International Journal of Plant & Soil Science

Volume 35, Issue 2, Page 45-56, 2023; Article no.IJPSS.96658
ISSN: 2320-7035

Underutilized Nutrient Rich Millets: Challenges and Solutions for India's Food and Nutritional Security: A Review

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Authors' contributions

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

Article Information

DOI: 10.9734/IJPSS/2023/v35i22758

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/96658

Review Article

Received: 01/12/2022
Accepted: 02/02/2023
Published: 22/02/2023

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ABSTRACT

The productivity of the rice and wheat farming system is now fast approaching stability, in spite of the fact that the green revolution assisted India in becoming self-sufficient. To introduce traditional grains that are both nutrient-dense and environmentally sustainable, agricultural diversification is necessary. Security in food and nourishment for everyone must be ensured. However, getting there is really difficult. Data readily available indicates that hunger levels are rising globally. Small millets are adaptable, less labor-intensive, resilient, nutritious, and sustainable crops that can help to some part mitigate the issues facing modern agriculture. Small millets are far less commonly consumed than major cereals. Small millets have been marginalized and neglected as a result of overdependence on a few numbers of plant species, namely, rice, wheat, maize, and potatoes. Energy, complex carbs, minerals, and phytochemicals are abundant in little millets. These can be used, according to studies, to effectively combat malnutrition, including both undernutrition and overnutrition. Millets are small-seeded grasses, appear to meet this description. These are eco-friendly and contain a macronutrient, and micronutrient content that is well-balanced. Millets can aid in the prevention of a variety of non-communicable diseases and have nutraceutical benefits. Millets are more palatable after soaking, roasting, germination, and fermentation processes, which also reduce anti-nutrients, enhance the physiochemical accessibility. of micronutrients, and increase their bioavailability. Value-added goods can increase millet demand and farmer revenue by being prepared and made widely available to the consumer. It's essential to create as well as spread millet-based food goods that offer low-income individuals' affordability, convenience, flavor, texture, and shelf stability. As a result, these superfoods have the potential to achieve nutritional and food security.

Keywords: Millets; nutritional; soaking; fermentation.

1. INTRODUCTION

One of the early crops to be farmed is millets, which are grains from the Poaceae grass family. The phrase "little millets" is a general word for the coarse cereals. There are several types of millet in it, such as finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*), barnyard millet (*Echinochloa crusgalli*), kodo millet (*Paspalum scrobiculatum*), small millet (*Panicum sumatrense*), guinea millet (*Brachiaria deflexa*), and browntop millet (*Urochloa ramosa*) [1]. Millets may grow successfully with less water, fertilizer, and herbicides in unfavorable soil conditions. In sense of soil climate adaptation, drought resistance, insect-pest tolerance and, management variables, millet has a competitive advantage over other cereals [2]. In addition, variables that are good for your health are crucial in addressing issues with hunger and malnutrition, especially in mid- and high-hill regions. With the help of subsidies, promoting millet products with agro-based companies, the dramatic improvement in tourism, and inspiring young farmers, millet has a strong potential for improving production. Proper national and local responses to the constraint will aid in raising millet growing from a minor cereal to standards fit for export [3]. Additionally thought to offer nutritional advantages for health, millets. These involve, but are not limited to, an improvement in the muscular, a decrease in cholesterol, the prevention of heart attack, protection against diabetes, and an increase in digestive system health [4,5]. Millets can tolerate water-limiting situations because of their improved water and nitrogen usage efficiency, which are agroecological features. For instance, while maize and wheat require 500 and 450 g of water, respectively, foxtail millet only require 250 g. Similar this, a study on finger millet found that for higher yield, nitrogen fertilizer requirements could be as low as 20–60 kg/ha. Micro- and macronutrients, total protein, fiber, and resistant starch are all abundant in small millets as well. In contrast, little millet and barnyard millet have high iron concentrations (between 10/100 g and 18 mg/100 g), while finger millet is high in calcium (around 364 mg/100 g) and potassium (about 320 mg/100 g). Foxtail millet and barnyard millet have significant levels of total protein (>10%), and small millet, foxtail millet, and fonio have high levels of crude fiber (7–14%). Additionally, most small millet is gluten-free, which makes it easier to prepare foods with a low glycemic index [1]. Numerous researchers have found that millets can be a significant source of critical nutrients like amino acids, minerals, and trace elements [6]. Wide variances in the nutritional makeup of pearl and finger millets should be obvious, of course [7]. According to Shweta [8], pearl millet is a significant source of thiamine, niacin, and riboflavin and has a higher energy content than cereal grains like rice and wheat [9]. Additionally, pearl millet contains similar amounts of nutrients including calcium, iron, and phosphorus as other grains [10]. Additionally, finger millet grows better in cooler climates with a little bit more rainfall (Tadele, 2020). As it considerably improves dietary health, finger millet is regarded as a crucial cereal. It is a crop that is neglected despite its important function in helping many disadvantaged farmers and families have access to food. Given that it contains essential amino acids like lysine, threonine, and valine, the protein contained in finger millet is regarded as excellent [11,12,13].

