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A Critical Review on Millets (Superfood of all Time): Importance, Challenges and Opportunities

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Climate change, water scarcity, population growth, rising food prices, and other socioeconomic repercussions are anticipated to pose a serious danger to agriculture and global food security in the twenty-first century, especially for the world's poorest residents of arid and subarid countries. We must concentrate on dry lands in order to significantly boost the production of grains because agricultural fields with irrigation systems have been fully utilized. It is difficult to use arid areas to produce sufficient quality grains because of their poor productivity. The most important source of food in the world is cereal grains, which also play an important part in the global diet of people. In the semiarid tropics of Africa and Asia, millet is one of the most significant drought-resistant crops and is a major source of carbohydrates and proteins for the local population. Additionally, millet grain is currently attracting more interest from food scientists, technologists, and nutritionists due to its significant contribution to national food security and potential health advantages. The

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phytochemicals found in millet grains have a beneficial impact on human health by reducing phytates and cholesterol levels. The quest for substitute grains is necessary to relieve the pressure caused by the frenetic demands on cereals and their uses in numerous industries. The performance improved when pearl and finger millets were substituted for maize in the diets of several animals. In terms of poor growth conditions and high nutritional value, millets outperform other grains like wheat and rice as crops that are climate change compliant. These strategies will aid in the fight against hunger and malnutrition while also providing monetary benefits to the millet growers and other stakeholders.

Keywords: Millets; nutritional security; malnutrition; carbohydrates; ecological stability.

1. INTRODUCTION

““The world's population is projected to grow to 9.1 billion people by 2050” [1]. “It is obvious that urgent action is required to ensure increased food supply and food security considering the restricted land resources [2,3]. Food security has grown more important on both the international and domestic fronts as a result of the global supply, economic growth, and rising population in emerging countries. Two of the largest difficulties facing the modern world are addressing hunger and feeding the planet's population. Conflicts, insufficient production of food, imbalances in supply and demand, and shortages in the supply of micro- and macronutrients are some of the causes of this problem causing global instability in a number of places” [4,5,6]. “The concept of food security encompasses both sustained access to wholesome nutrition as well as consistent access to physical food availability. Food insecurity is first divided into two categories by the Food and Agriculture Organization (FAO): moderate (limited access to food results in poorer dietary quality, eating patterns, health, and wellbeing) and severe (running out of food, experiencing hunger, and having health and wellbeing at severe risk) security [7]. The threat of climate change and global warming persists even while some of these causes of hunger can be addressed, resulting in a marginal decrease in the number of people suffering from hunger and malnutrition from about one billion in 1990–1992 to 850 million in 2010–2012” [1]. “Estimates indicate that by 2050, 2-3 billion people may experience hunger and other food and nutritional insecurities due to the decline in food production rates and the additional burden of feeding a population greater than 9 billion” [8]. “Crop yields, crop production, and the overall sustainability of our food systems are all said to be directly impacted by climate change and rising world average temperatures [9,10]. At both the macro and micro levels, ensuring food and nutrition security for India's enormous and diverse population is a challenge, and work has been done on numerous fronts. There is no question that significant efforts have been undertaken recently to achieve food and nutrition security in India, and the advancements made cannot be disputed. However, unless concerted efforts are made, food insecurity and malnutrition appear to be continuing and may get worse in the near future. So, the goal of sustainable improvement in food and nutrition security continues to be the main objective. According to some estimates, a few places may gain from climate change because of higher production and yields, but this would not be enough to feed the growing population around the world” [11]. “Furthermore, the majority of scientists concur that crop output would be severely decreased by the current rates of global warming and greenhouse gas emissions [12,13,14]. Therefore, ensuring food security depends greatly on reducing greenhouse gas emissions in order to control global temperatures. However, one of the main sources of greenhouse gases like methane in the environment is the agriculture industry. Intensive agricultural practices, which are practised in various parts of the world, typically result in higher emissions” [15]. “In addition to being a large source of macronutrients including carbohydrates, lipids, and proteins, cereal crops also have a sizable potential to contribute to global warming. Wheat has the biggest global warming potential of all the major cereal crops, with an estimated 4 tonnes CO_2 eq/ha, followed by rice and maize (an estimated 3.4 tonnes CO_2 eq/ha). Additionally, the carbon equivalent emissions from these crops are considerable, with an average of 1000, 956, and 935 kg C/ha for wheat, rice, and maize, respectively” [16]. “They are widely cultivated and the main sources of nutrition for the entire world's population despite having greater emission rates [17,18,19]. Other minor cereal crops, including millet and sorghum, have significantly lower carbon footprints. This is one of the primary reasons why millets could be one of the crops that reduce the global carbon footprint” [20]. “Improved nutritional security can also be achieved by diversifying the

