Millets: Superfood of the Century: Importance, challenges and opportunities: A review

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 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.

Introduction:

The world's population is projected to grow to 9.1 billion people by 2050 (FAO, 2009a). It is obvious that urgent action is required to ensure increased food supply and food security considering the restricted land resources. 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 resulting in 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. 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 (Food and Agriculture Organization, 2019). 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 (FAO,2012). Estimates indicated 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 (Wheeler and Braun, 2013). 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. 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 continue 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 won't be enough to feed the growing population around the world (Downing *et al*., 2000). Furthermore, the majority of scientists concur that crop output would be severely decreased by the current rates of global warming and greenhouse gas emissions. 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 practises, which are practised in various parts of the world, typically result in higher emissions (Olesen et al., 2002). 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 (Jain *et al*., 2016). They are widely cultivated and the main sources of nutrition for the entire world's population despite having greater emission rates. 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 (Prasad and Staggenborg, 2009). 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 (Gupta *et al*., 2017). 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. Ninety-seven percent of millet is produced in developing nations, making millet significant crops in the semiarid tropical regions of Asia and Africa (Vinoth and Ravidran, 2017). 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, millet have played a significant role as a staple meal, especially in Asia and Africa. Since millets are C4 plants, they have a much more efficient photosynthetic system than C3 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 (Lu *et al*., 2009). The most significant varieties include foxtail, finger, proso, and pearl millet. Pearl millet accounts for roughly half of the world's millet production. 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. 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 (Singh et al., 2019). 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). Millions of people every day 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 (Prasad and Staggenborg, 2009). 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 (Awika, 2011). 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 provides detailed nutritional composition and its benefits to humans and livestock, need of growing millets, various constraints and perspectives associated with it.

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	Guigaz and Del'agronome, 2002
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.	Devi *et al.*, 2014
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	Zarnkow *et al.*, 2009
Foxtail Millet	*Setaria italic*	Italian millet, German millet, or hay millet	Less water, short duration	Vetriventhan et al., 2012
Barnyard Millet	*Echinochloa crusgalli var. Frumentacea*		Drought tolerant, rapid maturation rate	Zhang et al., 2007
Kodo Millet	*Paspalum scorbiculatum*		High drought resistance, Good yields, period of 80–135 days	Arendt and Dal Bello, 2011

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 (IFPRI, 2016). 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 (FAO, 2015). The World Health Organization has previously classified obesity-related problems like diabetes and cardiovascular disease as an epidemic (WHO,2015). The majority of undernourished people in the world reside in India. Globally, 4 69,000 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 (Von Grebmer *et al*., 2017). 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.

Millets are equivalent to and occasionally have higher nutrient levels than conventional cereals in terms of calorie value, protein, and macronutrients. As a result of their high quantities of calories, calcium, iron, zinc, lipids, and high-quality proteins, they significantly contribute to the diets of both humans and animals. They are also abundant providers of vitamins and dietary fibre. Here, is the nutrient composition of millets:

1. **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 % (Cheik *et al*., 2006) 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 (Hadimani *et al*., 2001). However, according to Bhatt *et al*., 2003, the total carbohydrate content of finger millet ranges from 72 to 79.5 %. Additionally, Wankhede *et al*., 1997 (a) 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.
2. **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 (Jha *et al*., 2013). Additionally, Anitha *et al.* (2019) 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 (Burton *et al*., 1972). Contrarily, finger millet has about 5-8 % protein (Chethan and Malleshi, 2007) recorded the greatest protein level for finger millet at nearly 11 %, and Anitha *et al.* (2019) documented a proportion of 6.32 % in finger millet. Furthermore, Taylor (2004) 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 *et al.* (2003) 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 contains more lysine, threonine, and valine than other millet, it is somewhat balanced in terms of its concentration of important amino acids (Ravindran, 1991).

3. **Dietary fibre:** Fibre is thought to be beneficial for gut health, and a moderate diet of foods high in fibre may help to promote gut health (McIntosh *et al*., 2003). Fibre plays a similar role in the prevention of diabetes, colon cancer, and heart disease (Eshak *et al*., 2010). Bowl movement is enhanced by the pearl millet's high dietary fibre content, which ranges from 8 % to 9 % (Rooney and Miller, 1982). Additionally, due to its slow digestion, it prolongs the transit time, reducing the absorption of glucose into the blood, which benefits non-insulin-dependent diabetic patients. People who eat millet have a lower incidence of diabetes (Shobana *et al*., 2009). Additionally, the fibre in millet may help lower bad cholesterol while raising good cholesterol. It inhibits the body from producing bile acids, which results in gallstones (Shweta, 2015). In addition, pearl millet's high fibre content slows the passage of food from the stomach to the intestines. This results in longer gaps between meals, which helps avoid obesity.
4. **Lipids:** The fat content of pearl millet is thought to be between 5 and 7 percent (Gopalan *et al*., 2003) as compared to 3.21 to 7.71 percent in maize (Ullah *et al*., 2010). The percentage of lipids in finger and pearl millet was also reported by (Himanshu *et al*., 2018) to be 1 % and 5 %, respectively. Pearl millet has a high concentration of fatty acids such

