Unleashing the Potential of Millets Promoting Nutritious Grains as Vital Cereal Staples during the International Year of Millets - A Review

Abstract

This comprehensive review highlights the multifaceted potential of millets as a nutritional powerhouse, a sustainable agricultural choice, and a means to tackle global nutritional challenges. Coinciding with the International Year of Millets, the paper focuses on the significance of millets as highly nutritious and resilient cereal staples that can address both food security and malnutrition issues, while enhancing agricultural sustainability. A comparative analysis of the nutritional composition of various millet types against major cereal crops reveals their superior micronutrient profile, protein content, and health benefits. Their role in combating micronutrient deficiencies such as iron, zinc, and vitamin A, as well as non-communicable diseases like diabetes, obesity, and cardiovascular diseases is underlined. Moreover, their immune-supporting properties are discussed. The climate resilience of millets and their potential to diversify agricultural systems while enhancing farmers' incomes are considered. The review also addresses challenges in promoting millet consumption and production, including perception issues, supply chain barriers, and policy constraints. Strategies to maximize millet potential, like enhancing value chains, promoting dietary diversification, incorporating millets into school feeding programs, and utilizing technological advancements for improved varieties are proposed. Policy recommendations emphasize the need for institutional support for millet farmers, raising consumer awareness, and strengthening research and development in millet agriculture. This paper serves as a call to action for researchers, policymakers, and stakeholders to promote millets as a key component in our food systems to tackle nutritional challenges and enhance agricultural sustainability.

Keywords: *Millets; Nutritional Composition; Food Security; Nutritional Challenges; Climate Resilience.*

Introduction

The global food system is facing immense challenges in the 21st century with climate change, population growth, malnutrition, and the increasing prevalence of non-communicable diseases (NCDs) [1]. Millets, a group of ancient, climate-resilient grains, are now recognized as a potential solution to these complex problems. They have rich nutritional properties that can help address dietary deficiencies and prevent NCDs. Furthermore, their adaptability to adverse climatic conditions makes them an important crop in achieving food security and sustainability [2]. This review explores the potential of millets and strategies to promote them as vital cereal staples during the International Year of Millets. Millets are small-seeded, hardy crops that have been cultivated for thousands of years, particularly in Africa and Asia. They are traditionally grown in semi-arid tropic regions, where they have adapted to conditions of low fertility and drought [3]. Millets encompass a wide range of species, including pearl millet, finger millet, foxtail millet, and proso millet among others [4]. Millets have been a part of the staple diet in many regions, providing essential nutrients, including proteins, dietary fibers, vitamins, and minerals. They are especially rich in micronutrients like iron, zinc, and vitamin A that are often

deficient in many populations, particularly in low-income countries [5]. Furthermore, these grains are low in glycemic index, making them beneficial for managing diabetes and obesity, health issues that are increasingly prevalent worldwide [6]. Despite their numerous benefits, millets have been largely neglected in global food systems, overshadowed by major cereal crops like rice, wheat, and maize. However, the growing challenges of malnutrition and climate change have revived interest in these 'smart foods' [7]. Recognizing the potential of millets in addressing current global challenges, the United Nations General Assembly declared 2023 as the International Year of Millets. This global campaign is designed to raise awareness about the benefits of millets and encourage actions to increase their production, consumption, and utilization [8]. The International Year of Millets is significant because it provides a platform to showcase the multifaceted benefits of millets and their potential to transform food systems. It helps to promote research, development, and investment in millets, which can drive their integration into agricultural and food policies [9]. The International Year also aligns with the Sustainable Development Goals (SDGs), particularly SDG2 (Zero Hunger), SDG3 (Good Health and Well-being), and SDG13 (Climate Action). By promoting millets, we can move towards healthier diets, improved nutritional outcomes, and resilient agricultural systems [10]. The objective of this review is to provide a comprehensive analysis of the potential of millets and strategies to promote them as nutritious and sustainable cereal staples. It will examine the nutritional profile of millets, their role in agriculture, the current challenges in their promotion, and successful case studies. It will also outline strategies and policy recommendations to capitalize on the International Year of Millets to foster the growth of millets.