agricultural system and using drought-resistant crops. A class of coarse grain cereals known as millets can be very helpful in achieving this. Millets are a group of diverse small-grain cereal crops grown belonging to the Poaceae grass family and are considered one of the oldest cultivated crops. They are composed of up to a dozen crop species, mostly from developing nations in Asia and Africa". "Ninety-seven percent of millet is produced in developing nations, making millet significant crops in the semiarid tropical regions of Asia and Africa" [21]. "Despite significant pressure from competing crops in terms of regulations and production support, India is the world's largest producer of millets, generating approximately 40% of the millets consumed worldwide. In temperate, subtropical, and tropical latitudes, the crop is primarily farmed on marginal lands in arid locations.[The crop is preferred because of its yield and brief growth season in hot, dry conditions. Throughout human history, millets have played a significant role as a staple meal, especially in Asia and Africa. Since millets are C_4 plants, they have a much more efficient photosynthetic system than C_3 plants like rice and wheat. The majority of millet grains are now commonly referred to as "Nutri-cereals" because they have higher protein, fibre, calcium, and mineral contents than the widely consumed grains of rice and wheat. For the past 10,000 years, East Asia has been cultivating them. Millets are native to many regions of the world, and pearl millet is the variety that is grown the most widely. It is a significant crop in India and several regions of Africa"[22]]. "The most significant species of millet in terms of cultivated land and contributions to food security in areas of Africa and Asia is pearl millet. The most significant varieties include foxtail, finger, proso, and pearl millet. Pearl millet accounts for roughly half of the world's millet production. In developed nations and some regions of Asia, proso millet is utilized for food and as bird seed. The crop of foxtail millet is significant in China and Eastern Europe" [23]. In the colder, higher-altitude regions of Africa and Asia, finger millet is widely grown as a food crop and used as a popular ingredient in traditional beer. The other species—barnyard, kodo, and little millets, as well as folios and teff—are regionally or internationally significant food grains. The physical traits, qualitative characteristics, soil, climate requirements, and growth cycles of the various species vary. The scientific and common names of various millets vary depending on the place in which they are grown, and these millets are grown in various parts of the world and require different growth conditions (Table 1). "Every day, millions of people consume rice, wheat, maize, and, to a lesser extent, millet as their primary sources of nourishment. The growth pattern of these crops is determined by temperature and water availability" [20]. "While wheat is mostly grown in regions that have restricted water supplies and suitable temperatures, rice and maize are grown where there is a plentiful supply of water. Sorghum and millets are cultivated in regions with limited water supplies. Due to its resilience to biotic and abiotic challenges and its large production on low-quality lands with little input, millets can even be grown in semi-arid and arid areas" [24]. Millets could be crucial functional foods for the prevention of non-communicable diseases because they are a rich source of antioxidants, fibre, and essential and non-essential amino acids, vitamins, and minerals. This review aims to provide detailed nutritional composition of millet and its benefits to humans and livestock, need of growing millets, various constraints and perspectives associated with it.

