

# A Review on Nutritional Profile of Millets and its Value-Added Food Products

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**Abstract** - Millets are nutrient-rich, climate-resilient grains with great potential to support global food and nutritional security. High in essential amino acids, minerals, dietary fiber, and bioactive compounds, millets offer numerous health benefits, including improved digestive health, cardiovascular support, and better blood sugar regulation. It is practicable to improve nutritional quality, health, encourage economic growth, and support sustainable food systems by including millets in value-added formulations. This review thoroughly examines the different types of millets, their nutritional profile, and processing techniques, which enable the production of various value-added products like baked goods, snacks, porridges, drinks, and ready-to-eat foods. The review also highlights opportunities for product innovation, sustainable practices, and market growth, while addressing challenges related to raw material supply, processing infrastructure, shelf-life management, and consumer acceptance.

**Keywords:** *Health benefits, Millets, Nutrition, Production, Processing, Value Addition.*

## I. INTRODUCTION

Millet are versatile, small-grained cereals that have therapeutic significance due to the presence of vitamins, minerals, and bioactive chemicals that support human health and recuperation. These archaeological staples are sometimes known as nutri-cereals because of their excellent nutritional content. Major millets include sorghum, finger millet, and pearl millet; minor millets include foxtail millet, tiny millet, kodo millet, proso millet, brown top millet, fonio, teff, and barnyard millet. Millets are composed of around 65–75% carbs, 7–12% proteins, 2–5% fat, and 8–15% fiber. They have a higher content of essential amino acids compared to conventional cereals. While the nutritional advantages of millets have been realized through knowledge sharing in recent times, the therapeutic value of millets needs attention. There is robust scientific evidence to suggest that consumption of millets reduces the progression of prediabetes, results in better glycemic control, reduces body mass index (BMI) and mitigates atherosclerotic cardiovascular disease risk [1]. Millets are gluten-free and are the choice diet for celiac patients. There has been a steep increase in awareness of the nutritional benefits of millets, thus increasing the demand for millets as food and value-added products [2]. Millet foods and products for health, prevention, and therapy are known from ancient times, yet are to be expanded worldwide. In this review, the production

trends, nutrient content, and different medicinal and therapeutic properties of millets in preventing and curing lifestyle disorders were presented.

## II. MATERIALS AND METHODS

The present review was conducted through a comprehensive and systematic search of scientific literature related to the nutritional profile, processing techniques, value addition, and health benefits of millets. Electronic databases including Scopus, Web of Science, PubMed, ScienceDirect, SpringerLink, Wiley Online Library, and Google Scholar were systematically searched to retrieve relevant peer-reviewed articles. In addition, reports and publications from authoritative organizations such as FAO, USDA, ICAR, and the Ministry of Agriculture and Farmers Welfare (Government of India) were included to obtain updated production and consumption statistics.

### Search Keywords and Selection Criteria

The literature search was performed using combinations of keywords such as millets, nutritional composition, processing of millets, value-added millet products, functional foods, health benefits, fermentation, extrusion, and gluten-free foods. Studies published primarily between 2013 and 2025 were considered, with greater emphasis on research from the last five years to ensure the inclusion of recent advancements.

### Inclusion and Exclusion Criteria

Original research articles, review papers, and authoritative reports published in English were included if they focused on millet production, nutritional characteristics, processing methods, product development, or health implications. Studies unrelated to food and nutrition, non-peer-reviewed articles, and publications lacking scientific validation were excluded from the review.

### III. DATA EXTRACTION AND SYNTHESIS

Relevant data regarding nutrient composition, processing effects, antinutritional factors, value-added products, and associated health benefits were extracted from the selected literature. The information was systematically analyzed, compared, and synthesized to present a coherent overview of current knowledge and emerging trends in millet research.

#### Millet Production and Consumption Trends

Over the past ten years, millet production has gradually but steadily increased globally, reflecting increases in yield and broader adoption of climate-resilient grain agriculture in semi-arid regions. According to FAOSTAT, global millet production grew from over 28.3 million tonnes to almost 30.1 million tonnes, primarily as a result of higher yields in the Asian continent and sub-Saharan Africa (FAO, 2024). According to the USDA Foreign Agricultural Service (2024), the world's millet output for the 2024–2025 crop year is expected to be approximately 29.2 million tonnes, with India continuing to provide the most ( $\approx 11.6$  Mt), followed by Niger ( $\approx 3.8$  Mt), China ( $\approx 2.7$  Mt), and Nigeria ( $\approx 2.5$  Mt). Together, developing countries produce around 95 per cent of the world's millet, demonstrating the crop's significance for food security in regions vulnerable to drought. Millet cultivation is expanding globally due to sustainable agriculture legislation and rising demand for nutrient-dense and gluten-free grains. As a result, by 2025, the worldwide millet industry will still be resilient, with moderate production growth supported by both increasing demand from the health-based market and yield increases [3].

