

## Review Article

# Millets as nutri-cereals and its health benefits: an overview

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## ABSTRACT

Millets are one of the oldest foods known to humans, possibly the first cereal grain used for dietary. Since ancient times, millet has been widely consumed in Asia and India. Although millets are highly nutritious, their consumption still needs to be improved in the general and poor population due to less awareness regarding their nutritional values and health benefits. With changing food habits, increasing population, and uncontrolled use of natural resources, providing nutritious food to all is challenging. Natural plant resources are quickly depleting, and we must explore new alternatives. Besides the usual rice and wheat, many underutilized millets are less consumed, with great potential to replace routine cereal crops. Millets are one of the significantly underutilized crops with a nutri-cereal potential. Regular and excess consumption of common cereals contributed to developing and increasing the burden of lifestyle diseases. Millets are highly nutritious, gluten-free, and have rich dietary properties. Millets are rich in carbohydrates, dietary fibres, energy, essential fatty acids, proteins, vitamin B and minerals which help to prevent diseases like diabetes, hypertension, hyperlipidemia, cancer, cardiovascular diseases. Cereal-based food products are supplemented with millet and have become popular due to nutritional and economic advantages. The millets have fostered immunity and health to continue the fight against malnutrition in children and adolescents. Ultimately, millet consumption furthers nutrition, food security and the welfare of farmers. This review furnishes crucial information about the compounds found in millets, highlighting their nutraceutical properties, health benefits, and other therapeutically significant elements that classify them as nutri-cereals.

**Keywords:** Anemia, Antioxidants, Dietary fibre, Millets, Malnutrition, Nuticereals

## INTRODUCTION

Millets belong to Poaceae (grass) and are a staple food for the population in dryland and low-rainfall regions, particularly in Asia and Africa. Millets were among the initial crops cultivated in India, with numerous indications of their consumption dating back to the Indus Valley civilization.<sup>1</sup> However, for many reasons, their consumption and cultivation in India have declined over the past three decades. It could play a significant role in the traditional diet of many states of India, and their different varieties are consumed in many regions of India.<sup>1</sup> Their

growing season is short and typically thermo-tolerant, pest-free, and requires no extra fertilizer for growth. Millet crops are still the principle sources of protein, energy, vitamins and minerals for millions of the poorest people in developing countries. Millets vary from one another by appearance, grain type, maturity, and morphological features. These are rich in functional compounds like slowly digestible carbohydrates, dietary fibre, high protein content, B-complex vitamins, calcium, iron, magnesium, manganese, copper and phytochemicals. Millets were the first known cereal used as food because, in the Middle Ages, Pauls and Romans consumed millets as porridges

instead of rice.<sup>2</sup> They are simple to digest, non-acid forming, and non-allergenic.<sup>3</sup> The high nutritional value of millet can make it even more valuable food for humans and a possible income source for farmers.<sup>4</sup>

Malnutrition refers to deficiencies, overabundance, or irregularity in a person's energy intake and nourishment as per the World Health Organization (WHO).<sup>5</sup> Healthy adolescents, youngsters, and pregnant and lactating women are high in India and can benefit from millets. It is helpful for newborn kids in several ways, including strengthening the weak immune system, improving chronic illness, survival and proper organ formation. The United Nations Children's Emergency Fund (UNICEF) report reveals that the newborn mortality rate in India is 8.8%, and malnutrition causes 69% of kids' deaths under five years. The issue of malnutrition has emerged as a significant concern for public health that needs prompt address. India has contributed significantly to the growth of the diabetic population. Due to the continuous upsurge in diabetes patients, India is known as the diabetic capital of the world.<sup>1</sup> Excessive intake of common cereals in daily meals also plays a role in the increased prevalence of diabetes. Global Heart Initiative WHO has indicated that more than 80% of deaths related to cardiovascular disease occur in low and middle-income nations.<sup>7</sup> So, millet could replace common cereals to reduce the burden of diabetes and other non-communicable diseases. And millet crops have additional advantages over cereals as they are resistant to diseases, can grow without pesticide use, and do not require fumigants.<sup>8</sup> Millets are stress-tolerant grains that can grow in low-quality soil or with less nutritional requirements, are tolerant to temperature fluctuations, and have a unique short growing season.<sup>9</sup> Commonly used millets are finger millet, Proso millet, Pearl millet, foxtail millet, little millet, barnyard millet, kodo millet, and sorghum. In their cultivating area, millets provide most of the energy and protein requirements to the population.