Nutritional Importance: "There are plenty of chronic diseases and health problems in the world today. According to the 2016 Global Nutrition Report, in 129 nations (countries with data available), 44% of the population suffers from very serious levels of undernutrition, adult overweight, and obesity" [25]. "The majority of these disorders are caused by nutrient imbalances in the diet. United Nations Food and Agriculture Organization estimates that 7.9% of the world's population, or 795 million people, were undernourished in 2015. However, more than 1.9 billion adults under the age of 18 (or 39% of the world's population) were reported to be overweight, and another 13% to be obese" [1]. "The World Health Organization has previously classified obesity-related problems like diabetes and cardiovascular disease as an epidemic" [26]. "The majority of undernourished people in the world reside in India. Globally, 469,000 deaths were attributed to protein energy malnutrition (PEM), while 84,000 deaths were attributed to a lack of other essential nutrients as iron, iodine, and vitamin A" [27]. With a prevalence incidence of 11% for men and 15% for women, obesity is a significant public health issue in India. Because millets are a great source of several essential elements, they offer an extra benefit in the fight against nutrient deficiencies in third-world countries.

Table 1. Scientific names, common names and growing conditions required for cultivation of different types of Millet around the world

Type of Millets	Scientific Name	Common Name	Growing Conditions	References
Pearl Millet	*Pennisetum typhoides*	Bulrush millet	Dry climates, marginal soils, Rainfall 200–500 mm	[28,29]
Finger Millet	*Eleusine coracona*	Birds' food millet or African millet	Resist higher temperatures and salt, with a soil pH range of 5 to 8.2 and a moderate amount of rainfall.	[30,31]
Porso Millet	*Panicum miliaceum*	Common millet, hog millet, broom corn, yellow hog, Hershey and white millet	Less water, Rainfall less than 600 mm, average temperature 17 ◦C during daytime	[32,33]
Foxtail Millet	*Setaria italic*	Italian millet, German millet, or hay millet	Less water, short duration	[34,35]
Barnyard Millet	*Echinochloa crusgalli var. Frumentacea*		Drought tolerant, rapid maturation rate	[36,37]
Kodo Millet	*Paspalum scorbiculatum*		High drought resistance, Good yields, period of 80–135 days	[38,39,40]

Table 2. Nutrient composition of millets in comparison to fine cereals (per 100 g)

Food grain	Carbohydrates (g)	Protein (g)	Fat (g)	Energy (KCal)	Crude fibre (g)	Mineral matter (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Sorghum	72.6	10.4	1.9	349	1.6	1.6	25	222	4.1
Pearl millet	67.5	11.6	5.0	361	1.2	2.3	42	296	8.0
Finger millet	72.0	7.3	1.3	328	3.6	2.7	344	283	3.9
Little millet	67.0	7.7	4.7	341	7.6	1.5	17	220	9.3
Kodo millet	65.9	8.3	1.4	309	9.0	2.6	27	188	0.5
Foxtail millet	60.9	12.3	4.3	331	8.0	3.3	31	290	2.8
Barnyard millet	65.5	6.2	2.2	307	9.8	4.4	20	280	5.0
Proso millet	70.4	12.5	1.1	341	2.2	1.9	14	206	0.8
Wheat (whole)	71.2	11.8	1.5	346	1.2	1.5	41	306	5.3
Rice (raw, milled)	78.2	6.8	0.5	345	0.2	0.6	10	160	0.7

[41]

Millets contain high amount of calories, protein, and macronutrients when comparable to regular cereals. Their high calorie content, together with calcium, iron, zinc, fats and high-quality proteins, make them an important part of both animal and human diets. They are also rich sources of nutritional fibre and vitamins. Here, is the nutrient composition of millets:

