International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Integrating Traditional Foods and Millets into Modern Diets for Sustainable Health, Wellbeing, and Food Security

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Abstract

Modern eating habits have shifted towards processed and refined foods, contributing to an increasing rate of obesity, type-II diabetes and deficiencies in micronutrient. Millets and traditional foods which were once staple of Indians diets are nutrient rich and climate-resilient crops that require minimal agricultural inputs and water. In spite of their nutritional and environmental strength, consumption of millets has declined because of the Green Revolution's emphasis on rice and wheat, increasing urbanization, and lack of consumer awareness. This paper review evidence from research in nutrition, clinical trials and policy reports to understand the role of millets in modern diet and food systems. Millets like sorghum, pearl millet and finger millets are high in dietary fibre, iron, calcium, essential amino acids and antioxidants which contribute to making them low in glycemic index and gluten free – properties that provide several health benefits like blood glucose regulation, gut health, and micronutrients status. Epidemiological and intervention studies have shown that consumption of millets regularly, reduces the risk of type-II diabetes, hypertension and anemia. Agroecologically, millets are low input crops with minimal irrigation, making them suitable for climatic-stress like drought, heat, and other resource limited areas compared to other staple crops. The paper emphasizes three strategies for millet promotion: the development of value added products, raising awareness and promoting nutritional education to increase demand and government support through improved processing, market access, and inclusion in public food programs. With increasing global interest in millets, there is great opportunity to promote millets. Integration of millets into diets can improve health and support food security. Gaining these advantages requires coordinated actions across agriculture, industry, public health and policies to ensure fair, and easy access. This paper shows contribution of millets to sustainable health and food security when included in regular diets.

Keywords: Millets, traditional foods, sustainable health, food security, climate resilience

Introduction

1.1 Background

Traditional foods and millets like jowar (*Sorghum vulgare*), bajra/pearl millet (*Pennisetum typhoideum*), ragi/finger millet/mandua (*Eleusine coracana*), amaranth seeds (*Amaranthus cruentus),* kodo, foxtail, and

barnyard millets have been part of India's agricultural and food system for very long time. Once, people used to think that millets was "poor man's food". Now millets are recognized as high nutritional value grains and their role in food security and sustainable agriculture (*Kaur et al., 2024)*. These nutrient-rich grains, known for their drought tolerance and resilience to marginal soil, played a important role in rural and tribal diets (*Bhardwaj et al, 2023*).

Due to the Green Revolution emphasis on high yielding variety of crops like rice , wheat to combat hunger, the predominance of subsidized staples under the Public Distribution System (PDS) substantially shifted India's food system. High-yielding varieties of rice and wheat replaced millets, resulting in monocropping and a loss of dietary diversity. Modern diets both in India and globally are progressively marked by high consumption of ultra-processed foods, excessive sugar, refined carbohydrates, low dietary fiber intake (*Eliazer Nelson et al, 2019., Kishore et al, 2015*).

These eating patterns contribute considerably to rise in lifestyle diseases; India leads in diabetes prevalence (*International Diabetes Federation, 2023*); more than half of Indian women are anaemic (*NFHS-5, 2019-21, p. 432*); micronutrient deficiencies and obesity are simultaneously growing. Millets offer a powerful solution to these challenges because their rich nutritional profile like high in dietary fibere, minerals like iron, calcium, phosphorus, magnesium, antioxidants, and more – combined with a low glycaemic index (GI), makes them beneficial to prevent metabolic diseases like diabetes and support long-term health *(Midhila et al., 2025).*

According to FAOSTAT (2023) production estimate data, India leads in global millet production at about 13.50 million tonnes, while Niger ranks second, producing nearly 3.34 million tonnes (Figure-1). In these areas, particularly African countries, these crops are primarily consumed as main food grains and serve as staple foods, especially among low-income populations (*Rao & Basavaraj, 2015*).

