Millets' Role in Addressing Malnutrition and Ensuring Food Security in a Changing Climate

Piyush Kankarwal[1], Swetha Priya Gali[2], Paulin[2], R. Meenatchi[2] and Pratibha Singh[1*]

[1]NIFTEM-T, Liaison office, Bathinda, Punjab – 151001, India
[2]NIFTEM-T, Thanjavur, Tamil Nadu - 613005, India

Abstract

Millets are regarded as an ancient grain and are utilized for human consumption, animal feed and bird feed. They are superior to other crops in several ways, including drought and pest tolerance. Additionally, they can endure inhospitable conditions and infertile ground. These advantages result from their genetic make-up and physical characteristics, such as their small size and toughness. It is extensively consumed in developing nations in Asia and Africa. Although millet seems to be a seed, it has a nutritional profile that is comparable to that of sorghum and other cereals. Because millets are gluten-free and contain high protein, fiber and antioxidant levels, they have become more popular in the West. Millets can increase hemoglobin levels and lessen an iron shortage. Urban consumers are becoming more aware of the fact that millets are a nutritional powerhouse that fight diabetes, obesity and lower the risk of heart and circulatory diseases. When compared to other common grains, millets are resource-efficient, have a high nutritional content and are frequently referred to as "nutri-cereals" or "superfoods."

Introduction

Malnutrition is a global issue affecting millions of people and posing a serious threat to food security. This has emerged as a new obstacle to the fight against the unpredictability of the food supply. Malnutrition varies, including hidden hunger and micronutrient deficiency, which are life-threatening for children and women, making them vulnerable to common and deadly diseases. Millets are ancient heritage grains that are appreciated for their nutritional characteristics, high tolerance to abiotic stresses, and minimal input. These coarse grains are a high source of carbohydrates, dietary fibers, lipids, proteins, vitamins, critical minerals, trace elements, necessary amino acids, and antioxidants and hence can be considered a miracle (Charan et al., 2023).

Furthermore, millet is gluten-free, making it an accessible nutritional option for individuals with celiac disease or gluten allergies. This improves their accessibility and usefulness in a variety of dietary regimes in line with

[*]***Corresponding author's e-mail***: pratibhasingh@iifpt.edu.in

Enhancing Crop Resilience: Advances in Climate Smart Crop Production Technologies. Anjani Kumar, Rameswar Prasad Sah, Basana Gowda et al. (Eds).

fair food security principles. Millet farming is also aligned with long-term environmental aims. Millet farming promotes biodiversity conservation, reduces the need for chemical pesticides and synthetic fertilizers, and protects vulnerable habitats. Furthermore, millet production has important economic and social benefits, including diversifying income streams for smallholder farmers and revitalizing rural communities. The promise of millet in sustainable agriculture has been increasingly recognized by governments and legislators worldwide. Policies, subsidies, and efforts are being implemented to enhance millet production, market growth, and nutritional programs, and to support food security and climate resilience (Girase et al., 2023).

Policies, subsidies, and efforts are being implemented to boost millet production, market growth, and nutritional programmes, thereby promoting food security, climate resilience, and livelihood improvement. Because the global community seeks long-term solutions to hidden hunger and nutritional insecurity, millet serves as a durable and nourishing ally. Harnessing their potential, together with ongoing research, investment, governmental support, and increased consumer awareness, is critical for ensuring a sustainable, nutritious, and egalitarian future. Finally, incorporating millet into global food systems provides a method to improve nutritional security, combat hidden hunger, and advance sustainability goals (Girase et al., 2023).

Millets help prevent cancer, reduce the risk of cardiovascular disease, limit tumor growth, lower blood pressure, slow fat absorption, delay gastric emptying, and increase gastrointestinal bulk. Value-added millet grains as ready-to-eat and ready-to-cook foods provide farmers with an excellent opportunity to boost income generation, stimulate production, and foster commercialization, all of which lead to job development, income, and nutritional security. However, the successful harvest of small millets supports the use of tried-and-true climate-smart technologies to meet the future needs of the population.

This chapter focused on how millets are booming in today's changing climate and how their excellent nutritional profile is helping to tackle malnutrition and diseases. The socio-economic aspects of millet production and its impact on livelihoods: comparisons between millet and other cereals in terms of environmental impact and resource use.

By comprehensively examining these aspects, this review paper aims to show that millet is a promising solution for tackling malnutrition and ensuring food security in a world grappling with climate change.

Objectives

1. Promoting the cultivation and consumption of millet as a nutritious and climate-resilient crop.

2. Increasing awareness among communities about the nutritional benefits of millet and its role in combating malnutrition.

3. Supporting smallholder farmers in adopting millet cultivation practices through training and access to resources.

4. Integrating millets into national food security policies and programs to diversify food sources and enhance resilience to climate change.

1. Malnutrition

Malnutrition is a condition in which the body does not obtain enough nutrients or receives excessive amounts of them. Malnutrition is formalized into two categories: undernutrition and obesity. Under- nutrition is also classified as stunting, wasting, and underweight. The low height for age is called stunting. Wasting refers to being underweight for your height and underweight for your age. Malnutrition is a serious health problem, and it mostly affects the young population, particularly those under the age of five. Malnutrition is the most serious hazard to children's health since it is unseen (Adebisi et al., 2019). Malnourished children are more susceptible to diseases, and if not treated on time, they enter the vicious cycle of malnutrition-infections-malnutrition. Human development and health are eternally connected. Good health results in optimal productivity and well-being (Jariwala & Mataliya, 2017).

