items, pasta and extruded foods (Ali *et al.*, 2023; Jalgaonkar *et al.*, 2022) [3, 26].

**Sorghum:** Sorghum (*Sorghum bicolor*) is recognized as a highly nutritious cereal crop, cultivated in India, the United States, and several African nations. The grain serves as a major food source in Africa and India and as a vital livestock feed in developed countries. Sorghum contains 8-18% protein, 70-80% carbohydrates and approximately 6.7 g of dietary fiber per 100 g, along with various essential minerals. Its primary carbohydrate component is starch, located mainly in the endosperm and partially in the pericarp, which provides slow-digesting energy suitable for sustained activities (Huang *et al.*, 2022) [24]. Additionally, it contains fructosan, a trisaccharide contributing to its carbohydrate profile. The protein content of sorghum comprises albumins, globulins, glutelins and kafirins, with the latter being hydrophobic and protease-resistant, providing structural integrity and resilience against environmental stresses (Mohajeri *et al.*, 2015) [34]. Sorghum is also gluten-free, making it suitable for individuals with gluten intolerance. Its lipid profile includes linoleic acid (18:2), oleic acid (18:1), palmitic acid (16:0), linolenic acid (18:3) and stearic acid (18:0), with linoleic and oleic acids occurring in high proportions (Serrano *et al.*, 2023) [51]. Rich in dietary fiber, sorghum supports digestive health, regulates blood sugar levels, lowers cholesterol and promotes satiety. It also provides B-complex vitamins, such as thiamine and riboflavin, essential for metabolism, along with niacin for improved digestion, skin health and neurofunction. Essential minerals like phosphorus, magnesium, iron and copper contribute to bone health, red blood cell production, nerve function and overall well-being. Trace amounts of zinc, calcium and potassium further enhance its nutritional profile. Moreover, sorghum contains unique antioxidants, including 3-deoxy anthocyanins, which help reduce inflammation and may lower cancer risks. The grain's nutritional content varies based on variety, cultivation practices and processing methods, with grain sorghum generally containing higher protein and lipid levels than sweet sorghum (Olawole *et al.*, 2019) [38]. These attributes make sorghum a versatile and nutrient-dense addition to a balanced diet.

**Finger millet:** Finger millet (*Eleusine coracana*) is a highly nutritious cereal, rich in calcium, minerals, and dietary fiber. Carbohydrates form a significant component of ragi, ranging between 72% and 79.5% (Pore & Magar, 1979) [44]. Starch constitutes the majority of these carbohydrates, ranging from 59.4% to 70.2% (Joshi & Katoch, 1990; Bhatt., 2003; Wankhede *et al.*, 1979) [27, 8, 59]. Additionally, residual amylose accounts for 15% to 20%, while amylopectin makes up 80%-85% of (the starch (Pore & Magar, 1979; Antony *et al.*, 1996; Nirmala *et al.*, 2000) [44, 5, 36]. Non-starch polysaccharides contribute 20%-30% of the total carbohydrates in ragi (Nirmala *et al.*, 2000) [36]. The high fiber content in millets, including ragi, is associated with hypoglycemic effects due to the slow absorption and assimilation of complex carbohydrates, leading to reduced postprandial blood sugar levels (Geetha & Easwaran, 1990) [20]. Protein is the second most abundant component in ragi, ranging from 5.6% to 12.7%. Approximately 71% of its protein is digestible (Ravindran, 1991; Rao, 1994; Mbithi-Mwikya *et al.*, 2000) [47, 45, 33]. Essential amino acids, which play a crucial role in protein functionality, constitute 44.7% of the total amino acids in finger millet (Mbithi-Mwikya *et al.*, 2000) [33]. The amino acid profile of ragi is well-

balanced, with a high essential-to-non-essential amino acid ratio. Except for lysine, the essential amino acid content exceeds the recommended values for children aged 2-5 years. Unique among cereals, ragi contains tryptophan, along with balanced levels of valine, threonine and lysine (Ravindran, 1992) [46]. It also includes proline, valine, isoleucine, leucine and phenylalanine in higher proportions compared to arginine and glycine. Significant protein fractions include albumins and globulins. Ragi has a notable fat content, varying between 1.2% and 2.1%, depending on the variety (Patil *et al.*, 2023) [3]. Its lipid composition includes free lipids, bound lipids, structural lipids and phospholipids. Key fatty acids include oleic acid, palmitic acid and linoleic acid, with unsaturated fatty acids comprising 74.4% of the total lipid content, while saturated fatty acids account for 25.6% (Sridhar & Lakshminarayana, 1994) [54]. Finger millet also provides essential nutrients, including isoleucine (4.4 g), leucine (9.5 g), methionine (3.1 g) and phenylalanine (5.2 g), which are scarce in other starchy grains (Dykes & Rooney, 2006) [17]. Moreover, it is a good source of minerals such as calcium, iron, potassium, magnesium and zinc, as well as B vitamins like niacin, pyridoxine and folic acid (Hulse *et al.*, 1980) [25].