Approximately 40 per cent of the world's millets are produced in India, making it the world's greatest producer and consumer [3], [4]. India's total millet output for 2024–2025 was predicted to be 180.15 lakh tonnes (18.02 million tons), a slight rise over the previous year, according to the Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare [5]. The National Food Security Mission-Nutri Cereals policy initiatives, increased area under high-yielding cultivars, and better rainfall distribution are all credited with the increase [6]. According to the Global Centre of Excellence on Millets [7], Rajasthan contributes approximately 27 per cent of the overall output, followed by Karnataka ( $\approx 18$  per cent) and Maharashtra ( $\approx 14$  per cent). Tamil Nadu, Gujarat, and Uttar Pradesh collectively contribute another 20 per cent.

According to recent National Sample Survey Office data, India's per-capita millet consumption has drastically decreased over the past 50 years, from approximately 30 kg person<sup>-1</sup> year<sup>-1</sup> in the 1960s to less than 10 kg person<sup>-1</sup> year<sup>-1</sup>, despite this robust production base [8]. Urbanization, shifting dietary habits, and the substitution of rice and wheat for traditional staples have all been connected to the decline [9]. However, this tendency is starting to change thanks to fresh market and government initiatives, particularly in the midst of the 2023 International Year of Millets. Millet-based ready-to-eat products are becoming more popular in urban areas [10]. At the same time, governmental support for public procurement and awareness campaigns has improved access through the public distribution system. According to market forecasts, increased health consciousness, gluten-free diets, and the growth of the functional food industry will propel India's domestic millet demand at a compound annual rate of 5–6 percent through 2030 [11], [12]. According to these advances, India's millet economy is experiencing a structural shift from a subsistence grain to a nutrient-dense, commercially successful crop that is in line with national and international health concerns.

#### Nutritional Profile of Millets and Their Potential for Supplementation

Among cereal grains, millets stand out due to their high protein, antioxidant, and dietary fiber content (Table 1). They are mostly made up of carbohydrates, with different amounts of fiber, proteins, and lipids [13].

The predominant carbohydrate, starch, affects millets' glycaemic response and pace of digestion. It is mostly made up of amylose and amylopectin, with small amounts of free sugars like sucrose and glucose, and dietary fiber as a supplement [14]. Millets have a dietary fiber content that is comparable to whole wheat and almost twice that of rice. Pearl and finger millets are important sources of both soluble ( $\beta$ -glucans, arabinoxylans, and pectins) and insoluble (cellulose and hemicellulose) fibers [15].

Proso and foxtail millets have the highest protein content, which normally varies from 6 to 13 per cent. Lysine, methionine, and cysteine, essential amino acids that are scarce in other main grains like rice and wheat, are abundant in these proteins [16]. Additionally, millets have moderate fat content (2–8 per cent), with pearl millet having the highest fat content. Unsaturated fatty acids, particularly linoleic and oleic acids, make up the majority of these lipids and improve their nutritional and functional quality [17], [18].

Furthermore, millets are rich in vitamins like thiamine (0.15–0.60 mg/100 g), niacin (0.89–4.6 mg/100 g), and riboflavin (0.09–0.28 mg/100 g), as well as micronutrients like calcium (10–348 mg/100 g), iron (2.2–17.7 mg/100 g), zinc (0.4–2.8 mg/100 g), and phosphorus (189–293 mg/100 g) [19]. While finger millet is one of the greatest plant-based sources of

calcium (300–350 mg/100 g), about ten times more than wheat, pearl millet has the highest iron concentration (5–6.5 mg/100 g). Secondary metabolites such as phenolic acids,

flavonoids, tannins, phytosterols, and policosanols, which function as potent antioxidants and guard against oxidative stress, are also abundant in millets.