as palmitic, stearic, and linoleic acids, while maize has a lower percentage of oleic acid (Adeola and Orban, 1995). The overall lipid content of pearl millet grains is larger than that of other millet species, ranging from 1.5 to 6.8 % (Taylor, 2004). The contents of free and bound lipids in pearl millet are, respectively, 5.6 to 6.1 and 0.6 to 0.9 %. Sridhar and Lakshminarayana (1994) reported that the overall lipid content of finger millet, was 5.2% (2.2 % free lipids, 2.4 % bound lipids, and 0.6 % structural lipids). On the other hand, oleic, palmitic, and linoleic acids were found to be the main fatty acids found in finger millet. Unsaturated fatty acids make for 74.4 % of finger millet's total fatty acid production compared to saturated fatty acids' 25.6 % (Kunyanga *et al*., 2013).

5. **Macronutrients:** Martnez-Ballesta *et al.* (2010), environmental stresses such as high salt concentrations, limited water accessibility, and extreme temperatures have been shown to affect the mineral content of food. The overall mineral and trace element content of pearl millet depends on the type of soil. Ash concentration in pearl millet and maize, respectively, ranges from 1.6 to 3.6 % and 0.86 to 1.35 %. Pearl millet has higher quantities of minerals than maize, including calcium, phosphorus, magnesium, manganese, zinc, iron, and copper (Adeola and Orban, 1995). Due to its high oil content, pearl millet is also regarded as an excellent source of fat-soluble vitamin E (2 mg/100 g). The grain is regarded as an excellent source of vitamin A (Taylor, 2004). Florence *et al*. (2014), pearl millet contains between 45.6 and 48.6 mg of calcium per 100 g. Additionally, it contains a lot of phosphorus, a crucial component found in the mineral matrix of bone, as well as adenosine triphosphate, or ATP, the body's primary energy source. Also, it promotes bone development and healing. According to certain research (Nambiar *et al*., 2011) the bioavailability of iron may be hampered by phytates, oxalates, and polyphones, which are found in high concentrations in pearl millet. Contrarily, finger millet has a high calcium content that varies from 162 mg/100 g to 487 mg/100 g depending on the genotype (Vadivoo *et al*., 1998). According to a report by Singh Raghuvanshi (2012), finger millet has 344 mg of calcium per 100 g. Additionally, millets contain a significant amount of magnesium, which is thought to help the body fight diseases like cancer. Bachar et al. (2013) stated that magnesium content in finger millet ranged from 84.71 mg/100 g to 567.45 mg/100 g. Additionally, finger millet is regarded as a rich source of natural calcium, which promotes bone growth and lowers the incidence of fractures.

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

(Hariprasanna *et al*., 2014)

6. **Polyphenols:** The body's immune system is believed to be strengthened by the presence of the primary polyphenols, which are abundant in millet and include phenolic acids and tannins (Chandrasekara *et al*., 2010). The enzymatic hydrolysis of complex carbs can be somewhat inhibited by millet phenolics, which also inhibit malt amylase, -glucosidase, and pancreatic amylase, all of which lower postprandial hyperglycemia. Similarly to this, ferulic and p-coumaric acids, which are present in whole pearl millet, are thought to have the ability to reduce cancer cells (Chandrasekara and Shahidi, 2011). According to Devi *et al.* (2014), the phenols found in millets have been shown to offer several health benefits, including the ability to serve as an antioxidant, anti-inflammatory, and antiviral. In addition, celiac disease is a genetically predisposed condition brought on by consuming gluten. Millets help to prevent celiac disease by minimizing the discomfort brought on by typical cereal grains that contain gluten because they are gluten-free (Saleh *et al*., 2013).

Millets contain phenolic acids, which occur (60%) in bound and free forms. The most prevalent phenolics in millets are hydroxycinnamic acids, which are primarily located in the phenolic acids' insoluble-bound regions (Liang and Liang, 2019). Ferulic acid, an antioxidant, is the most prevalent form of hydroxycinnamic acid. Antioxidants are well-known substances that reduce the body's exposure to free radical damage and have anti-inflammatory properties (Lobo *et al*., 2010). Additionally, millet grains have been discovered to contain ferulate dimers, which exhibit considerable antioxidant activity (Emiola and Rosa, 1981).