1.1 Malnutrition in the World: A Global Scenario

Because the environment is changing day by day & rising nutritional insecurity, malnutrition is a big concern for both rich and poor countries (UNICEF 2018). WHO, 2020 refers to a person's deficit, excess, or imbalance in energy and nutritional intake and FAO ,2018 stated there are 821 million persons globally who are undernourished (have chronic food insecurity). Because malnutrition and obesity coexist on the planet, 462 million are low weight as well as 109 billion people are overweight (WHO 2020). UNICEF (2018) reports that 20 million infants are born underweight and that approximately from the total amount of women one third have anemia (low blood). Malnutrition has a devastating impact on developing countries, particularly among the economically destitute masses. For example, less than half of all fatalities are among children. Malnutrition is responsible for approximately half of all deaths in children under the age of five (UNICEF 2020). Masoud et al. (2018) stated malnutrition increases the chance of death, reduces physiological development as well as physical growth, and finally reduces national economic output. The many frequent kind of undernourishment', hidden hunger, is said to be exceedingly common in South Asian countries Sub-Saharan African. Hidden starvation may not be physically felt, yet it has an impact on health and vitality (Gautam, 2014). Hunger afflicted 150 million people in 2019, 828 million people in 2021 & 46 million more than the previous year. Following a period of relative stability since 2015, the number of persons afflicted by hunger climbed in 2020 (United Nations, 2021). While the enormous human and economic consequences of hunger are generally recognized (United Nations, 2021; Arcand JL., 2001 and FAO, 2021). However, a larger proportion of people

suffer from a separate, "hidden" kind of hunger, specifically a lack of vitamins and minerals that are necessary. Almost two-thirds of the global population, mostly women and children from low-income households, are suffering from at least one micronutrient deficit: up to 3 billion are at danger of zinc insufficiency (Hotz et al., 2004), 2 billion people are anemic, including many iron deficient (WHO, 2007).Vitamin A deficiency affects around 150 million individuals, whereas iodine insufficiency affects 2 billion people (United Nations, 2021). These deficiencies in minerals and vitamins place a considerable illness burden on affected people as well as society: premature mortality, blindness, adverse functional outcomes include stunting physical impairments and cognitive losses. Economically disadvantaged people may face considerable challenges in terms of nutritional and food security as a result of a lack of funds to prevent malnutrition as a consequence of the worldwide financial crisis (Braun Von , 2020).

1.2 Malnutrition in India: A Scenario

The nutritional situation in India is frequently criticized due to the high rate of malnutrition among mothers and children. According to the newly released Global Nutrition Report 2020, India, along with 87 other nations, will not meet the Global Nutrition Targets for 2025. Aside from the burden of under-nutrition, India has one of the highest rates of household nutritional inequality (Singh et al., 2023) and according to the Global Hunger Index (GHI), India was ranked 94th out of 107 nations in 2020 but has since declined to 101st out of 116 countries in 2021. Based on a GHI score of 27.5 out of 50 in 2021, India is classified as severe (Von Grebmer et al., 2021). According to the Human Development Report (HDR) 2021-22, India's Human Development Index (HDI) ranking has fallen from 130 in 2020 to 132 in 2022 and according to the Indian Council of Medical Research (ICMR) 2017, malnutrition is the leading cause of mortality in children under the age of five in every state of India (UNDP (United Nations Development Programme, 2022).Since 2019, the combination of the COVID-19 pandemic, the Ukrainian conflict and the influence of climate change has led to a serious deterioration of the situation of malnutrition and starvation. Unfortunately, this reversal of momentum has undone a decade's worth of attempts to address these critical challenges (GAIN, 2023). Malnutrition appears to have decreased in India over the last ten years, but there are still numerous gaps and a need for effective knowledge obtained through various research to combat it, as it impedes the nation's socio-economic progress. In economy, education, and technology, India is now the fastest expanding country in the South Asian area. However, India has failed to treat and eradicate malnutrition, which has a negative impact on individuals of all ages (Narayan, 2019).

Factors Contributing to Malnutrition in India

Micronutrient deficiencies usually result in malnutrition, which is a major public health concern, particularly in poor countries (Ramakrishna et al., 2011). Adults and females of reproductive age are more vulnerable

to micronutrient deficiencies (Harika et al., 2017). Mothers' low nutritional status is a major contributor to malnutrition in India; 36% of women and 56% of adolescent girls (15-19 years) are underweight and suffer from iron deficiency anemia (IDA) as a result of malnutrition (WHO-SEARO, 2016). Surprisingly, 75% of women (new and expecting) were anemic, and many of them gained only half as much weight (5 kg) as the global average for weight increase during pregnancy (10 kg). Blood loss during menstruation is one of the main risk factors for IDA in teenage women (IIPS, 2017). Gender disparities in low- and middle-income households lead to a greater frequency of anemia among teenage girls, as they do not consume as many protein and micronutrient-rich diets as boys. Because pregnant women and nursing mothers are malnourished, these factors contribute to preterm and low birth weight children. According to research, the nutritional state of a mother and the health of a baby are closely related. Women who endure malnutrition in childhood because of poverty and gender inequity produce unsuitable kids. Other limiting elements that contribute to the understanding of women and the necessity of a balanced diet include education and general awareness. An analysis of NFHS-3 data found that women's education is directly associated with a decrease in the rate of malnutrition and early marriage. Most Indian mothers are unaware of the value of breastfeeding and its length in keeping infants healthy and resistant to a variety of diseases (Saaka, 2014 and UNICEF, 2018). Poor hygiene and sanitation practices are also important impediments in India, leading to ailments such as malaria and diarrhea. This reduces the availability of healthy food and increases resistance to illness in youngsters (Singh, 2020). According to WHO, intestinal illnesses or diarrhea caused by inadequate sanitation account for 50% of malnutrition (WHO, 2017). Furthermore, malnutrition causes weight loss due to a loss of fat and muscle mass, which has a negative impact on muscular function. Food fortification is generally recognized as the most effective preventative strategy to combat malnutrition caused by micronutrient deficiencies (Bhagwat et al., 2014).