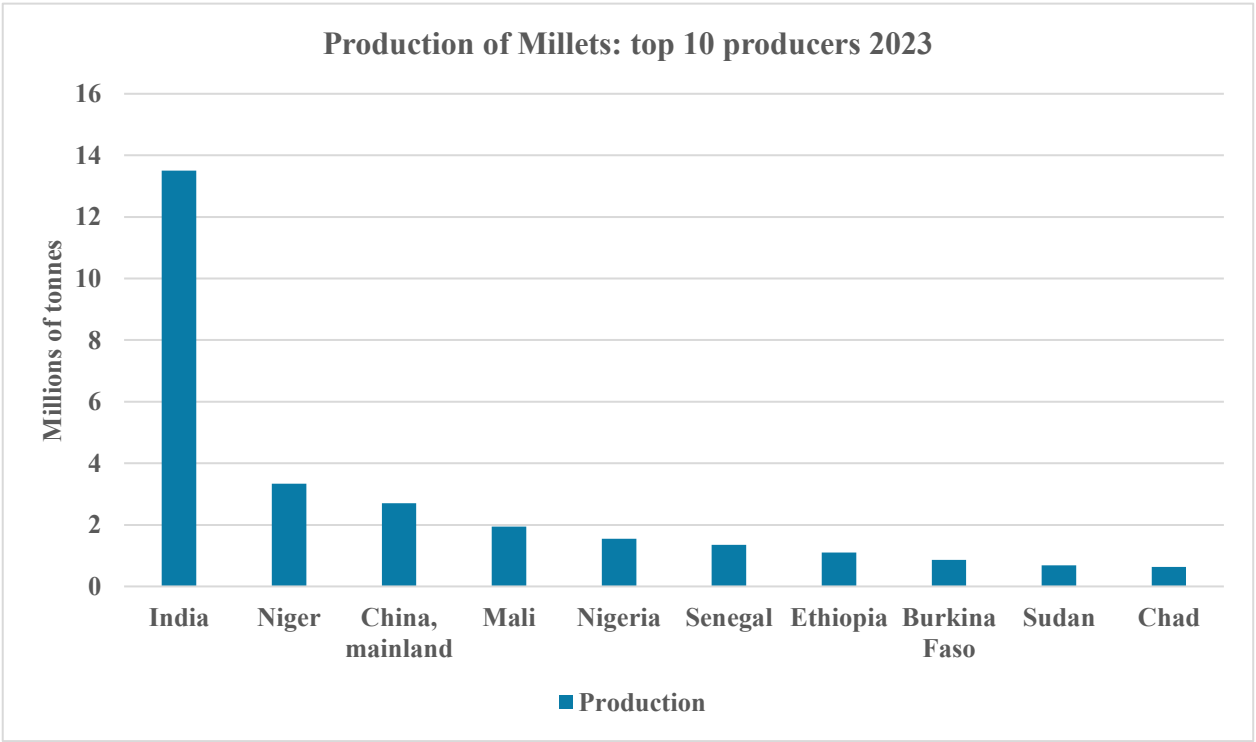

Figure 1: Top 10 Millet producing countries, 2023
Source: FAOSTAT (December, 2025)

1.2 Problem Statement

Although millets are highly nutritious, their consumption are low due to limited public awareness in terms of their nutritional value, inadequate availability in urban markets, and the perception of millets as a "food for the poor."

1.3 Research Gap

While studies exist on the nutritional benefits of millets, there is limited research on their integration into modern diets and food systems.

Literature Review

2.1 Nutritional benefit of Millets

Millets are highly nutritious grains that provide wide spectrum of nutrients. They contain significant amounts of protein, healthy fats, carbohydrates, vitamins, minerals, dietary fiber, and essential amino acids (*Longvah et al, 2017., IFCT NIN*). Research shows that millets contain more dietry fiber than wheat and rice, with a higher iron content e.g., pearl millet: 6.42mg/100g and amaranth seed black: 9.33mg/100g (*IFCT, 2017*). As compared to other cereals such as wheat, brown rice, maize, Finger millet has the highest calcium content: 364±58 mg/100g (*IFCT NIN, 2017*) and potassium content (408 mg/100g). Finger millet has 10 times more calcium than wheat, and three times more than milk (*Kaur, Kumari, et al., 2024*). Although its calcium bioavailability depends on processing and preparation, it is still a good source of calcium (*IFCT NIN, 2017*).

