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# An overview of millets-the nutri-cereals: Its nutritional profile, potential health benefits and sustainable cultivation approach

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## Abstract

**Background:** Millets have emerged as a focal point in a search for sustainable and nutritious food sources in recent years, particularly in India. Millets are a group of ancient cereal grains that stand as nutritional powerhouses with diverse health benefits, making them a valuable addition to diets worldwide. These hardy crops grow in a variety of agro-climatic conditions, requiring less water and inputs in comparison to other primary cereal grains. Millet's low glycemic index helps to stabilize blood sugar levels, while its high fiber content benefits heart health by lowering LDL cholesterol levels and increasing good cholesterol. Millets have recently attracted global attention for their potential to alleviate nutrition concerns along with promoting environmental sustainability. The Government of India proposed declaring 2023 the International Year of Millets at the United Nations General Assembly, which was supported by 71 countries. Governments, non-governmental organizations and research institutions are working together to promote awareness, produce improved millet varieties and implement policies that benefit millet farming communities.

**Aim:** To prepare comprehensive data on millet's nutritional profile, potential health benefits, and sustainable cultivation practices.

**Review Results:** In the available literature, it is observed that various types of millets are available and some of them are nutrition-rich while others have different health benefits.

**Conclusion:** By promoting the cultivation of millets, we can diversify our food systems, reduce the pressure on staple crops, enhance agro-biodiversity and contribute to sustainable agricultural practices.

**Keywords:** Nutri-cereals; Sorghum Millets; Pearl Millet; Finger Millet; Proso Millet

## 1. Introduction

Millets are a highly varied group of small-seeded grasses and are commonly known as the grass family [1]. These millets are small-grained cereals belonging to the Poaceae family [2]. They are grown as cereal crops or grains for fodder and human food. India has been cultivating millet for thousands of years, as shown by the archaeological records [3]. These ancient grains are highly nutritious and have gained popularity due to their health benefits, environmental sustainability, and versatility in cooking [4]. There are several types of millets, including pearl millet (*bajra*), sorghum (*jowar*), finger millet (*madua*), foxtail millet (*kangni*), little millet (*kutki*), barnyard millet (*jhangora*), kodo millet (*kodra*) and proso millet (*barri*) each with its own unique characteristics and culinary uses [5]. Millets are gluten-free and rich

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in dietary fiber, vitamins, minerals and antioxidants, making them a valuable addition to a balanced diet. The major millet varieties grown in India include pearl millet (*bajra*), sorghum (*jowar*), finger millet (*madua*), foxtail millet (*kangni*), little millet (*kutki*) and barnyard millet (*jhangora*) are cultivated in India.[2] These millets are primarily cultivated in dryland areas, such as the arid and semi-arid regions of Maharashtra, Rajasthan, Gujarat, Karnataka, Andhra Pradesh and Tamil Nadu [1]. They have served as a staple food source in many regions around the world, particularly in Asia and Africa [6].

Millets have a wide range of culinary applications and can be used in various forms, including whole grains, flour, flakes and puffed grains. They have a nutty flavor and a pleasantly chewy texture. In many traditional cuisines, millets are used to make porridge, bread, pancakes and alcoholic beverages. They can also be incorporated into salads, soups, stir-fries and baked goods, providing a nutritious alternative to refined grains. The consumption of millet offers numerous health benefits. Being gluten-free, they are suitable for individuals with celiac disease or gluten sensitivities [7]. Millets also have a low glycemic index, which means they cause a gradual rise in blood sugar compared to refined grains, making them suitable for individuals with diabetes [8]. Furthermore, the abundant antioxidants present in millet help reduce the risk of chronic diseases, including heart disease, cancer and neurodegenerative disorders [9].

Traditionally, millets were cultivated through rain-fed farming methods, where the seeds were sown directly into the prepared field [1]. Millets are known for their ability to withstand drought, high temperatures and poor soil conditions, making them an ideal crop for sustainable agriculture and food security. One of the significant advantages of millets is their durability in harsh environmental conditions and their remarkable ability to grow in arid (dry) and semi-arid regions with poor soil quality, making them a reliable crop for communities facing challenging environmental conditions [10]. They are well-adapted to arid and semi-arid regions, requiring minimal water and fertilizer inputs compared to other cereal crops like rice and wheat [11]. Millets have a short growing season, allowing farmers to harvest multiple crops in a year [1]. They are resilient to drought, pests and diseases, making them a reliable choice for farmers in regions with limited water resources and unpredictable weather patterns. However, with advancements in agricultural practices, farmers now employ techniques such as contour bunding, moisture conservation and integrated pest management to enhance millet yields. The adoption of organic and sustainable farming practices has also gained traction, as millets are naturally pest-resistant and require fewer chemical inputs [12].

In addition to their nutritional value, millets play a key role in sustainable agriculture and biodiversity conservation [13]. They require fewer chemical inputs compared to other staple crops. By promoting the cultivation and consumption of millets, we can reduce the environmental impact of agriculture, conserve water resources and enhance soil health [14]. Millets have gained recognition globally and several initiatives are underway to promote their production and consumption. The United Nations has declared 2023 as the International Year of Millets, recognizing their importance in achieving sustainable development goals [15]. Governments, NGOs and research institutions are working together to raise awareness, develop improved varieties and establish policies that support millet farming communities. Promoting the consumption of millet can significantly contribute to addressing the nutrition challenges in India [16].