2. Millet: Status and Nutritional Composition

2.1 Millets

Millets are cereal grasses that are raised for grain and animal feed. Millet comes in white, green, yellow, and red varieties and is small in shape and spherical.

2.2 Types

Based on size millets are divided into two categories: large millets and little millets. (Fig.1). Large millets category include sorghum pearl millet, sorghum, & finger millet. Minor millet category include barnyard millet, kodo millet, little millet, & proso millet and according to Budhwar & Chakraborty (2020) there are another category which include two pseudo-millets amaranth and buckwheat.

Figure 1: Types of millets

2.3 Millets (cost-effective)

The potential for improving the nutritional outcomes of school-aged children through the incorporation of millet-based meals in school feeding programs is substantial when compared to fortified rice-based meals. Moreover, it has been found that children favor these meals, and they can be cost-effective if millets receive government pricing support equal to that of rice. (Table 1)

Table 1: Millets common name and price in market

Millets	Common name	Price (per kg) rupees
Finger millet	Ragi	30/kg
Foxtail millet	Kangni	40/kg
Sorghum millet	Jowar	24/kg
Pearl millet	Bajra	38/kg
Buckwheat millet	Kuttu	50/kg
Kodo millet	Kodo,Gondil, Kodra	60/kg
Amaranth millet	Chola, Razgira	110/kg
Little millet	Sama, Kutki, Swank	27/kg
Barnyard millet	Samvat kechawal, Sanwa	25/kg

(Source: prices from https://www.indiamart.com/)

2.4 Millets Production in World

Millets are a variety of genera which are small-seeded crops that are commonly produced for grains and fodder throughout the world (Fig. 2 & Table 2). Developed nations create and consume only a small portion of the

world's millets, and the remaining comes from the remainder of the world. Millets are important crops throughout Asia, Africa, and semi-arid tropics of Europe, accounting for 97% of millet production and according to the most recent output data (2016-2018). Africa grew most millets, exceeding Asian countries, which was followed by Europe, the United States, & Oceania. In Asia the millets cultivation is carried out largely in India, China & Nepal. While millets are essential food crops throughout most of Africa, Africa accounts for a sizable share of global millet output (Nigeria, Sudan, Mali, Guinea, & Ghana) among the biggest millet producing African countries (FAOSTAT, 2018).

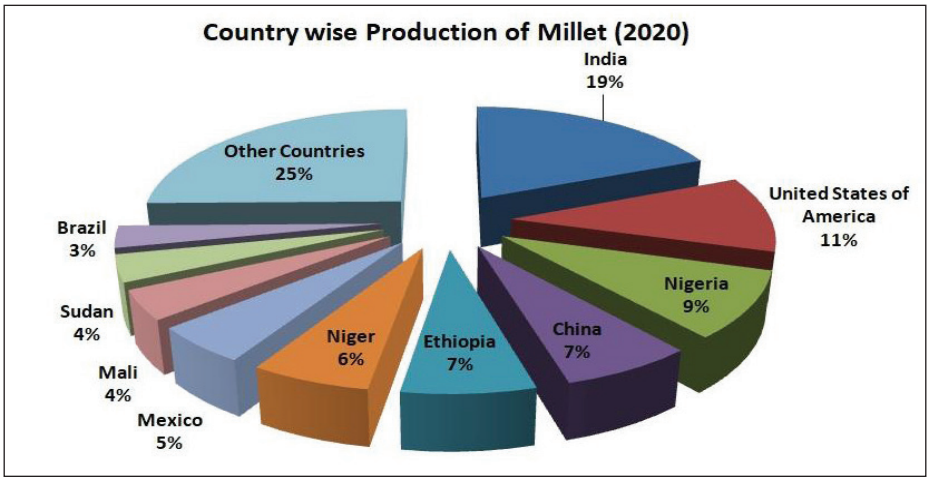

Figure 2: Country wise production of millet; (Source: AEPDA data of 2020 millet production in different countries)

Table 2: Millet production worldwide

S.No.	Regions	Area (Million Hectare) (2018-2019)	Production (Million Tonnes) (2018-2019)	Area (Million Hectare) (2018-2019)	Production (Million Tonnes) (2018-2019)
1.	South America	1.71	5.10	1.80	5.88
2.	North America	2.21	9.53	2.26	9.68
3.	Africa	50.6	46.1	47.0	41.3
4.	Europe	0.49	1.40	0.85	1.98
5.	Australia	0.50	1.30	0.24	0.43
6.	Asia	17.6	23.5	18.6	25.0
7.	World	73.11	86.96	70.75	84.17

(Source: FAOSTAT, 2021)

In North America, the US is the major millet grower, and Argentina leads in South America.Australia & New Zealand are the top millet producers and in the drier regions of Europe which include Eastern Europe and Oceania, produce 90% of the total millet production.The increase in African output was caused by area extension into drier places as a result of climatic whims, which ultimately led to land loss beneath crops like maize that require a lot of water to grow. In two different categories—millet (small millets and pearl millets) and sorghum—the Food and Agricultural Organization (FAO) site (FAOSTAT 2018) offers data on millet region, yield, and efficiency. Out of the 93 nations that cultivate millet, just 7 (Niger, Burkina Faso, Sudan, Nigeria, Mali, India, and Chad) have more than one million hectares of harvested land, and about 25 nations have more than 0.1 million ha. Their share of the world's 34.1 million hectares of millet cultivation is more than 97%. With 15.29 million hectares harvested, India leads the top 7 millet-producing nations in the world, followed by Niger, Sudan , Nigeria , Mali , and Burkina Faso. According to estimates, the worldwide area under millets cultivation has decreased by 25.7%, while output has increased by 16.26 percent between 1961 and 2018. Among the continents, Europe had the greatest decline in area (90.14%) and output (73.76%), followed by Asia (59.79%; 8.77%), while Africa had the greatest growth in area and production (74.90%; 102.49%).