Together with high nutritional value, millets are also therapeutic because they contain phenolic compounds such as phytosterols, lignins, polyphenols, phytocyanins, and phytoestrogens. Phenolics are the major plant secondary metabolites. These phenolics have antioxidant properties and protect the body by preventing cellular and DNA membrane damage which occur due to lipid peroxidation of the membrane. Millet phenolics have various health-supporting benefits, such as antimicrobial, immune-boosting, anti-inflammatory, antiviral, anticancer, protective actions against cataract formation and certain digestive enzymes. *(Jacob et al., 2024).*

For bone health: Finger millet contain high amount of calcium (364 ±58 mg/100g) and is balanced with other mineral such as zinc and magnesium *(Longvah et al., 2017)*. It can help strengthen bones during childhood and adolescence, when the body adds most of its calcium. Building strong bones early in life supports higher peak bone mass and reduces the risk of osteoporosis and fractures later in life *(Sopher et al., 2015 & Bailey et al., 2000).* Finger millet is exceptionally high in calcium content; even modest inclusion of finger millet in the diet can adequately contribute to calcium availability. Moreover, recent evidence indicates that calcium derived from finger millet exhibits higher bioavailability than that obtained from commercial calcium supplements (*Purnaik et al., 2017*). Even though finger millet contains phytates, tannins, polyphenols, which are considered as antinutrient due to their metal ion chelating and enzyme inhibition activities (*Devi et al., 2014*), cooking makes about 28.6% of its calcium available – almost the same as milk (32.1%). This means it can be a good, sustainable source of calcium as methods like germination, fermentation, and malting can reduce phytates by about 60% and increase the amount of bioavailability of calcium by around 61% *(Anitha et al., 2021).*

Gut Health: Higher dietary fibre content of millets makes them good for gut health because fibre keeps digestive system functions properly and helps in absorbing nutrients more efficient and effectively and reduces the risk of problems such as ulcers and colon cancer (*Longvah et al., 2017*). From the bran of foxtail millet, a peroxidase enzyme was isolated which shows the inhibition of cell migration in cancer cells in human by supressing epithelial-mesenchymal transition (EMT) via modulation of the STAT3 signaling pathway (*Jacob et al., 2024*). Higher fibre content of millets also support smooth bowel movement and helps in issues like gas, bloating, and stomach discomfort (*Longvah et al., 2017*). Celiac disease, an immune-associated disorder develop in people who are allergic to gluten proteins, shows symptoms when they consume it (*Catassi et al., 2008).* Gluten is the major protein component of rye, wheat and barley so individual with gluten intolerance and who follow gluten free diets can replace cereals like wheat, rye, and barley with naturally gluten free grains such as rice, corn, sorghum, millets, amaranth seeds, buckwheat, quinoa, and wild rice (*Thompson, 2009, p.42).*
Since millets are gluten-free, they can be used to make many types of foods, such as flat breads (India), Injera (pancake) in Ethiopia, Dosa, Porridges and non-alcoholic beverages such as oskikundu – a fermented drink made from pearl millet (In Namibia) and alcoholic drink like African beer (*Taylor & Emmambux, 2008, p. 131-134*). They also meet the growing demand for gluten-free products and are suitable for people with celiac disease. Recent trends indicate that gluten free products are increasingly consumed not only by gluten sensitive individuals but also widely preferred by population without any gluten related issues. (*Selladurai et al., 2023*).

Diabetes management: Diabetes mellitus is major complex metabolic disease and health issue in many countries. In current scenario the numbers of the people with type-II diabetes increasing day by day rapidly worldwide, and India is among the most prevalent nation with diabetes with prevalence of 10.5 % in adults (*IDF, 2024).* A healthy lifestyle, like eating healthy and balanced diets and staying physically active, is required to prevent type-II diabetes. Research shows that higher intake of whole grains, dietary fibre, fruit fibre per day particularly cereals with higher fibre content and diets with low glycemic index (GI) – have a lower risk of developing insulin resistance and metabolic syndrome, which are early indicators of type-II diabetes and coronary heart disease *(McKeown et al., 2004., Anderson et al, 2009).*
Due to low glycemic index, millets are beneficial for diabetes management because low GI means slow release of glucose in the blood, thus managing blood glucose level and do not spike blood glucose level instantly after a meal.
As millets are high in dietary fibre and rich in phytochemicals and type of starch present particularly in foxtail millet is slow digestible which breakdowns slowly into the intestine, which means glucose absorbs slowly as a result it can improve insulin sensitivity and reduce post meal hyperglycemia – reduced level of blood glucose after meal thus control blood sugar level and prevention of diabetes related problems (Ahamed et al., 2024). Diets rich in whole grain foods also helps to reduce the level of serum LDL cholesterol, triglycerides levels and high blood pressure while improving serum HDL cholesterol levels and reduce the risk of cardiovascular disease (Anderson, 2003).