## 2. Materials and Methods

To review the research on the nutritional, health benefits and sustainable cultivation approach of millets, an electronic search was conducted on the Ayush Portal, PubMed, Research Gate, Scopus, Google Scholar, Academia and Google. The text that contained the data about millets was examined carefully and after omitting the repeated information, it was presented in a precise tabular format in a systematic manner. Keywords used for database analysis were “Sorghum millet,” “Pearl millets,” “Finger millet,” “Barnyard millet,”, “Foxtail millet,” “Kodo millet,” “Proso millet,” and “Little millet”.

### 2.1. Nutritional Significance

India, being a diverse country with a rich culinary heritage, has a unique nutrition profile influenced by various factors such as regional cuisines (method of cooking), cultural practices and socioeconomic conditions. The Indian diet typically includes a variety of food groups, including grains, cereals, vegetables, fruits, dairy products and spices. However, it is important to note that malnutrition remains a significant challenge in certain segments of the population. One way to address these nutrition challenges is by promoting the consumption of millet.

Millets are a group of small-seeded grasses that have been cultivated for a long time in India [1]. Millets commonly consumed in India include pearl millet (*bajra*), sorghum (*jowar*), finger millet (*madua*), foxtail millet (*kangni*), little millet (*kutki*), barnyard millet (*jhangora*), kodo millet (*kodra*) and proso millet (*barri*) [5]. Millets offer numerous health benefits due to their impressive nutritional content, making them an excellent addition to a balanced diet [17]. These

grains are also abundant in essential minerals like iron, calcium, magnesium and phosphorus, which play a crucial role in maintaining healthy bones, supporting muscle function and overall well-being [18]. Millets are often recommended for individuals with iron deficiency anemia due to their iron content [18,19]. Furthermore, millet is a good source of essential minerals such as iron, magnesium, phosphorus, potassium and zinc [20]. Iron is important for oxygen transport and preventing iron-deficiency anemia [21]. Magnesium supports bone health. Phosphorus contributes to bone strength and potassium helps maintain electrolyte balance and regulates blood pressure [22]. Millets are also rich in B vitamins, including niacin, thiamin and riboflavin, which are important for energy metabolism and overall well-being [23].

Millet cultivation in India represents a traditional agricultural practice that is deeply ingrained in the country's cultural and culinary heritage. With its ability to thrive in adverse conditions and provide numerous nutritional benefits, millets are poised to play a vital role in achieving sustainable agriculture and ensuring food security [24]. Furthermore, the cultivation of millets contributes to biodiversity conservation and environmental sustainability. These crops have a minimal water footprint and do not require excessive use of fertilizers or pesticides. By promoting millet cultivation, India can foster sustainable agriculture, reduce pressure on water resources and enhance food security for its growing population [25].

**Table 1** Types of Millets with Scientific names and Vernacular names

| **Common Name** | **Scientific Name as per WFO Plant list** | **Vernacular Names according to Indian Continent** |
|---|---|---|
| Sorghum, Great Millet, *Milo*, *Chari* | *Sorghum bicolor* (L.) Moench | *Juar* (Bengali, Gujarati, Hindi), *Jola* (Kannada), *Cholam* (Malayalam, Tamil), *Jwari* (Marathi), *Janha* (Oriya), *Jonnalu* (Telugu) |
| Pearl Millet, Spiked Millet, *Bajra* | *Cenchrus americanus* (L.) Morrone | *Bajra* (Hindi), *Baajri* (Marathi), *Sajje* (Kannada), *Kambu* (Tamil), *Saujalu* (Telugu) |
| Finger Millet, *Rajika* | *Eleusine coracana* (L.) Gaertn. | *Mandua/ madua* (Hindi), *Nachni* (Marathi), *Ragi* (Kannada), *Ragulu*, *Chodi* (Telugu), *Keppai* (Tamil), *Marwa* (Bengali), *Nagli* (Gujrati), *Mandiya* (Oria), *Mandhuka* (Punjabi) |
| Barnyard Millet, Japanese Millet, *Sawank* | *Echinochloa frumentacea* Link | *Jhangora/ Shama* (Hindi), *Shamul* (Marathi), *Oodalu* (Kannada), *Kavadapullu* (Malayalam), *Kuthiravalli* (Tamil), *Udalu* (Telugu), *Kira* (Oriya) |
| Foxtail Millet, Moha Millet, Italian Millet | *Setaria italica* (L.) P.Beauv. | *Kangni* (Hindi), *Rala* (Marathi), *Kang* (Gujrati), *Navane* (Kannada), *Kangu* (Odia) |
| Kodo Millet, Pakodi, *Manakodra* | *Paspalum scrobiculatum* L. | *Kodra* (Hindi), *Harik* (Marathi), *Harka* (Kannada), *Koovaragu* (Malayalam), *Varagu* (Tamil), *Arikelu* (Telugu), *Kodua* (Oriya) |
| Proso Millet, French Millet, Common Millet | *Panicum miliaceum* L. | *Barri* (Hindi), *Vari* (Marathi), *cheena* (Bangali, Punjabi), *china, bachuri*, *bagmu* (Odia), *baragu* (Kannada), *Cheno* (Gujarati), *Pani varagu* (Tamil), *Dudhe* (Nepali) |
| Little Millet, *Goudli*, *Gondola* | *Panicum miliare* Lam. | *Kutki* (Hindi), *Sava* (Marathi), *Sama* (Bengali), *Samai* (Tamil), *Gajro* (Gujrati), *Samalu* (Telugu), *Suan* (Oriya), *Samme* (Kannada), *Chama* (Malayalam) |

### 2.2. Nutritional Content and Benefits of Various Millets

#### *2.2.1. Sorghum Millet*

Sorghum millet, scientifically known as *Sorghum bicolor* (L.) Moench, is a versatile and nutrient-rich grain that has been cultivated for centuries. It is one of the oldest known cereal crops and has been a staple food source for many cultures around the world [18]. Sorghum millet is primarily grown in Africa, Asia and the Americas. It is highly adaptable to various environmental conditions and can thrive in both arid and semi-arid regions, making it an important crop for food security in regions with limited water availability [26].