According to FAOSTAT (2021), global millet output in 2019-20 was 84.17 million metric tones on 70.75 million hectares with India accounting for 20.50%. Millets are currently consumed by around 90 million people in Africa and Asia. Africa accounts for more than 55% of worldwide output, followed by Asia, which accounts for about 40%, while Europe accounts for approximately 3% of the global market. According to reports, the African continent was the greatest in terms of area and millet production, followed by Asia, North America, South America, Europe, and Australia. Sorghum is the most widely farmed millet in the world, accounting for 65.8% of total millet output. Sorghum & pearl millet account for 92.6% of worldwide millet production, with remaining millets accounting for 7.94%. Unfortunately, there has been a progressive fall in the area and output of millets worldwide. The millet area decreased to 72.3 million hectares in 2020 from 74.6 million hectares during 2018, and output decreased from 91.8 million to 89.2 million metric tonnes.

Dayakar Rao et al. (2018) also indicated a diminishing trend in area and production from 2010 to 2018.

Global Scenario of Millets Production

2.5 Millets Production in India

Millet production in India (Fig. 3) is mostly focused in dry and desert regions with poor and unpredictable rainfall. India produces the most pearl millet in the world, and other millets, with an annual production of around

12.46 million metric tonnes on an area of 8.87 million hectares. Rajasthan leads the way in millet production, with 7.29 million tonnes produced from 5.91 million hectares, followed by Karnataka (6.45 million tonnes), Madhya Pradesh (4.82 million tonnes), Maharashtra (4.73 million tonnes), and Uttar Pradesh (4.73 million tonnes), Tamil Nadu (3.33%), and Telangana (3.12%), respectively. Dayakar Rao et al. (2018) also indicated a diminishing trend in area and production from 2010 to 2018.

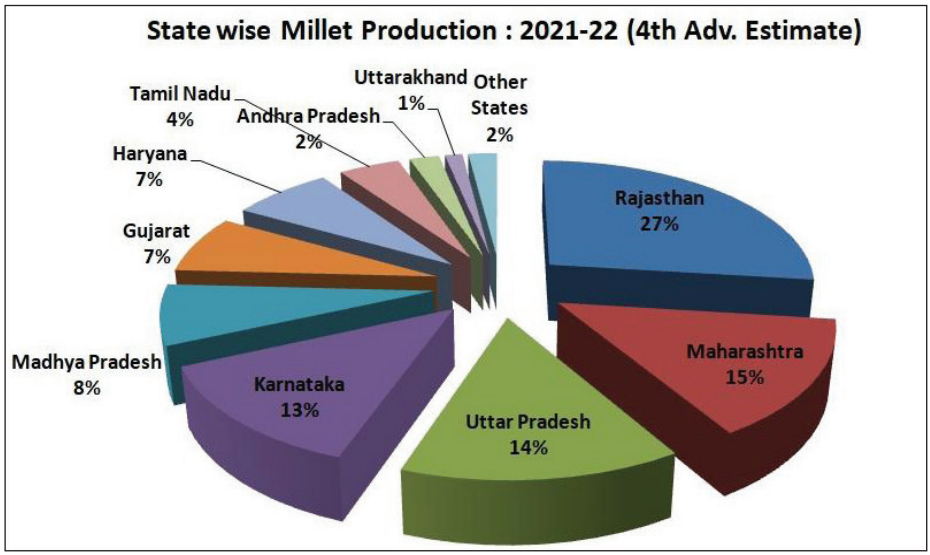

Figure 3: Millet Production state wide; (Source: AEPDA Data 2021-22)

Karnataka is well-known in India for farming minor millets, with finger millet (granted with a Geographical Indication (GI) tag for finger millet by the national government) serving as a staple meal in the state's southern region (Ashok et al., 2020). Telangana ranks seventh in millet production, with 3.12 million tonnes produced over an area of 0.66 million hectares. The statistics, on the other hand, revealed a reduction in the area under millets from 1950 - 1955 to 2015 - 2019 at a Crop Growth Rate (CGR) of 16.21%; similarly, output was declining at a CGR of 13.58%.

India has a total planted area of 1.17 million hectares producing 1.79 million tonnes of finger millet, with Maharashtra, Tamil Nadu, Andhra Pradesh, Odisha, Uttarakhand, and Karnataka being the main states producing more than 90% of the country's supply and kodo millet is the second minor millet that is produced on large scale in Indiaafter finger millet. India produces 4.77 million tonnes of sorghum annually, placing it sixth in the world.

Recently millet crop is getting popular because of its high yield and short growing season in hot, dry conditions. Because of their shorter growth seasons, they suit well in a variety of cropping systems under rainfed circumstances and adapt well to climate change. Millets are commonly referred to as famine crops due to their climate change, since they can

ensure yield under famine circumstances and grain can be stored for years without substantial pest attack.