Combating anemia: Iron deficiency anemia is major global health problem. According to WHO global anemia estimates, considerably large portion of the world suffered from anemia. With the prevalence of anemia worldwide about 39.8 % of children aged 6-59 months were affected by anemia in 2019, and 35.5 % of pregnant women, and 30.7 % of women between 15-49 years were suffered from anemia in 2023.

Children below 5 years of age particularly infants and toddlers along with menstruating adolescent girls, adult women and women during pregnancy and postnatal are the groups which are at highest level risk of anemia (*WHO, 2025).*

Millets are naturally rich in iron, making them highly useful in preventing iron-deficiency anaemia, Bajra (pearl millet) has 6.42 mg/100g, black amaranth seed has 9.33 mg/100g of iron *(Longvah et al, 2017 IFCT, NIN 2017, p. 3).* Research has shown that diets based on millets can significantly improve haemoglobin levels, serum ferritin level and overall blood health when compared with low-iron cereal diets or non-millets based diets (*Anitha et al, 2021)*. Research finding shows that iron-deficient children and adolescent girls who ate ragi-based porridge (prepared every day for 90 days showed a notable increase in their haemoglobin and serum ferritin levels. *(Karkada et al., 2018)*.

Adolescence is time phase when physical, emotional, and mental growth are faster, during this phase individuals are more vulnerable to health issues like anemia, and it has been shown to affect cognitive performance in adolescents *(karkada et al , 2018)*.

These studies shows that millets such as finger millets and pearl millets helps in lowering the risk of being affected by anemia, particularly in the population which are most likely to get affected by it. Together with iron, millets also contain other important minerals like magnesium, calcium, zinc, which many people across the world lack in their diets. Thus promoting millet consumption can be an effective way to tackle multiple micronutrient and mineral deficiencies, particularly in communities which are mainly depend on plant based food.

Table-1: Proximate Composition Of Millets and Cereals (per 100 g)

Grain	Protein(g)	Dietry Fiber(g)	Carbohydrate(g)	Calcium(mg)	Iron(mg)
Bajra (Pearl millet)	10.96	11.49	61.78	27.35	6.42
Ragi/Mandau (Finger millet)	07.16	11.18	66.82	364 ± 58	4.62
Sorghum (Jowar)	09.97	10.22	67.68	27.60	3.95
Little millet (Kutki)	08.92	06.39	65.55	16.06	1.26
Kodo millet (Kodo)	08.92	06.39	66.19	15.27	2.34
Foxtail millet (Kangani)	12.30	-	60.09	-	-
Barnyard millet	06.20	-	65.55	-	-
Proso millet	12.50	-	70.04	-	-
Whole wheat Flour	10.59	11.23	64.72	39.36	3.97
Rice, raw, milled	7.94	2.81	78.24	7.49	0.002
Amaranth seed black	14.59	7.02	59.98	181	9.33
Amaranth seed, pale brown (Chaulai)	13.27	7.47	61.46	162	8.02

Source: Indian Food Composition Tables, NIN-2017 and Nutritive value of Indian foods, NIN-2007