In terms of nutritional content, sorghum millet offers a range of essential nutrients that contribute to its health benefits (Table 2) [27,17]. It adds bulk to the stool and helps regulate bowel movements, aiding in the prevention of digestive

disorders. Additionally, the fiber content in sorghum millet can aid in weight management by promoting a feeling of fullness and reducing calorie intake [28].

**Figure 1** Sorghum Millet [*Sorghum bicolor* (L.) Moench]

Sorghum millet is relatively low in fat, making it a suitable choice for individuals looking to reduce their fat intake. It is also a good source of carbohydrates, providing sustained energy release and serving as a valuable energy source, particularly for individuals engaged in physical activities or requiring increased energy expenditure [29,30].

**Table 2** Nutritional Profile of Sorghum Millets Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 193 |
| 2. | Protein | gm | 7.1 |
| 3. | Fat | gm | 0.6 |
| 4. | Carbohydrates | gm | 39.8 |
| 5. | Fiber | gm | 0.9 |
| 6. | Calcium | mg | 10 |
| 7. | Iron | mg | 3.5 |
| 8. | Niacin | mg | 1.7 |

Additionally, the antioxidants present in sorghum millet, including phenolic compounds and flavonoids, help protect the body's cells from damage caused by harmful free radicals and oxidative stress. These antioxidants contribute to potential anti-inflammatory and disease-fighting properties [31]. Sorghum millet also plays a role in diabetes management [32]. With its low glycemic index, it releases glucose into the bloodstream at a slower and more controlled rate, helping regulate blood sugar levels and promoting better glycemic control.

Dietary fiber in sorghum millets helps reduce cholesterol levels by binding to bile acids in the digestive system and promoting their excretion. This can help lower the risk of cardiovascular diseases, including heart attacks and strokes [33].

In conclusion, sorghum millet is a versatile and nutrient-rich grain that offers numerous health benefits. Its high fiber content, essential minerals, low-fat content and gluten-free nature make it a valuable addition to a healthy and balanced diet. Incorporating sorghum millet into meals can contribute to better digestive health, weight management and overall well-being.

*2.2.2. Pearl Millet*

An ancient grain crop used for generations in dry and semi-arid regions of Africa and Asia is known scientifically as pearl millet or *Cenchrus americanus* (L.) Morrone. Pearl millet, also known as *bajra*, is recognised for its toughness and capacity to thrive in challenging growing environments, making it an essential crop for food security in areas vulnerable to drought and climatic change. This adaptable grain provides numerous advantages to both farmers and consumers [26].

One of the key characteristics of pearl millet is its adaptability to arid environments. The plant has a deep root system, which enables it to access water stored deep in the soil, allowing it to survive and even produce decent yields under limited rainfall conditions. This makes pearl millet a suitable choice for farmers in regions with low water availability, where other crops may struggle to survive. Additionally, pearl millet exhibits tolerance to high temperatures, further enhancing its suitability for arid and semi-arid climates [34].

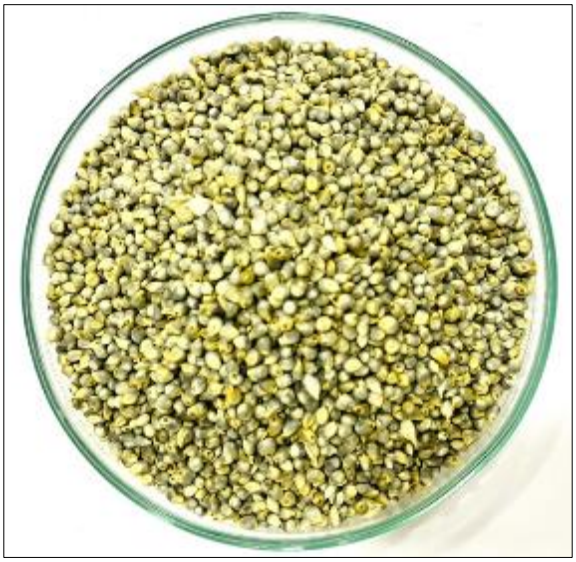

**Figure 2** Pearl Millet [*Cenchrus americanus* (L.) Morrone]

From a nutritional perspective, pearl millet is a highly valuable grain (Table 3) [35]. The grain also contains antioxidants, vitamins and amino acids, contributing to a well-rounded and nutritious diet. Its nutritional composition makes it a valuable dietary staple, particularly in regions where access to diverse and nutrient-rich foods is limited [29].