1.1 Nutrition Scenario and Food Security

Food security' exists when all people, at all times, have physical, social, and economic access to safe, sufficient, and nutritious food meet their dietary needs and food choices for an active and healthy life. The four pillars of food security are availability of food, access to food, utilization of food, and food stability. The term "food security" does not explicitly define the nutrition aspect of food of adequate sanitation, health care, and services, allowing for a healthy and active lifestyle." The world's population is steadily increasing, which is unquestionably not helping to the world's food security and nutrition, but rather is a significant threat. In order to fulfil the increased food demand of a population that is expected to grow by almost 40% between 2005 and 2050, agricultural production in general and crop production in particular must increase significantly. Aside from this, climate change is affecting agricultural productivity, food production, and natural resources, with impacts on food systems and rural livelihoods. For example, decline in the number of farmers has resulted in significant changes in how food is produced, distributed, and consumed globally. More than 820 million people throughout the world still experience hunger as of 2019, according to the FAO data, emphasizing the enormous difficulty of achieving the Zero Hunger objective by 2030. Another unsettling statistic is that 2 billion people all over the world suffer from moderate to severe food insecurity [14,15]. The world population is rapidly increasing, which is undoubtedly posing a serious threat to global food security and nutrition. Agricultural production in general and crop production in particular must increase significantly in order to fulfil the increased food demand of a population that is projected to expand by almost 40 % between 2005 to 2050. Aside from this, climate change and increasing climate variability and extremes are affecting agricultural productivity, food production, and natural resources, with impacts on food systems and rural livelihoods, including a decline in the number of farmers has resulted in significant changes in which food is produced, distributed, and consumed globally. According to the FAO, "2019 report, more than 820 million people throughout the world still hungry today, underscoring the immense challenge of achieving the Zero Hunger objective by 2030". "Another disturbing fact is that about 2 billion people worldwide suffer from moderate to severe food insecurity" [14].

Fig. 1. Different variant of millets

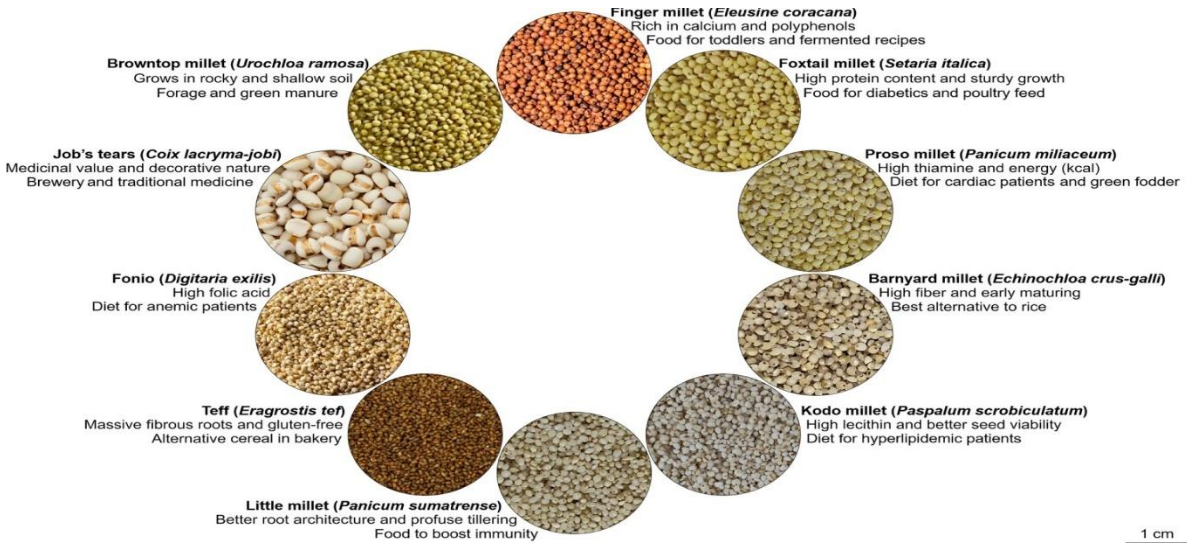

Fig. 2. Characteristic features of millets [1]

2. BALANCED DIET: CHOICES OF FOODS TO MEET THE REQUIREMENTS AND MILLET ROLE

"Balanced diet is one that includes a variety of foods in amounts and ratios that satisfy the body's requirements for calories, protein, fat, vitamins, and minerals. Foods are divided into five types based on the presence of the main nutrients. Cereals and millet are among them, along with pulses and legumes, milk and meat items, fruits and vegetables, and fats" [16].

The main criterion is satisfaction with hunger; hence grains are crucial to the discussion of food security. While millets and cereals are abundant in calories and other nutrients, they are low in many others. When compared to flesh meals, they have lower protein quality, less lysine, and less mineral bioavailability. Numerous diet surveys conducted in rural and urban areas of India's various regions have shown that diets are not balanced. A balanced meal consists of 60 to 70 percent of energy coming from grain, 15 to 20 percent from fat, and no more than 5 percent from sugar.

Rural Indians' diets largely consist of a single staple food and little else. Ascorbic acid, folate, zinc, iron, calcium, riboflavin, vitamin-A, and vitamin-B12 are among the nutrients that are inadequate in such a diet, which can, to some extent, guarantee adequate calorie intake. A recent survey conducted in rural India found that 62–76% of a family's energy comes from cereals, 7 percent from fats, and 2 to 5 percent from sugars, indicating that overall calorie consumption is adequate. However, compared to a balanced diet, there is a more than 50% shortfall in fat consumption, which not only reduces polyunsaturated fatty acids (PUFA), but also reduces the bioavailability of vitamins and phytonutrients that are fat-soluble.