Carbohydrates: The carbohydrates in pearl millet grains includes dietary fibre, starch and soluble sugars. The endosperm of pearl millet contains glucose in the form of amylase and amylopectin and is regarded as having a high starch content. The starch content of different pearl millet grain genotypes varies from 62.8 to 70.5 % and approximately 71.82 to 81.02 %. Soluble sugars range from 1.2 to 2.6 %, and amylose from 21.9 to 28.8 % and amylose from 21.9 to 28.8 %. The starch included in pearl millet can be employed as bulking, thickening, and gelling agents for food texture [42]. However, according to Bhatt et al., [43], the total carbohydrate content of finger millet ranges from 72 to 79.5 %. Additionally, Wankhede [44] noted that the detailed profile of the carbohydrates ranged between 59.5 and 61.2 % for starch, 6.2-7.2 % for pentosans, 1.4-1.8 % for cellulose, and 0.04-0.6 % for lignin.

Protein: Protein is the second main component of millet. Pearl millet has 11.6 % protein, which is more than the 7.2 % in rice, 11.5 % in barley, 11.1 % in maize, and 10.4 % in sorghum [45]. Additionally, Anitha [46] noted that pearl millet contained 9.79 % protein. The crude protein content of pearl millet grain is thought to be 8–60 % higher by weight compared to maize [47]. Contrarily, finger millet has about 5-8 % protein [48] recorded the greatest protein level for finger millet at nearly 11 %, and [46] documented a proportion of 6.32 % in finger millet. Furthermore, Taylor [49] revealed that the amino acid profile of pearl millet is equivalent to that of wheat, barley and rice but contains more lysine, threonine, methionine and cysteine than sorghum and maize proteins. Moreover, the distribution of proteins in pearl millet grain is thought to be similar to that of maize, notably true prolamins, which are thought to be soluble in alcohol. Additionally, McIntosh [50] noted a high degree of critical amino acid balance and endorsed pearl millet as a crucial source of protein and energy for people. Additionally, arginine, threonine, valine, isoleucine, and leucine were discovered to have greater digestibilities in pearl millet than in maize. Because finger millet

As millets are gluten-free, they reduce the discomfort associated with eating normal cereal grains that contain gluten, which helps to prevent celiac disease [51]. Sixty percent of the phenolic acids found in millets are found both in bound and free forms. Hydroxycinnamic acids are the most common phenolics in millets, and they are mostly found in the insoluble-bound portions of phenolic acids [52]. Hydroxycinnamic acid is most commonly found in the form of the antioxidant ferulic acid. Antioxidants are well-known compounds with anti-inflammatory and anti-free radical damage effects on the body [53]. Furthermore, it has been found that ferulate dimers, which have significant antioxidant activity, are present in millet grains [54,55,56].

Additionally, anthocyanidins, chalcones, amino phenolics, flavanols, flavones, and flavanones are among the flavonoids included in millet grains. Additionally, Dykes [57] state that some millet cultivars may contain proanthocyanidins, also referred to as condensed tannins. The majority of coloured millet varieties contain significant levels of tannin [58]. Condensed tannins were found to be primarily responsible for the grain's colour, which was linked to this finding. However, the bioavailability of minerals and proteins may be adversely affected by a high concentration of condensed tannins [59].

Other health benefits: Sireesha [60] reported that the aqueous extract of foxtail millet (*Setaria italica*) has been shown to have anti-hyperglycaemic and anti-lipidemic effects in streptozotocin-induced diabetic rats. The study found that when diabetic rats were given 300 mg of Setaria italica seed aqueous extract per kilogramme (kg) of body weight, their blood glucose levels significantly decreased (by 70%) after six hours. They also found that in diabetic treated rats as opposed to diabetic untreated rats, there were higher levels of HDL (high-density lipoproteins) cholesterol and lower levels of triglycerides, total LDL (low-density lipoproteins), and VLDL (very low-density lipoproteins) cholesterol, which is indicative of the hypolipidemic effect of the aqueous extract. Dietary protein from Korean foxtail millet has been shown to improve insulin sensitivity and lipid levels [61,62]. This experiment demonstrated a significant drop in insulin levels in rats given foxtail millet. When Lee [63] looked into the impact of consuming millet on lipid levels and C-reactive protein concentration, they discovered that, contrary to their earlier studies [62], hyperlipidemic rats fed foxtail millet had