**Table 3** Nutritional Profile of Pearl Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 360 |
| 2. | Protein | gm | 12 |
| 3. | Fat | gm | 5 |
| 4. | Carbohydrates | gm | 67 |
| 5. | Fiber | gm | 1 |
| 6. | Calcium | mg | 42 |
| 7. | Phosphorous | mg | 242 |
| 8. | Iron | mg | 8 |

The cultivation of pearl millet is relatively straightforward, making it accessible to small-scale farmers. It is often grown using traditional farming methods, requiring minimal inputs and resources [36]. This allows farmers to save costs and reduce their dependence on external inputs. Pearl millet is a relatively fast-growing crop, with a typical growing cycle

of 70 to 100 days [37]. This short duration enables farmers to achieve quick turnaround times and adapt their farming practices to changing climatic conditions.

Because of its high magnesium concentration, pearl millet may provide health advantages for those who suffer from both asthma and migraines. Magnesium has been linked to a reduction in asthmatic patients' respiratory issues and a reduction in migraine symptoms. The high fiber content of pearl millet also contributes to a number of health advantages, including gallstone formation, which aids in reducing excessive bile production. It also promotes satiety, aids in weight loss, and promotes slower digestion, which results in longer periods of feeling full and less food consumption. Millets are a useful weapon in the fight against obesity and other metabolic diseases because of their qualities. Millets have earned the term "miracle grains" since they provide a practical solution with outstanding nutritional advantages [28]. According to traditional knowledge, pearl millets were useful in the treatment of Pain and Tenesmus [38].

Pearl millet grains can be processed into various food products, contributing to their versatility [39]. The grains can be popped like popcorn, offering a healthy and nutritious snack option. Additionally, pearl millet is used as animal feed, providing a valuable source of nutrition for livestock [17].

In summary, pearl millet is an adaptable grain crop that is essential for providing food security in arid and semi-arid areas. It is a useful resource for both farmers and consumers due to its adaptability to difficult growing circumstances, nutritional value and straightforward farming techniques. Communities can become more resilient to climate change and have better access to nutritious food by introducing pearl millet into their agricultural practices and diets. Pearl millet is grown and used in ways that encourage sustainable agricultural methods and the general well-being of people and communities in areas with limited resources.

*2.2.3. Finger Millet*

Finger millet, scientifically known as *Eleusine coracana* (L.) Gaertn. is an ancient cereal crop that has been cultivated for thousands of years, particularly in Africa and Asia. Also referred to as *ragi* or African millet, finger millet holds significant importance due to its exceptional nutritional value and adaptability to diverse agroecological conditions [40].

The thin, tiny and varyingly colored grains of finger millet range in color from white to red, brown, or black. It is a hardy crop that can thrive in a variety of difficult growing environments, including drought, low soil fertility and high elevations. Due to its versatility, finger millet has become a staple meal in areas where other crops find it difficult to grow [41]. Additionally, finger millet is renowned for using nutrients and water efficiently, making it an ecologically friendly crop and a sustainable choice for farmers.

**Figure 3** Finger Millet [*Eleusine coracana* (L.) Gaertn]

The finger millet plant is a powerhouse of nutrition. In actuality, finger millet has a lot more calcium than other cereal grains, making it a great option for people who are calcium deficient or at risk of osteoporosis [42]. Due to its high calcium content, finger millet is beneficial for children, the elderly, and pregnant women. It is also highly beneficial for

lactating women as it aids in the production of enough breast milk [28]. Additionally, the grain has methionine and cysteine, two necessary amino acids that are frequently lacking in other cereal grains [43].

The cultivation of finger millet varies by region, although it is a low-input crop. It can be cultivated in both rainfed and irrigated structures, however, rainfed agriculture is best because it requires less water [26]. Finger millet may be grown as a stand-alone crop or in intercropping arrangements with other plants, which has the added advantages of reducing weed growth and improving soil fertility [44]. It is frequently cultivated using traditional methods of agriculture and small-scale farmers receive support for its production since it offers a reliable source of food and revenue.

Beyond its direct consumption, finger millet is used in a variety of ways. The grain may be processed into flour, a useful component for a variety of culinary preparations. Also, it may be used to thicken sauces, stews and soups [41]. Additionally, finger millet straw and residue are attractive resources because they may be utilized to make biofuels, animal feed and other goods with additional value.

Finger millet's capacity to adapt to difficult agroecological conditions guarantees that communities in locations with a lack of resources have access to a dependable food supply [26]. Particularly in areas where malnutrition and vitamin deficiencies are common, finger millet's high nutritional content (Table 4) [45] promotes better health and well-being [46]. Additionally, growing finger millet boosts biodiversity, helps local economies and makes agricultural systems more resilient.

**Table 4** Nutritional Profile of Finger Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 336 |
| 2. | Protein | gm | 7.7 |
| 3. | Fat | gm | 1.5 |
| 4. | Carbohydrates | gm | 72.6 |
| 5. | Fiber | gm | 11.5 |
| 6. | Calcium | mg | 350 |
| 7. | Phosphorous | mg | 283 |
| 8. | Iron | mg | 3.9 |
| 9. | Zinc | mg | 2.3 |
| 10. | Sodium | mg | 11 |
| 11. | Potassium | mg | 408 |

In summary, finger millet is a remarkable crop that successfully combines nutritional value and sustainability. Its versatility and great nutritional value make it an essential resource for overcoming worldwide issues with food security and hunger. Finger millet is a crop worth attention and investment since it can be grown and consumed while providing a variety of advantages to both farmers and consumers. Finger millet is a crop with tremendous potential for influencing the development of a more resilient and food-secure future because of its favorable effects on nutrition, livelihoods and environmental sustainability.