Due to their high nutritional qualities, these are considered nutri-cereals. Indian Council of Agricultural Research and Indian Institute of Millets Research (ICAR-IIMR) described nutri-cereals as highly nutritious grains that contain comparable nutrients to staple rice and wheat. So, to strengthen efforts against the food crisis, to support and

encourage the farmers to produce millets and for agri-industries in millets utilization, the Government of India announced 2018 as the national year of millets and sponsored a resolution in the United Nations to declare a year as the International year of millets, on subsequent acceptance of resolution in the general assembly of united nations, the year 2023 is declared as the International year of millet.

Keeping the significance of millet as nutri cereals, this review focused on millet compounds and their nutraceutical properties, their health benefits, and other therapeutically essential compounds that make them nutri-cereals.

## METHODS

A search was done in "Google search, Google Scholar, Web of Sciences and various research organizations' and public health authorities' publications". Articles including review articles and reports of Govt. of India, WHO, UNICEF, ICAR ect. were included.

## RESULTS

Based on the search, the following results were obtained. Millets could be considered as nutri-cereals.

### *Nutritional value of millets*

The Millet Network of India (MNI), a non-profit organization, considers millets as nutri-cereals rather than coarse cereals. For any nutritional parameter, millets are miles ahead of rice and wheat in terms of mineral content.<sup>2</sup> Each type of millet has more fibre than rice and wheat, including some as much as fifty times that of rice. Finger millet has thirty times more calcium than rice, while every other millet has at least twice the amount. While many people use pharmaceutical pills and capsules to obtain micronutrients like beta-carotene, millet provides a rich source of these essential nutrients.<sup>2</sup> Every millet is extraordinarily superior to rice and wheat and is the solution to combat and conquer malnutrition affecting most Indian populations.<sup>2</sup>

**Table 1: Nutritional profile of millets in comparison with cereals (per 100 g).**

| Grains                 | Energy (kcal) | Protein (g) | Carbohydrate (g) | Starch (g) | Fat(g) | Dietary fiber (g) | Minerals (g) |
|------------------------|---------------|-------------|------------------|------------|--------|-------------------|--------------|
| <b>Sorghum</b>         | 334           | 10.4        | 67.6             | 59         | 1.9    | 10.2              | 1.6          |
| <b>Pearl millet</b>    | 363           | 11.6        | 61.7             | 55         | 5      | 11.4              | 2.3          |
| <b>Finger millet</b>   | 320           | 7.3         | 66.8             | 62         | 1.3    | 11.1              | 2.7          |
| <b>Proso millet</b>    | 341           | 12.5        | 70.0             | -          | 1.1    | -                 | 1.9          |
| <b>Foxtail millet</b>  | 331           | 12.3        | 60.0             | -          | 4.3    | -                 | 3.3          |
| <b>Little millet</b>   | 329           | 8.7         | 65.5             | 56         | 5.3    | 6.3               | 1.7          |
| <b>Barnyard millet</b> | 307           | 11.6        | 65.5             | -          | 5.8    | -                 | 4.7          |
| <b>Wheat</b>           | 321           | 11.8        | 64.7             | 56         | 1.5    | 11.2              | 1.5          |
| <b>Rice</b>            | 353           | 6.8         | 74.8             | 71         | 0.5    | 4.4               | 0.6          |
| <b>Maize</b>           | 334           | 11.5        | 64.7             | 59         | 3.6    | 12.2              | 1.5          |