**Proso millet:** Proso millet (*Panicum miliaceum*) is a nutritionally rich cereal with significant health benefits. It is a valuable source of macronutrients, including proteins and dietary fibers, as well as essential micronutrients such as magnesium, phosphorus, potassium, and trace minerals (Pilati *et al.*, 2016) [43]. Proso millet proteins play a critical role in cholesterol metabolism, improving HDL cholesterol levels and insulin sensitivity, as highlighted by Park *et al.* (2011) [28]. These properties make it beneficial for managing cardiovascular diseases (CVDs) and diabetes. Additionally, it contains phytochemicals like phenolic acids, polyphenols, and flavonoids that exhibit antioxidant and anti-inflammatory properties (Chandrasekara & Shahidi, 2011; Bora *et al.*, 2018) [14, 10]. The high antioxidant capacity of proso millet, attributed to its phenolic acids such as ferulic, syringic, and chlorogenic acids, protects against oxidative stress and chronic diseases, including cancer (Zhang *et al.*, 2014; Aburai *et al.*, 2007) [62, 1]. Studies indicate its dietary fibers enhance satiety, improve gut health, and reduce the risk of lifestyle diseases like obesity and breast cancer (Cade *et al.*, 2007; Fardet, 2010) [11, 18]. Furthermore, it has been shown to reduce triglycerides and C-reactive protein levels in hyperlipidemic models, demonstrating its potential in combating hyperlipidemia and associated risks (Lee *et al.*, 2010) [31]. Proso millet is also known for its nutrigenomic effects, particularly in producing short-chain fatty acids (SCFAs) and improving skeletal health through oligosaccharides acting as prebiotics (Asharani *et al.*, 2009; Amadou *et al.*, 2013) [6, 4]. Its liver-protective properties were demonstrated in studies where proso millet protein suppressed liver injury caused by D-galactosamine (Nishizawa *et al.*, 2002) [37]. Collectively, proso millet stands as a nutritionally superior cereal with vast potential for enhancing human health and addressing global nutritional challenges.

**Foxtail millet:** Foxtail millet (*Setaria italica*), a highly nutritious and underutilized crop, surpasses commonly consumed cereals like wheat and rice in nutritional value. It

is a rich source of essential nutrients, including carbohydrates, proteins (10%-15%), dietary fiber (6%-8%), crude fat (7%-8%) and minerals such as iron, calcium and zinc (Sharma & Niranjana, 2017; Muthamilarasan *et al.*, 2016) [52, 35]. Foxtail millet contains significant amounts of essential amino acids, including methionine and cysteine, as well as sulfur-containing amino acids, which are crucial for human health. Its resistant starch content, ranging from 13% to 15%, makes it an ideal choice for diabetic individuals. Chen *et al.* (2013) [15] and Yang *et al.* (2013) [60] conducted extensive analyses of foxtail millet, reporting crude fat content between 4.4 and 7.3 g/100 g, total carbohydrates ranging from 65.59 to 83.8 g/100 g, and protein content varying from 9.5 to 20.58 g/100 g. Additionally, its gluten-free nature and slightly higher fat content contribute to its nutritional superiority. Foxtail millet also contains polyphenols, phenolic acids, tannins and flavonoids, which provide antioxidant properties and support the immune system (Devi *et al.*, 2011) [16]. Moreover, its lipids, including linoleic acid and tocopherols, enhance its health benefits (Liang *et al.*, 2010) [32]. Collectively, these attributes highlight foxtail millet as a sustainable and health-promoting cereal grain with the potential to address global nutritional challenges.