*2.2.4. Barnyard Millet*

Barnyard millet, scientifically known as *Echinochloa frumentacea* Link, is a healthy and adaptable cereal crop that has become well-known for its distinctive qualities and health advantages. Barnyard millet, also called "*Sanwa*" or "*Sawa* millet," has been grown for many years in many parts of Asia, notably in India, China and Japan [47]. The properties of barnyard millet, its nutritional composition, growing methods and its importance in promoting sustainable agriculture and food security.

**Figure 4** Barnyard Millet (*Echinochloa frumentacea* Link)

Barnyard millet is characterized by its small, round grains, which can vary in colour from white to pale yellow. It is a crop with a brief growing season that adapts to many agro-climatic circumstances, including marginal soils with low soil fertility [26]. Because of its toughness, farmers who use rain-fed agriculture or live in areas with few water supplies may choose barnyard millet. Additionally, barnyard millet is known for its ability to outcompete weed, reducing the need for chemical herbicides and supporting sustainable farming practices [48].

Nutritionally, barnyard millet has several advantages for our health, (Table 5) [49] which are important for a number of physiological processes [26]. Additionally, antioxidants and phytochemicals found in barnyard millet help it fulfill its promise as a functional food with anti-inflammatory and antioxidant qualities [50].

**Table 5** Nutritional Profile of Barnyard Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 398 |
| 2. | Protein | gm | 10.1 |
| 3. | Fat | gm | 3.9 |
| 4. | Carbohydrates | gm | 68.8 |
| 5. | Fiber | gm | 12.5 |
| 6. | Calcium | mg | 19 |
| 7. | Phosphorous | mg | 281 |
| 8. | Iron | mg | 5 |
| 9. | Magnesium | mg | 83 |

The cultivation of barnyard millet is relatively simple and can be practiced using traditional farming methods. It is a low-input crop that requires minimal water and fertilizer compared to other cereal grains. This makes barnyard millet a sustainable choice, by reducing the environmental impact of agriculture [51]. It can be grown as a pure crop or as part of a diversified cropping system, providing additional benefits such as weed suppression and improved soil fertility [26]. Due to the crop's early maturity, farmers may plan their cropping schedules more freely and have quick turnarounds.

Beyond its direct ingestion, barnyard millet is used in a variety of ways. Flour, semolina and flakes are just a few of the culinary items that may be made from grain [52].

The significance of barnyard millet in promoting food security and sustainable agriculture is noteworthy. In areas where other crops could struggle, its capacity to adapt to a variety of agro-climatic conditions guarantees a steady food supply [53]. The nutritional value of barnyard millet contributes to improved health and nutrition, particularly in communities facing malnutrition and dietary deficiencies. The consumption of functional foods in our diet boosts immunity, prevents lifestyle diseases and promotes overall excellent physical and mental health [52]. Additionally, it is an effective tool in promoting sustainable agricultural methods and climate change resistance because of its low environmental impact and capacity to survive with little maintenance.

In conclusion, barnyard millet stands as a versatile and nutritious cereal crop with immense potential. Its adaptability, nutritional value and sustainability make it a valuable resource for addressing food security challenges and promoting sustainable agriculture. The cultivation and utilization of barnyard millet offer numerous benefits, from improving nutrition and health to supporting local economies and preserving agro-biodiversity. With its positive impact on multiple fronts, barnyard millet deserves attention and investment as a crop that can contribute to a more sustainable and food-secure future.

*2.2.5. Foxtail Millet*

Foxtail millet, scientifically known as *Setaria italica* (L.) P.Beauv., is a versatile and nutritious cereal grain that has been cultivated for centuries in different parts of the world, particularly in Asia. The oldest foxtail millet archaeological remains have been discovered in northern China [54]. Foxtail millet, which is renowned for its hardiness and flexibility, has become popular as a staple crop in areas with difficult growing circumstances. The features of foxtail millet, its nutritional makeup, growing methods and its importance in fostering sustainable agriculture and food security [55].

Foxtail millet gets its name from the appearance of its inflorescence, which looks similar to a bushy fox's tail [56]. The grains are small and oval-shaped, varying in color from yellow to gray. Because of its well-known resistance to drought, extreme heat and low soil fertility, foxtail millet is a popular crop for desert and marginal soils [29]. Its tolerance to challenging growth circumstances is further increased by the deep root system's excellent water and nutrient uptake.

**Figure 5** Foxtail Millet [*Setaria italica* (L.) P.Beauv.]

Foxtail millet has a lot of nutritional advantages for our health. (Table 6) [57,58] It also has phytochemicals and antioxidants, which add to its potential as a functional diet with positive effects on health [26,29,55].

**Table 6** Nutritional Profile of Foxtail Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 331 |
| 2. | Protein | gm | 12.3 |
| 3. | Fat | gm | 4.3 |
| 4. | Carbohydrates | gm | 60.9 |
| 5. | Fiber | gm | 8 |
| 6. | Calcium | mg | 31 |

Foxtail millet may be grown in a variety of farming methods and is relatively easy to grow. It is a short-duration crop, typically maturing within 70 to 120 days, allowing for some flexibility in cropping plans [26]. Depending on the availability of water resources, foxtail millet can be grown using either rainfed or irrigated methods [28]. It is an environmentally beneficial option due to its effective water utilization and minimal input needs. The outstanding weed-suppressing abilities of foxtail millet also help to maintain the ecological balance of agricultural environments by lowering the demand for chemical pesticides.

Beyond its use for food, foxtail millet has a variety of uses. Jawarish Mastagi Murakkab is a type of traditional formulation with foxtail millet in it, which is useful as a stomachic [59].