Image 1: Millet: The Nutri-Cereals

Millets

Millets are defined as small-seeded cereal grains that belong to the Poaceae (or Gramineae) family. They are characterized by their robustness and ability to grow under harsh environmental conditions where most other crops fail [11]. Millets are generally grouped into two broad categories: Major millets, which are widely cultivated and consumed, and minor millets, which are grown and consumed locally on a smaller scale [12]. Major millets include pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), and foxtail millet (*Setaria italica*). Minor millets include proso millet (*Panicum miliaceum*), kodo millet (*Paspalum scrobiculatum*), little millet (Panicum sumatrense), and barnyard millet (Echinochloa spp.) (Baltensperger, 2002). Pearl millet is the most widely grown, primarily in Africa and Asia. Finger millet, on the other hand, is highly valued in parts of Africa and South Asia for its high nutritional value. Foxtail millet, native to East Asia, is the oldest cultivated millet and is consumed in China, India, and other parts of Asia [13].

Global Millet Production Statistics

As of 2023, global millet production stands at approximately 30 million tons annually, with the majority produced in developing countries. India is the largest producer, contributing around 40% of the global output. Other major producers include Nigeria, Niger, and China [9]. Despite being native to Africa, the continent's millet production has lagged behind, accounting for about 30% of the world's output. However, millet remains a crucial staple food in many African countries, particularly in the Sahel region, where it is often the primary cereal crop [9]. Millet production is primarily for domestic consumption, with only about 1% of the global output traded internationally. This limited trade is due to various factors, including the diversity of millet types, lack of standardized quality parameters, and local food preferences [9].

Millets in Food Security and Nutrition

In the food security and nutrition, millets offer significant advantages. They are often grown in marginal areas with low fertility soils, where major cereals cannot survive. This resilience makes millets an important crop in ensuring food security in many vulnerable regions, particularly in the context of climate change [14]. Millets are rich in essential nutrients and can significantly contribute to tackling malnutrition. They are a good source of energy, proteins, and dietary fibers. Millets are particularly high in micronutrients such as iron, zinc, and B vitamins, which are essential for human health but often deficient in many diets [15]. Beyond nutrition, millets also have health-promoting properties. They have a low glycemic index, which helps manage blood sugar levels and is beneficial for diabetes management. They are also gluten-free, making them suitable for individuals with celiac disease or gluten sensitivity [16].

Types of Millets and their Specific Benefits

- Pearl Millet: The largest produced type of millet, pearl millet is a robust cereal grain that can grow in harsh conditions and nutrient-poor soils [17]. It is an excellent source of energy and rich in proteins, fiber, and minerals like iron and zinc. It also contains phytochemicals that have antioxidant properties [18].

- Finger Millet: Known for its high nutritional value, finger millet is rich in calcium, which is

essential for bone health. It also contains substantial amounts of dietary fiber, phenolic compounds, and essential amino acids [19].

- Foxtail Millet: Foxtail millet is a rich source of dietary fiber and minerals. It also contains bioactive compounds like phytosterols and flavonoids that have been associated with health benefits such as lowering cholesterol and anti-inflammatory effects [20].

- Proso Millet: Proso millet is an energy-rich grain that is a good source of protein, fiber, and essential minerals like magnesium, manganese, and phosphorus. It is also gluten-free and has a low glycemic index [21].

- Other Minor Millets: Kodo millet, little millet, and barnyard millet are also nutritionally rich, providing energy, protein, fiber, and various vitamins and minerals. They also have health-promoting properties like low glycemic index and gluten-free nature [22].

Nutritional Composition of Millets

Millets are a rich source of macro and micronutrients that contribute to a balanced diet. Below is an exploration of the nutritional value of different millet types, underlining their nutritional diversity.

- Pearl Millet: It is rich in carbohydrates, serving as an excellent source of energy, while also providing high-quality proteins (10-11% by weight) [23]. Its protein content contains essential amino acids, especially tryptophan, cystine, and methionine [24]. Pearl millet is also a good source of micronutrients, including iron, zinc, phosphorus, and B-vitamins, especially niacin, which contributes to metabolism and nervous system function [25].