"When comparing the distribution of nutrients among food groups, cereals and millet account for around 50% of nutrients like iron. A diet heavy in cereal-millet contains a lot of phytate, which is known to prevent the absorption of minerals. Consumption of minimally processed vegetables, fruits, milk, and meat products must be promoted in order to ensure the bioavailability of these nutrients and to enhance iron absorption. But among Indians, intakes of food groups that are crucial for enhancing the bioavailability of these minerals—400 vs. 153 vegetables and fruits; 300 vs. 103 milk and meat products CU/day—are just one-third of the intakes 7 recommended as per RDA. Similar to the requirement for folate, it can only be satisfied by eating enough of the four dietary categories (cereals, pulses, vegetables in particular green leafy and meat). In order to attain food and nutrition security, focus should be placed on providing food groups that contain both macro and micronutrients in suitable levels" [16].

"Diets of the poor will continue to be grossly inadequate for a long time to come unless there is a phenomenal improvement in their economic status to afford an adequate diet. Therefore, as an immediate measure, attempts should be made to improve the nutritional value of the cereals by the inclusion of inexpensive locally available food commodities, to prevent at least the major micronutrient deficiencies of vitamin A, iron, and zinc" [16].

3. NUTRITIONAL IMPORTANCE

"Maintaining nutritional well-being, which is a consistent force for health and development as well as the achievement of human genetic potential, is essential for the preservation of human overall physical well-being. Therefore, dietary quality should be taken into account in order to address the issues of widespread food insecurity and malnutrition" [18,19]. "Millets were discovered to have a high nutritional content that is comparable to that of main grains like wheat and rice, in addition to the advantages of their cultivation" [20]. "With the exception of lysine and threonine, millet proteins have also been discovered to be great sources of methionine. Millets are abundant in phytochemicals and minerals" [21]. As an illustration, it has been shown that resistant starch, soluble and insoluble dietary fibers, minerals, and antioxidants are all present in large concentrations in pearl millet. It is made up of 63.2% starch, 7.8% crude fiber, 7.8% crude fat, 2.1% ash, and 92.5% dry matter [22]. Because of its high lysine content, the protein concentrate from foxtail millet may be used as an additional source of protein in most cereals. As a result, it might be a useful culinary additive. Additionally, finger millet is believed to provide a number of possible health benefits, some of which are related to its polyphenol concentration. Comparable to other cereals and millets, it has a carbohydrate content of 81.5%, a protein content of 9.8%, a crude fibre content of 4.3%, and a mineral content of 2.7%. Its crude protein is generally more evenly balanced than that of other millets, with larger amounts of lysine, threonine, and valine than those found in wheat (1.2% fibre, 1.5% minerals) and rice (0.2% fibre, 0.6% minerals) [23]. Additionally, each gramme of dry weight of black finger millet contains 8.47 g of protein and 8.71 mg of fatty acids [24]. Despite having more polyunsaturated fatty acids in their fat content than any other cereal, kodo millet and small millet had the highest levels of dietary fibre. Unfortunately, since industrial methods for processing millets are not as well developed as those used for processing wheat and rice, adverse changes to these qualities during processing cannot be avoided. The millet grains can therefore be used to create a variety of nutritious food products with the help of value-added processes and suitable processing equipment, which may lead to significant demand from large urban populations and unconventional millet users [25].

In comparison to wheat protein, proso millet grain had significantly higher levels of leucine, isoleucine, and methionine. Its protein concentration (11.6 percent of dry mass) was also equivalent to wheat [26]. Millets can be used widely to produce a variety of food products, including baby foods, snack foods, and nourishing foods because they contain all the necessary ingredients. Additionally, a wider range of millet products are becoming available, such as millet porridge, millet wine, and millet nutrition powder made from both grain and flour [27]. Table 1 provides a summary of the usual nutritious makeup of several millet grains and other grains. Millets can be used widely to produce a variety of food products, including baby foods, snack foods, and nourishing foods because they contain all the necessary ingredients. Additionally, a wider range of millet products are becoming available, such as millet porridge, millet wine, and millet nutrition powder made from both grain and flour [27]. Table 1 provides a summary of the usual nutritious makeup of several millet grains and other grains.

List 1. Millets: An approach for sustainable agriculture and a healthy world [17]

Food Security	Nutritional Security	Safety from disease	Economic security
1. Sustainable foo source for combating hunger in changing world climate 2. Resistant to climate stress, pests and diseases	1. Rich in micronutrients like Calcium, iron, zinc, iodine etc. 2. Rich in bio active compounds 3. Better amino acid profile	1. Gluten free: a substitute for wheat in celiac diseases 2. Low GI: a good food for diabetic persons 3. Can help to combat cardiovascular disease, anaemia, calcium deficiency etc.	1. Climate resilient crop 2. Sustainable income source for farmers 3. Low investment needed for production 4. Value addition can lead to economic gains

Table 1. Nutrient composition of millets and other cereals (per 100 g edible portion; 12% moisture)