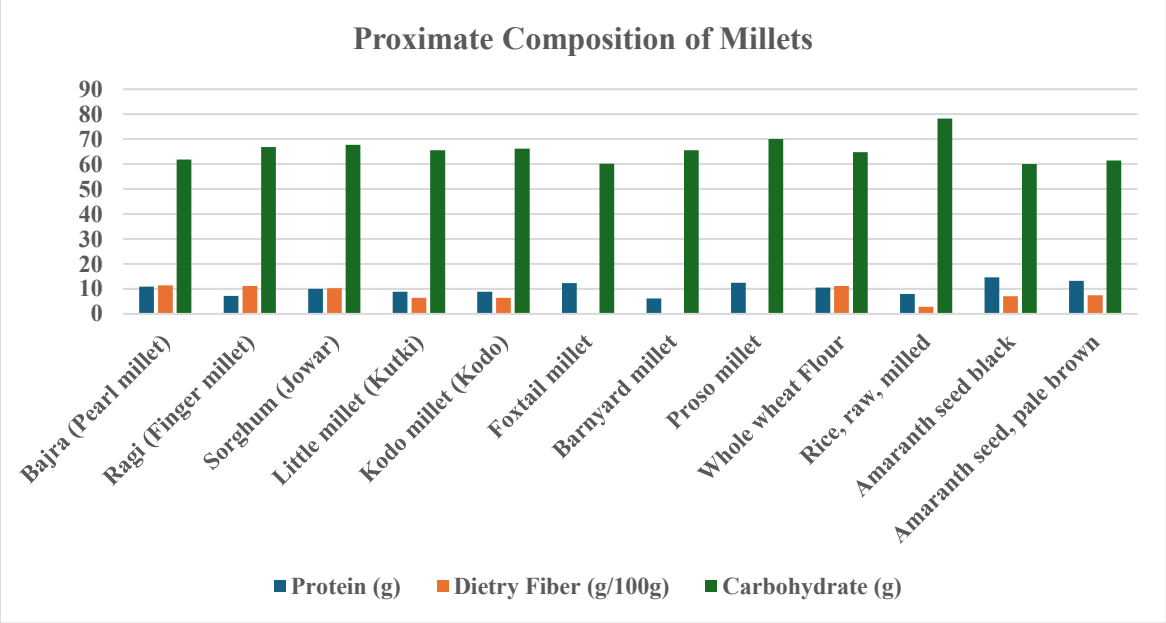

Figure-2: Source : by author based on the data of table-1

2.2 Food Security

As the global population continues to rise, ensuring an adequate and nutritious food supply for everyone has become a major challenge (*Frona et al, 2019*). Recent estimates indicating a global prevalence of undernourishment (PoU) of 9.1 % in 2023. In terms of population, between about 713 and 757 million people (8.9 and 9.4 % of the global population, respectively) were estimated to be undernourished in 2023. (*FAO et al, 2024, p. 4*). Thus, while ensuring food security, it is equally important to ensure that the foods we produce and consume have a minimal impact on the environment and have a low carbon footprint. In this context, promoting climate-resilient foods is crucial; mong plant-based options, millets emerge as a sustainable and reliable future crop that can grow even in low-fertility soil with minimal water under adverse climatic conditions. This makes millets a sustainable and reliable food choice for the future (*Saxena et al, 2018*).

Global population is projected to 9.1 billion in 2050 and global food, feed, fiber demand expected to grow by 70 percent between 2005 and 2050 and production of food in the developing countries would need almost double, driven by rising incomes and population growth (*FAO, 2009, Tilman et al, 2011*). Recent research shows that millets are rich in essential nutrients, offering significant amounts of protein, healthy fats, dietary fiber, minerals, various macro- and micronutrients, amino acids, vitamins and antioxidants *(Longvah et al, IFCT, NIN 2017).* Pearl millet naturally contains a relatively high iron content – about 6.4 mg per 100 g (*Tables:1 Longvah et al, IFCT NIN, 2017*). Which can significantly boost hemoglobin levels. Regular millet consumption increased hemoglobin by 13.2% in anaemic individuals. (*Anitha et al, 2021).* Finger millet are high in minerals like calcium and phosphorus i.e. 364 mg and 283 mg per 100g *(Longvah et al, 2017 IFCT, NIN),* contributing considerably to bone health and keep the minerals balance of the body. Along with these minerals ragi also contain phenolic compounds which act as antioxidants and helping to neutralize free radicals and support overall health *(Chandrasekara et al, 2022).*

In current scenario of climatic conditions like rising temperatures, greenhouse gas emissions and drought, pose a concern of food security and agricultural sustainability, leading to reduced productivity and yield of crops. However, millets are known for their climate-resilient property to withstand adverse climatic

conditions and capable of thriving under heat, drought, and poor soil conditions, making them a reliable option in changing environmental conditions *(Bezbaruah et al, 2024)*. These properties highlight the vital role of millets in promoting sustainable agriculture also supporting better health and long-term food security.

