Review Article

Millets: The Sustainable Ancient Superfood for the Modern World

Abstract

Millets are frequently referred to as "superfoods" or "nutricereals" because of their high nutritional content, ability to withstand climatic change, and reduced resource requirements when compared to other common grains. Millets have historically been consumed in larger quantities and are beneficial to diets worldwide, but both their cultivation and consumption are drastically reducing. To provide food and nutrition security, resource sustainability, and economic development, millet may be essential.Therefore, it is imperative to develop strategies aimed at reversing the global trends of declining millet production and consumption and raising consumer knowledge of the dietary and health benefits of millets. For thousands of years, millets—a class of small-seeded, nutrient-rich grains—have been an essential part of human existence, particularly in Asia and Africa. Pearl millet, finger millet, foxtail millet, Indian barnyard millet, kodo millet, tiny millet, and proso millet are the millets that are produced most widely around the world, especially in India. In Ayurveda, millets are explained under the Dhanya Varga and are known by the names Trina Dhanya, Kudhanya, and Kshudra Dhanya in different Samhitas.Furthermore, millets have long been employed by indigenous people as an ethnomedical and hunger-reduction tool. Since millets are usually grown on degraded, nutrient-deficient soil with little rainfall, they are an extremely resilient crop. Because millets are high in dietary fibre, proteins, vitamins, minerals, antioxidants, phytochemicals, and other nutrients, they are a cure-all for a wide range of illnesses. Due to shifting agro-climatic conditions that have resulted in a decrease in the yield of major staple grains, millets have emerged as a viable solution to address current issues in agriculture, food security, and public health. Millets have demonstrated excellent nutritional makeup and great adaptability. In light of government and civil society initiatives to promote millet farming in India, this research paper offers a succinct overview of millets, emphasising their historical significance, use in folklore, cultivation techniques, health benefits, and potential to contribute to sustainable farming systems and food security. For this study paper, a thorough review of numerous literatures, journals, published papers, and books was conducted.

Keywords

Millets, Processing equipment, Traditional, Advancement

Introduction

Globally, the number of diabetics is predicted to rise by 51% by 2045, from 463 million in 2019 to 700 million [1], with type 2 diabetes making up almost 90% of the total. The majority of diabetes-related deaths-87 percent occur in low- and middle-income nations where the variety of staple foods is lower. It's vital to remember that, in addition to obesity and a sedentary lifestyle, the kind of food ingested has a significant impact on diabetes. Approximately 80% of the energy consumed in developing nations comes from main staples including maize, refined wheat, and refined rice [2]. To control and prevent diabetes, it is crucial to diversify dietary mainstays and mainstream traditional, nutrient-dense, and less glucogenic staples in most developing nations; millets and sorghum are at the top of this list.

Businesses understand the importance of a Triple Bottom Line, which has sparked the development of innovative goods and significant investments. The Smart Food Triple Bottom Line, which defines solutions [3] that together are good for the environment (environmentally sustainable), good for you (nutritious and healthful), and good for the farmer (resilient), can be customised to the food system. This method is being applied to evaluate the benefits of sorghum and millets as staples. This analysis is the first to compare the "good for you" effects of millets and sorghum on diabetes prevention to the "Big 3" primary staple foods of Asia and Africa: rice, wheat, and maize. Of these, 80 percent of energy intake comes from polished rice, which is naturally low in micronutrients [4] in nations where rice consumption is high. It is critical to investigate dietary solutions that address significant health issues and incorporate nutrition in response to the rising prevalence of lifestyle diseases like type 2 diabetes. Increasing dietary diversity through the substitution of nutrient-dense, healthful foods for staples can significantly lower the burden of certain health issues.

The world market offers five different varieties of millets: foxtail millet, Guinea millet, Job's tears, fonio, proso millet, proso millet, barnyard millet, brown top millet, proso millet, proso millet, and teff. All of the other millets except for teff, fonio, and Job's tears are extensively available in India. While fonio is commonly found in Western Africa, Job's tears is found in northeast India, southern and eastern Asia, and southern China, finger millet is extensively found in India, China, and several Eastern and Southern African countries. Conversely, Ethiopia is the primary location of teff [5]. These days, the USA, which produces the most sorghum, is joined by Africa and Asia in the cultivation of these crops. Additionally, millets are grown as a minor crop or as feed and fodder in various parts of the world (www.smartfood.org/millets-sorghum-production-trends/).