Food	Protein[a] (g)	Fat (g)	Ash (g)	Crude fiber (g)	CHO (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Rice (brown)	7.9	2.7	1.3	1.0	76.0	362	33	1.8	0.41	0.04	4.3
Wheat	11.6	2.0	1.6	2.0	71.0	348	30	3.5	0.41	0.10	5.1
Maize	9.2	4.6	1.2	2.8	73.0	358	26	2.7	0.38	0.20	3.6
Sorghum	10.4	3.1	1.6	2.0	70.7	329	25	5.4	0.38	0.15	4.3
Pearl millet	11.8	4.8	2.2	2.3	67.0	363	42	11.0	0.38	0.21	2.8
Finger millet	7.7	1.5	2.6	3.6	72.6	336	350	3.9	0.42	0.19	1.1
Foxtail millet	11.2	4.0	3.3	6.7	63.2	351	31	2.8	0.59	0.11	3.2
Common millet	12.5	3.5	3.1	5.2	63.8	364	8	2.9	0.41	0.28	4.5
Little millet	9.7	5.2	5.4	7.6	60.9	329	17	9.3	0.30	0.09	3.2
Barnyard millet	11.0	3.9	4.5	13.6	55.0	300	22	18.6	0.33	0.10	4.2
Kodo millet	9.8	3.6	3.3	5.2	66.6	353	35	1.7	0.15	0.09	2.0

All values except protein are expressed on a dry weight basis

Sources: (Hulse et al.[28]; United States National Research Council/National Academy of Sciences [29]; FAO [30]

3.1 Problems Associated with Millets

- Low profitability and productivity
- Less bio-availability
- Lesser attractive color
- More processing is needed
- Problems associated with marketing
- Lack of seed quality
- Ignorance by the government and researchers [31].

4. PROCESSING OF MILLETS

4.1 Effects of Processing Technologies on the Nutritional Quality of Millet Grains

In order to improve food items' nutritive value, sensory appeal, and practicality, some processing methods are applied. The bioavailability of micronutrients in plant-based diets can be increased using a number of typical home food processing and preparation techniques. These include germination/malting, heat processing, fermentation, soaking, and mechanical processing. By using these techniques, one can raise the physicochemical accessibility of micronutrients, decrease the amount of antinutrients such phytates, or increase the bioavailability of nutrients. The makeup of several millet grains and other grains is listed in Table 1.

4.2 Mechanical Processing Technologies

4.2.1 Decortication

Before eating, millet and a variety of other coarse grains are typically dehulled and given various treatments to enhance their flavour and suitability for meals [27]. According to others, finger millet is exclusively used in dishes made with flour because it cannot be decorticated like other cereals. This is mainly because millet grains are much smaller than other cereal grains. However, it was discovered that millet's endosperm structure was stiffened by hydrothermal treatment, which made it possible for decortication. Millet could not previously be cooked separately like rice to get a soft, pleasing texture in less than 5 minutes. The product's ability to make dough and paste, together with some of its functional characteristics, suggested that it may be employed for a variety of food applications [32]. The addition of ornamentation significantly altered the nutritional profile of finger millet that had been heatedly processed.

It was compared to abrasive decortication in the lab using equivalent kernel lots. Traditional decortication of pearl millet and white sorghum was carried out by manual pounding or by using a mechanical equipment. The grains' decortication qualities as well as their contents of iron, zinc, phytates, lipids, fibre, and starch were measured. Although there were no visible changes between the two typical decortication procedures, the data demonstrated that decortication had a number of effects on grain composition. Additionally, it was demonstrated that while millets' protein and fat levels were unaltered by decortication, their crude fibre, dietary fibre, mineral, total phenol, and antioxidant contents were noticeably decreased. As a result, millets lose some of their value as a food source [33]. Additionally, it was discovered that dehulling pearl millet grains reduced total phytic acid, polyphenols, and tannin considerably

($P \leq 0.05$) while enhancing the protein digestibility and millet's qualitative characteristics. Since different nutrients (such as minerals, fibre, and antioxidants) and antinutrients (such as phytates and tannin) are primarily concentrated on the outermost parts of grains (the pericarp and aleurone layer), shifting the pericarp during decortication lowers their contents [34]. Although decortication has been found to diminish a number of nutritional levels, including fibre and minerals, it is nevertheless commonly done to millet grains before eating in order to enhance their edible and sensory qualities as well as the appearance of their food items. Therefore, instead of employing outdated techniques, sophisticated decortication equipment is needed to efficiently and profitably decorticate vast quantities of grains.

4.2.2 Milling and sieving

Particularly in rural areas and for personal use, millet grains are typically ground using a non-motorized grain mill that is run by hand or in another non-electric fashion. However, another choice is to use a manual grain mill connected to a gas or electric engine by a pulley system. Numerous researchers have looked into how milling affects the nutritional content of millet grains and their milling fractions. One investigation found that grinding pearl millet changed the grain's overall chemical makeup. Particularly in rural areas and for personal use, millet grains are typically ground using a non-motorized grain mill that is run by hand or in another non-electric fashion. However, another choice is to use a manual grain mill connected to a gas or electric engine by a pulley system. Numerous researchers have looked into how milling affects the nutritional content of millet grains and their milling fractions. One investigation found that grinding pearl millet changed the grain's overall chemical makeup. Semirefined flour was low in antinutrients and had better mineral bio-accessibility due to the partial removal of the bran section, making it more nutrient-dense. The amount of ash in the bran-rich fraction, a byproduct of flour milling, is considerably ($P \leq 0.05$) higher. Steaming the millet at high pressures and temperatures also boosted the milling yield, albeit steaming above a certain point had a negative impact on the yield of head grains [35].