It is impossible to exaggerate how important foxtail millet is for fostering agricultural sustainability and food security. Its capacity to flourish in difficult growing circumstances assures a steady supply of food, especially in areas subject to water scarcity and climate change. The nutritional content of foxtail millet helps to enhance diet and health, particularly in regions where malnutrition and dietary deficits are common [29,55]. Furthermore, it is a crucial element of sustainable agricultural practices due to its little impact on the environment and appropriateness for a variety of farming systems.

In conclusion, foxtail millet stands as a versatile and nutritious cereal grain with significant potential. Its adaptability, nutritional composition and sustainability make it a valuable resource for addressing food security challenges and promoting sustainable agriculture. The cultivation and utilization of foxtail millet offer numerous benefits, from improving nutrition and health to supporting local economies and preserving agro-biodiversity. With its positive impact on multiple fronts, foxtail millet deserves attention and investment as a crop that can contribute to a more sustainable and food-secure future.

*2.2.6. Kodo Millet*

Kodo millet, scientifically known as *Paspalum scrobiculatum* L., is a centuries-old cereal grain that has been cultivated around the world, mainly in Asia and Africa [26,60]. Kodo millet, also known as "*varagu*" or "*kodra*" is gaining popularity due to its high nutritional content and adaptability as a crop [57]. This section will look at the properties of Kodo millet, including its nutritional composition, farming practices and importance in fostering sustainable agriculture and food security.

Kodo millet has tiny, spherical grains that vary in color from light brown to dark grey [57]. It is a hardy crop that may thrive in a variety of agro-climatic situations, including dry and semi-arid locations with low soil fertility. Because of its adaptability, Kodo millet is a desirable crop for farmers in areas where other staple crops may struggle to grow. Furthermore, Kodo millet is known for its resistance to water stress and may be produced in places with inadequate irrigation [61]. In terms of nutrition, Kodo millet has several health advantages. (Table 7) [62] It also includes phytochemicals and antioxidants, which help it to be a functional meal with health-promoting effects [26,28,60].

**Table 7** Nutritional Profile of Kodo Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 300 |
| 2. | Protein | gm | 8.03 |
| 3. | Fat | gm | 1.29 |
| 4. | Carbohydrates | gm | 64.9 |
| 5. | Fiber | gm | 8.5 |
| 6. | Calcium | mg | 21.7 |
| 7. | Iron | mg | 2.9 |

Kodo millet cultivation is quite simple and may be done using traditional agricultural methods. It is a low-input crop that requires minimal water and fertilizer compared to other cereal grains. This makes Kodo millet an environmentally sustainable choice, reducing agriculture's carbon impact. Furthermore, Kodo millet has strong weed-suppressing characteristics, which reduces the need for chemical pesticides and promotes agroecological balance [63].

**Figure 6** Kodo Millet (*Paspalum scrobiculatum* L.)

The utilization of Kodo millet extends beyond its direct consumption. It may also be used in thickening soups, stews, and sauces [60].

The significance of Kodo millet in promoting food security and sustainable agriculture is noteworthy. Its adaptability to diverse agro-climatic conditions ensures a stable food supply, particularly in regions where climate variability and water scarcity are prevalent. The nutritional content of Kodo millet leads to better health and nutrition, particularly in places where malnutrition and dietary deficits are common. In addition, because of its minimal environmental impact and adaptability for organic agricultural practices, it is an important component of sustainable agriculture [61,63]. Kodo millets are essential for a number of health advantages. The chemical reaction between the amino group of proteins and the aldehyde-reduction group of sugars is the one that mostly causes diabetes and ageing, hence it is helpful in treating these conditions. Kodo millet has a high concentration of phenolics and antioxidants, including phytates, phenols, and tannins, which may have substantial antioxidant effects on ageing, metabolic syndrome, and general health. Due to its increased level of free radical scavenging activity, it has been demonstrated to be effective in decreasing the risk of cardiovascular disease and is also beneficial in the prevention of cancer [64].

In conclusion, Kodo millet stands as a versatile and nutritious cereal grain with immense potential. Its adaptability, nutritional composition and sustainability make it a valuable resource for addressing food security challenges and

promoting sustainable agriculture. The cultivation and utilization of Kodo millet offer numerous benefits, from improving nutrition and health to supporting local economies and preserving agro-biodiversity. With its positive impact on multiple fronts, kodo millet deserves attention and investment as a crop that can contribute to a more sustainable and food-secure future.

*2.2.7. Proso Millet*

Proso millet, scientifically known as *Panicum miliaceum* L., is a versatile and nutritious cereal grain that has been cultivated for thousands of years. After pearl millet and foxtail millet, it is the third most significant millet crop grown [26]. Proso millet, also known as common millet or broomcorn millet, is valued for its hardiness, adaptability and nutritional content [26,65]. The Proso millet has good properties to be mentioned, such as its nutritional makeup, production methods and its importance in fostering sustainable agriculture and food security [65].

Proso millet is characterized by tiny, spherical grains that range in colors may be white or creamy-white, yellow, or red, but may also be gray, brown, or black [66]. It is a resilient crop that can withstand a variety of growth situations such as drought, high temperatures, and low soil quality. Because of its adaptability, Proso millet may be grown in a variety of agroecological zones [66]. Furthermore, Proso millet has a short growing season, with maturation in 60 to 90 days, which allows for flexibility in cropping systems and the potential for multiple harvests in a single growing season [65,66].