### Carbohydrate

The millet grain comprises approximately 65% carbohydrates, with a notable content of non-starchy polysaccharides and dietary fibre. These components prevent constipation, reduce blood cholesterol, and ensure a gradual release of glucose into the bloodstream during digestion.<sup>2</sup>

### Fibre

Millet grains are rich sources of insoluble (IDF) and soluble (SDF) dietary fibre and have comparable or even higher total dietary fibre (TDF) than other cereals.<sup>2</sup> The high fibre content in millets improves bowel movements. In addition, due to its low digestive features, it increases the transit time, reducing the rate of glucose release in the blood, which helps diabetic patients.

### Protein

The average protein content of millet is from 7.7-11.8%.<sup>10</sup> The albumin and globulin fraction forms 8.5-16.26%, prolamin fraction forms 15-30%, while glutelin forms 45-55% of the total protein in minor millets except foxtail has higher prolamin (60%) than glutelin (15.23%) content.<sup>10</sup> Millets generally contain significant amounts of essential amino acids, particularly sulphur-containing ones (Methionine and cysteine). It also has high quantities of Methionine, an amino acid deficient in most grains, giving millet a valuable place in a vegetarian diet. The essential amino acid profiles of the millet protein are better than those of maize.

### Fat

The essential fatty acids like linoleic, oleic and palmitic acids found in free form (60-70%) and mono-galactosyl,

diacylglycerols, di galactosyl diacylglycerols, phosphatidyl serine and phosphatidylcholine in the bound form present in millets.<sup>11</sup> Other fatty acids like arachidic acid, behenic acid, and erucic acid are found in trace amounts.

### Vitamins

Millet grains are also rich in essential vitamins like thiamine, riboflavin, niacin and folic acid.<sup>12</sup> The niacin content in pearl millet is higher than all other cereals. Kodo millet is rich in B vitamins, especially pyridoxine, niacin, and folic acid. Sorghum and millets, in general, are rich sources of B-complex vitamins. Detectable amounts of other fat-soluble vitamins, namely D, E and K, are also available in millet.<sup>2</sup>

### Minerals

Millets are more nutritious compared to refined cereals. Millets contain several minerals, including calcium, iron, potassium and magnesium. Finger millet stands out as the most abundant source of calcium (300-400 mg/100 g), and other minor millet is an excellent source of phosphorous and iron. Magnesium is a micronutrient used for bone mineralization, teeth maintenance, the building up of proteins, enzyme activities, regular muscular contractions and transmission of nerve impulses.<sup>2</sup>

### Phytochemicals

Phytochemicals are virtually present in all the commonly consumed fruits, vegetables, pulses/legumes, and grains, so it is easy to incorporate them into our daily diet. The primary polyphenols found in millets are phenolic acids and tannins. Although flavonoids are present in limited amounts, they serve as antioxidants and fulfil various functions within the body's immune system.<sup>2</sup>