We investigated the chemical composition, bio accessible Fe, Zn, and Ca, in vitro digestible starch (IVSD), and digestible protein (IVPD) of whole finger millet flour (WFM), sieved finger millet flour (SFM), wafers, and vermicelli (polyphenols and flavonoids). The WFM and SFM flours were discovered to have extremely different compositions. Sifting boosted the WFM's digestibility and bio accessibility while reducing the number of nutrients and antinutrients present. WFM contained the largest levels of total polyphenols and flavonoids (4.18 and 15.85 g/kg, respectively), but SFM vermicelli had the highest bio accessibility [36]. Another study discovered that after polishing barnyard millet in a rice polisher for three minutes at 8% to 10% (db) moisture content, little to no nutritional value is lost. Protein, fat, ash, and fibre levels dropped as moisture and grinding time rose [37,38]. In order to enhance health, it is therefore suggested that utilizing whole grains flour is preferable to screening out the bran fraction, which is known to be rich in nutrients. Grains consequently lose some of their nutritious content and potential health benefits. Consequently, to assure a reliable source for industrial food uses on a commercial scale and to encourage their use, practical and motorized milling equipment for millet grains is needed to create a sizable amount of flour. The grinding and sieving of millet grains is usually carried out manually, as was already indicated for decortication. In return, millers must have access to a steady supply of high-quality millet grains. Future studies should concentrate on milling parameters that would boost millet flour yields while preserving its nutritional value and composition.

5. POTENTIAL HEALTH BENEFITS OF MILLET GRAINS AND THEIR FRACTIONS

“Diets rich in plant foods are protective against a variety of degenerative diseases, including cancer, cardiovascular disease, diabetes, metabolic syndrome, and Parkinson's disease, according to epidemiological evidence from research studies” [39]. Whole-grain cereals may also shield the body from age-related diseases like diabetes, cardiovascular disease, and various malignancies, according to compelling epidemiological research. But for a long time, it was thought that the fibre, essential fatty acids, vitamins, and minerals included in whole grains were what gave them their health advantages. However, the new research raises the possibility that a combination of additional bioactive compounds may be involved. They contain lipids, lignans, and phytosterols, which have hormonal effects, as well as tannins and phytic acid, which are antinutrients. Additionally, they contain oligosaccharides, phenolic acids, avenanthramides, flavonoids, resistant starch, and flavonoids. Given that they contain dietary fibres, proteins, energy, minerals, vitamins, and antioxidants that are essential to human health, millets must also be recognized as functional foods and nutraceuticals. Millets have been linked to several potential health benefits, including the reduction of blood pressure, cardiovascular risk, cholesterol, and the rate of fat absorption, the prevention of cancer and cardiovascular diseases, a decrease in the frequency of tumors, a delay in gastric emptying, and the provision of digestive bulk. In order to underline the significance of including grains or grain products in a regular diet for optimal health, the U.S. Department of Agriculture has adjusted its nutritional guidelines to place grains and grain products at the bottom of the food guide pyramid [40,41].

5.1 Antioxidant Contents and Activities

Dietary fibre and polyphenols, for example, have the potential to be phytochemicals with health-promoting qualities, according to research on food and health [42]. A lower risk of chronic diseases like cardiovascular disease, type 2 diabetes, some malignancies, and all-cause mortality has been linked to increased consumption of whole grains and meals containing whole grains [43]. Furthermore, when ingested with fruits and vegetables, whole grains' special phytochemical content raises the nutrient content of those foods [44]. The largest class of phytochemicals present in plant-based meals, polyphenols, has been associated with numerous health advantages. Due to their importance to human health, dietary polyphenols have drawn a lot of interest from nutritionists, food scientists, and consumers [45]. Kodo, finger, foxtail, proso, pearl, and tiny millet are just a few of the varieties of millet that are reported to contain large amounts of phenolic compounds and possess properties that decrease and chelate metals as well as act as antioxidants. However, the way specific millets are used will affect how effective they are as providers of antioxidants [46]. Studies on the antioxidant and nutraceutical benefits of important millet types, such as finger millet, pearl millet, and foxtail millet, have drawn a lot of attention. According to reports, foxtail millet has a polyphenol content of 47 mg per 100 g and tocopherol content of 3.34 mg per 100 g (on a wet basis), compared to proso millet's 29 mg and 2.22 mg, respectively, per 100 g and aatocopherol content of 3.34 mg per 100 g (on a wet . (wet basis).

A positive and significant relationship between polyphenolic content and radical cation scavenging capacity was also discovered (R2 0.9973, P 0.01) [47]. Only around 30% of the main constituent phenolics in the finger millet's polyphenols could be identified using high-performance liquid chromatography (HPLC) examination [48]. Additionally, phenolic acids were extracted using the milling fractions of finger millet (whole flour, seed coat, 3%, 5%, and 7%). It was shown that acidic methanol extracts from seed coat to whole flour were stable for up to 48 hours at pH 4, 7, and 9. They were high in polyphenol [49]. More than 50 phenolic compounds from various classes, including phenolic acids and their derivatives, dehydrodiferulates, and dehydrotriferulates, flavanof monomers and dimers, flavanols, flavones, and flavanonols (kod), have currently been positively or tentatively identified in four phenolic fractions of several whole millet grains (MS). However, in the in vitro test techniques used, the insoluble bound fraction of Kodo millet had the greatest phenolic content and antioxidant activity. Consequently, millet grains can be employed as functional dietary components and as sources of natural antioxidants, according to research findings. Dehulling and hydrothermal treatments have been found to have an impact on the phenolic content and antioxidant capacity of pearl millet grains. The oxidation and degradation processes that take place during heat treatments like frying, boiling, and roasting are what cause the decrease in antioxidant concentrations and activity. The removal of the pericarp layer from the grains, which is known to be high in polyphenol and antioxidant chemicals, is what causes the reduction brought about by dehulling. To preserve the quality and potential health advantages of millet grains, their fractions, and food products, the optimum processing practices must be used. Additionally, the endogenous enzyme's conversion of complex components to simpler compounds with enhanced antioxidant activity during germination may be responsible for the rise in antioxidant levels and their activities.