Millets' high fibre, polyphenol, and antioxidant content has been linked to the management of diabetes, according to a systematic evaluation of research studies [6]. Millets were originally eaten in Asian and African nations, but rice, wheat, and maize eventually took their place. In light of dietary needs, the prevalence of non-communicable diseases like diabetes, and the effects of climate change, it's critical to promote "smart foods," or meals that meet all three of the planet's well-being, health, and farmer requirements.

Millets have been shown in numerous trials to be effective in lowering blood glucose levels after meals, lowering insulin resistance and the insulin index, lowering fasting and postprandial blood glucose increase, and lowering the level of glycosylated haemoglobin (HbA1c) [8–12]. The amount that the carbohydrate content of a meal influences the rate and magnitude of change in postprandial blood glucose concentration is measured by the GI, or glycaemic index. Eating low-GI foods is the general dietary strategy to improve glycaemic control [13]. Post-prandial blood glucose is checked at frequent intervals up to two hours after eating, and fasting blood glucose is often obtained after an overnight fast. Insulin resistance, which raises the risk of type 2 diabetes, is linked to hyperinsulinemia [14]. Therefore, to assess a food's potential to lower insulin resistance, it's crucial to measure insulin concentration in addition to post-prandial glucose concentration. Additionally, the HbA1c marker [15] can be used to monitor long-term glycaemic management.

Despite the fact that there are multiple millets studies linked to these results, the information in them is inconsistent. In order to provide a dietary guide for millets, it is crucial to compile scientific data pertaining to all types and stages of processing, including cooking, in order to ascertain whether or not studies confirm millets' ability to control blood sugar levels. This paper aims to conduct, for the first time, a comprehensive systematic review and meta-analysis, simple descriptive statistics, and regression analysis of all the studies conducted to test GI, fasting and post-prandial blood glucose concentrations, insulin response, and HbA1c biomarker level in millet-based diets, in light of the growing prevalence of diabetes among high and low socioeconomic groups in both developed and developing countries. This contains one mixed millet, eleven different types of millets, and numerous tested processing methods. In addition to being helpful to the scientific community, dieticians, nutritionists, food processors, and governments in developing policies and programmes on health, nutrition, and agriculture, this data will serve as the scientific foundation for any claims made regarding millet and diabetes.Currently, processing millet presents various challenges, but it also has the potential for creating innovative products using various technologies that can mechanize the process and produce nutritious foods according to customer preferences. This technological shift and changes in consumer food preferences could lead to the expansion of millet cultivation, preservation of ecological balance, assurance of food security, prevention of malnutrition, and scaling up the industrial use of millet grains.

Millets are typically processed before being consumed in order to eliminate the parts that are inedible, increase shelf life, and enhance sensory and nutritional qualities. To prepare millets for human consumption, basic processing methods like dehulling, soaking, germination, roasting, drying, polishing, and milling (size reduction) are used. Simultaneously, millet-based value-added processed food products are developed using secondary or modern processing techniques as flaking, extrusion, frying, puffing, popping, fermenting, parboiling, baking, and so forth [8]. Subsequent processing results in a considerable loss of nutrients, despite the fact that these processing techniques are intended to improve the digestibility and nutrient bioavailability [18]. The purpose of this review paper is to give a general overview of the nutritional qualities of significant Indian millets, such as small millet, foxtail millet, proso millet, and pearl millet.

The variables that affect millet production

The following demand-side variables affect the amount of millet produced:

- Growing urbanisation and per capita earnings, which are altering consumer preferences and tastes.

- Low social standing and ignorance of traditional millet preparation methods.
- Millet grain shelf life is reduced.
- A higher proportion of wheat and rice than millets are distributed through the public distribution system (PDS).

The following are the supply-side factors:

- Farmers are discouraged from producing millets due to the absence of industry demand for value-added millet goods.
- Poor earnings and compensation.
- During the Green Revolution, rice and wheat production was encouraged.
- Inability to obtain high-quality seeds.
- Inadequate milling and processing technology and infrastructure.

Environmental, sociological, and cultural factors can all have an impact on millet production and consumption. Although these elements are the main reasons behind the reduction in the world's consumption and production of millet, they also offer remedies that can stop the downward trends in the world.

