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Research Article

MILLETS AS A POWERHOUSE OF NUTRIENTS, PLAUSIBLE HEALTH BENEFITS AND ITS CHALLENGES: A REVIEW

[1,] *Neha Pandey, [2]Dr. Vijay Laxmi Gautam and [3]Dr. Rajendra Prasad

[1, 2]Department of Rachana Sharir, Faculty of Ayurveda, IMS, India
[3]Department of Kayachikitsa, Faculty of Ayurveda, IMS, BHU, India

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Abstract

This comprehensive review paper scrutinizes into the nutritional value of millets and their multifaceted role in global nutrition and health. Through an exhaustive investigation, we unveil the health advantages of millets, indicating their ability to manage chronic conditions. Millet grains are a drought-resistant crop with high output in water-scarce places. They are also highly nutritious and considering as super food. They are store house of high nutrition like protein, mineral, fiber as well as various phytochemicals which included therapeutic properties owing to their anti- inflammatory and anti-oxidative properties. Sorghum, finger millets, pearl millets, foxtail, tiny kudo, proso and barnyard millet are among the major millet. The sheer affordability of millets also known as 'poor men's food grains. Millets have been used in India since ancient time and Govt. of India also focusing on millets and 2018 declared as millets years to encourage and promote millets production. Because of their nutritional quality and health boosting factors it can be 'miracle grains' and hon'ble PM of India addressed it as 'Shree Anna' in 2023. Millets can be contributed to addressing some of the burning issues of the world: poor diet (malnutrition to obesity), food security, good health and well-being. The goal of this study was to analyse recent breakthroughs in research for evaluating the nutritional content and possible health advantages of millet grains.

Keywords: Millets, Food security, Nutrition, Poverty eradication, Shree Anna.

INTRODUCTION

Millets are a group of small seeded crops that belongs to the grass family. Millets can be classified as major millets which include sorghum (jowar) and pearl millets[1]. Minor millets include finger millets (ragi), small millets (kutki), foxtail millets (kangari or Italian millets), barnyard millets (sanwa), brown top millets (koale), and proso millets (cheena). Minor millet crops, often known as Nutri-cereals, are small-seeded annual grass family crops [2]. Millets are rich source of macro as well as micro nutrients e.g. dietary fiber, minerals & vitamins, proteins, lipids, phenolic compounds, these nutrients playing a vital role in body functioning e.g., anti-inflammatory agent, prebiotics, antioxidant, bowl movement [3]. The united Nation General Assembly celebrated 2023 as millets years, India also promoting millets on global level, in 2018 ministry of Agriculture and Farmer Welfare has highlighted the importance of millets and declared it as Nutri- cereal[4]. According to FAO data India is the world's largest producer of millets with a share of 38.4% of world's production in 2024**.** Geographically India considered as the most diverse country i.e., dissert area, hilly area, semi-arid and unpredictable mansoon[5]. So, millets may be demonstrated as a godsend for the Indian area with the quality of climatic adaptation in tough heat (up to 50 degrees Celsius), growing on poor soils with minimal external input, therefore, it can be "miracle grains" or crop of the future [6]. Millets, such as pearl, barnyard and finger millet may be easily farmed in sandy, low fertile, salty regions and it can be farmer friendly but other crops like pulse, rice, and wheat require suitable fertile soil and excellent irrigation for cultivation [7]. Despite all this, their cultivation area and production have decrease with decline in their consumption due to lack of awareness of its nutritional importance and beneficial impact of on health and low investment in Research and Development.

Corresponding Author:** ***Neha Pandey,
Research scholar, Department of Rachana Sharir, Faculty of Ayurveda, IMS, India.

MILLETS: The Future Food

Millets are a viable answer for food security and sustainable agricultural techniques. Millets provide a wide range of advantages, including excellent nutritional content with abundant

High in fiber, vitamins, and minerals, these foods promote overall health and well-being. Millets, such as sorghum, pearl millet, and finger millet, are resilient grains that thrive in various agro-ecological conditions. They are high in essential nutrients and fiber, contributing to a balanced diet and better health outcomes:

Pearl millets (Bajra): It can be good for semi-arid region because of its strongest drought tolerance potential. After rice and wheat, it is the most widely grown cereals in India[8]. Pearls millets have vital source of nutrients like; energy (Kcal) 347, protein (g) 10.9, fat (g) 5.43, carbohydrate (g) 61.8, Ca (mg) 27.4, Fe (mg) 6.4, folic Acid (µg) 36.1 [9].Millets include important fatty acids such as linoleic, oleic, and palmitic acids in their free form, as well as monogalactosul, diacylglycerols, digalactosyl, diacylglycerols, phosphatidylethanolamine, phosphatidyl serine, and phosphatidyl choline in bound form [10]. Pearl millet grain contains the following vitamins: thiamine (B1; 0.27-0.38 mg/100 g), riboflavin (B2; 0.15-0.25 mg/100 g), pyridoxine (B6), niacin [0.89-2.7 mg/100 g], folic acid [34.9-45.5 µg/100 g], and pantothenic acid (1.09-1.40 mg/100 g) [11].So, it has numerous important roles in health maintenance such as cholesterol reducing agents, beneficial in

stomach ulcer and heart and reduce the risk of inflammatory bowel disease, diabetes mellitus[12].

Sorghum (jowar): It is a cereal of the family Poaceae. It is the fifth most produced cereal in the world, after wheat, rice, maize, and barley. Sorghum is containing major nutrients like energy (Kcal) 334, Protein (g) 9.9, Fat (g) 1.73, Carbohydrate (g) 67.7, Ca (mg) 27.6, Fe (mg) 3.9, Folic Acid (µg) 39.4., [13]. Because the non-starch carbohydrate in sorghum is mostly made up of soluble fibres (10% to 25%) and insoluble fibres (75% to 90%) [14], which are present in the pericarp and endosperm cell walls and make up roughly 6 to 15 g per 100 g of grain, sorghum is a rich source of fibre [15]. It may, however, lack lysine, just like other cereal grains, though this issue can be resolved through sorghum breeding or dietary fortification [16].Various studies shown that sorghum have potential of antioxidant, anti-inflammatory, and anti-cancer activities, and could reduce the glycaemic response and insulin-related disorders like diabetes mellitus and obesity, prevent dyslipidaemia and cardiovascular diseases, and influence gut microbiota and promote colonic health [17].

Barnyard millets (sanwa): Barnyard millet is a self-pollinating crop that belongs to the Poaceae family, including the Panicoideae subfamily and the genus Echinochloa. Barnyard millet is classed as a minor cereal crop and provides greater nutrients than other cereals [18]. Barnyard millet grain is a rich source of protein, carbohydrate, fibre, and most importantly, contains more micronutrients (iron and zinc) than other main grains. Barnyard millet had a slightly higher protein content (11.2-12.7%) than other major cereals and millets, and while total minerals, ash, fat, and amino acid content were comparable, the grain's iron content was significantly higher than others[19].Barnyard millet contains alkaloids, steroids, carbohydrates, glycosides, tannins, phenols, and flavonoids that have ethno-medical properties such as antioxidant, anti-carcinogenic, anti-inflammatory, antimicrobial, wound healing capacity, biliousness, and a decrease of constipation-associated diseases [20].

Finger millets (Ragi): Finger millet (Eleusine coracana), a minor grain, has various health advantages, some of which are due to its polyphenol and dietary fibre content[21]. Its nutritional value is widely established due to its high calcium content (0.38%), dietary fibre (18%), phytochemicals, phenolic compounds (0.3-3%)[22]are found in finger millet in general and the seed coat in particular, ferulic acid and p-coumaric acid are the two main phenolics found in finger millets, and the bound phenolic fraction makes up 64–96 and 50–99% of the millet grains' total ferulic acid and p-coumaric acid contents, respectively[23]. This could be advantageous to health and is well-known for its positive health effects, including anti-inflammatory, anti-tumorogenic, anti-diarrheal, anti-ulcer, anti-diabetic, anti-atherosclerogenic, antioxidant, and antibacterial qualities[24].Finger millet enhances children's haemoglobin status, lowers blood pressure, avoids diabetes, promotes anti-aging, strengthens bones, and aids in natural weight loss[25].

Little millets (kutki): The nutrient-dense kutki millet (Panicum sumatrense) is a major source of macro- and micronutrients as well as bioactive compounds like phenols, tannins, and phytates [26]. Little millet has the greatest iron concentration (of any millet type) at 9.3 mg/100 gm, which is sufficient to meet about one-third of the daily iron need for pregnant women (35 mg/d, the highest iron requirement of all population categories) [27]. It is a good source of potassium, calcium, zinc, and B vitamins. Additionally, it gives the body the kind of fats that are necessary for weight loss [28].