5.2 Millet for Diabetics

Hyperglycemia and changes in the metabolism of proteins, carbohydrates, and lipids are features of the chronic metabolic condition known as diabetes mellitus. The most prevalent endocrine condition is characterized by insufficient insulin production (type 1) or by a concomitant resistance to the effects of insulin and the insulin-secretory response (type 2). Despite the likelihood that natural inhibitors are safer, alpha-glucosidase and pancreatic amylase chemical synthetic inhibitors are essential in the clinical therapy of postprandial hyperglycemia. Consuming whole grains is advised as a way to prevent and manage diabetes mellitus, and epidemiological studies have shown that people that consume millet have a lower incidence of the condition [50]. Eating meals high in finger millet, for example, resulted in considerably lower plasma glucose levels, mean peak rise, and area under the curve. This is because finger millet has more fibre than rice and wheat. The antinutritional components in whole FMF, which are known to restrict starch digestion and absorption, may also be to blame for the reduced glycemic response of diets based on finger-millet. Additionally, feeding finger millet has been demonstrated to affect skin antioxidant status, nerve growth factor (NGF) production, and wound healing parameters in early diabetic rats with poor wound healing. Higher levels of oxidative stress indicators and lower levels of antioxidants are the key contributors to the poorer wound healing in diabetic rats. However, diabetic mice fed finger millet for four weeks saw a reduction in glucose levels and an improvement in their antioxidant status, which sped up the healing of cutaneous lesions. Studies show that cooked, dehulled barnyard millet is good for type 2 diabetes. Heat-treated millet has a low glycemic index of 41.7, compared to 50.0 for dehulled millet [51].

5.3 Millet and Cardiovascular Disease

“The risks of heart attacks and strokes are increased by obesity, smoking, eating badly, and not exercising. Cardiovascular disease is prevalent and on the increase in most countries throughout the world. When compared to rats on a diet of rice and other minor millets, rats fed a diet of native and processed starch from barnyard millet had the lowest levels of blood sugar, serum cholesterol, and triglycerides” [52]. “Furthermore, administration of proso millet protein raised plasma levels of adiponectin and high-density lipoprotein (HDL) cholesterol in genetically obese type-2 diabetic mice fed a high-fat diet” [53]. Additionally, compared to groups of hyperlipidemic rats given white rice and sorghum, animals fed finger millet and proso millet had considerably reduced serum triglyceride contents. In terms of blood total, HDL, and low-density lipoprotein (LDL) cholesterol levels, the sorghum group significantly outperformed the white rice, finger millet, and proso millet groups. Both finger millet and proso millet lower plasma triglycerides and protect against cardiovascular disease in hyperlipidemic mice. Additionally, a variety of dietary model systems, including cooked minced pork and stripped corn oil, were used to assess the inhibitory effects of phenolic extracts on in vitro copper-mediated oxidation of human LDL cholesterol. Millet extracts reduced the amount of LDL cholesterol that was oxidized by 1% to 41% at a final concentration of 0.05 mg/mL. However, kodo millet revealed the best prevention of lipid peroxidation, being comparable to butylated hydroxy anisole at 200 ppm, among all the food types employed in this investigation. All types of foods included in this study demonstrated efficient lipid oxidation suppression [54].

5.4 Millet and Aging

Nonenzymatic glycosylation, a chemical interaction between the amino group of proteins and the aldehyde group of reducing sugars, is a significant factor in diabetic problems and ageing [55]. Although it has been shown that phytates, phenols, and tannins can contribute to antioxidant activity crucial for health, ageing, and metabolic syndrome, millet grains are a rich source of antioxidants and phenolics. Additionally, it was discovered that methanolic extracts of kodo and finger millet may inhibit the glycation and cross-linking of collagen. Therefore, millets might help slow down the ageing process.

6. MILLETS ROLE IN PROMOTING NUTRITION SECURITY

Only two crops—wheat and rice—are necessary for India to have enough food supplies. Millets were the foundation of India's food and farming systems, but output and consumption have significantly reduced for a number of reasons, and farmers have neglected millions of hectares of dry land. In the most underdeveloped regions of India, these lands may provide employment if they could be put under agriculture. Besides, not only will food sovereignty be protected, but also, food security. The Government of India is implementing numerous initiatives that offer grains to lower-income households at reduced costs, but the Food Security Bill is supposed to be the first one to include millet in the Public Distribution System (PDS). As was previously mentioned, millets have a larger mineral content than other grains, however because of anti-nutrient factors, their bioavailability is limited. According to scientific research, millets' mineral availability can be increased by soaking, malting, popping, puffing, germination, and fermentation—simple and affordable home processing techniques that have been shown to increase the availability of nutrients from millets. As a result, if recipients of Food Security Bills are informed about these straightforward methods, nutriment security will also be handled to some extent within the constraints of the available resources.