**Barnyard millet:** Barnyard millet (*Echinochloa spp.*) is a nutritionally superior grain compared to other major and minor millets, offering a rich composition of dietary fiber, protein, iron, zinc, calcium, magnesium, fat, vitamins and essential amino acids (Singh *et al.*, 2010; Saleh *et al.*, 2013; Chandel *et al.*, 2014a) [53, 49, 12]. It has a lower carbohydrate content (51.5-62.0 g/100 g) compared to other millets, making it a favorable choice for managing blood sugar levels (Saleh *et al.*, 2013) [49]. With crude fiber content ranging from 8.1% to 16.3%, barnyard millet promotes a slower release of sugars into the bloodstream, beneficial for glycemic control (Ugare *et al.*, 2014) [57]. Research indicates that resistant starch in barnyard millet can help lower blood glucose levels, serum cholesterol, and triglycerides, as demonstrated in animal studies (Kumari & Thayumanavan, 1998) [29]. Clinical studies have also confirmed its low glycemic index in patients with type 2 diabetes (Ugare *et al.*, 2014) [57]. The protein content (11.2%-12.7%) is notably higher than that of other cereals and in barnyard millet the iron content (15.6-18.6 mg/100 g) is significantly elevated, making it ideal for addressing iron deficiency and anemia, particularly in women (Saleh *et al.*, 2013; Renganathan *et al.*, 2017; Vanniarajan *et al.*, 2018) [49, 48, 58]. Additionally, the lower phytate content (3.30-3.70 mg/100 g), which decreases further upon dehulling, enhances mineral bioavailability (Panwar *et al.*, 2016) [39]. The grain also contains high levels of polyphenols and carotenoids, which provide antioxidant, anti-inflammatory and antimicrobial properties, contributing to its ethnomedical uses in managing various health conditions (Kim *et al.*, 2011; Panwar *et al.*, 2016) [28, 39]. These nutritional and health-promoting attributes position barnyard millet as an excellent food choice for overall physical and nutritional well-being.

**Kodo millet:** Kodo millet (*Paspalum scrobiculatum*) is recognized as a nutrient-dense cereal grain, often referred to as a "nutria-cereal" due to its rich composition of vitamins, minerals, and essential phytochemicals. It is particularly

abundant in essential amino acids, including lysine, threonine, valine, and sulfur-containing amino acids like methionine and cysteine, though it is deficient in tryptophan (Ravindran, 1992; Antony *et al.*, 1996) <sup>[46, 5]</sup>. The grain is an excellent source of vitamin B3, vitamin B6, and folic acid, along with essential minerals such as calcium, potassium, magnesium, and zinc. The protein content of Kodo millet is approximately 8.3%, with glutelin as the primary protein component (Sudharshana *et al.*, 1988) <sup>[55]</sup>. It contains a notably high crude fiber content of 9%, significantly exceeding that of wheat, which contains just 1.2% (Devi *et al.*, 2011) <sup>[16]</sup>. Kodo millet provides about 353 kcal of energy per 100 grams, with its carbohydrate content accounting for 66.6%, fat content at 1.4%, mineral content at 2.4% and ash content at 2% (Chandel *et al.*, 2014a) <sup>[12]</sup>. Furthermore, the iron content in Kodo millet ranges from 25.86 to 39.60 ppm, making it a valuable source of dietary iron (Chandel *et al.*, 2014b) <sup>[13]</sup>. These nutritional properties highlight Kodo millet's potential in improving diet quality and addressing nutrient deficiencies.

**Little millet:** Little millet (*Panicum sumatrense*) is a nutritious grain with several health advantages, making it an ideal supplement to a well-balanced diet. It is a good source of macronutrients, with about 7.7 grams of protein and 7.6 grams of dietary fiber per 100 grams, which help with muscle maintenance and digestive health (Sushmita *et al.*, 2020) <sup>[56]</sup>. Little millet also contains vital minerals such as iron (9.3 mg/100 g), calcium (17 mg/100 g), phosphorus (250 mg/kg), and magnesium (118 mg/kg), all of which are required for oxygen transport, bone strength, and numerous metabolic activities (Kumari *et al.*, 2022) <sup>[30]</sup>. This millet is especially high in B vitamins, particularly niacin (vitamin B3), which promotes energy metabolism and general health (Gahalawat *et al.*, 2024) <sup>[19]</sup>. It also includes phenolic compounds and flavonoids with antioxidant capabilities, which serve to counteract oxidative stress and protect the body from chronic illnesses. Its low glycemic index and high fiber content make it ideal for controlling blood sugar, lowering the risk of diabetes, and aiding digestion.

## Conclusion

Millets are becoming increasingly popular in diets, which is in line with current initiatives to adopt sustainable, healthier lifestyles. Because of their many culinary uses, millets are a popular option for those who are concerned about their health and support sustainable eating. They are emerging as a key component of initiatives to solve global nutritional issues and promote ecologically sustainable farming systems as awareness of their advantages rises. People may improve their own health and the health of the earth by including millets in their regular meals, guaranteeing future generations a more nourishing and sustainable future. Despite its numerous health advantages, bioavailability of nutrients and the presence of anti-nutritional substances remain significant issues of millets that should be addressed via more investigation. Last but not least to promote long-term health and nutritional benefit, this study emphasizes the need of reintroducing millets into modern diets as a functional food and advocates for their inclusion in dietary guidelines and food policy. Achieving this will require increased investment in millet research and support comparable to that provided for wheat and rice.

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