Patterns of millet production and consumption

The Food and Agriculture Organisation (FAO) estimates that 33 million hectares of millets would be grown worldwide in 2020. This only includes a small number of the world's millets growing nations. The largest millet acreage in the world in 2021 was 9.76 million hectares in India, with 6.14 million hectares in Niger and 2.8 million hectares in Sudan.16 According to FAO forecasts, millet output reached a peak of 30.08 million tonnes in 2021 from 28.33 million tonnes in 2019. With a 43 percent global market share in 2021, India is the leading producer; the principal products are finger millet (ragi), pearl millet (bajra), sorghum (jowar), and other minor millets. As seen in Figure 1, production volume has stayed close to 1961 levels, ranging from 25 million to 30 million tonnes, even though the amount of millet grown has decreased globally since 1971. Since 1981, there has been a fall in the production trends, from 43.4 million to 37.4 million hectares. After 1991, the loss in harvested area continued, falling to 30.93 million hectares, but the production trends almost stabilised.

The importance of millets

Millets are C4 plants that use the C4 pathway for photosynthesis. As a result, they have a greater ability to create dry matter and very high levels of photosynthetic efficiency[15]. Because of their brief growing season, millets are less susceptible to unpredictable weather. Damaged soils that are acidic, salty, and aluminum-toxic are easily adjusted to by them. They withstand illnesses and pests quite well. Millets are a great material for developing millet-based climate-resilient technologies for sustainable agricultural practises since they can flourish in hot, dry climates where other cereals frequently fail to germinate. The demand for millet-based products has increased due to the extreme reliance on cereals following the green revolution and lifestyle disorders (obesity, diabetes, coronary diseases, gastrointestinal disorders, etc.) brought on by the modern sedentary lifestyle [44, 45, 46, 47]. Compared to other whole grain cereals, millet is a storehouse of nutrients like calcium, protein, iron, crude fibre, etc. Additionally, the introduction of millets into the agricultural production system has been made easier by the decline in the primary staple grain yields brought about by climate change.

Therefore, it can be said that the importance of millets in different Indian states is largely influenced by their diverse climate, ease of cultivation, and other unique qualities [39, 40 ,41, 42, 43].

The Nutritiousness of Millets

Despite the fact that studies to biofortifygrains such as rice and wheat, the substantial quantity of these cereals' gluten makes it challenging to producewholesome cuisine. Thus, more possible sourcesof natural foods and nutraceuticals with respectable functional features need to be identified immediately.In light of this, millets might be the answer.addressing lifestyle conditions through raising public awarenessof diet and medical care.[18]Millets make up an excellent superfood as they are acalcium reservoir (10–348 mg/100 g), iron reservoir (2.2–17.7 mg/100 g), phosphorus, zinc, and 32.7–60.6 mg/100 g(200–339 mg/100 g), and vitamins such thiamin between 0.15 andNiacin (0.09–1.11 mg/100 g), 0.60 mg/100 g), and0.28–1.65 mg/100 g of riboflavin.[19] Millets work well for those with diabetes due to insufficient carbs60%–70% of the content; primarily non-starchypolysaccharides and the absence of gluten.[20]Milletsare especially rich in lipids; one such example is millet oil.excellent supply of palmitic acid, oleic acid, and linoleic acidand tocopherols, which are all widely recognised for theirfunction in the defence mechanism and immunological system of the anatomy of humans [21]Particularly, barnyard, foxtail millet. Protein content in millet and proso millet is high (>10%).The calcium content of finger millet grains is remarkably high content (>350 mg/100 g), barnyard foxtail millet. In terms of crude fibre, millet and small millet are superior.Little millet and foxtail millet have high percentages (6.7%–13.6%).Barnyard millet and small millet have a higher fat content (>4.0%).high level of iron (9.3–18.6 mg/100 g) in comparison toto other important grains such as sorghum, barley, wheat, and rice,as well as corn.[16,17]