2.6 Nutrient composition of millets

Millets are nutritionally equivalent to other cereal grains (FAO, 1995), with the main nutrients being lipids (1.5-5%), crude fiber (2-7%), carbs (60-70%), proteins (7-11%), minerals and vitamins (Table 3). They are high in calories, iron, & phosphorus in comparison to other cereals. Millets contain a high concentration of phytochemicals that have a variety of biological activities that may aid in the prevention and postponement of the onset of non-communicable diseases (NCDs).

Table 3: Proximate composition of millet

Component (g/100g, dry basis	Foxtail millet flour	Pearl millet whole grain	Finger millet native grain	Proso millet DE-hulled grain	Fonio whole grain
Fat	2.38	4.86	1.8	4.9	3.3–3.8
Ash	0.47	1.64	2.7	NA	1–1.1
Crude fiber	NA	12.19	3.5	0.7	NA
Total CHO*	75.2	59.8	83.3	80.1	84–86
Protein	11.50	14.8	8.2	11.58	9–11

Sarita and Singh, 2016 stated that the nutritional value of meals has a significant impact on your physical and mental well-being. Cereal grains are a vital component of many people's diets across the world. Millets are annual grasses with tiny seeds that are grown in temperate, tropical, and subtropical areas around the world. These have an extremely high nutritional content. According to Kumar et al. (2018), they have the same or more protein as cereals such as maize and wheat. This is 3 to 5 times better than rice and wheat for proteins, minerals, and vitamins. They also include all the necessary minerals. Saleh et al., 2013 stated that in addition to having more protein, dietary fibre, zinc, iron, phosphorus, calcium, potassium, & vitamin B compared to traditional cereals, millets also include a range of essential amino acids. The Food and Agriculture Organisation (FAO) council asked for India's participation during its 116th session in 2018 in order to establish 2023 as the International Year of Millets (FAO 2018). Millets are gluten-free and low in glycemic index. Malnutrition & micronutrient deficiencies have a significant death rate, affecting 7.2 billion people worldwide, especially children. Poor nutrition and poverty are key causes of malnutrition; millet is high in nutrition, superior to most non-millet cereals, and affordable, making them the greatest answer to this problem. Millets are high in dietary fibers, antioxidants, phytochemicals, and polyphenols, all of which have a wide range of beneficial effects on human health. Millets contain numerous nutritive elements, but their use is limited due to non-

nutrients such as trypsin inhibitors, tannins, and phytic acid, which can be decreased by fermentation, and so increase the total nutritional value of millets. Furthermore, germinated millet-based food items have a greater cell count and better proliferation of helpful bacteria; hence, millet germination improves millet probiotic fermentation.

Consumption

African countries such as Niger, Mali, Nigeria, Burkina Faso, & Sudan eat more than 40% of the world's millet. Millet consumption per capita varies widely between nations; as an essential food in dry climates that's why it is the greatest produced in African countries. When Sahel nations compared with Niger in total cereal food intake it accounts for 75% where Sahel nations have more than 30% millet consumption in Africa, in Namibia 25% and Uganda 20% of total cereal food consumption. Millet grain is mostly used for animal feed in underdeveloped nations, with relatively little feed in Africa.

Uses of Millets

Millets have been farmed in semi-arid regions on marginal soils for over 3000 years by tiny & marginal farmers & consumed throughout Asia as well as Africa. However, because of their high nutritional contents and numerous health advantages, millets have recently earned enormous demand in national and international markets (Taylor & Emmambux, 2008).

Foods made from Flour:

- Flatbreads: These are the basic food of Africa and in this millet, flour undergoes fermentation with lactic acid bacteria & yeast to provide soft- textured bread that has an acidic flavor (Gashe et al., 1982). E.g., Badi et al., 1990, in Africa's two most famous flatbreads (Kisra & injera), which are eaten along spicy sauces.
- Roti: Murty& Kumar, 1995 stated in India roti is a staple meal and well-known as unfermented millet flatbreads. Rotis are soft pancakes with a puffy feel. Pickles, veggies and sauce are common accompaniments.
- Dosa and Idli: Murty & Kumar, 1995 stated in southern India, dosas and idlis are made from half-fermented millet flour and served with chutney and sambar.
- Porridges: Around the world, people enjoy a variety of traditional porridges, and in Africa, millet meal is used to make porridge. According to Rooney et al. (1997), porridges can be categorized based on their solid content (10–30%), pH range (alkaline to acidic), consistency (runny to stiff), and serving temperature (very hot to cold), for example, porridges made with little millet flour from India, pearl millet flour from South Africa, finger millet flour from the Sahel region of Africa, and foxtail millet flour from China.

Foods Made from Whole Grains

● Grain popping: Before popping the grains, they are soaked to 19% moisture content. After that temper it for several hours and put it in hot sand bed at 240 degrees Celsius for few minutes it will remove the outermost layer. The popping grains are eaten as a snack or milled.

● Germinated millet seeds: The protein, mineral, & vitamin content increases during soaking seeds overnight and enabling them to sprout and these are consumed raw or cooked by babies and elderly people easily.

● Kichadi: a rice-like product, is made by heating entire grains (different millets) (Subramanian and Jambunathan, 1980).

Millets-Based Alcoholic Beverages

● Beers: Millet grains pearland finger millet) are fermented to create traditional African beers, which are well-liked in both India and Africa. These often have a brownish green or opaque appearance, a sour-bitter flavor, and a frothy feeling reminiscent of milk because of millet particles that are partially suspended in gelatinous starch and yeast. They are consumed while actively fermenting and neither are they pasteurized nor do they contain much alcohol (up to 3% ABV) (Quin, 1959).