2.3 Health Outcome of Millets

For the metabolic health, millets play an important role by helping in lowering the blood glucose level in diabetic individuals (Dayakar et al, 2017). Especially finger millets are beneficial because it contain the good amount of calcium, i.e. 344 mg and potassium, i.e. 408 mg per 100 grams of cereals. Calcium is also important for keeping your bone and teeth healthy (Dayakar et al, 2017). Due to their low glycemic index (GI), millets are usually recommended for the individuals with type-II diabetes. Particularly sorghum is rich in slow digestible starch (SDS), which slow down the process of digestion and absorption of carbohydrates. Due to slow digestion and absorption of carbohydrate it is good for the management of diabetes and high cholesterol. Due to its high dietary fibre and low glycemic index, it support prevention and control of type-II diabetes. The presence of magnesium, vitamin E, and phenolic compounds further helps in reducing sudden spike in blood glucose and insulin levels (Dayakar et al, 2017).

2.4 Climate Resilience and Sustainability

Millets are the favourable and efficient crop for the regions facing the water scarcity, arid and semi-arid lands because it require significantly less water than rice and other crops. They are favourable for the farming in drylands due to their minimal requirements of agricultural inputs like fertilizers and thrive under challenging environmental conditions like heat, drought, less fertile or nutrient poor soils. Because of these properties, millets contribute to improving security of food for the future demands while promoting environmentally sustainable agricultural practices (Saxena et al, 2018).

2.5 Millets as Catalysts for Achieving the UN Sustainable Development Goals

To achieve multiple sustainable development goals (SDGs), 2023 was declared as International Year of Millets (IYM, 2023) by the United Nation and highlighted their importance in promoting sustainable food system. Due to their high nutritional value, millets contribute considerably to reduce malnutrition and addressing SDG-2 (Zero hunger), particularly in the regions of limited food availability and food security like African countries. Furthermore, water requirement for the millets are minimal, and they exhibit strong drought tolerance property and thrive in degraded and marginal soil, thereby supporting SDG-13 (Climate Actions) by strengthening climate-resilient agriculture systems.

In addition, cultivation of millets supports smallholder farmers and improve their income stability because millets require comparatively less inputs and resources than other crops, and thus promoting sustainable agricultural practices and contributing directly to SDG-1 (No Poverty) and SDG-12 (Responsible Consumption and Production). Overall, the integration of millets into dietary patterns and agricultural systems, offers a feasible pathway to improve nutritional outcomes, strengthening climate resilience and enhancing rural livelihoods (*Manimalathi, 2023, p. 215*).

2.6 Cultural Importance of Traditional Foods

Many traditional Indian dishes – such as khichdi, cheela, ragi roti, bajra khichri, ragi mudde (ragi ball), dosa, bhakri, churma etc. play a vital role in everyday diets because they offer balanced nutrition at an affordable cost. These preparations are deeply rooted in local food practices and provide essential nutrients while remaining accessible to diverse socioeconomic groups (*Rai et al, 2008, Rathore et al, 2019*).

Research Methodology

3.1 Research Design

This study uses a descriptive-analytical design based on secondary data from journals, government reports, and credible online sources. Data on millets' nutritional profile, health benefits, and policy initiatives were systematically compiled and analyzed to draw meaningful insights.

3.2 Data Sources

FAO, WHO, ICAR, PubMed, Google Scholar, Scopus, Government reports & databases (MoA).

3.3 Inclusion Criteria

All studies, government reports, reputable online resources to ensure comprehensiveness and datasets that provided relevant information on millets, their nutritional content, health benefits, and role in public health or food policy were considered for inclusion.

3.4 Exclusion Criteria

The Non-English publications, studies with unclear methods or incomplete data, non-relevant content, non–peer-reviewed articles were excluded.

Results & Discussion

4.1 Nutritional Superiority and Climate Resilience

Charts above clearly shows millets have higher content of iron and dietary fibre than rice and wheat. Millets provide substantially higher iron and dietary fiber compared to rice and wheat, with several varieties offering 2–4 times more iron and markedly greater fiber content. This indicate their strong potential for improving micronutrient intake and reducing conditions like iron-deficiency anaemia (IDA). Alongside their good nutritional profile millets also exhibits high resilience to various environmental conditions, thriving under low water, heat-stress, and poor soil conditions. Due to this dual advantage millets considered as superior option for regions facing both nutritional deficiency and climate related challenges for the cultivation of other crops which require more resources and inputs. Overall, the finding suggests that integration of millet into staple diets can significantly enhance nutrition while supporting food system resilience (*Longvah et al, 2017 IFCT, NIN*).