From a nutritional point of view, Proso millet has several health advantages. (Table 8) [26,67] It also includes important antioxidants and phytochemicals, which contribute to its potential as a functional diet with excellent health impacts [29,66]. Proso millet is useful in preventing Pellagra, a skin disorder that causes the skin to become dry, scaly and rough. Proso millet is high in protein and Vitamin B3. It has traditionally been used as a recuperative meal, particularly after pregnancy or sickness [28].

**Figure 7** Proso Millet (*Panicum miliaceum* L.)

Proso millet cultivation is relatively simple and may be adapted to many farming methods. In comparison to other cereal grains, it is a low-input crop that requires little water and fertilizer [68]. Proso millet is well-suited to rainfed agriculture, which reduces reliance on irrigation water. It can be grown as an intercrop or rotated with other crops, promoting ecological balance and enhancing soil fertility. The crop is weed-resistant, minimizing the need for chemical pesticides and promoting agroecological sustainability [65].

Proso millet is used in many ways other than direct eating. It may also be used to thicken soups, stews and sauces [65,66]. The importance of Proso millet in improving food security and sustainable agriculture is remarkable. Its capacity to adapt to a wide range of growing circumstances enables a consistent food supply, particularly in areas prone to drought or with limited water resources [65]. The nutritional content of Proso millet helps to promote nutrition and health, especially in places where malnutrition and dietary deficits are common [69]. In addition, because of its minimal

environmental impact and adaptability for organic farming practices, it is an important component of sustainable agriculture and agroecology [65].

**Table 8** Nutritional Profile of Proso Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 341 |
| 2. | Protein | gm | 12.5 |
| 3. | Fat | gm | 1.10 |
| 4. | Carbohydrates | gm | 70.4 |
| 5. | Fiber | gm | 14.2 |
| 6. | Calcium | mg | 14 |
| 7. | Iron | mg | 10 |
| 8. | Phosphorous | mg | 206 |

Ultimately, Proso millet is a versatile and healthy cereal grain with enormous potential. Its versatility, nutritional content, and long-term viability make it an important resource for tackling food security issues and encouraging sustainable agriculture. Proso millet production and utilization provide several benefits, ranging from improved nutrition and health to supporting local economies and maintaining agro-biodiversity. Proso millet needs attention and investment for its good impact on various fronts as a crop that may contribute to a more sustainable and food-secure future.

*2.2.8. Little Millet*

Little millet, scientifically known as *Panicum miliare* Lam., is a small and nutritious cereal grain that has been farmed for generations in many parts of the world. Little millet, also known as "*kutki*" or "*samai*" is valuable for its nutritional qualities, flexibility and versatility. This millet has features like nutritional makeup, farming practices and its role in fostering sustainable agriculture and food security [70,71].

Little millet is identified by its small, spherical grains that range in color from pale yellow to off-white. Despite its small size, Little Millet delivers a nutritious impact. (Table 9) [72,67] Little millet is also high in antioxidants and phytochemicals, making it an excellent supplement to a healthy diet [29,70]. It has a high amount of magnesium, which helps in maintaining a healthy heart rate and also boosts bone density [73].

**Table 9** Nutritional Profile of Little Millet Per 100 gm

| Sr. No. | Parameters | Unit | Amount |
|---|---|---|---|
| 1. | Energy | Kcal | 1449 |
| 2. | Protein | gm | 8.92 |
| 3. | Fat | gm | 2.55 |
| 4. | Carbohydrates | gm | 65.55 |
| 5. | Fiber | gm | 6.39 |
| 6. | Calcium | mg | 16.06 |
| 7. | Iron | mg | 1.26 |
| 8. | Magnesium | mg | 91 |

Little millet production is reasonably straightforward and may be adapted to a variety of agro-climatic situations. It is an adaptable crop that can endure both dry and humid conditions, making it appropriate for cultivation in a variety of climates [74]. Little millet is recognized for its short growth season, often ripening in 60 to 75 days, allowing for rapid

harvests and cropping system flexibility. Depending on local conditions, it can be cultivated as a rainfed crop, minimizing reliance on irrigation water, or in irrigated systems [70].

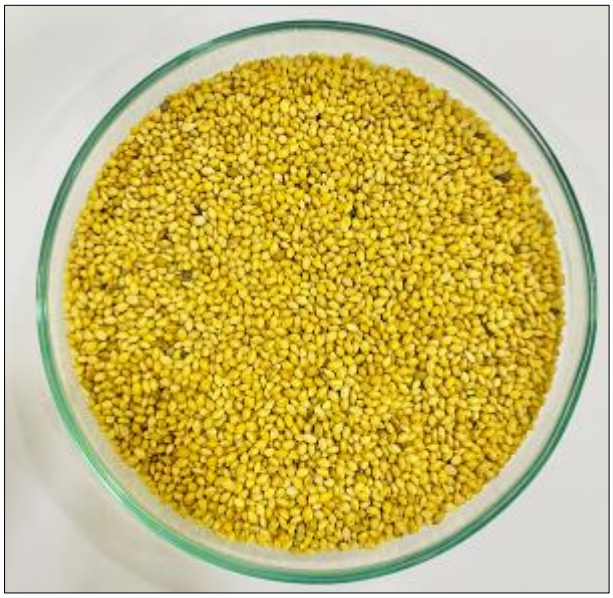

**Figure 8** Little Millet (*Panicum miliare* Lam.)

Little millet has various advantages in terms of sustainability. It is a low-input crop that requires less water and fertilizer in comparison to other cereal grains [75]. This makes it an environmentally beneficial alternative, as it has a lower effect on water resources and uses fewer synthetic inputs. Little millet may also be grown organically, which promotes soil health and biodiversity. It also has strong weed-suppressing qualities, which reduces the demand for chemical pesticides while also promoting ecological balance in agricultural areas [70,74].