- Finger Millet: The protein content in finger millet ranges from 7-12%, and it has an excellent amino acid profile, particularly methionine, which is usually lacking in the diet of millions of the poor who live on starchy staples. Furthermore, it has the highest calcium content (344 mg/100g) among all cereals, which is crucial for bone health and growth [26].

- Foxtail Millet: This variety contains about 65-70% carbohydrates and 11-12% proteins, along with dietary fiber, which aids in digestion. It is rich in minerals such as iron, zinc, and copper and B-group vitamins (B1, B2, B6) [27].

- Proso Millet: It has a high protein content (around 12-16%), and the essential amino acids, leucine, isoleucine, and methionine, are present in greater concentration than in wheat, rice, or maize [28].

- Other Minor Millets: Kodo millet, little millet, and barnyard millet are also nutritionally rich, providing good amounts of macronutrients like carbohydrates and proteins. They are also sources of essential vitamins and minerals like iron, magnesium, and phosphorus [29].

Comparison of Millets with Other Major Cereal Crops

When compared to other major cereals like rice, wheat, and maize, millets often have superior nutritional profiles. The protein content in millets is similar to wheat and higher than rice, with better essential amino acid profiles [30]. Millets also have higher fiber content, promoting satiety, and improving digestive health compared to rice and wheat [31]. Millets are an excellent source of several essential minerals, like iron and zinc. The iron content in millets, particularly in finger and pearl millets, is significantly higher than in rice and wheat [32]. The same goes for zinc content, especially in pearl millet [33]. Millets contain more calcium than any other cereal. The calcium content in finger millet is about 10 times that in rice or wheat [34]. Thus, millets can contribute significantly to overcoming the common global challenge of micronutrient malnutrition, often referred to as "hidden hunger".

Health Benefits Associated with Millet Consumption

The health benefits of millets are mainly attributed to their rich nutritional profile. They have high dietary fiber content, which aids digestion and promotes a feeling of satiety, aiding in weight management [35]. Millets are rich in phytochemicals, including phenolic compounds and phytosterols, which have antioxidant and anti-inflammatory properties, reducing the risk of chronic diseases such as diabetes and heart disease [36]. The high magnesium content in millets also contributes to their cardio-protective properties by playing a vital role in regulating blood pressure and reducing the risk of stroke [37]. Millets, being gluten-free, are suitable for individuals with celiac disease or gluten sensitivity [38]. Also, millets have a low glycemic index, helping to control blood sugar levels, which is beneficial for people with diabetes [39]. The high content of iron and zinc in millets can help combat anemia and boost immune function, respectively [40]. The high calcium content, especially in finger millet, is beneficial for bone health [41].

Role of Millets in Combating Nutritional Challenges

Micronutrient deficiencies, often termed as 'hidden hunger,' affect over two billion people globally [42]. Particularly, deficiencies of iron, zinc, and vitamin A are widespread and of significant public health concern. The high concentration of these micronutrients in millets offers potential solutions to these challenges.

Iron: Iron deficiency is a common cause of anemia, affecting around 30% of the world's population (Stevens et al., 2013). Millets, especially finger millet and pearl millet, are rich in iron, and regular consumption can help meet iron requirements and combat anemia [43].

Zinc: Zinc deficiency affects around 17% of the population and is particularly harmful during pregnancy and childhood, affecting immune function and cognitive development [44]. Again, millets, particularly pearl millet, are a good source of zinc, and their incorporation into diets can contribute significantly to addressing zinc deficiency [45].

Vitamin A: Although millets do not contain vitamin A, they are rich in carotenoids, which are precursors of vitamin A [46]. Therefore, millet consumption can help address vitamin A deficiency, which affects about 29% of preschool children globally and is a leading cause of blindness in children [47].

Millets and Non-Communicable Diseases

Non-communicable diseases (NCDs), including diabetes, obesity, and cardiovascular diseases, are responsible for around 70% of all deaths globally [48]. Millets have demonstrated potential in managing these conditions due to their high fiber content, low glycemic index (GI), and abundance of antioxidants.