The Government's Role in Millets Promotion

2018 was proclaimed "The Year of Millets" in India.The Food and Agriculture Organisation declared 2023 to bewith the goal of promoting the "International Year of Millets"raise awareness, boost millet production, and advance theirconsumption and help independent millet growers. The Indian government has initiated numerous regional andnationwide initiatives to support millet cultivation, particularly inthe Initiative for Nutritional Security through the previous ten yearsPromoting Intensive Millets (INSIMP) as a component of RashtriyaKrishi Vikas Yojana (RKVY): Development of Rainfed AreasProgramme (RADP), Integrated Cereals, a division of RKVYDevelopment Programmes in Coarse Cereals BasedAreas of Cropping Systems (ICDP-CC) operating under MacroAgriculture Management (MMA).The MSSRF, or M. S. Swaminathan Research Foundationhas been encouraging the traditional production of millet byorganising the different millet processes, such asthe millets value chain by supporting over 35Kolli Hills Self Help Groups (SHGs), with moremore than 386 members, 214 of whom are female.The Kolli Hills Agrobiodiversity Conservers' Federation(KHABCoFED), a group of SHGs came together andare proficient at operating mills and involved in the processing,packing, and labeling.Over 65 institutes working together across IndiaMillet Network of India (MINI) was the name of theestablished to support different types of millet in India bycomprising the alliance's more than 50,000 farmers andextending their business into Nagaland, Uttarakhand,and Odisha. With the help of the Kutia Kandhacommunity in Odisha, an association of volunteers run by thethe name "Nirman" brought back twelve nativemillets that were nearly extinct and were kept aliveattacked seven Kandhamal region villages by tribalpeople. Guruji, one of the twelve, is a small millet preserved grains. The state-owned Mandi in UttarakhandParishad, which is a wholesale market, will buy directlymillets from farmers as part of the Uttarakhand. The "maiden initiative" of the government to boost milletsfarmers' earnings. This is a breakthrough initiative,and farmers will benefit greatly from it asThey'll probably get paid a reasonable amount for their millet.It has been proposed that one of these foods made from millet. Include grains in the noon meal plan forschools.

Depletion of Water Resources

The majority of research on the future of global water resources focuses on "blue water," which is found in aquifers, lakes, reservoirs, and rivers [22, 23, 24, 25]. It's critical to take "green water" into account when evaluating the population's actual access to water resources [28]. Rainwater that percolates into the soil is known as "green water" [26], and it is utilised in the majority of agricultural operations [27] and sustainably grows all terrestrial ecosystems. Additionally, it was estimated by Rockström et al. [29] that nations with annual total green and blue water storage of less than 1300 cubic metres would not be able to grow enough food to provide each person with a balanced daily diet of 3000 kCal. The Food and Agriculture Organisation (FAO) also supported this value as the objective that developing nations should all accomplish by 2030 [30].

Due to the over 2 billion people who lack access to water, food production, economic growth, human health, and ecological services are all negatively impacted. Insufficient water can result in groundwater depletion, which can cause crop failure, wildfires, irreversible land subsidence, and urban water shutoffs. Water scarcity is a result of several factors, including population growth and climate change [31]. According to MacDonald [32], climate models predict that there will be more droughts in the South West of the United States in the twenty-first century. These droughts will be more severe, arid, and last longer. Although food output would not change, the growing population would require more food. Future food insecurity will result from this [33].

A simplified system or prototype that depicts the entire world is called a hydrological model. The hydrological processes and system behaviour are both understood through the use of these models. The model's properties are defined by the parameters that are used. The two inputs required for all models are the area of drainage and rainfall data. Other significant variables taken into account for the modelling process include the topography of the watershed, the features of the groundwater aquifer, soil moisture content, and the vegetation cover and soil qualities of the watershed. Therefore, it is believed that hydrological models are an essential tool for managing environmental resources and water [34].

Impact of Global Warming on Farm Productivity

The amount of food consumed, expressed as kcal/person/day, is used as a criterion to assess the global food situation. From 2360 kcal/person/day in 1960 to 2800 kcal/person/day at present, food consumption has increased. There are now seven emerging nations with a combined population of over 100 million people. Bangladesh is the only one of them that still has a low rate of food intake. While Nigeria, Pakistan, and India have also made progress in raising their consumption rates, other nations on the list, like Brazil, China, and Indonesia, have rates of consumption between 2900 and 3000 kcal. Furthermore, less than 2200 kcal per person per day are consumed by about 30 poor nations worldwide [35]. FAO (2015) reports that one-fourth of the disasters brought on by climate change have had a severe negative impact on the agriculture sector in these developing nations in recent years.

[36] stated that unfavourable weather conditions, such as sharp temperature increases, droughts, and other events, have impacted cereal crop yield by 9–10% in recent years. By the end of 2050, an additional 2.4 billion people will be living in South Asia and Sub-Saharan Africa. The majority of people who live in these areas rely on the agriculture industry for their daily sustenance and survival. More than 20% of the people who live in these regions currently struggle to get enough food to meet their needs, and things will only become worse in the years to come. In order to meet the growing population's demand for food, it is suggested that agricultural productivity be boosted by 60% by 2050. Therefore, increasing agricultural output should be the main priority as this will raise emerging nations' incomes [37, 38].