**Table 1: Nutritional Composition of Millets (per 100 g)**

Millets	Carbohydrate (g)	Protein (g)	Fat (g)	Dietary fibre (g)	Calcium (mg)	Iron (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)
Sorghum	67.7	10.0	1.7	10.2	27.6	4.0	0.4	0.1	2.1
Pearl Millet	61.8	11.0	5.4	11.5	27.4	6.4	0.3	0.2	0.9
Finger Millet	66.8	7.2	1.9	11.2	364.0	4.6	0.4	0.2	1.3
Kodo Millet	66.2	8.9	2.6	6.4	15.3	2.3	0.3	0.2	1.5
Proso Millet	70.4	12.5	1.1	-	14.0	0.8	0.4	0.3	4.5
Foxtail Millet	60.1	12.3	4.3	-	31.0	2.8	0.6	0.1	3.2
Little Millet	65.6	10.1	3.9	7.7	16.1	1.3	0.3	0.1	1.3
Barnyard Millet	65.6	6.2	2.2	-	20.2	5.0	0.3	0.1	4.2

Source: IIMR & Indian Food Composition Tables, NIN-2017

Table 1 summarizes the nutritional composition of major and minor millets per 100 g, highlighting their richness in macronutrients and essential micronutrients. All millets provide high carbohydrate content (60–70 g/100 g) along with moderate protein levels, with proso and foxtail millets showing the highest protein content. Pearl and finger millets are notable for their high dietary fiber, supporting digestive health and glycaemic control. Finger millet stands out as an excellent source of calcium, while pearl millet contains the highest iron levels. Additionally, millets contribute B-complex vitamins essential for energy metabolism, reinforcing their potential in value-added and functional food formulations.

### Processing of Millets

The inedible parts of millet grains must be removed to transform them into a cooked, edible form. As a result, processing is essential since it reduces antinutrients and improves the bioavailability of nutrients and organoleptic qualities [20]. Dehusking /decortication, milling, soaking, germination, fermentation, malting, heating, and roasting are just a few of the methods used in processing. These processes result in physicochemical changes that modify food's nutritional value, functionality, and physical qualities [21].

Primary and secondary processing are the two categories of processing. Major millets can be used directly after harvest and cleaning, while the minor millets need primary processing for gentle removal of the outer layers of grain that also contain many antioxidants. Primary processing includes procedures like cleaning, washing (soaking/germination), dehulling, milling (into flour and semolina), and refining to eliminate the unwanted seed coat and antinutritional elements. Secondary processing, on the other hand, entails transforming primary processed raw materials into "ready-to-cook" (RTC) or "ready-to-eat" (RTE) products through flaking, popping, extrusion, and baking [20]. The goal of these processing methods is to transform grains into edible forms that have a longer shelf life, better texture, a particular

flavour and taste, as well as better nutritional value and digestibility [22]. The optimal utilization of millets' nutritional potential is limited by significant quantities of phytates, tannins, phenols, and trypsin inhibitors, which reduce nutrient bioavailability and quality [23].

Processing millet into a variety of by-products can boost its consumption and use while lowering phytate and tannin levels, increasing the bioavailability of minerals and amino acids, and improving the digestibility of starch and protein. These bioactive substances found in whole grains undergo particular morphological, anatomical, or modulated alterations as a result of processing. The nutritional and antinutrient profiles may be affected by the processing techniques in both positive and negative ways. Numerous investigations on millet processing have produced encouraging findings regarding the efficient use of millets in a range of conventional and convenient health foods.

### Value Added Millet Products

From an industrial perspective, there has been a notable increase in investments directed towards the development of the value chain, driven by the recognition of millets as climate-resilient and sustainable crops. Initiatives such as the FAO's International Year of Millets 2023, along with programs spearheaded by NABARD and APEDA, have motivated small-scale enterprises and entrepreneurs to innovate and produce novel millet-based products targeted at both domestic and international markets [24], [25], [26]. Consequently, the sustainable utilization of millets through value addition in the food sector represents a strategic approach to enhancing food security, increasing farmer income, and improving nutritional well-being.

Value addition in millets refers to the intentional application of processing techniques and innovative approaches to transform raw grains into a diverse array of marketable and nutritionally enhanced products. This process is crucial for enhancing the economic value of millets, extending their

shelf life, improving palatability, and accommodating the evolving health-conscious preferences of consumers [27], [28]. Recent technological advancements have facilitated the development of a variety of millet-based value-added products, including breakfast cereals, extruded snacks, baked goods, beverages, health mixes, and convenience foods [29].