Diabetes: Millets have low GI, which means they cause a slower increase in blood glucose levels compared to high-GI foods. Regular consumption of millets can thus contribute to better glycemic control in diabetics and prevention in high-risk individuals [49].

Obesity: The high fiber content in millets promotes a feeling of fullness, reducing overeating and assisting in weight management, making millets an essential dietary component in combating obesity [50].

Cardiovascular Diseases: Millets are rich in magnesium and potassium, essential nutrients for heart health. They help in blood pressure regulation, reducing the risk of hypertension, a key risk factor for cardiovascular diseases [51]. Moreover, the antioxidants in millets can prevent atherosclerosis by reducing oxidative stress and inflammation [52].

Millets in Supporting Immunity

Adequate nutrition is a critical determinant of immune function. Millets, with their rich nutritional profile, can play a vital role in supporting immunity. Millets are rich in antioxidants, including phenolic compounds, which can boost immunity by protecting immune cells from oxidative damage [53]. The high zinc content in millets can enhance immune function as zinc is involved in the growth and function of various immune cells [54]. The high fiber content in millets supports gut health, which is closely linked to immune function. A healthy gut microbiota helps in the optimal functioning of the immune system [55].

The Potential of Millets in Agriculture

As climate change impacts become more evident, there is an urgent need for crops that can withstand harsh environmental conditions. Millets, known for their drought tolerance and ability to grow under marginal soil fertility, offer a viable solution [56]. Millets are highly resistant to drought due to their robust root system and the ability to reduce their metabolic activity under water stress conditions [57]. This allows millets to survive and produce grains even under low rainfall scenarios, making them critical in arid and semi-arid regions affected by climate change. Millets can withstand higher temperatures than most other staple grains. They can thrive in temperatures up to 46-50°C, which is well beyond the tolerance limits of rice, wheat, or maize [58]. As global temperatures continue to rise, millets offer a climate-resilient alternative to traditional staples.

Millets in Diversifying Agricultural Systems and Enhancing Farm Income

Millets can play a pivotal role in diversifying agricultural systems, enhancing farm income, and providing nutritional security. Millets, with their various types and varieties, offer excellent opportunities for crop diversification. They can be grown in different seasons, making them suitable for crop rotation and intercropping, thereby reducing dependency on a single crop and enhancing system resilience [59]. The rising health consciousness among consumers is driving up the demand for nutrient-rich millets, opening up new market opportunities. Farmers can leverage this trend to enhance their incomes by switching to millet cultivation [60].

Effect on Soil Health and Contribution to Sustainable Farming

In addition to their adaptability to harsh climates, millets also contribute positively to soil health and promote sustainable farming. Millets have a deep and extensive root system that improves soil structure and aids in soil conservation. Furthermore, millets have a lower nutrient demand than most cereals, reducing the need for synthetic fertilizers and contributing to soil fertility preservation [61]. Millets require less water than other staple crops. For example, to produce one kilogram of rice, approximately 2500-3000 liters of water are needed, whereas for millets, it's just 250-300 liters [62]. This water efficiency contributes to the sustainable use of scarce water resources, particularly in regions prone to drought.

Challenges in Millet Promotion and Consumption

Despite their nutritional benefits and resilience, millets face challenges related to perception and demand. In many regions, millets are perceived as 'poor people's food' or 'famine food,' which deters their consumption by the middle and upper classes [63]. This perception needs to be changed to enhance the demand for millets. Millets, due to their somewhat bitter taste resulting from the presence of phenolic compounds, are not as palatable as rice or wheat to many consumers [64]. Furthermore, millets' coarse texture and long cooking time also hinder their adoption [65]. Millet yield is often less stable than that of other cereals due to its vulnerability to pests, diseases, and bird attacks [66]. Millets often suffer from significant post-harvest losses due to inadequate storage facilities and lack of modern processing technologies [67]. Dehulling millets is a significant challenge due to their small size and hard seed coat. Also, processing can lead to nutrient loss, especially if not done carefully [68].

