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Millets for food and health security: A review

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Abstract

Millets are small sized cereal food crops that are mostly native to Asia, especially India. The nutritional composition of these small grained crops has earned them the name of 'Nutri-cereals'. These belong to 'Pseudo' cereals and are a member of the family 'Poaceae'. In the field, these crops can withstand conditions generated by climate change and off-field their nutritional content helps them fight hunger and other health conditions thereby providing positive effects on health. Millets are rich in both macro and micronutrients, however, their health benefits are more pronounced due to the presence of micronutrients including vitamins, minerals, antioxidants, flavonoids, and polyphenols. The present world is struggling for food. Both, growing food and feeding the population is the biggest challenge, the whole world is facing today. Adverse climatic conditions are continuously challenging the productivity and yield of cereal crops and at the same time hidden hunger, malnutrition, obesity, and other degenerative diseases are affecting a large portion of the population due to unhealthy and non-nutritious food. Millets are a suitable answer to these problems. The present review is an attempt to explore the nutritional aspects of millets which makes it a suitable food option for the world's population. The benefits of its nutritional composition to support a normal healthy human life are also attempted to discuss health security.

Keywords food security, health security, millets, nutri-cereals, pseudo-cereals

Introduction

The whole world is fighting for survival amongst many existing and upcoming problems including climate change, malnutrition, hidden hunger, and many more. Natural calamities, extreme weather conditions, and fluctuating environmental temperatures are worsening the conditions of food production and endangering food security. Ever increasing population and availability of limited resources are now challenging the health security of the population. Today, deficiency of nutrients is not only the problem but excess consumption of unhealthy food stuff is becoming a challenge. There is a shift in the food consumption pattern of people and it has become a cause of concern because it is no longer a balanced diet but has become an unhealthy imbalanced nutrient diet. Thus, it is the urgent need of the hour to address this problem at the earliest so that the population especially the younger generation can be provided with a healthy and balanced diet or at least we should come up with such options which are good for the security of both food and health. Millets are small-seeded grass crops that are climate change-resistant as well as nutritionally beneficial with various health benefits. These crops are resistant to extreme climatic changes viz., temperature, water, and humidity. They can thrive well in drought-hit areas and areas of prolonged high temperature, less groundwater, and even in the least irrigated soils that too without compromising their yield. Their inherent genetic traits help them to perform well in all types of extreme weather conditions, especially harsh high temperatures. These crops are native to the Asian and African subcontinent and have been cultivated for ages. However, the green revolution and hybridization of crops for better production and ease of processing covered the cultivated area of millets and now these are mostly found in uncultivated, barnlands. Still, in some of the pockets of Asia and Africa, the major millets are cultivated for food, feed, fodder, and other related uses.

During the last couple of decades, climate change and related environmental conditions have affected the production of food crops and it has affected the nations economically. This has given a boost to millet production and cultivation and now millets are being recognized as a global food commodity. These are now being considered as food that is nutritious, healthy, and can serve as a functional food for the population. India recognized the potential of millets and the celebrated year 2018 as the "Year of Millets". Also, the Ministry of Agriculture and Farmers Welfare, GoI declared them as "Nutri-cereals" recognizing their potential for production, consumption, and trade [1]. In this process of global change where food is recognized to play a vital role in improving the health status of the population, especially the malnourished and the ailing population, the United Nations decided to declare the year 2023 as the "International Year of Millets" [2-3]. The objective of the declaration was to create awareness about the nutritional and health benefits of millet and popularize as well as adapt its cultivation amongst the farmers facing hard times due to climatic harshness.

India lives in villages and some of our farmers still in practice of growing traditional crops including millets and this makes India the largest producer of millets during the years 2001-2009 [4]. Some millets are grown as major crops in some states and some as minor crops by farmers eg., pearl millet is a primary crop of Rajasthan and Gujrat and Finger millet is dominantly grown in Gujrat and Tamilnadu. Sorghum is widely cultivated in parts of Maharashtra, Telangana, Central India, and Andhra Pradesh.