Further, the flavonoids found in millet grains include anthocyanidins, chalcones, amino phenolics, flavanols, flavones, and flavanones. Furthermore, according to Dykes and Rooney (2006), proanthocyanidins, also known as condensed tannins, are thought to be present in certain millet cultivars. Significant amounts of tannin are primarily found in colored millet types (McDonough *et al*., 2000). This finding was linked to the presence of condensed tannins because they significantly contribute to the colour of the grain. However, a high concentration of condensed tannins may negatively impact the bioavailability of minerals and proteins (Chavan *et al*., 2001).

Other health benefits: Sireesha *et al*. (2011) 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. According to the study, diabetic rats received a dose of 300 mg of *Setaria italica* seed aqueous extract per kilogram (kg) of body weight, which led to a significant decline (70%) in blood glucose levels after 6 hours. As evidence of the hypolipidemic effect of the aqueous extract, they also discovered 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 in diabetic treated rats compared to diabetic untreated rats. Choi *et al*. (2005), stated that Korean foxtail millet's dietary protein has a positive impact on cholesterol and insulin sensitivity. This experiment showed that rats fed foxtail millet had a substantial decrease in insulin levels. When Lee *et al*. (2010) looked into the impact of consuming millet on lipid levels and C-reactive protein concentration, they discovered that, contrary to their earlier studies (Choi *et al*., 2005), hyperlipidemic rats fed foxtail millet had lower levels of triglycerides. In rats fed foxtail millet, the levels of C reactive protein, a sign of inflammation, were also shown to be lower. Kodo millet aqueous and ethanolic extracts have been shown to cause a dose-dependent decrease in fasting blood glucose (Hegde *et al*., 2002).

Dual use of millets as food and feed:

Due to their abundance in essential minerals like calcium, dietary fibre, polyphenols, and protein, millet grains are regarded as one-of-a-kind crops (Devi *et al*., 2014). Many Asian and African nations rely on them as a primary food supply. A larger portion of the millet produced is mostly used for human use, and a smaller portion is used to make beer, livestock, and bird feed. In some regions of Africa, millet is prepared as a porridge with a thin or thick consistency, whereas in other regions, it is prepared as couscous (Obiana, 2003). The effectiveness of pearl millet as a feed item for poultry production was confirmed by research utilizing whole grain or crushed grain that was used in chicken diets (Cisse *et al.*, 2016). The primary goal of pearl millet production in Africa and Asia is thought to be grain, while the forage is a significant secondary product used for construction, fire, and animal feed (Andrews and Kumar, 1992). While all-season millets ensure food security, fodder, nutrition, health, and sustainable livelihood, in contrast to season-specific crops like wheat and rice (Shivananjappa, 2018). Because they are free of gluten and have a higher level of nutritional fibre than rice, pearl millet grains have a great deal of promise as a source of nourishment for people. Additionally, they have the same amount of fat as maize cereal and more critical amino acids like leucine, isoleucine, and lysine than traditional cereals like wheat and rye (ICRISAT, 2016). In India, where millet is frequently used, it is converted into the dense bread known as dosa, which is formed from a combination of millet and other grains. Additionally, it is used to make roti, sushi, no-yeast pizza, biscuits, and couscous (Dias-Martins *et al*., 2018). Another item manufactured from millet is Madua, a popular finger millet-based beverage in India. Additionally, millet is used to make Oshikundu, a traditional alcoholic or non-alcoholic drink in Namibia (Kumar *et al.*, 2018).

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 (Gomes *et al*., 2008). Silva *et al*. (2014) 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 *et al*., 2011) and 21 ± 2.4 kg DM/ha/mm water for the Brazilian maize cultivars (Dos Santos *et al*., 2010). 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 *et al*., 2011); and 21 2.4 kg DM/ha/mm water for the Brazilian maize cultivars; (Dos Santos et al., 2010).In an investigation by (Gomes *et al*., 2008), 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 (Silva *et al*., 2020). 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 *et al*. (2002) 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 *et al*. (2010), 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 *et al*. (2007) 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 (World Food Summit, 1996). The scope of food security problems is frequently reduced to the availability of agricultural products like cattle (Hatab *et al*., 2019). The difficulties are thought to be more intricate than simply increasing the supplies. Several elements, including urbanization and accessibility, are among the restrictions Hatab *et al*. (2019) listed. The structure and procedures that govern economies and societies, as well as institutional failings, are frequently mentioned as contributing reasons to food insecurity (Pangaribowo *et al*., 2013). Fraval *et al.* (2020) 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 *et al*. (2013) 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 (Muthamilarasan and Prasad, 2021). 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 (Muthamilarasan and Prasad, 2021). 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 *et al*. (2009) 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 (Garí,2020).