7. CONCLUSION

The most recent studies that have been done to increase the nutritional content of millet grains and the foods made from them are presented in this overview. The results of the tests demonstrate that millet grains have levels of different nutrients that are healthy and comparable to major cereals. These nutrients include phytochemicals such phenolic compounds, minerals, vitamins, and dietary fiber. They might also have several positive health effects. To increase the standard of millet diets and the bioavailability of the micronutrients, however, new processing and preparation techniques are required. The bio-availability, metabolism and, health benefits of millet, grains and their many compounds in peoples require more investigation. It is also necessary to develop highly improved millet goods in order to stimulate the use of millets rains in urban, areas and open, up new markets for farmers to enhancement their revenue.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Muthamilarasan M, Prasad M. Small millets for enduring food security amidst pandemics. Trends in Plant Science. 2021;26(1), 33-40.
2. Tadele Z. Drought adaptation in millets; 2016.
   doi.org/10.5772/61929
   Available:http://dx.doi.org/https://.
   Access on 12 Feb 2020
3. Gyawali P. Production trend, constraints, and strategies for millet cultivation in Nepal: A study from review perspective. International Journal of Agricultural and Applied Sciences. 2021;2(1):30-40.
4. Sobana S, Sreerama YN, Malleshi NG. Composition and enzyme inhibitory properties of fnger millet (*Eleusine coracana* L.) seed coat phenolics: Mode of inhibition of α-glucosidase and pancreatic amylase. Food Chem. 2009;115(4):1268–73.
5. Amadou I, Gounga ME, Le GW. Millets: Nutritional composition, some health benefits and processing-a review. Emirates Journal of Food and Agriculture. 2013:501-508.
6. Anitha S, Govindaraj M, Kane-Potaka J. Balanced amino acid and higher micronutrients in millets complements legumes for improved human dietary nutrition. Cereal Chemistry. 2020;97(1):74-84.
7. FAO; 2017.
8. Shweta M. Pearl millet nutritional value and medicinal uses. IJARIIE-ISSN (O). 2015;1(3):2395–4396.
9. Taylor JRN. In: Wrigley C, Corke H, Walker CE, editors. Millet: In encyclopedia in grain science. London: Elsevier. 2004;2:253–61.
10. Adeola O, Orban JI. Chemical composition and nutrient digestibility of pearl millet (*Pennisetum glaucum*) fed to growing pigs. Journal of Cereal Science. 1995;22(2):177-184.
11. Ravindran G. Studies on millets: Proximate composition, mineral composition, and phytate and oxalate contents. Food Chem. 1991;39(1):99–107.
12. NNMB Technical Report No. 26. National Nutrition Monitoring Bureau (NNMB) Report of third repeat survey. Diet and nutritional status of rural population, prevalence of hypertension & diabetes among adults and infant & young child feeding practices. Hyderabad, India. National Institute of Nutrition, Indian Council of Medical Research; 2012.
13. Nutrient requirements and recommended dietary allowances for Indians. A report of the expert group of the ICMR. National Institute of Nutrition, ICMR; 2010.
14. Jeena AS, Rohit DC, Soe W. Millets for food and nutritional security in global climate change scenario. Souvenir; 2020.

15. Von Grebmer K, Bernstein J, Hossain N, Brown T, Prasai N, Yohannes Y. Global hunger index: The inequalities of hunger. International Food Policy Research Institute; 2017. Available:http://www.globalhungerindex.org/pdf/en/2017.pdf Access on 21 Jan 2018
16. Konapur A, Gavaravarapur SRM, Gupta S, Nair KM. Millets in meeting nutrition security: Issues and way forward for India. Indian J. Nutr. Diet. 2014;51:306-321.
17. Kumar A, Tomer V, Kaur A, Kumar V, Gupta K. Millets: A solution to agrarian and nutritional challenges. Agric Food Secur. 2018;7:31.
18. Singh P, Raghuvanshi RS. Finger millet for food and nutritional security. Afr J Food Sci. 2012;6(4):77–84.
19. IFPRI. Global Nutrition Report: Malnutrition Becoming the "New Normal" Across the Globe; 2016.
20. Parameswaran K, Sadasivam S. Changes in the carbohydrates and nitrogenous components during germination of proso millet (*Panicum miliaceum*). Plant Foods Hum Nutr. 1994;45:97–102.
21. Singh KP, Mishra A, Mishra HN. Fuzzy analysis of sensory attributes of bread prepared from millet-based composite flours. LWT—Food Sci Technol. 2012;48:276–82.
22. Ali MAM, El Tinay AH, Abdalla AH. Effect of fermentation on the *in vitro* protein digestibility of pearl millet. Food Chemistry. 2003;80(1):51–4.
23. Sripriya G, Antony U, Chandra TS. Changes in carbohydrate, free amino acids, organic acids, phytate and HCl extractability of minerals during germination and fermentation of finger millet (*Eleusine coracana*). Food Chem. 1997;58(4):345–50.
24. Glew RS, Chuang LT, Roberts JL, Glew RH. Amino acid, fatty acid and mineral content of black finger millet *(Eleusine coracana*) cultivated on the Jos Plateau of Nigeria. Food. 2008;2(2):115–8.
25. Mal B, Padulosi S, Ravi SB.. Minor millets in South Asia: learnings from IFAD-NUS project in India and Nepal. Maccarese, Rome, Italy: Bioversity Intl and Chennai, India: M.S. Swaminathan Research Foundation. 2010:1–185.
26. Kalinova J, Moudry J. Content and quality of protein in proso millet *(Panicum miliaceum L.)* varieties. Plant Foods Hum Nutr. 2006;61:45–9.
27. Liu J, Tang X, Zhang Y, Zhao W. Determination of the volatile composition in brown millet, milled millet and millet bran by gas chromatography/ mass spectrometry. Molecules. 2012;17:2271–82.
28. Hulse JH, Laing EM, Pearson OE.. Sorghum and the millets: Their composition and nutritive value. New York: Academic Press. 1980:1–997.
29. United States National Research Council/National Academy of Sciences. United States-Canadian tables of feed composition. Washington, DC: National Academy Press; 1982.
30. FAO (Food and Agriculture Organization).. Sorghum and millets in human nutrition. Rome, Italy: FAO; 1995.
31. Meena PC, Meena PC. Millets crop role in food and nutritional security of India. Int J Food Sci Nutr. 2018;3(6):216-218.
32. Shobana S, Malleshi NG. Preparation and functional properties of decorticated finger millet (*Eleusine coracana*). J Food Eng. 2007;79(2):529–38.
33. Bagdia A, Bala´zsa G, Schmidt J, Szatma´ria M, Schoenlechner R, Berghofer E, To¨ mo¨ sko¨ zi S.. Protein characterization and nutrient composition of Hungarian proso millet varieties and the effect of decortication. Acta Alimentaria. 2011;40(1):128–41.
34. Hama F, Icard-Vernie`re C, Guyot JP, Picq C, Diawara B, Mouquet-Rivier C. Changes in micro and macronutrient composition of pearl millet and white sorghum during in-field versus laboratory decortication. J Cereal Sci. 2011;54:425–33.
35. Dharmaraj U, Ravi R, Malleshi NG. Optimization of process parameters for decortication of finger millet through response surface methodology. Food Bioprocess Technol; 2011. DOI: 10.1007/s11947-011-0728-y Available:http://www.springerlink.com Access on November 22, 2011
36. Oghbaei M, Prakash J. Bioaccessible nutrients and bioactive components from fortified products prepared using finger millet (Eleusine coracana). J Sci Food Agric. 2012;92(11):2281–90.
37. Lohani UC, Pandey JP, Shahi NC. Effect of degree of polishing on milling characteristics and proximate compositions of barnyard millet (*Echinochloa*