Classification of millets

Millets are small seeded crops that grow well in warm climates, low irrigated, and tough soils. These are annual crops that are hardy and require the least inputs for cultivation. In addition to their nutritional benefits, they exhibit many health benefits protecting the population against many deadly diseases. These are referred to as nutri-cereals for their nutritional quality and health benefits. As per FSSAI Guidance note on millets [1], millets are classified into three categories:

1. Major millets: Sorghum (*Sorghum bicolor*), Pearl millet (*Pennisetumglaucum*) and Finger millet (*Eleusinecoracana*)

2. Minor millets: Foxtail millet (*Setaria italic*), Kodo millet (*Paspalumsetaceum*), Barnyard millet (*Echinochloautilis*), Little millet (*Panicumsumatrense*), Proso millet (*Penicummiliaceum*)

3. Pseudo millets: Amaranth and Buckwheat

In addition, barley (*Hordeum vulgare*), oats (*Avena sativa*), and maize (*Zea mays*) are also included and considered coarse cereals. Millets belong to the family Poaceae and subfamily of grasses i.e., Panicoideae [5], and are a suitable alternative to cereal crops as they grow well in conditions in which major cereal crops fail [6].

Sorghum (Sorghum bicolor)

The most popular and widely cultivated millet is sorghum. It is also popularly referred to as great millet and guinea corn. The seed germ contains 80 percent protein as albumins and globulins and the remaining protein is available as storage protein in the endosperm as prolamins, and glutalins [1, 7]. Additionally, minerals and vitamins are available in the aleurone layer. Sorghum is a rich source of slow digestive starch (SDS) and dietary fiber (9.7 - 14.3 g) which helps reduce cholesterol [4].

Pearl millet (Pennisetum glaucum)

It is one of the most common millet grown in the Indian subcontinent and parts of Africa. It is commonly used as bird feed. Pearl millet contains considerably higher quantities of proteins (12-16 percent) and lipids (4-6 percent). The presence of dietary fiber (11.5 percent) makes it an idle option for diabetics, as it takes more time to digest [1]. Additionally, it is a rich source of niacin, Vitamin E, and B-complex vitamins. Amongst minerals, it contains folic acid, magnesium, iron, copper, zinc, and calcium. The millet contains approximately 62.8 to 70.5 percent starch, 1.2-2.6 percent soluble sugar, 21.9-28.8 percent amylase [8].

Finger millet (Eleusinecoracana* L. Gaertn*)

It is a common millet available in fields whose panicles are finger-shaped and thus is referred to as finger millet. The millet contains sulphur rich amino acids making it a more desirable option as food. In the cereal category, it is one of the richest sources of calcium (350 gm/100gm). As the crop grows well in hills, drought and famine affected areas, it is a suitable option to support food security [9]. Also, the calcium content of the finger millet can easily meet the 50 percent requirement of daily calcium, as recommended by ICMR, in all categories. Additionally, it is suitable for pregnant and lactating women, as it meets 40 percent of their daily calcium requirements [10]. Finger millet contains the highest amount of flavonoid (1896 μg/g) in soluble fraction [11].

Foxtail millet (Setaria italic)

Foxtail millet is valued for its nutritional properties and medicinal importance. It is also known as Italian millet and is known to be cultivated since ages [12]. It contains approximately 12.3 percent good-quality protein and 3.3 percent minerals. It is found to have the highest thiamine content, amongst millets, which is approximately 0.59mg/100g. In traditional medicine, it is used as an emollient, astringent, and stomachic and is a suitable option to treat dyspepsia and food stagnancy [13].

Kodo millet (Paspalum setaceum)

This millet is indigenous to the Indian sub-continent and forms the mainstay of dietary requirements of people in Kerala, Tamilnadu, North Uttar Pradesh and is known by the names of *varagu*, *harakaand arakaluamongstlocal* population. It is a crop of tropics and sub-tropics especially the damp areas. The millet is high in protein (11 percent) and fiber (14.3 percent) and low in fat content (4.2 percent). It is a rich source of B vitamins, especially niacin, folic acid, and pyridoxine. It contains a good amount of lecithin and thus is appreciated for its use in enhancing nervous strength. It is an excellent source of both macro and micro minerals namely calcium, potassium, iron, zinc, and magnesium. The millet lacks the protein ‘gluten’ and is dominantly used as a ‘gluten-free’ food which is beneficial for people with gluten intolerance. Also, it is found to help people with high blood pressure and cholesterol levels and is beneficial for women proceeding toward menopause [1, 14].