**Table 2: Vitamins and minerals composition of millets (mg per 100 g of edible portion).**

| Parameter                    | Finger | Proso | Foxtail | Little | Kodo  | Barnyard | Pearl | Sorghum | Rice raw milled | Wheat |
|------------------------------|--------|-------|---------|--------|-------|----------|-------|---------|-----------------|-------|
| <b>Vitamins</b>              |        |       |         |        |       |          |       |         |                 |       |
| Total carotenoids            | 154    | -     | 32      | 120    | 272   | -        | 293   | 212     | 16.9            | 287   |
| Thiamine                     | 0.37   | 0.20  | 0.59    | 0.26   | 0.29  | (0.33)   | 0.33  | 0.35    | 0.05            | 0.45  |
| Riboflavin                   | 0.17   | 0.18  | 0.11    | 0.05   | 0.20  | (0.10)   | 0.25  | 0.14    | 0.05            | 0.17  |
| Niacin                       | 1.34   | 2.3   | 3.2     | 1.29   | 1.49  | 4.2      | 2.3   | 2.1     | 1.69            | 5.5   |
| <b>Minerals and elements</b> |        |       |         |        |       |          |       |         |                 |       |
| Calcium                      | 364    | 14    | 31      | 16.06  | 15.27 | 20       | 42    | 27.6    | 7.49            | 41    |
| Phosphorus                   | 283    | 206   | 290     | 220    | 188   | 280      | 296   | 274     | 160             | 306   |
| Iron                         | 4.61   | 0.8   | 2.8     | 1.26   | 2.34  | 5.0      | 8.0   | 3.95    | 0.65            | 5.3   |
| Magnesium                    | 137    | 153   | 81      | 133    | 147   | 82       | 137   | 1.33    | 64              | 138   |
| Sodium                       | 11     | 8.2   | 4.6     | 8.1    | 4.6   | -        | 10.9  | 5.42    | -               | 17.1  |
| Potassium                    | 408    | 113   | 250     | 129    | 144   | -        | 307   | 328     | -               | 284   |
| Copper                       | 0.67   | 1.60  | 1.40    | 0.34   | 0.26  | 0.60     | 1.06  | 0.45    | 0.23            | 0.68  |
| Zinc                         | 2.3    | 1.4   | 2.4     | 3.7    | 0.7   | 3.0      | 3.1   | 1.96    | 1.3             | 2.7   |

Source: IFCT 2017, Nutritive value of Indian Foods, 2009.

## Commonly using millets

### *Finger millet*

Finger millet or "ragi" profusely tillering plant with characteristic finger-like terminal inflorescences bearing tiny reddish seeds. Finger millet contains high amounts of calcium, a protein with a well-balanced essential amino acid composition, and vitamins A, B, and phosphorous. Ragi flour in Karnataka is mainly prepared into balls, popularly known as "ragi mudde", made into leavened dosa, flatbreads and thinner, unleavened rotis. Its high fibre content also checks constipation, high blood cholesterol and intestinal cancer. The protein content in finger millet is high, making it an essential factor in preventing malnutrition. It has been considered that finger millet is probably the only millet that contains tannins in some of its brown varieties.<sup>13</sup> It is also the best food for diabetic people and controls hyperglycemia and sugar levels.<sup>14</sup>

### *Pearl millet*

Pearl millet is known as 'Bajra' and possesses phytochemicals that lower cholesterol. Pearl millet has a high energy content compared to other millets. Additionally, it contains ample amounts of calcium and unsaturated fats, making it beneficial for the body.<sup>2</sup> It contains folate, copper, zinc, iron, magnesium, calcium, vitamin B complex, and unsaturated fatty acids.<sup>14</sup> It has high folate, making it a biofortificant against the frail population. Magnesium can foster the treatment of migraine and reduce respiratory problems in asthmatic patients.<sup>4</sup> Pearl millets also contain some phytonutrients such as apigenin, flavonoids, lignin, and myricetin that help prevent breast cancer and cardiovascular disease and are anti-fungal and anti-ulcerative.<sup>8</sup>

### *Foxtail millet*

Foxtail millet, commonly known as Kangni, is the second highest-grown millet in India. Foxtail millets contain a good amount of protein, dietary fibre, calcium, vitamins, iron, and copper. They also help increase disease resistance capacity.<sup>14</sup> It is non-glutinous and non-acid-forming, so easily digestible. It helps steadily release sugars in the body without hindering metabolism.<sup>15</sup> Due to its magnesium content, it is known as a healthy heart food. It is antimicrobial and antitumorigenic and helps detoxify the body.<sup>8</sup> Lin et al demonstrated that foxtail millets show an anti-ulcer response and pervasive antioxidant effect and protect the gastric mucosa.<sup>16</sup>