4.2 Millets in Public Health and Policy

Indian public health programs are increasingly incorporating millets to improve nutritional outcomes. The Mid-Day Meal Scheme in several states like Karnataka has added millet-based dishes to enhance micronutrient intake among school children (*Anitha et al,2019*). Karnataka has also integrated millets into

the Public Distribution System (PDS), improving access for low-income households *(Sasirekha et al., 2025)*. Since 2021, millet-based items such as ragi laddoo mix have been included in morning snacks for pre-school children under the Integrated Child Development Services (ICDS) programme in Odisha. These foods are distributed through Anganwadi centres, and raw ragi is procured from local farmers at the Minimum Support Price (MSP) (NITI Aayog). In addition, government-supported outlets and initiatives now promote millet-based food products, helping increase public awareness and healthier food choices ; National Food Security Act (NFSA), enacted in 2013, is a key government initiative designed to ensure food security for India's large population. The Act acknowledges the importance of millets by permitting their inclusion in the Public Distribution System (PDS), thereby enabling the provision of subsidized grains to eligible beneficiaries. *(Vidhya et al., 2023).*

4.3 Availability and Dietary Contribution of Millets

Table-2: Per Capita Availability, Energy, and Protein Supply from Millets in India (2014 - 2023)

Year	Food supply of millets and products (kg/capita/yr)	Food supply of millets (Kcal/capita/day)	Protein supply from millets (g/capita/day)
2014	7.77	69.71	1.86
2015	8.81	79.02	2.11
2016	7.85	70.41	1.88
2017	7.43	66.67	1.78
2018	7.27	65.24	1.74
2019	6.82	61.17	1.63
2020	7.2	64.54	1.72
2021	7.67	68.75	1.84
2022	6.71	60.18	1.61
2023	7.56	67.8	1.81

Source : Author's compilation based on FAO Food balance sheet data (FAOSTAT)

According to national food availability estimates of various cereals crops, per capita availability of millets in India was approximately 7.56 kg/year in 2023, which is equivalent to about 20.7 g/person/day, indicating that there is limited availability of millets in regular dietary patterns (FAO, 2025). In spite of their nutritional advantages, millets contribute for only small share of total dietary energy supply which is roughly around 67.8 Kcal per capita per day underline their marginal role in contemporary diets. Additionally millets provide less than 2 gm of protein per capita per day, highlighting their relatively minor contribution to national protein availability (FAO, 2025).

Table-3: Comparative Per Capita Availability of Millets, Wheat, and Rice in India (2014–2023)

Year	Millets and Products (kg/capita/yr)	Wheat and Products (kg/capita/yr)	Rice and Products (kg/capita/yr)
2014	7.77	60.54	104
2015	8.81	58.65	97.96
2016	7.85	65.18	99.29
2017	7.43	64.3	99.28
2018	7.27	60.8	97.44
2019	6.82	60.04	101.23
2020	7.2	62.32	104.46
2021	7.67	61.55	102.49
2022	6.71	65.92	98.49
2023	7.56	66.5	101.09

Source : Author's compilation based on FAO Food Balance Sheet Data (FAOSTAT)