Barnyard millet (Echinochloa spp)

Barnyard millet is also known as *Japanese* barnyard millet and is cultivated both for feed and fodder purposes. The crop is an important small millet with an approximate production of 87000 tons per annum) and productivity (857 kg/ha) ranks India in second position amongst millets [15]. The millet is a rich source of easily digestible protein and dietary fibers of both soluble and insoluble fractions. It is the richest source of niacin vitamin (4.2 mg/100gm) amongst millets. It is a convenient source of important fatty acids including linoleic acid, palmitic acid, and oleic acid. It is found to be effective in reducing blood glucose and lipid levels and is also recommended for persons suffering from cardiovascular disease and diabetes mellitus. The grains of barnyard millets contain Gamma-amino-butyric acid (GABA) and beta-glucan which is a popular antioxidant and helps in reducing blood lipid levels [1, 14].

Little millet (Panicum sumatrense)

The millet as per its name is smaller in size than the usual millet seeds. This annual herbaceous plant was domesticated in India and is grown up to the latitude of 2100m above sea level. The plant grows up to the height of 30cm to 1m with slightly folded, linear, and hairy leaves. It is considered a reliable crop that can withstand adverse climatic conditions and responds well, both in water logged or drought conditions. The millet is nutritionally rich and contains about 38 percent dietary fiber and high iron content. The seeds have an excellent antioxidant activity [1, 14].

***Proso millet (Panicum miliaceum* L.)**

It is somewhat similar to little millet but the seeds are slightly bigger than that. The crop is grown annually in summer and resembles drooping grass and thus is also called 'broom corn'[16]. Millets are the richest source of proteins (12.5 percent). It forms a cheaper source of manganese and calcium. It holds various health benefits including reducing cholesterol levels in the blood thus reducing the risk of heart disease. It contains the highest amount of carotenoids among millets and it is more than wheat also [11].

The millet usually appears as grass and is annually grown in summer. The panicles of crop droop down and resembles a thus is also referred to as "broom corn". Amongst the millets, proso millet contains the highest carotenoid and is also more than wheat.

Amaranth (Amaranthus)

It is a high protein (13-14 percent) pseudo cereal which is a carrier of an essential amino acid lysine. It consists of 6-9 percent oil which consists of about 77 percent unsaturated fatty acid. It is a good source of iron, magnesium, phosphorous, potassium, and calcium. Amaranthus is appreciated for its dietary fibers and phytosterols which help lower cholesterol. Additionally, Amaranthus is rich in bioactive peptides which are found to help prevent hypertension and cancer in human beings [1]. The plants sometimes grow as weeds in the fields and are also consumed as green in the fresh state.

Buckwheat (Fagopyrum esculentum)

It is a commonly consumed pseudo cereal rich in protein with lysine as an important amino acid. It is a good source of starchy carbohydrates and fats having essential fatty acids mainly PUFA (polyunsaturated fatty acid) linoleic acid. The pseudo cereal is a source of vitamins B1, C, and E with minerals including copper, zinc, and manganese. The bioavailability of these minerals is very high in amaranthus as compared to other cereal grains. Amaranthus is rich in soluble fibers and polyphenol compounds. The pseudo cereal is considered important in preventing high blood pressure, inflammation of tissues, and cancer due to the presence of a bioflavinoid named rutin [1]. It grows well in extreme weather conditions and is a common food for fasting Indians.