● Bouza: Proso millet is fermented to create Bouza in Egypt and Turkey. Alcohol makes up 1% to 7% of the mixture (Arici & Daglioglu, 2002).

Millets Non-Food Products

• Bioethanol: Shivran, 2016 stated that various starch-rich millets are used in bioethanol production and the major millets have a starch content ranging from 65% to 73%, making them appropriate use to develop bioethanol. Schaffert, 1992 did extensive study on large-scale bioethanol production using maize grain, sweet-stemmed sorghum & sorghum (House *et al.*, 2000). The use of millet grains and stems for synthesis of bioethanol, this research is still in its early stages.

• Bio-coatings: The wax found in the majority of grain pericarps can be used to create coatings and films. According to Weller et al. (1998), sorghum pericarp wax and carnauba palm wax are used to create an edible coating for sweets and confections.

3. Government Initiatives towards Millets: National and International

The General Assembly of the United Nations has proclaimed 2023 to be the International Year of Millets, a move supported by India. During its presidency of the G20, India has the potential to become a global learning center on millet production. This policy brief presents options to mainstream the millets produced and consumed in the G20 countries. It employs agro ecological concepts and promotes the formation of farmer collectives to address the supply-side issues of mainstreaming millets. It also suggests behavioral treatments to address the demand-side issues involved with

mainstreaming millets (Pandey *et al.,* 2023).

Ministry of Agriculture and Farmer Consumption

The PLISMBP is a production-linked incentive programme for the food processing industry has been approved by the Ministry of Food Processing Industries (MoFPI) with a budget of Rs. 800 crores for implementation from 2022–2026. The PMFME Scheme, which was created within the framework of the government's Atmanirbhar Bharat initiative, is presently being executed in thirty-five states & union territories (UTs). In addition, the government is pushing the Agri-Infrastructure Fund Scheme, a scheme that enables farmers/FPOs/Entrepreneurs to receive government incentives offering up to two crores in loans for the establishment of millet's main manufacturing facilities. Higher MSPs for Jowar, Bajra, & Ragi have been declared in order to motivate farmers to produce millet.

Center's initiatives to encourage millet production

Since the year 2018, the Indian government has implemented many actions to encourage the production of millets:

1. The Poshan Mission Abhiyan of the Ministry of Women and Child Development includes millets.

2. To encourage farmers to produce millet, the Indian government raised the minimum support price.

3. To ensure a consistent market, the government has added millet to the public distribution system.

4. By developing value chains through farmers' producers' associations, the government has additionally aided in increasing millet's marketability.

According to Behera, M. K. (2017) Government of India has launched a number ofprogrammes to promote millet farming, particularly in the last decade.

1. According to Bohri C. (2016), the three most significant current programmes are the Integrated Cereals Development Programmes in Coarse Cereals Based Cropping Systems Areas (ICDP-CC) under the Macro Management of Agriculture (MMA), and the Rainfed Area Development Programme (RADP) as part of the Rashtriya Krishi Vikas Yojana" (RKVY).

2. For nutritional security the only complete programme that supports millet planting efforts is Intensive Millet Promotion (INSIMP). When millets were introduced in 2011–2012, "nutri-cereals" were aggressively pushed. The programme aims to increase millet production while simultaneously enhancing India's nutritional security. The programme suggested giving farmers hybrid seeds and cultivating millet on 0.5 million hectares (ha). Additionally, it has been recommended to spend Rs 400,000 to create composite millet processing facilities around the country that will handle the de-stoning, dehulling, flaking, and Rava-making processes. Civil society

organizations criticized the strategy during the early phases of implementation since it aimed to promote extensive millet monocropping, which would defeat the purpose of millet farming. As a result, the Indian government ought to reconsider the notion and implement the required adjustments to sustain the conventional mixed-farming system that adheres to organic principles.

3. According to Patil (2015) stated prior to 2013, the PDS basket was limited to wheat and rice, which decreased the use of larger grains. In the National Food Security Bill, the Indian government expanded the PDS basket in 2013 to incorporate more coarse grains such millet at a price of Rs 1 per kg.

Initiatives led by the state

A few states have launched outstanding measures to increase millet production and consumption.

1. The Hindu (2016) stated that a mega millet growing endeavor in a backward district, with the Attappady community actively participating in Kerala, initiated by the Agriculture Department . The activities aim to reach all 192 indigenous tribes in the area at an initial cost of Rs 1.8 crore.

2. Odisha has made initiatives to implement a millet campaign during 2016 in order to increase millet production and cereal crop output. The government also plans to provide millet producers with market access.

3. Previously, the Maharashtra government announced millet subsidies.

4. Karnataka has set an example for the other states in terms of consumption by selling sorghum in the northern part & finger millet in the south via well-established PDS networks.

4.1. Millets: Climate resilience

Compared to main cereals, millets have several biochemical, molecular, physiological, and morphological traits that improve their ability to withstand environmental challenges (Bandyopadhyay et al., 2017). Several characteristics like tiny area of the leaf, small structure, cell walls being dense, and the ability to establish thick root systems, mitigate the occurrence of stress situations and their effects (Li & Brutnell, 2011). Small millets are primarily planted in dry and semi-arid environments because of their variety of climatic tolerance characteristics (Vetriventhan et al., 2020). Around the world, 18–20 million ha of the 76 million hectares of millets planted are used for small millets farming. Although biotic and abiotic stimuli have little effect on small millets, there is a considerable variance in small millets' ability to tolerate stress among various germplasms (Nagaraja et al., 2016).