Amaranth Millet (Rajgira): Amaranth is one of the ancient millets in used and rich source of amino acids and bioactive peptide[29]. Amaranth oils contain oleic, linoleic, and linolenic fatty acids, they are significant, tocopherols, which scavenge lipid peroxyl radicals, are among the chemicals with antioxidant potential found in amaranth's lipid component [30]. Along with other phenolic components, it also contains a number of flavonoid and anthocyanin classes. The phenolic acids protocatechuic, hydroxybenzoic, caffeic, and ferulic acid, as well as nicotiflorin, and isoquercetin, are among the bioactive substances found in amaranth grain. Daily consumption amaranth can reduce the risk of osteoporosis, anemia and improve the immune system. Amaranth having cancer preventive and anti-hypertensive properties [31].

Kodo Millet (Kudo): Kudo can be easily grown in semi-arid and drought area and on stony or gravelly soils[32]. Kodo millet is referred to as "nutria-cereals" since it is high in vitamins, minerals, and sulphur-containing phytonutrients. The ratio of leucine to isoleucine is roughly 2.0, and it is also abundant in important amino acids such as lysine, threonine, valine, and sulphur-containing amino acids [33].

Buckwheat Millet (kuttu): The scientific name for buckwheat is Fagopyrum esculentum, and it is gluten-free and high in fiber [34]. The entire grain buckwheat is very nutrient-dense. It's also regarded as a superfood. Numerous health advantages are associated with buckwheat's high fiber and antioxidant content [35].It is good source of lysine and polyphenolic compound. It has low glycemic characteristic because it contains carbohydrate particularly starch, so it makes this beneficial in diabetes and obesity[36].

Foxtail Millet (Kakun): Foxtail millet has high quantities of protein, fiber, minerals, and phytochemicals. Because of the coarse form of foxtail millet grains, the digestible fraction amounts around 79%, while the remaining undigestible half of the grain includes relatively high levels of fiber as well as various anti-nutritional components[37]. In addition to having a higher protein content and a variety of vitamins and minerals than rice and wheat, foxtail millet's high polyphenol content makes it an excellent supplement for the treatment of diabetes, cancerand cardiovascular disease [38].

Teff Millet (Abyssinian lovegrass): It is excellent source of amino acids particularly lysine as well as polyphenols. While the protein level of teff is comparable to that of other more widely consumed cereals, such as wheat, it is comparatively higher in the vital amino acid lysine than other cereals [39]. Additionally, teff is a good source of fiber, minerals (particularly calcium and iron), vital fatty acids, and phytochemicals (phytates and polyphenols) [40]. So, it can be substitute of cereal and presence of phenolic acid make it suitable for celiac disease. In general, millets have more protein and fat than non-millet grains such as wheat and rice. They also provide a variety of essential fibres and minerals.

Millets: Nutritional components and health benefits in Indian Perspective: Millets are special among cereals because they are high in protein, calcium, dietary fiber, and polyphenols.

Table 1. Composition of millets and non-millet cereals

Composition (per 100-gram grain)

Grain	Protein (g)	Fat (g)	Ash (g)	Crude fiber (g)	Carbohydrate (g)	Energy (kcal)	Thiamin (mg)	Riboflavin (mg)
Finger millet	7.3	1.3	2.7	3.6	72.0	344	0.38	0.19
Barnyard millet	6.2	2.2	4.4	9.8	65.5	307	0.30	0.1
Foxtail millet	12.3	4.3	3.3	8.0	60.9	331	0.42	0.11
Kodo millet	8.3	1.4	2.6	9.0	65.9	309	0.33	0.09
Little millet	7.7	4.7	1.5	7.6	67.0	341	0.41	0.9
Proso millet	12.5	3.1	1.9	2.2	70.4	341	0.59	0.28
Pearl millet	11.8	4.8	2.2	2.3	67.0	363	0.38	0.21
Sorghum	10.4	3.1	1.6	2.0	70.7	329	0.38	0.15
Wheat	6.8	0.5	1.6	1.2	78.2	345	0.41	0.1
Rice	11.8	1.5	0.5	0.2	71.2	346	0.41	0.04

Source: Kunal Narwal *et al.,* (2022), Karuppasamy Pushpavalli (2015)

It has numerous documented nutritional and therapeutic benefits, making its nutritional quality the most crucial factor in preserving human health and overall physical well-being.

Phenolics and flavonoids: Additionally, it is a good source of phytochemicals, particularly phenolic compounds, which can lower the risk of chronic illnesses like diabetes, cancer, and heart disease[41]. The majority of the phenolic acids found in millets are free and conjugated forms, including hydroxybenzoic and hydroxycinnamic acid derivatives. Additionally, millets contain a number of flavonoids, including chalcones, anthocyanidins, flavanols, flavones, as well as amino phenolic compounds [42].