Millets for food security

Availability of food, that is balanced or nutritious, has become a dream in today's world. The population of the world is multiplying and the availability of land for food is shrinking. Additionally, rapid development and urbanization have converted villages and farmlands into concrete jungles which has changed the farming systems and cropping patterns in the fields. Changing food habits, preference for easy-to-process and cooked foods, social status, etc., have contributed to the economic imbalance in food availability. Today, either substandard quality food is available at subsidized rates or the so called healthy food or good quality food is available for high payers. This has created a nutritional gap in the population where they are malnourished either due to non-availability of proper nutrition or, their diet is over-nourished with a specific nutrient. Climate change is posing another threat to crop cultivation and thus the availability of food. Changing environmental temperatures, floods, drought, and other extreme conditions are worsening the condition of farmers. Soils are depleting and the use of bio-chemicals for crops is causing a dual threat to the environment as well as the human population. It's poisoning the environment as well as the food. Therefore, it is an urgent need of the hour to look for an alternative that is safer for humans and is environmentally friendly. Millets are a suitable answer to this crisis, which is easy to cultivate and nutritious as food. It is a suitable crop for extending food security to the population in the long run. It is a sustainable crop that can be easily grown in varied kinds of soils and environmental conditions. It is a sustainable crop for adverse agro-climatic conditions [17]. Millets possess substantive potential to add diversity to the food basket thus helping food security [18]. Presently, Food security is a major concern for all countries of the world. Climate change, pandemics, and insufficient crop production are contributing to malnutrition, hidden hunger, and many health problems among the population. at this time, millet is a suitable option to be included in the diet as a staple food [3]. Millets grow well in marginal areas with complex conditions of soil, environment, water, and more, where major cereal crops fail to give significant yields [6]. These can serve as a source of nutrition for millions of people, both healthy and malnourished, and people living in hot, humid, and dry regions of the world [19].

Millets for health security

The nutritional composition of millets is promising as it includes carbohydrates (60-70%), fats (1.5-5%), proteins (7-11%) and crude fiber (2-7%) in sufficient amounts. These are loaded with B vitamins mainly, riboflavin, niacin, thiamine, folacin, and minerals, especially calcium, iron, manganese, magnesium, and phosphorus. These are a rich source of both free and bound essential fatty acids including oleic, palmitic, linoleic acids and diacylglycerols, digalactosyl diacylglycerols, p-serine, p-ethanolamine, p-choline, monogalactosul respectively[20]. Proteins in millets are made up of essential amino acids especially sulphur-containing i.e. methionine and cysteine but lack in lysine and threonine [21-22]. Oil from millets is a good source of linoleic acid and tocopherols [23]. In addition to these major nutrients, millets contain ample amounts of phytochemicals as bound phenolics (ferulic acid) and free phenolics (protocatechuic acid), β-glucan, phytates, inulin, lignan-resistant starch, and sterols [24]. Millet grains are alkaline in nature and are gluten-free [25]. Along with nutritional benefits, millets, if included in daily diet, help in health management by controlling the conditions causing diseases like diabetes mellitus, obesity, hyperlipidemia, etc. [26]. Millets act as reservoirs of both macro and micro nutrients including carbohydrates, fats, essential amino acids, minerals, vitamins, and organic compounds, and are superior to most cereals. This makes millets anti-carcinogenic, anti-mutagenic, anti-oxidative, and anti-microbial in nature.

Cancer

Millets contain some “antinutrients” in the form of phenolic acids, tannins, and phytates [27], which hinders the absorption of some of the macronutrients in one form or another. However, these antinutrientsare found to be effective against the initiation and progression of breast and colon cancer in animals [28-30]. A novel Fibroin-modulator-binding protein 35kD protein is found helpful in inhibiting cell growth causing colon cancer (*in vivo*) and is successfully extracted from foxtail millet (*Setaria italic*). The protein arrests the G1 phase and initiates the loss of mitochondrial the transmembrane potential resulting in apoptosis *viz*., a programmed cell death by activating caspase [31]. Another study on the dietary supplementation of foxtail millet was reported to activate gut receptors thus treating colitis-associated colorectal cancer. The said in vivo study [32] revealed the suppressing effect of millet based diet on the STAT-3 (Signal Transducer and Activator of Transcription) signaling pathway [29] which is responsible for evasion of apoptosis in cells responsible for causing cancer through uncontrolled cell proliferation and angiogenesis.