lower levels of triglycerides. Reduced levels of C reactive protein, an indicator of inflammation, were also observed in rats given foxtail millet. There is evidence that the aqueous and ethanolic extracts of Kodo millet reduce fasting blood glucose in a dose-dependent manner [55,64,61].

Dual use of millets as food and feed: Millet grains are considered unique crops because they are rich in calcium, dietary fibre, polyphenols, and protein, among other vital elements [30]. They serve as the main source of food for many Asian and African countries. The majority of the millet produced is consumed by humans, with the remainder going towards making beer, animal feed, and bird feed. Millet is prepared as a porridge with a thick or thin consistency in some parts of Africa, and as couscous in other parts [65]. Research using whole grain or crushed grain fed to chickens verified the usefulness of pearl millet as a feed item for poultry production [66]. The primary goal of pearl millet production in Africa and Asia is thought to be grain, with forage serving as a key secondary product utilised for animal feed, construction, and fire [67]. While season-specific crops like wheat and rice guarantee food security, all-season millets ensure fodder, nutrition, health, and a sustainable livelihood [68]. Pearl millet grains hold considerable potential as a human food source due to their gluten-free nature and higher nutritious fibre content than rice. Furthermore, compared to traditional cereals like wheat and rye, they include more essential amino acids like leucine, isoleucine, and lysine and the same amount of fat as maize cereal [69]. In India, millet is transformed into the dense bread known as dosa, where it is commonly used, by combining millet with other grains. Furthermore, according to Dias-Martins [70], it's used to make couscous, sushi, roti, biscuits, and pizza made without yeast. Another product made from millet is madua, an Indian beverage made with finger millet. Also, Oshikundu, a customary alcoholic or non-alcoholic beverage in Namibia, is made using millet [71].

2. MONETARY BENEFITS OF USING MILLET

The cost of millet is believed to be 40% cheaper than that of maize, making it a cheap and gluten-free cereal [72]. Silva [73] estimated that trade value of pearl millet was less than or equal to 77.78 % of the price of maize grain. Pearl millet grain has more protein per grain than maize, it might allow diets to be formulated without protein supplements, lowering the price of food and feed in the process. Aside from that, millet is less expensive to produce than other cereals like sorghum and maize. For instance, the water use of Brazilian pearl millet cultivars is more efficient than that of sorghum and maize grown in semi-arid regions of the country (56 ± 2.8 kg DM/ha/mm water vs. 45 ± 1.9 kg DM/ha/mm water for sorghum; Silva [73] and 21 ± 2.4 kg DM/ha/mm water for the Brazilian maize cultivars [74]. For instance, the water use of Brazilian pearl millet cultivars is more efficient than that of sorghum and maize grown in semi-arid regions of the country (56 2.8 kg DM/ha/mm water vs. 45 1.9 kg DM/ha/mm water for sorghum [73]; and 21 2.4 kg DM/ha/mm water for the Brazilian maize cultivars; [74]. In an investigation by Gomes [72], it was discovered that completely substituting pearl millet for maize in the diet of feedlot cattle was the most cost-effective option. The price of lean and fat cattle, initial weight, final weight, cost of concentrate, cost of roughage, consumption of concentrate, and consumption of roughage were listed as the factors that influenced the financial indicator [75]. Furthermore, it is reasonable to believe that millet's positioning as a grain that competes with maize will shift the supply's balance and release pressure on maize consumption, thus, lowering its prices. A different study by Rao [76] found that the cost of feed needed to create one kilogram of live weight gain in chickens fed on maize was higher than the cost for the same amount of gain in chickens fed on pearl millet, finger millet, and sorghum. According to Medugu [77], millet grain feed has the lowest cost per kg of feed and the lowest cost of feed per unit weight gain, making broiler chicken production more affordable and cost-effective. Wilson [78] found that the annual net profit from using pearl millet as the only feedstock was $25,175,000 in comparison to $23,758,000 for maize feedstocks, a difference of almost $1.4 million.