Phytochemical: Millets include a variety of phytochemicals, including phenolics, sterols, lignans, inulin, resistant starch, β-glucan, phytates, tocopherol, dietary fiber, and carotenoids [43]. A number of beneficial phytochemicals that are linked to health, such as phytosterols, polyphenols, Phyto-oestrogens, and phytocyanin, are also present in millets. In addition to being prebiotics, millets can increase the potency of probiotics [44].

Carbohydrate: Millet carbohydrate in milled grains is comprised of free sugars (2-3%), non-starchy polysaccharides (15-20%), and starch (60-75%). Millets include non-starchy polysaccharides such as cellulose, hemicellulose, and pectinaceous material, as well as sugars that are free such as glucose, fructose, and sucrose [45]. In comparison to other cereals, millets such as foxtail, proso, and Kodo have a high total dietary fiber content. Millet grains have lignin and cellulose as major insoluble fiber components, with soluble fiber containing glucoarabinoxylans, β-glucan, and hemicellulose depending on branching and degree of cross-linking [46].

Protein: After starch, protein is the second most abundant nutrient in millet, accounting for around 10% of its total weight. Because it is the largest of the seed's structural components, the endosperm portion of millet contains the majority of the grain's total protein, which varies from 7.52% to 12.1% in different millet seed species [47].

The essential and non-essential amino acids leucine, phenylalanine, proline, serine, tyrosine, aspartic, and glutamic acid are more abundant in millet protein [48]. Low levels of specific amino acids (lysine, threonine, methionine, cysteine, or tryptophan) in storage reserves, especially the prolamin fraction [38], in various millet flours have an impact on how well protein is used for nourishment and other uses.

Fat: Lipids are found in comparatively smaller amounts in finger and Kodo millet, ranging from 1% to 5%, and in the highest concentrations in pearl, foxtail, and proso millet. Since the majority of millet's fat (24%) is found in the germ section and polyunsaturated fatty acids (PUFA) are abundant in millet oil (78–82%)[49]. Based on seed dry weight, the percentage of lipids extracted from millets was 7.2%. Neutral lipids, phospholipids, and glycolipids made up 85%, 12%, and 3% of this fraction, respectively. The main phospholipid found in millet seeds was lysophosphatidylcholine (42%).There were also trace levels of phosphatidic acid, phosphatidylglycerol, phosphatidylinositol, phosphatidylserine, and lysophosphatidylethanolamine (21%), as well as phosphatidylcholine (24%)[50].

Health benefits of Millets: Millets are regarded a high-energy, carbohydrate, and protein source, equivalent to other cereals, but with greater fat, calcium, iron, dietary fiber, and Vitamin E (tocopherols and tocotrienols) content. Millets have a favourable nutrigenomic function in human health because to their hypoglycaemic, anti-tumorigenic, anti-atherosclerogenic, antioxidant, antihypertensive, anti-inflammatory, and antimicrobial characteristics. Millets have a high nutritional profile and nutraceutical potential, making them an excellent crop for reducing food insecurity across the world.

Millets as antimicrobial elements: A study was conducted by Vishwanath and Malleshi on finger millet to compared the lowering power of seed coat extract to the whole flour extract and seed coat extract was substantially higher. Using the β-carotene–linoleic acid assay, antioxidant activity (AA) was found to be highest in seed coat extract (86%), but it was only 27% in whole flour extract at the same dosage. When compared to whole flour extract, the seed coat extract exhibited greater antibacterial efficacy against Aspergillus flavus and Bacillus cereus[51]. Another study was conducted by Radhajeyalakshmi et al. and reported that the greater antifungal efficacy of pearl millet millets' protein extract compared to other millets' varieties against phytopthogenic fungus such Fusarium oxysporum, Macrophomina phaseolina, and Rhizoctonia solani [52].

Millets against Diabetes and Prediabetes: Millets are well-known as having a low Glycaemic Index (GI) which helps regulate diabetes. The beneficial effects of multigrain flatbread in managing lipid profile and carbohydrate homeostasis among type 2 diabetes, millets are helpful in regulating of insulin and HbA1c levels. in a study is reported that LDL was decrease, however triglycerides and VLDL levels increased dramatically and HDL levels remained unchanged. The test group's average blood pressure (systolic/diastolic) decreased significantly. The

human RBP4 and hs-CRP levels were unchanged [53]. A study was conducted to determine the glycaemic index of traditional meals made from a created millet-based food mix and their influence on pre-diabetics. Dietary intervention on pre-diabetic participants resulted in substantial reductions in FBS (120.50 ± 18.73 to 97.81 ± 20.00) and HbA1c (6.14 ± 0.30 to 5.67 ± 0.40), making it a superior choice for managing diabetes [54].