### *Little millet*

Little millet is commonly known as Gajrao. It contains around 37–38% of dietary fibre and protein. It can be used for snacks, baby foods, and processed foods.<sup>14</sup> It contains apigenin that helps combat diabetes, celiac disease, cardiovascular disease, and high cholesterol levels and is anti-cancerous.<sup>8</sup> These are also good for wheat-intolerant

people. Little millets are rich in phosphorous and iron and carry a high amount of vitamin B. Germinating little millets are excellent sources of  $\alpha$ -amylase with higher purity and specific yield.<sup>17</sup>

### *Barnyard millet*

Barnyard millet is a highly digestible protein and an excellent dietary fibre source. It is rich in protein and dietary fibre but low in carbohydrates. The carbohydrate content of barnyard millet is soft and slowly digestible, which makes the barnyard millet a nature's gift for present-day people who are engaged in sedentary activities. The major fatty acid in this millet is linoleic acid, followed by palmitic and oleic acid. It is helpful for patients with cardiovascular diseases and diabetes. Barnyard millet most effectively reduces blood glucose and lipid levels. It contains phenolic compounds, flavonoids, and serotonin derivatives and shows potent antioxidative activity.<sup>18</sup>

### *Kodo millet*

Kodo millet was cultivated in India almost 3,000 years ago. It serves as a cornerstone for meeting essential dietary nutritional needs, boasting notable characteristics such as an 11% protein content, low fat at 4.2%, and remarkably high fibre content at 14.3%. Kodo millet is easily digestible, abundant in lecithins, and highly beneficial for reinforcing the nervous system. Enriched with B vitamins, particularly niacin, B6, and folic acid, and minerals, including calcium, iron, potassium, magnesium, and zinc, it provides a gluten-free option suitable for individuals with gluten intolerance. It is gluten-free and is ideal for people who are gluten intolerant.<sup>2</sup> Kodo millet has the highest dietary fibre concentration compared to other millets and is ideal for diabetic patients. The consumption of Kodo millet is suitable for post-menopausal women suffering from high cholesterol problems or dyslipidemia, high blood pressure, and heart-related diseases.<sup>14</sup> The stem of the Kodo millet plant can be used as a poultice if suffering from beriberi, while the concentrate of Kodo roots can be used as a diuretic and galactagogue.<sup>19</sup>

### *Sorghum*

Sorghum or "Jowar" cereal is considered an essential coarse-grained food crop. Generally, sorghum grains are a principal source of protein, vitamins, energy and minerals for millions, especially in semi-arid regions. It has a nutritional profile better than rice, the staple food of most of the human population, for its rich protein, fibre, thiamine, riboflavin, folic acid, calcium, phosphorous, iron and iron  $\beta$ -carotene.<sup>2</sup> Sorghum is rich in potassium, phosphorus and calcium, with iron, zinc and sodium. Adding sorghum to meals of pregnant women helps them attain dietary mineral and vitamin requirements. Sorghum is a highly nutritious and prosperous millet that contains a higher nutritional value than rice or wheat and has nutraceutical properties that help in fighting arthritis, CVDs, less body weight, BMI, malnutrition, and obesity.<sup>20</sup>

### Proso millet

Proso millet is a short-season crop that grows in low-rainfall areas. The common name of proso millet is Chena, which has a shorter growing season.<sup>21</sup> It releases energy over a more extended period after consumption, allowing one to work longer without fatigue. This has rich protein content, crude fibre, minerals and calcium. Proso millet offers a health advantage owing to its distinctive characteristics. It is entirely gluten-free and contains substantial quantities of carbohydrates and fatty acids. Manganese in proso millet is cheaper than conventional sources like spices and nuts. It is proven to reduce cholesterol levels and the risk of heart disease, besides preventing breast cancer.<sup>2</sup> Carotenoid extract of proso millet has very high cellular antioxidant activity compared to fruits and vegetables. It contains around 65% phenolic compounds and is rich in some bioactive phytochemicals like caffeic acid, chlorogenic acid, ferulic acid, and syringic acid, all beneficial for human health.<sup>22</sup>