Constraints with food security in developing nations: A condition where people have physical and financial access to wholesome food that satisfies their dietary needs is referred to as food security [79]. The scope of food security problems is frequently reduced to the availability of agricultural products like cattle [80]. The difficulties are thought to be more intricate than simply increasing the supplies. Several elements, including urbanization and accessibility, are among the restrictions [80] listed. The structure and procedures that govern economies and societies, as well as institutional failings, are

frequently mentioned as contributing reasons to food insecurity [81]. Fraval [82] reported that the casual intervention to prevent food insecurity is not always simple, therefore proxies of actions and a deeper comprehension of the various potential pathways are crucial for successful interventions. To overcome these intricate obstacles, multisectoral strategies and planning are needed. Pangaribowo [81] stated that the best strategy to address the problems of food and nutrition security is to combine the indicators of food insecurity with the relevant socioeconomic and environmental variables of a specific entity. Despite the difficulties facing food security in developing nations, the importance of locally grown and underutilized grains like millet cannot be understated. Some of these problems cannot be solved by standard grain crops [83]. The expansion of small grains like millet could worsen poverty among the underprivileged population, especially in light of recent events like the extraordinary COVID-19 epidemic [83]. Millets are crops that, in the context of climatic change, have the potential to endure challenging circumstances and contribute to the stability of food security. Padulosi [84] reported that minor millets like finger, kodo, foxtail, tiny, porso, and barnyard have the capacity to flourish in a variety of soils, different climatic conditions, distinct photoperiods, and in due to their genetic adaptability. These qualities make millets suitable for replacing staples like wheat and rice in difficult climate zones, eventually resulting in food security in these regions. However, millet is regarded as a neglected agro-biodiversity, despite the fact that it has the ability to improve the food security of underprivileged people in developing countries [85].

3. EFFECT OF PROCESSING ON THE ANTIOXIDANT ACTIVITY OF MILLET GRAINS

It was also found that millet grains' antioxidant content and activity were affected by several processing methods, including boiling, soaking, decortication, and malting. According to Rao [86], after 96 hours of malting finger millet, the antioxidant capacity of the fraction containing free phenolic acids increased twofold, whereas the fraction containing bound phenolic acids showed a drop in antioxidant capacity. In a different study, a growth-promoting media was developed to boost the germination of millet and raise the production of a water-soluble protein that inhibits hydroxyl radicals. The single-factor test revealed that H2O2 is necessary for inhibitory function, according to Li [87]. To further increase the yield of the water-soluble protein that inhibits hydroxyl radicals from stress-germinated millet, the effects of the sprouting circumstances (temperature, duration, and pH of stress medium) on the hydroxyl radical inhibition were also investigated. It was discovered that the stress medium's pH should be 7.5, the culture should last for 54 hours, and the temperature should be 28 °C. Under optimal conditions, the maximum inhibition of 60.38 percent was reached [87]. Furthermore, researchers were able to create flour with a significant DPPH-scavenging activity after 3 days of foxtail millet germination [88]. Roasting or boiling kodo or finger millet reduced its antioxidant activity. Separating the husk and endosperm of kodo millet decreased its DPPH quenching activity as well, and the phytochemicals seemed to complement one another [64]. It was also investigated how little millet's antioxidant properties were affected by germination, steaming, and roasting. The results showed that compared to the original sample, the total phenolic, flavonoid, and tannin contents of small millet increased by 21.2, 25.5, and 18.9 mg/100 g, respectively [89,90].