frumentacea). Food Bioprocess Technol. 2012;5:1113–9.
38. Lost Crops of Africa: Volume I: Grains. Washington, DC: The National Academies Press; 1996. Available:https://doi.org/10.17226/2305.
39. Chandrasekara A, Naczk M, Shahidi F. Effect of processing on the antioxidant activity of millet grains. Food Chem. 2012;133:1–9.
40. USDA. Dietary guidelines for Americans. US Government Printing Office. US Department of Agriculture, Department of Health and Human Services. Washington, DC; 2000.
41. USDA. Nutrition and your health: dietary guidelines for Americans. US Department of Agriculture. Department of Health and Human Services, Washington, DC; 2005.
42. Devi PB, Vijayabharathi R, Sathyabama S, Malleshi NG, Priyadarisini VB. Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: A review. J Food Sci Technol; 2011. DOI: 10.1007/s13197-011-0584-9 Available:http://www.springerlink.com Access on November 22, 2011.
43. Lozano R, Naghavi M, Foreman K. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: A systematic analysis for the global burden of disease study 2010. Lancet. 2012;380:2095–128.
44. Liu RH. Whole grain phytochemicals and health. J Cereal Sci. 2007;46:207–19.
45. Tsao R. Chemistry and biochemistry of dietary polyphenols. Nutrients. 2010;2:123–146.
46. Chandrasekara A, Shahidi F. Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. J Agric Food Chem. 2010;58:6706–14.
47. Choi Y, Jeong H-S, Lee J. Antioxidant activity of methanolic extracts from some grains consumed in Korea. Food Chem. 2007;103(1):130–8.
48. Chethan S, Malleshi NG. Finger millet polyphenols: Optimization of extraction and the effect of pH on their stability. Food Chem. 2007;105(2):862–70.
49. Viswanath V, Urooj A, Malleshi NG. Evaluation of antioxidant and antimicrobial properties of finger millet polyphenols (*Eleusine coracana*). Food Chem. 2009;114(1):340–6.
50. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabet Care. 2005;28:37–42.
51. Ugare R, Chimmad B, Naik R, Bharati P, Itagi S. Glycemic index and significance of barnyard millet (*Echinochloa frumentacae*) in type II diabetics. J Food Sci Technol; 2011.
DOI: 10.1007/s13197-011-0516-8.
Available:http://www.springerlink.com
Access on September 2
52. Kumari SK, Thayumanavan B. Comparative study of resistant starch from minor millets on intestinal responses, blood glucose, serum cholesterol and triglycerides in rats. J Sci Food Agric. 1997;75:296–302.
53. Park KO, Ito Y, Nagasawa T, Choi MR, Nishizawa N. Effects of dietary korean proso-millet protein on plasma adiponectin, HDL cholesterol, insulin levels and gene expression in obese type 2 diabetic mice. Biosci Biotechnol Biochem. 2008;72(11):2918–25.
54. Chandrasekara A, Shahidi F. Antioxidant phenolics of millet control lipid peroxidation in human ldl cholesterol and food systems. J Am Oil; 2011b.
55. Monnier VM. Nonenzymatic glycosylation, the Maillard reaction and the aging process. J Gerontol. 1990;45:105–11.

Peer-review history:
The peer review history for this paper can be accessed here:
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