Millets have enormous potential in Asia and Africa as the crops of farmers that are restricted to only few resources and as a wholesome food source for expanding populace (Fischer et al., 2016). Minor millets grow faster, are having more resistance for climatic extremes, and are adaptable to a variety of growing circumstances. Compared to wheat, rice, or maize, they are higher in useable protein, offer a wider range of vitamins, and contain more

antioxidants in addition to being high in micronutrients like calcium, iron, and dietary fiber (Ravi et al., 2010). An important idea to promote dietary diversity and food security is to increase the usage of small millets (Padulosi et al., 2015). 800 million people in world would get sufficient fundamental caloric needs if the yield gaps are closed or at least reduced. (West et al., 2014) (Grovermann et al., 2018). Foxtail millet's whole genome sequencing and gene family comparisons with the genomes of 15 other sequenced plants revealed that 1517 genes were unique to foxtail millet. Among them, 586 number of genes were labeled as water responsive, that may play important roles in causing drought and dehydration stresses and helping this crop's adaptability to arid and semi-arid regions (Zhang et al., 2012).

Pearl millet is the crop, which has the capacity to produce significantly larger economic returns in marginal settings than other major cereals, besides climatic extremities with fluctuating temperatures (Satyavathi et al., 2021). It is a crop that must be completely utilized because it is underutilized and has a higher grain yield ceiling temperature. It is more resistant to adverse weather conditions including drought and water scarcity, and it can be extremely helpful in guaranteeing food security in an ever changing climate, that is escalating to alarming levels (Krishnan and Meera, 2018). Because C4 plants have "Kranz" anatomy in their leaves, they are better able to fix inorganic CO2 and use water more effectively than C3 plants. Thus, coupled with other C4 plants like maize and sorghum, pearl millet can contribute 30% of the world's terrestrial carbon fixation (Choudhary et al., 2020).

4.2. Millets: Future of Food Security

Since little millets are high in bioactive substance, vitamins, fiber, and protein, along with macro and micro mutrients, they are nutritionally five to seven times better than main grains (Singh et al., 2021). They serve as a storehouse of nutrients due to their high amounts of nutritional qualities concerning proteins, carbohydrates, vitamins and minerals, antioxidants, phytochemicals, and dietary fiber (Muthamilarasan et al., 2016) (Table 4). The proteins found in millet are a great source of several necessary amino acids that also contain sulfur (Singh et al., 2012). Millets also differ from other cereals in terms of their starch quality; millet flour contains about twice as much resistant starch (13–15%) as rice. The millet-based food products have been identified as a diet that is healthy and nutritious for the patients with type II diabetes due to their high dietary fiber content and low glycemic index (Ugare et al., 2014). Millet grains that are gluten free lessen the likelihood of developing celiac disease because of gluten intolerance. Gallic acid, catechol, ascorbic acid, caffeic acid, syringic acid, gentisic acid, p-hydroxybenzoic acid, kaempferol, p-coumaric acid, vanillic acid, chlorogenic acid, sinapic acid, and salicylic acid are just a few of the many polyphenols found in millet whole grains. Millets are rich in antioxidants, that has significant advantages for reducing heat (Xiang et al., 2019), (Ofosu et al., 2020). Millets are a superior crop that is crucial for ensuring the security of food, nutrition, and health

because of its great nutritional qualities (Singh et al., 2021).

Pearl millet is widely farmed on 30 million ha of land, is a staple food for around 85 – 90 million people living in poverty, grown in the tropical parts of African and Asian cotenants. Over 50 % of the millet in the world is produced by it, utilized as food and feed (Srivastava et al., 2020). This millet is mostly grown on minimal soils in circumstances of no proper irrigation, and the soils which are prone to droughts with an average precipitation of less than even 300 mm annually, it can sustain and yield a sizable amount of grain (Nambiar et al., 2011). While the major cereals like rice, maize, wheat, barley, and sorghum may not thrive in harsh climates or on poor soil, pearl millet may endure and yield a significant amount of grain. When compared to wheat and rice, which solely give food security, it can offer a variety of security in the form of nutrition, livelihood, nutrition, health, feed, food, and ecological benefits, making it a crop for food security (Gupta et al., 2015). Sorghum is a C4 photosynthetic crop that thrives in hard environments and produces grain and feed. When limited by temperature and water, it works best (Chaturvedi et al., 2022), (Prasad et al., 2021), (Hao et al., 2021).

5. Millet-A Sustainable Solution to Combat Malnutrition

Malnutrition is a problem that is becoming more widespread due to the increasing unpredictability of food availability. According to the Food and Agriculture Organization's most recent estimates, 821 million people worldwide were considered undernourished as of 2017. Millets are highly nutritious, containing essential vitamins, minerals, and macronutrients like protein and fibre. Millets are rich in nutrients and minerals like calcium, iron, magnesium, and B vitamins. These nutrients are vital for overall health and can help to fight against various forms of malnutrition. Each millet variety offers a unique nutritional profile, making it possible to address specific nutrient deficiencies effectively. A brief note on role of millet against some common malnutrition is given.

5.1. Anemia: Iron is a primary nutrient necessary for various functions, including the production of hemoglobin, which carries oxygen in the blood. Iron deficiency can have a wide range of negative health effects namely fatigue, weakness, and impaired cognitive function. Pearl millet has a high bioavailability of iron, which can provide more than 50% of the daily iron requirement for adult and children (Anitha et al., 2021).

5.2. Celiac disease: It is caused by an immune reaction to specific proteins found in wheat, barley, rye, and their derivatives. Instead of protecting the body, the immune system targets and damages the inner wall of the small intestine in response to gluten intake. Celiac disease can cause a wide range of symptoms include severe abdominal pain, bloating, diarrhea, fatigue, and weight loss. Finger, proso and pearl millet found to have a lower glycemic index as compared to staple cereal products. The dietary fiber in this millet are not broken down and absorbed in the small intestine like other carbohydrates (Patil et al., 2015). Instead, it moves to the large intestine

relatively intact. This can slow down the digestion and absorption of glucose.