However, it was found that the phenolic content and antioxidant potential of pearl millet grains were affected by dehulling and hydrothermal treatments [91]. Oxidation and chemical degradation during heat treatments such as boiling, roasting, and frying have resulted in a decrease in antioxidant activity and levels. The reduction that came about as a result of dehulling, however, can be attributed to the removal of the grains' pericarp layer, which is known to be rich in polyphenol and antioxidant compounds. Consequently, in order to maintain their quality and potential health benefits, millet grains, their fractions, and food items need to be processed under optimal conditions. Additionally, the endogenous enzymes that are converted to simpler molecules with enhanced antioxidant activity during germination are responsible for the rise in antioxidant levels and their activities.

4. CHALLENGES AND FUTURE PERSPECTIVES

The information discussed above demonstrates that millet grains were similar to other grains like wheat, rice, and maize despite their high nutritional content and possible health benefits. Additionally, although millet grain has been shown to improve its nutritional value and

edibility through processing methods such soaking, fermentation, malting, and fortification/supplementation, its household usage remains mostly limited to rural populations. This is due to the lack of state-of-the-art millet processing methods that can provide large quantities of safe, manageable, ready-to-cook, or ready-to-eat commodities and meals that can be used to feed a large number of people in urban settings [92]. However, the need for food, fuel, and other requirements rises along with the global population. Therefore, there will be pressure on society to either alter its current crop-consumption patterns or boost agricultural output [93]. Crop diversification needs to be encouraged at the national and household levels in addition to higher yields. Offering more conventional and wholesome whole-grain and multigrain substitutes for refined carbohydrates is a vital component of therapeutic dietary modification and promoting the consumption of minor-grain meals [23]. It is commonly known that gluten protein plays a crucial part in producing excellent yet manageable baked goods and other grain-based foods that require elastic and extensible dough. However, considering that millet grains are gluten-free and based on the outcomes of several laboratory testing, it appears that they are not ideal for making pure-millet bread and other solid food products that are simple to handle. In order to encourage the use of millet grains, it appears that using it as a substitute for wheat in composite flours, complementary foods, and food blends is the best way to create nutrient-dense, "healthy," and secure food products that are of high caliber and can be stored for a long time. Additionally, there is a need for cutting-edge processing technology for decortication, milling, and other preparation procedures of millet grain food in order to make high-quality products on a commercial scale for urban consumers. In return, it is necessary to produce millet cultivars with high essential amino acid content and maintain a steady supply of premium millet grains for industrial needs. Future research studies should assess the nutritional value and potential health advantages of millet grains and their fractions in animal and human models to support efforts to promote their use as food.

5. CONCLUSIONS

There is a lot of potential for millets to increase food and nutritional security. It follows those millets, along with wheat and rice, should be included in the list of staple foods. Even in harsh environments like drought, millets grow well; certain wild types can even flourish in wetlands and inhabited regions. They are rich in minerals (calcium, iron, copper, magnesium, and other elements), B vitamins, antioxidants, and low-glycaemic index. They are also free of gluten. Millets are nutrient-dense and climate change-resistant crops because of these remarkable characteristics. These not only give farmers an extra source of income, but they can also improve the general health of the community. Initiatives for research and development as well as the establishment of policies are therefore necessary; some of them have already been carried out internationally, notably in India, whereas others must be done. Minor millets are highly nutritious and have a simple cultivation technique, but the scientific community needs to pay more attention to them. Scientists refer to them as "orphan cereals" since they are often overlooked. However, novel processing and preparation methods are needed to improve the millet diet's quality and enhance the bioavailability of the micronutrients. More research is needed on the metabolism, bioavailability, and health advantages of millet grains and all of its constituent parts in people. We'll examine the existing dietary inadequacies in underdeveloped countries in terms of protein, calcium, and iron by the inclusion of millet-based foods in international, national, and state-level feeding programmes.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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