The food industry is increasingly focusing on incorporating millets into a variety of ready-to-eat and ready-to-cook products, including extruded snacks, convenient mixes, breakfast cereals, baked goods, and beverages [29], [27].

Advanced processing techniques, such as extrusion heating, fermentation, germination, and malting, are commonly employed to improve the functional, nutritional, and sensory attributes of millet-based foods [28]. Moreover, the integration of millets into nutraceutical and gluten-free products aligns with contemporary consumer preferences for health and wellness [30]. The rising demand for functional foods has motivated the food industry to innovate millet-based offerings that are rich in dietary fiber, antioxidants, and bioactive compounds, which promote cardiovascular health and support glycemic control [31].

#### Millet-Based Traditional Product Formulations

In Asia and Africa, millets have long been an essential part of traditional diets. They are processed into a variety of culinary dishes that are appropriate for regional tastes and customs. Finger millet (*ragi*), pearl millet (*bajra*), foxtail millet (*Setaria italica*), and small millet (*Panicum sumatrense*) are frequently used to make traditional dishes, including idli, dosa, roti, upma, kheer, khichdi, laddu, puttu, and ambali. Particularly in semi-arid and rural areas, these foods are important sources of calories, protein, and minerals [32]. The majority of traditional millet-based foods are fermented or sprouted, which improves flavor and texture, reduces anti-nutritional factors such as phytates and tannins, and increases nutrient absorption. For example, because of microbial activity during fermentation, fermented finger millet batters for idli and dosa offer better digestibility and increased levels of B-complex vitamins [33].

To improve shelf stability, hygiene, and sensory quality, many historic recipes have been recreated using contemporary scientific and technological methods. In order to satisfy urban customer demand for convenience, ready-to-cook or instant mixes of ragi idli, barnyard millet dosa, and foxtail millet upma are currently extensively marketed. To appeal to consumers who are health-conscious, millet-based snacks and sweets like laddu, chakli, and murukku have also been created using composite flours and low-fat processing methods [30].

Furthermore, owing to their probiotic and functional qualities, traditional millet drinks like kanji, rabdi, and ambali (a fermented ragi drink) are being re-examined [34]. These drinks offer gut health advantages similar to those of contemporary probiotic drinks since they are high in lactic

acid bacteria, antioxidants, and minerals. Many ancient millet recipes have been turned into nutritionally improved, shelf-stable products fit for broader commercialization through the integration of traditional processing knowledge with contemporary value addition processes like extrusion, freeze-drying, and vacuum packaging. Therefore, traditional millet-based dishes serve as a durable link between cultural legacy and modern dietary requirements.

#### Recent Advances in Processing and Product Innovation of Millets

Recent developments in product formulation have led to a variety of value-added millet products, including noodles, pasta, baked goods, probiotic beverages, and energy bars [35], [36]. The utilization of millet-based composite flours in the production of gluten-free baked goods and health mixes tailored for consumers with diabetes and obesity is on the rise. To achieve complementary protein balance and enhance sensory qualities, millets have also been combined with legumes, pulses, or fruit powders [37]. The growing emphasis on clean-label and sustainable foods has motivated researchers and companies to incorporate millets into functional and fortified food formulations [38]. Furthermore, modern analytical techniques such as machine learning and near-infrared spectroscopy (NIRS) are being utilized to standardize quality control and processing parameters for millet products [39].

Millets, recognized for their gluten-free nature and high nutritional value, have garnered significant attention in the functional food industry regarding their application in baked goods, smoothies, and porridges. These grains are exemplary ingredients for developing health-oriented products due to their richness in micronutrients, dietary fiber, essential amino acids, and bioactive compounds such as flavonoids and phenolics [30]. Research indicates that the incorporation of millet flour into bakery recipes, including biscuits, cookies, cakes, and breads, enhances the nutritional profile without compromising palatable sensory attributes. Specifically, substituting refined wheat flour with finger millet, pearl millet, or foxtail millet flour has been shown to improve protein, mineral, and antioxidant content while maintaining acceptable texture and consumer satisfaction [40], [41].

Millet-based cookies and crackers have gained popularity among consumers, particularly those with diabetes and health-conscious individuals, owing to their high fiber content and low glycemic index [42]. Furthermore, millet-based beverages and smoothies have emerged as popular ready-to-drink options that align with contemporary lifestyle preferences and functional nutrition trends. These products are rich in energy, fiber, and antioxidants and are commonly combined with fruits, dairy, or plant-based milks and probiotics [43]. For instance, fermented millet smoothies enhance the viability and digestion of probiotics, contributing positively to intestinal health and cholesterol

reduction [44]. Additionally, traditional yet nutrient-dense porridge formulations made from finger millet, sorghum, or barnyard millet are gaining traction. These instant and precooked millet porridges offer improved shelf life and reconstitution properties, which are advantageous for infants, the elderly, and individuals with gluten intolerance [45].