Diabetes

Daily consumption of millet is found to help reduce the risk of diabetes. The presence of phenolic compounds (alpha-glucosidase and pancreatic amylase) partially inhibits enzymatic hydrolysis of complex carbohydrates thereby reducing postprandial hyperglycemia [33]. Millets help to strengthen the body's immune system due to the presence of ‘Flavonoids’ which act as antioxidants in the body. Consumption of millet on a daily basis reduces the risk of diabetes in humans. The presence of aldose reductase, a classic phenolic compound, acts as an inhibitor for sorbitol buildup. This helps to reduce the risk of cataracts (eye disease) which is usually triggered by diabetes [34]. In addition, starch available in millets is enriched with leucine and gets slowly digested which makes millets a good food for diabetics [35-37]. Further, both *in vitro* and *in vivo* studies have found the postprandial hypoglycemic effect of millets when used as a functional food ingredient [38-42].

Heart disease

Niacin is found to play an important role in lowering the risk of Cardio Vascular Diseases (CVD's) by improving lipoprotein abnormalities and lowering HDL and triglycerides [43]. Additionally, phytic acid helps to lower the cholesterol levels in the body [44]. Millets are rich in both, niacin and phytochemicals containing phytic acid and thus are recommended as food for lowering the risk of CVD's. *In vivo*, studies have shown the lowering effect of millets on LDL and triglyceride levels and increasing HDL [41, 45]. Also, consuming millet had a decreasing effect on blood glucose and lipid levels without affecting HDL levels [46]. Furthermore, millets are the storehouse of antioxidants [29-30] and they are available in abundance. This makes it a more important food to reduce ROS (Reactive Oxygen Species) and inhibition of oxidative stress which effectively prevents the risk of radical-mediated diseases and other related degenerative diseases [47-48].

Also, the presence of flavonoids including apigenin, catechin, daisein, orientin, isoorientin, lutolin, quercetin, vitexin, isovitexin, myricetin, sponarin, violanthin, lucenin-1, and tricin in millets [30, 38, 47, 49] makes it more powerful. The antioxidant capacity of millet is complemented by the presence of Vitamin E in it [11].

Celiac disease

Consumption of cereal-based diets having a portion of gluten can be life threatening for gluten-sensitive/ intolerant people. Millets can be a supporting and healthy option for these people as millets are gluten-free [29, 30, 50]. Additionally, the presence of antioxidants and carotene in millets supports the normal body physiology of such individuals [51].

Anti-fungal and Anti-bacterial effects

Millets exhibit anti-bacterial and anti-fungal properties [48, 52-53] against many pathogens *viz*., *E. coli*, *B. cereus*, *L. monocytogens*, *P. mirabilis*, *S. typhi*, *P. aeruginosa*, and *Y. enteroclitica* [54-55].

Probiotic and Prebiotics benefits

Fermentation of millets is an easiest option for the purpose of consumption by common people. It will act as a natural probiotic to benefit the gut of individuals. Additionally, the presence of polysaccharides in millets makes it a 'Prebiotic' food as it helps to increase the population of friendly intestinal bacteria in the gut thus improving digestion. Fermented millet-based food is recommended for the treatment of diarrhea in young children [56]. In Africa, millet-based *koko* (food product) as porridge and drink is prepared by fermentation [57]. The use of lactic acid bacteria in the preparation of fermented porridge is also common [23].

Conclusion

With the advancement in technology, the food is affected and thus the physiology of humans. The food that is cultured to provide more nutritional benefits is adversely affected by the factors of climate change and vice-versa. Now it's high time that we realize the importance and health benefits of our traditional food crops and include them generously in our daily diet. The population increase is expected to mark a 9 billion stat by 2050 of which a major portion of the population will be suffering from hunger resulting in food and health security [58-59]. Emission of greenhouse gases, global warming unexpected rains and droughts are directly affecting crop yield and productivity negatively. The said agriculture sustainability and food security are endangered [60]. Millets are an answer to this well-predicated chaos as their productivity and yield is not affected by climatic changes. These can easily be cultivated in semi-arid and arid regions, they can conveniently withstand biotic and abiotic stresses and they can give a considerable output (yield) in lowlands that too with minimal inputs [61]. The nutritional richness of millets holds the capacity to fight hunger and deadly and degenerative diseases. It is a potential crop for providing food and health security to the nations of the world.

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