Prospects

It is clear from the research in the preceding sections that both developed and emerging nations will need to adapt to changing climatic circumstances. In the regions most impacted by climate change i.eIndia, China, and Sub-Saharan Africa there are a few strategies that help lessen stress. Initially, they have the option to import food items from nations with ample water resources and lush terrain yielding excess. On the other hand, this can result in a trade imbalance and harm the nation's GDP and economy. In addition, the exporting nations will need to raise crop yields, which will put more strain on the available resources and hasten their depletion. According to certain projections, a few nations may see a rise in yields due to climate change, but not significantly enough to guarantee global food security. In nations like China and India, where a sizable section of the populace depends on agriculture for a living, a loss of revenue would exacerbate poverty and have an impact on GDP.

The second choice is for governments to alter their policies about the current resource management practises. It is time to phase out support for crops that use a lot of water, like rice, and promote the growth of substitutes that use fewer resources. Governments pushing for consumer education and the formation of a commitment to conservation of resources for future generations may cause the transition to happen gradually as the population gradually modifies its diet with appropriate inputs from the marketplace. Change will be encouraged as a workable alternative as more people realise that maintaining the current farming practises, eating habits, and lifestyles will endanger the survival of future generations in many ways.

So, the question is: What steps may be taken to lessen these negative consequences? This important question has numerous responses. With very few exceptions, it can be seen that the production of main crops like rice, wheat, and corn is rising globally, but the output of other crops like barley, millet, rye, and sorghum varies by region. Millets and other low-resource intensive crops may be cultivated practically anywhere in the world, as this figure demonstrates. Compared to other cereal crops like rice and wheat, millet has a higher nutritional value, can withstand drought, and requires less water for growth [9,20]. The current population finds it difficult to include millets into their diet, but if governments take the right steps and implement sensible policies that take the gravity of the issue into account, millets have the potential to become a crop with huge capacity to feed the world's population growth. Because millets may be cultivated in unfavourable conditions, they will be able to prevent losses for farmers and the agri-food sector. Since it is not a crop that requires a lot of water, the absence of irrigation infrastructure in developing nations like Asia and Africa does not prevent the growth of this crop. It can grow in soil that is drier. Thus, it is possible to shorten the time needed for cultivation by avoiding tillage practises [10,18].

Millet is a non-glutinous food with an outstanding nutritional profile. This makes them foods that are non-allergenic and readily digested. While millet releases less glucose when consumed as a food, diabetic individuals can safely consume it because polished rice creates a high percentage of glucose, which is not good for them. Iron, magnesium, potassium, and phosphorus are abundant in millets. Ten times more calcium is found in finger millet than in rice or wheat [139]. Globally, India produces more millet than any other country [25]. Even in unfavourable soil and climate circumstances, small millets like finger millet and Kodo millet can be cultivated. Short-growing millet varieties can be grown under both irrigated and dry circumstances in a variety of cropping systems [14, 30]. Furthermore, millets are considered "famine reserves" since they can be kept for a long period of time in the right storage conditions [41].

With a crop yield of 1111 kg/ha, millet is grown on 15.48 million hectares in India, yielding around 17.2 million tonnes of millet annually. Between 1950–1951 and 2011–2012, this crop's share of the total food grain production decreased dramatically, from 22.17% to 6.94% [41,42]. [43] investigated the Indian millets' growth trend. The investigation came to the conclusion that over the previous few decades, the area set aside for millet production had significantly decreased. Government initiatives that support the production of important grains like rice and wheat, as well as crops like oilseeds, cotton, fruits, and vegetables, may be the main cause of this reduction. Nevertheless, in spite of these problems, finger millet productivity climbed by 247.48% with a 255.61% rise in crop output, while pearl millet productivity increased by 47.41% with a 147.49% increase in crop yield. These figures imply that crop yield has been rising despite a considerable decrease in the area under millets production.

According to this review's outlook, the following regions will experience negative consequences from soil degradation, water scarcity, and climate change: China, India, Western, Middle, and Southern Africa, parts of South America, and the United States. These nations might not be able to handle circumstances that would pose a major danger to food security and crop productivity. The inability of farmers to grow crops owing to water scarcity could lead to widespread hunger and poverty, which would have an impact on the economies of the nation. These negative consequences can be lessened and, if appropriate action is done early on, a healthy environment with food security may be established, giving the next generation a sense of security and safety. Without a doubt, a swift change in the way millets are cultivated and consumed by the current population is essential. In a world with sufficient water resources for its subsistence, this would enable the 9.1 billion people that are expected to inhabit the planet by 2050 to live healthy lives.

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