Millets against Cardiovascular: Millets are known to be high in phytochemicals, including phytic acid, which aids in cholesterol reduction and the prevention of cardiovascular disease by lowering plasma triglyceride levels. According to certain studies, eating whole millet grains on a daily basis lowers the incidence of CVD. Studies show that millet-based diets can reduce LDL and triglycerides while raising HDL[42]. Millets, which are high in magnesium, aid in lowering blood pressure and the risk of heart attacks, particularly in cases of atherosclerosis. Furthermore, the potassium in millets helps to maintain blood pressure low by acting as a vasodilator, which helps to minimize cardiovascular risk. The high fiber content in millets also plays an important role in cholesterol reduction by removing LDL [55].

Millets against Cancer: Millets include a lot of micronutrients including calcium, iron, zinc, and B-complex vitamins, as well as bioactive substances like dietary fiber, essential fatty acids, and phytochemicals [42]. Their phytochemical concentrations, such as phenolic acids, flavonoids, and tannins, are many times greater than those of staple grains. These non-nutritional components have been shown to have antioxidant, anticancer, antibacterial, anti-inflammatory, antiulcer, and wound-healing properties [56].

Millets against Gastrointestinal Disease: Millets' prebiotic attributes and fermentation cause the synthesis of short-chain fatty acids, which promote intestinal barrier function and reduce inflammation. Millet eating may also affect gut hormones and have antioxidant and anti-inflammatory properties [57]. Finger millet's insoluble fiber, which has a high cellulose content, bulks the stool, serves as a laxative to improve bowel motility, and avoids constipation by holding water in stools and stimulating peristalsis. Soluble fibres, on the other hand, help lubricate and soothe an irritated digestive system [22].

Challenges: After Green Revolution in 1960s, all these extraordinary qualities of millets & millet farming system, cultivation area has been shrinking over the last few decades. Farmers also avoiding millet farming because of its low market access and people fascinated towards rice, wheat. In hilly area farmer facing challenges of invading wild animal in agriculture area. Increasing urbanisation and globalization, that change the human life-style as well as taste preference, they attracted towards wheat and rice made products. Millets grains have lower shelf life and presence of certain phytochemical with anti-nutritional factor which interfere with carbohydrate, protein digestibility and mineral bioavailability limits their importance. Inadequate infrastructure, low investment in research and development such as processing technologies and weak value chain, insufficient primary processing at ground level. Despite their numerous benefits, millets suffer a variety of challenges that impede their production and use. Insufficient investment in R&D is a serious barrier for millet production. Millets have been overlooked by governments, researchers, and private sector groups, resulting in insufficient knowledge about their genetic variety, growing techniques, and processing processes. Millet growers face severe challenges due to limited infrastructure and market links. Smallholder farmers sometimes face challenges in reaching markets and delivering products to metropolitan areas [58]. Other major challenges in millets are anti-nutritional factors. Anti-nutrients are chemicals that bind to nutrients in food, reducing the quantity of nutrients and bioavailability that the body can absorb After consumption, various anti-nutrients such as tannins, polyphenols, and phytic acid bind key cations such as K+, Mg2+, Zn2+, and Ca2+ in the human body, lowering millets' nutritional value. They bind to natural or synthetic molecules or chemicals, making it more difficult for the body to absorb, digest, and assimilate nutrients. Furthermore, millet grains are indigestible due to a range of enzyme inhibitors, including amylase and protease inhibitors. Some examples of enzyme inhibitors are protease inhibitors, trypsin inhibitors, and alpha-amylase inhibitors. Trypsin proteins bind to peptides and impede protein digestion by significantly contributing to the loss of trypsin and chymotrypsin. Proteases are protein enzymes that catalyze the hydrolytic cleavage of target proteins' peptide links. Protease inhibitors bind to proteins, slowing the small intestine's ability to digest them [59].

Conclusion

A comprehensive study of millets Jowar, Bajra, Ragi, and other micro millets explores their nutritional content and nutraceutical properties. The current findings provide information on the nutritional and antinutritional activity of millet, which will be useful in gathering vital information on nutritional elements and their nutraceutical qualities. The findings of these papers focused on the principal benefits of millets, which are high in nutritional content and include key vitamins, minerals, and antioxidants. These grains, which are high in iron, calcium, and zinc, are beneficial to human health because they play a major role in strengthening strong bones, teeth, and blood vessels while also boosting the immune system. Millets offered essential nutrients in malnutrition-prone areas while also promoting the population's general health.

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