Little millet is classified as a minor millet crop, which indicates it is planted less often than main cereal crops such as rice or wheat. By cultivating little millet, farmers contribute to the preservation of crop diversity and help prevent genetic erosion [74]. Little millet production and consumption help to preserve traditional food systems and local agricultural expertise.

Little millet may grow on marginal grounds, relieving strain on important agricultural regions and promoting crop diversity [28,70]. Its short growing season allows for greater crop rotation and intercropping flexibility, improving soil fertility, pest control and overall ecological balance.

Finally, small millet emerges as a potent grain with many qualities of value. It is important for biodiversity conservation since it helps to preserve crop variety and traditional food systems. Its cultivation promotes sustainable agricultural practices while also improving ecological balance and soil fertility. Furthermore, Little Millet gives economic prospects for small-scale farmers, aiding rural development and improving livelihoods. Highlighting the numerous importance of small millet can encourage its development and utilization, resulting in a more sustainable and food-secure future.

Incorporating millet into your diet can offer a range of health benefits while diversifying your culinary options. Whether you're looking to boost your micronutrient intake, explore gluten-free alternatives, or experiment with new recipes, millets can be a valuable addition to your pantry. Some of the common health benefits of millet are mentioned below. (Table 10)

**Table 10** Common benefits of millets

| Sr. No. | List of Common Benefits | Name of Millets |
|---|---|---|
| 1. | Rich in micronutrients like Iron, Calcium, Magnesium and Potassium | Sorghum millets, Pearl millets, Finger millets, Barnyard millets, Foxtail millets, Kodo millets, Proso millets and Little millets |
| 2. | Gluten-free, safe and nutritious alternative to gluten-containing grains like wheat, barley and rye. | Sorghum millets, Pearl millets, Barnyard millets, Foxtail millets, Kodo millets and Proso millets |
| 3. | Grounded flour is used to make porridge, flatbreads and other baked foods. | Pearl millets, Finger millets, Barnyard millets, Foxtail millets, Kodo millets and Proso millets |

## 3. Discussion

The nutritional and health benefits of millet have significant contributions to human health and well-being. Millets, with their amazing nutritional profile and unique composition, provide a number of benefits that make them an important part of a balanced diet [26,28]. The dietary components of all the millets are essential for general strength, illness prevention and the treatment of different nutritional deficiencies [75].

The comprehensive study of millet's nutritional advantages indicates their positive influence on human well-being. Millets provide several benefits due to their remarkable nutritional profile and unique composition, making them a perfect addition to a balanced diet [26,36]. Millets include a significant amount of material, which supports digestion, regulates blood sugar levels and assists with weight management. Essential minerals, including iron, calcium, magnesium and phosphorus, contribute to overall physiological functions, such as bone health, muscle contraction and nerve function. The presence of beneficial phytochemicals and antioxidants in millets increases their functional dietary potential, offering protection against oxidative stress and chronic illnesses inflammation and chronic illnesses such as cardiovascular disease, cancer and neurological disorders [26,28,67]. These minerals play important roles in key physiological activities including oxygen transfer, bone health, muscular contraction and neuron function. Incorporating millet into the diet helps satisfy the necessary daily intake of essential minerals while also lowering the risk of deficiency [76]. Building healthy gut bacteria aids absorption and digestion. Furthermore, the gradual release of carbohydrates due to the high fiber supports maintaining stable blood glucose levels, making millet an appropriate fortified choice for people with diabetes or trying to lose weight.

Millets may be used in a variety of recipes, including porridges, bread, pancakes, snacks and baked items [67]. One of the key roles of millets is their suitability for individuals with gluten intolerance or celiac disease [28]. Millets are naturally gluten-free grains, providing a safe and healthy alternative that allows persons with dietary limitations to enjoy a wide range of dishes [26,28,67]. Individuals with diabetes can better regulate their condition and lower the risk of complications by adding millet to their meals [76].

Millet cultivation and consumption help to ensure sustainable agriculture and food security. Millets are well known for their tolerance to a number of agro-climatic conditions, making them a good crop for water scarcity areas and marginal lands [26,67]. Their resistance to pests and diseases minimizes the need for chemical inputs, hence encouraging environmentally beneficial agricultural practices. Besides, millets improve agricultural sustainability and help solve global food security concerns by diversifying food systems and reducing reliance on a few main crops [26,28]. Millet's market potential is growing as more people recognize its nutritional worth and health benefits. This creates chances for value-added goods, local entrepreneurship and economic growth in millet-growing regions.

## 4. Conclusion

The nutritional and health benefits of millet make them a treasure trove for our diets. Their high fiber content, essential minerals and beneficial phytochemicals promote overall health, illness prevention and better management of a variety of conditions. Millets are extremely beneficial in gluten-free diets, diabetic treatment and sustainable agriculture. Millets play a crucial role in supporting the dietary needs of millions of Indians. We can adopt and encourage a better lifestyle and food-secure future by recognizing the benefits of millet. By promoting the cultivation and consumption of millet, India can not only improve the nutritional status of its population but also strengthen its agricultural resilience and preserve its traditional food heritage for future generations.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest is to be disclosed.

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