Impact of processing on millet grains' antioxidant activity:

The quantity and activity of the antioxidants in millet grains were also discovered to be impacted by processing techniques such as malting, decortication, soaking, and boiling. In one study, finger millet was malted for 96 hours, and the antioxidant capacity of the fraction carrying free phenolic acids rose (2-fold), while the antioxidant capacity of the fraction holding bound phenolic acids was decreased (Rao and Muralikrishna, 2002). In another study, a growth-promoting medium was created to increase the production of a water-soluble protein from germinated millet that is inhibitory of hydroxyl radicals. Li *et al*. (2007) reported that the single-factor test showed that H_2O_2 is essential for inhibitory activity. Additionally, the effects of the sprouting conditions (temperature, duration, and pH of stress media) on the hydroxyl radical inhibition were examined in order to further boost the yield of the water-soluble protein that inhibits hydroxyl radicals from stress-germinated millet. The ideal parameters were found to be pH 7.5 in the stress medium, a culture duration of 54 hours, and a temperature of 28 ◦C. The maximum inhibition (60.38 %) was attained under ideal circumstances (Li *et al*., 2008). Additionally, 3 days of foxtail millet germination allowed researchers to produce flour with a strong DPPH-scavenging activity (Coulibaly and Chen 2011).

The antioxidant activity of Kodo or finger millet decreased after roasting or boiling. Kodo millet's DPPH quenching activity was likewise reduced by fractionating it into husk and endosperm, and the phytochemicals appeared to work synergistically with one another (Hegde and Chandra 2005). The impact of germination, steaming, and roasting on the antioxidant qualities of little millet was also examined. The outcomes revealed that the total phenolic, flavonoid, and tannin levels of little millet increased by 21.2, 25.5, and 18.9 mg/100 g, respectively, over the original sample (Pradeep and Guha, 2011). Dehulling and hydrothermal treatments, however, were discovered to have an impact on the phenolic content and antioxidant potential of pearl millet grains (Chandrasekara and Shahidi, 2012). Due to oxidation and degradation of chemicals that occur during heat treatments like cooking, boiling, and roasting, antioxidant levels and activity have decreased. However, the removal of the pericarp layer from the grains, which is known to be high in polyphenol and antioxidant chemicals, can be blamed for the decline that resulted from dehulling. As a result, millet grains, their fractions, and food products must be processed under ideal circumstances to preserve their quality and possible health advantages. 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.

Challenges and future perspectives:

The data reviewed above shows that despite the nutritious richness and potential health advantages of millet grains, were comparable to popular grains like wheat, rice, and maize, and although processing techniques like fermentation, soaking, malting, and fortification/supplementation were discovered to improve its edibility and nutritional qualities, millet grain consumption is still primarily restricted to rural communities at the household level. This is a result of the absence of cutting-edge millet processing technologies that can produce safe, easy-to-handle, ready-to-cook or ready-to-eat goods and meals on a big scale that can be utilized to feed numerous people in metropolitan areas (Ushakumari *et al*., 2004). Nevertheless, as the world's population grows, so do the demands for food, fuel, and other basic necessities. As a result, society will be under pressure to either change its current crop consumption habits or increase agricultural production (Licker *et al*., 2010). Along with increased yields, crop diversification must also be promoted at the national and household levels. One crucial element of therapeutic dietary modification and encouraging consumption of minor-grain foods is the provision of more traditional and nutritious whole-grain and multigrain alternatives for refined carbohydrates (Singh and Raghuvanshi 2012). The role of gluten protein in generating high-quality, manageable baked goods and other grain-based dishes that demand elastic and extensible dough is well established. 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.

Conclusions: Millets were shown to offer a significant potential to improve food and nutritional security. Millets should therefore be added to the list of staple foods together with wheat and rice. Millets may grow well in adverse conditions like drought, and some wild varieties can even thrive in wetlands and populated areas. These contain gluten-free protein, low glycemic index carbohydrates, an abundance of minerals (such as calcium, iron, copper, magnesium, and others), B vitamins, and antioxidants. These exceptional qualities make them nutrient-dense and resistant to climate change crops. These can benefit the health of the community as a whole in addition to providing farmers with an additional source of revenue. As a result, research and development initiatives as well as the creation of policies are needed; some actions have already been done globally, particularly in India and some are required to be taken. Minor millets have received very little attention in the scientific community despite their great nutritional qualities and easy production method. They are frequently disregarded, leading to the term "orphan cereals" being used by scientists to describe them. However, in order to increase the micronutrients' bioavailability and raise the calibre of millet diets, new processing and preparation techniques are required. The bioavailability, metabolism, and health benefits of millet grains and their many components in humans require further study. The current nutrient deficiencies of protein, calcium, and iron in poor nations will be addressed by the inclusion of millet-based foods in international, national, and state-level feeding programmes.

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