Policy and Institutional Constraints

There are several policy and institutional constraints that hinder the promotion and consumption of millets. Compared to other cereals like rice and wheat, millets have received less attention in agricultural policies and research. This lack of policy support has led to lower productivity and reduced farmer interest in millet cultivation [69]. There is limited research on improving millet varieties and developing farming techniques that could increase their yield and resistance to pests and diseases [70]. There are inadequate efforts in developing markets for millets and creating value-added products that can attract consumers and fetch better prices for farmers [71]. Despite these challenges, there is growing recognition of the importance of millets for nutritional security, climate resilience, and agricultural sustainability. Addressing these challenges will require concerted efforts from policy-makers, researchers, farmers, and other stakeholders.

Strategies for Unleashing the Potential of Millets

An efficient and effective millet value chain is essential for promoting millet cultivation and consumption [73]. Building Processing and Storage Capacities: Post-harvest losses can be reduced by providing better storage facilities and modern processing technologies. Efforts should also be made to develop simplified and affordable millet processing technologies that can be used at the community level [74]. Developing Markets: There is a need to develop and promote markets for millets and millet-based products. Marketing strategies such as branding and packaging can help increase their appeal to consumers [75].

Incorporating millets into school feeding programs can help promote their consumption and improve the nutritional status of children. Millets, being rich in essential nutrients, can improve the nutritional quality of school meals [76]. Incorporating millets into school feeding programs can help establish a sustained demand for millets, thereby providing an assured market for millet farmers [77].

Policy Recommendations for Millet Promotion

An essential strategy for millet promotion is to improve institutional support for millet farmers, which involves the provision of technical, financial, and marketing support [78]. Strengthening of extension services is necessary to equip farmers with the knowledge and skills needed for efficient millet cultivation. This includes providing training on best farming practices, pest and disease management, post-harvest handling, and value addition [79]. There is a need for more comprehensive financial support to millet farmers, including access to affordable credit, insurance services, and incentive schemes such as minimum support prices for millets [80]. It is crucial to assist farmers in marketing their produce. This could be done by linking farmers to potential buyers, supporting the formation of farmer cooperatives, and facilitating participation in local and international trade fairs [81].

Building Consumer Awareness and Changing Perceptions about Millets

Public Awareness Campaigns: Public awareness campaigns can be instrumental in changing negative perceptions about millets and promoting their nutritional and environmental benefits. These campaigns could involve the use of mass media, social media, public lectures, food fairs, and cooking demonstrations [82]. School and Community Nutrition Programs: Incorporating millets in school feeding programs and community nutrition programs can familiarize children and communities with millets and promote their consumption. This also provides an opportunity for nutrition education [83]. Celebrity Endorsement: Celebrity endorsements and culinary influencers could be used to promote millets, especially among urban consumers. High-profile endorsements could enhance the image of millets as a healthy and trendy food choice [84].

Research and Development in Millet Agriculture

There is a need for more robust agricultural research on millets, focusing on the development of high-yielding, drought-tolerant, and disease-resistant varieties, as well as improved farming techniques [85]. More research is needed on the nutritional properties of different millet varieties

and their health benefits. This information could be used for breeding programs and for marketing purposes [86]. Investment in technology development is critical for enhancing millet production and processing. This includes machinery for millet cultivation, harvesting, processing, and storage, as well as for the development of innovative millet-based products [87].

To conclude, policy interventions for millet promotion should aim to improve institutional support for millet farmers, build consumer awareness and change perceptions about millets, and strengthen research and development in millet agriculture.

Conclusion

This review underscores the substantial potential of millets as nutritional and resilient cereal staples. Despite the challenges in promoting millets, strategic efforts such as enhancing value chains, institutional support, consumer awareness, and intensified research can help elevate millets to a mainstream food choice. The importance of millets in addressing malnutrition and food security, while promoting agricultural sustainability, is incontrovertible. The International Year of Millets presents an unprecedented opportunity to reposition millets as a key dietary component, benefiting both consumers and producers. This will require a concerted effort from all stakeholders, including policymakers, researchers, agribusinesses, and consumers. Ultimately, the promotion of millets will contribute significantly to the global pursuit of a sustainable and nutrition-secure future.

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