### DISCUSSION

Indeed, millets need to be utilized more, the availability of millet is not enough because the crops are neglected due to their lower cooking quality and lower preference determined by affluence, as well as the longer time and effort involved in processing the millets.<sup>1</sup> The availability of millet everywhere is the biggest challenge to avail enormous health benefits. The prevalent habit of incorporating common cereals into daily meals markedly contributes to the onset of various lifestyle diseases such as diabetes and other non-communicable conditions. Millets generally abound in antioxidants and phenolic compounds such as phytates, phenols, and tannins. These components promote antioxidant activity and significantly address ageing and metabolic syndrome. Antioxidants in millet prevent tissue damage and stimulate the wound-healing process. Its high protein level benefits vegetarians as the protein sources from other vegetarian foods might be inadequate. The rich magnesium content in it reduces menstrual cramps and has the potential to regulate the menstrual cycle. Its amino acids lower cholesterol levels in the blood by reducing the formation of plaques in the blood vessels. Moreover, the rich fibre content satiates hunger and prevents food cravings. Due to this phenomenon, millet is advised as a substitute for a weight-loss program. Daily consumption of millet can significantly reduce incidences of non-communicable diseases. However, finger millet high intake could increase the quantity of oxalic acid in the body and is not recommended for patients with kidney stones.<sup>2</sup> Certain millets, particularly kodo millet, contain goitrogens, substances that disrupt the production of thyroid hormones and hinder the absorption and utilization of iodine by the thyroid gland. Further, to address people's dietary requirements and due to the increased demand for cereal-based wholegrain foods, the food industry is developing new products, facilitating the incorporation of underutilized crops in food products and giving a healthier alternative to staple food.<sup>23</sup> With the

increasing demand for gluten-free grains, millets are expeditiously gaining popularity. Food technologists and researchers have developed many gluten-free functional foods, including noodles, pasta, various cookies, extrudate, injera, sourdough bread, non-sourdough bread, and fat replacers for gluten-intolerant people.<sup>24</sup> Omoba et al have developed biscuits as ready-to-eat food supplements for school-going children using sorghum, pearl millet, and soya, and the study also reveals that two biscuits per day can contribute to an average of 13% of total dietary reference intake of fibre among 4–8 years aged child, whereas it can contribute around 11, 16, and 8% of Fe, Mg, and Zn, respectively.<sup>25</sup> Many researchers have studied the pro and prebiotic aspects of millets and successfully suggested that using millets as a prebiotic is acceptable and beneficial.<sup>26</sup> The soluble fibre in millets reduced the risk of developing cardiovascular diseases by reducing triglycerides by 8% and 10% reduction in LDL and VLDL lipoproteins. In addition, consuming the millet decreased blood pressure, with the diastolic blood pressure by 5%. Studies also show that consuming millet reduced the BMI by 7%.<sup>27</sup> People with celiac disease and other intolerances to wheat, barley, or rye drive demand for gluten-free goods and beverages in developed countries. Millets are gluten-free food and drink that could be suitable for persons with celiac disease.<sup>28</sup> Although millets have enormous advantages, they are not as well-known as other staple crops such as rice, maize, and wheat. Many people are not aware of the nutritional value and health benefits of millet. However, these must be utilized more since millions have consumed it as a staple food for thousands of years. According to the World Health Organization (WHO), malnutrition encompasses deficiencies or excesses in nutrient intake, imbalances in essential nutrients, or impaired nutrient utilization. The dual challenge of malnutrition involves both undernutrition and issues related to overweight, obesity, and diet-related non-communicable diseases, which could be addressed by effectively incorporating millet into the diet.

### CONCLUSION

Potential millet are nutrient-cereals and have enormous health benefits. It must be implemented in developing countries like India due to its high nutritional qualities, high dietary fibre concentration, effectiveness in small and large-scale supplements, and effectiveness as the best agent for fortification. Ultimately, millet consumption furthers nutrition, food security and the welfare of farmers.

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