5.3. Diabetes: Blood glucose levels are regulated by a hormone Insulin, secreted in the pancreas. Stimulating insulin production can improve the body's ability to manage blood sugar level effectively (Vedamanickam et al., 2020). Foxtail millet are rich in essential nutrients, including minerals, vitamins, and dietary fiber, which aids in better digestion, prevents constipation, and supports overall gut health.

5.4. Cardiovascular disease: Millet are rich in dietary fiber, which can play a significant role in reducing cholesterol levels, particularly low-density lipoprotein (LDL) cholesterol (Lee et al., 2010). Dietary fiber binds to cholesterol and helps carry it out of the body, reducing its absorption in the intestines. This can lead to lower LDL cholesterol levels. A favorable balance of HDL to LDL cholesterol reduces the risk of heart disease.

5.5. Gastrointestinal disorder: A high-fiber diet, including millets, is associated with a lower risk of colorectal cancer (colon and rectal cancer). Dietary fiber adds bulk to stool, promoting regular bowel movements and reducing the time that potentially harmful substances are in contact with the colon lining. Development of colon cancer can be prevented (Anderson et al., 2009). The fiber in millets can help alleviate common digestive discomforts such as constipation, excess gas, bloating, and cramping. It promotes regular and healthy bowel movements, reducing the likelihood of these issues.

5.6. Anti-oxidant properties: Phytochemicals, including polyphenols, are known for their antioxidant properties. Free radicals that cause oxidative stress and can be a damage to cells are the harmful molecules which can be neutralized by the antioxidants. Millets are associated with a reduced risk of various chronic diseases. This includes a lower risk of cancer, neurodegenerative diseases such as Parkinson's and Alzheimer's, diabetes, and cardiovascular diseases. Lignan a phytochemical, present in millet help to protect cells from oxidative stress and reduce the risk of inflammation and damage to blood vessels. This in turn can contribute to heart health by reducing the risk of atherosclerosis and cardiovascular diseases.

Table 4: Millets and their nutritional benefits

S. No.	Millet name	Nutrient property	Health benefit	References
1.	Finger millet	Rich in protein, calcium and potassium	Prevent from osteoporosis. Recover from anemia Controls blood pressure, liver disorders, asthma and cardio diseases	Ramashia et al., 2019
2.	Foxtail millet	High in iron, calcium, and dietary fibre	Controls blood sugar and cholesterol	Sharma & Niranjan, 2018

S. No.	Millet name	Nutrient property	Health benefit	References
3.	Pearl millet	Rich in protein and dietary fibre	Prevents constipation. Controls type-2 diabetes Good for glucose intolerants	Satyavathi et al., 2021
4.	Proso millet	High in lecithin and oxidants Best source of protein, magnesium, and potassium	Reduces nervous disorder and blood pressure. Delays aging	Agarwal & Chauhan, 2019
5.	Little millet	Rich in anti-oxidants (tannins and flavonoids) and Niacin	Prevents from diabetes, cancer, cardio disease and gastrointestinal disorders Lowers cholesterol	Dey et al., 2022
6.	Barnyard millet	Rich in fibre, calcium and phosphorous	Less glycemic index and helps to control diabetes	Bhatt et al., 2023
7.	Sorghum	Rich in Phenolic compound (3-deoxyantho-cyanidins)	Anti-inflammatory and anti-cancerous effect Improves metabolism	McGinnis & Painter, 2020
8.	Kodo millet	High number of vitamins, potassium, magnesium and phytochemicals Rich in polyphenol	Prevents from atherosclerosis, heart attack, stomach cramp and diabetes	Bunkar et al., 2021

The potential of millets as a sustainable solution to combat malnutrition, it's essential to implement strategies that promote their cultivation, consumption and integration into national food and nutrition policies. This includes raising awareness about the nutritional benefits of millets, supporting research and development efforts, and encourage farmers to grow millets through appropriate policies and subsidies. Additionally, educational programs and culinary initiatives can help to popularize millet-based dishes and recipes, making them more accessible and appealing to a broader population.

6. Conclusion

India backed the resolution that the United Nations General

Assembly adopt the year 2023 as the International Year of Millets. India can advance in the field of millet production during its G20 leadership. The possibilities to mainstream millets produced and consumed in G20 nations are presented in this policy brief. Different foods can be made from millets flour such as flat breads, roti, dosa, idly, and porridges. Grain poppings, germinated millet seeds and kichadi can be made from whole millet grains. Alcoholic beverages & non -food products also can be made from millets such as Beer and bouza & bioethanol and bio-coatings respectively. Millets appear to hold considerable promise for nutrition and food security in the face of rising agricultural expenses, climate change, and a growing global population. They require much lower input expenditures for production, are naturally resilient to most biotic such as insects, pests, virus, fungus, and bacteria *etc.,*& abiotic stressors such as drought, salinity, heat, floods *etc.*, and have extra health benefits. These characteristics highlight millets as the preferred crop for the global populace not withstanding rising concerns about climate change. Millets can help with agricultural security besides addressing issues with energy, nutrition, and food. Millets are old heritage grains that have been cultivated without the use of pesticides on poor soils; as a result, they might be considered organic grains. They are referred to as miracle grains because of their remarkable nutritional profile in terms of gluten-free status, micronutrient concentration, different phytochemicals, fiber content, resistant starch, and with medicinal benefits.

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