To enhance the functional and sensory qualities of these products, millets have also been combined with fruits, pulses, or herbs. The incorporation of fruit purées such as banana or mango has increased consumer appeal and antioxidant levels, while blending millet flour with oat or quinoa has improved protein quality [46]. In light of the rising consumer demand for plant-based and clean-label products, millet-based baked goods, smoothies, and porridges represent a wholesome and sustainable alternative to traditional grain products. These innovations not only promote dietary diversity but also align with the growing emphasis on sustainable food systems and health-promoting diets globally.

#### Health Benefits of Millets and Their Value Addition

Millets represent nutritionally superior grains, demonstrating a high content of fiber, minerals, and bioactive compounds, which position them as functional ingredients within health-promoting diets. The introduction of millets into value-added products enhances their nutritional and medicinal potential. The low glycaemic index and slow carbohydrate digestion of millets make them advantageous for the management of obesity and diabetes [47]. Value addition through processes such as fermentation and extrusion effectively reduce antinutritional factors, including phytates and tannins, while simultaneously enhancing protein digestibility and antioxidant capacity [48].

Millet-based formulations enriched with prebiotics and dietary fiber may promote gastrointestinal health and contribute to lower cholesterol levels [8]. Germination and malting significantly improve the bioavailability of iron and zinc, thereby aiding in the prevention of micronutrient deficiencies [48]. The promotion of processed millet-based foods as a means to enhance sustainable nutrition and mitigate the incidence of lifestyle-related diseases such as type 2 diabetes and cardiovascular conditions. Hence, the value addition of millets not only expands product offerings but also enhances market value, sensory characteristics, and health benefits, aligning with global initiatives aimed at fostering sustainable and healthful dietary practices [3].

#### IV. CHALLENGES AND FUTURE PROSPECTS

The value addition of millets offers significant potential for enhancing nutrition, promoting sustainable agriculture, and diversifying food products. However, several challenges must be addressed. Issues such as seasonal variability, the limited availability of high-quality raw materials, inadequate processing infrastructure, and technical limitations can

adversely affect product consistency and quality. Additionally, the short shelf life, storage challenges, and consumer unfamiliarity with millet-based products further impede broader acceptance. The large-scale commercialization of millets is additionally constrained by the need to manage production costs and ensure compliance with regulatory standards. Despite these challenges, the future of millets remains promising. Innovative processing techniques such as extrusion, fermentation, and fortification can significantly improve nutritional value, extend shelf life, and enhance sensory attributes.

Integrating millets into everyday food products, such as breads, biscuits, snacks, beverages, and ready-to-eat meals, can enhance their familiarity and appeal to consumers. Additionally, effectively utilizing processing by-products and implementing environmentally sustainable production methods will contribute to sustainability and add value to millet-based foods. With consistent research initiatives, advancements in processing technologies, increased public awareness, and strategic marketing efforts, millets have the potential to become a significant component of modern, health-focused diets. Furthermore, this shift could support rural economies, encourage dietary diversity, and improve overall community nutrition.

#### V. CONCLUSION

This review consolidates recent scientific evidence on the nutritional composition, processing methods, and value-added applications of millets, emphasizing their significance as nutrient-dense and climate-resilient cereals. The findings highlight those millets possess superior dietary fiber, mineral content, essential amino acids, and bioactive compounds compared to conventional cereals, supporting their role in the prevention and management of lifestyle-related disorders such as diabetes, obesity, and cardiovascular diseases. Processing techniques including germination, fermentation, malting, and extrusion were found to significantly enhance nutrient bioavailability, reduce antinutritional factors, and improve functional and sensory properties of millet-based foods. The review further establishes that value addition through the development of baked goods, snacks, beverages, porridges, and ready-to-eat products has expanded the commercial and nutritional potential of millets, aligning with current consumer demand for gluten-free and functional foods. Overall, the evidence confirms that strategic processing and product diversification can effectively transform millets from traditional staples into modern, health-oriented food products, thereby contributing to sustainable food systems, improved public health, and enhanced economic opportunities.

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