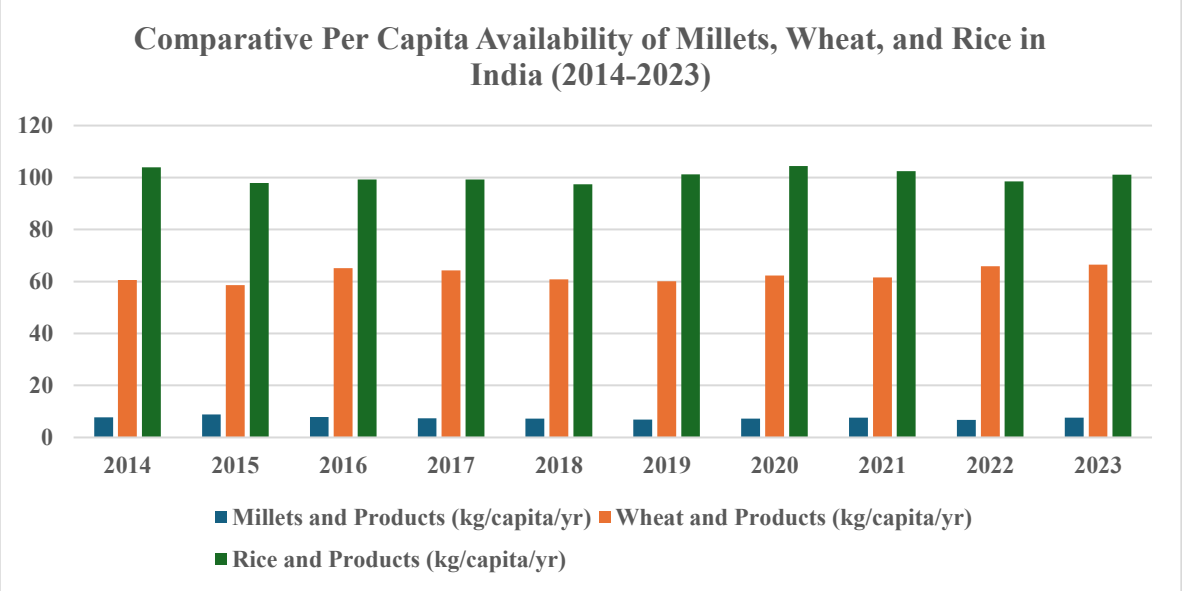

Figure-3, Source: By author based on the data of table-3

The data of food balance sheet (FBS) indicates that rice and wheat are dominant persistently in India's per capita availability of cereals, while millets contribute only a marginal share to national diets over the period of 2014-2023 (FAO, 2023). Per capita availability of millets remained nearly one tenth of wheat and less than one fifteenth of rice, indicating a highly concentrated consumption structure of cereals. In spite of increasing emphasis of policies on diversification of crops, nutritional security and climate-resilient agriculture, availability of millets shows little variations over the time. During the COVID-19 phase, the per capita availability of rice and wheat remained stable or even increased, whereas millets did not show comparable rise, indicating limited integration of millets into food security provisions. Due to

continued marginal role, millet shows structural bias in food policies and preferences of consumption toward rice and wheat, which may undermine the efforts to promote diversity in dietary patterns, and adaptability in the food systems (FAO, 2023).

These findings shows the gap between the production potential of millets and actual dietary utilization, underlining the need for targeted interventions to integrate millets into modern diets more efficiently.

4.4 Millets in Modern Diet

Millets improve nutritional security and sustainable health so there is requirement of integration of traditional foods like millets into modern dietary patterns. Millets are small-seeded climate resilient cereals that thrive in harsh environmental conditions and require less inputs compared to staple crops like rice and wheat *(Kumar et al., 2024).* Their nutrient rich profile which includes protein, dietary fibre, essential amino acids, minerals such as calcium, magnesium, zinc , iron and vitamin B-complex making them highly relevant for addressing hidden hunger and reducing the risk of chronic diseases caused by modern food system which is characterized by processed and refined foods. Moreover, biofortification of millets of millets with essential micronutrients further enhance their potential to combat with hidden hunger by improving overall nutritional and health outcomes *(Alagendran et al., 2025, Vidhya et al, 2023).*

Key considerations to successful integration of millets are value addition; processing into consumer-friendly products such as ready-to-cook flours, extruded snakes, porridges, ready to eat mixes, upma, ragi pasta, cookies, biscuits, muffins, vermicelli, noodles, semolina, restaurant millet menus and fermented products such as idli, dosa can keep their nutrition value intact while making them convenient and easy for modern lifestyles (*Verma and Patel, 2013*).

Primary processing such as cleaning, washing, dehulling, milling into flour and semolina, and refining to remove seed coat, while secondary processing include converting primary processed material into value added ready-to-cook (RTC) or ready-to-eat (RTE) products by flaking, baking, popping, and extrusion. Simple methods like soaking, germination, and fermentation can considerably improve mineral bioavailability and digestibility, whereas over-milling may lead to loss in nutrients (*Verma and Patel, 2013*). By combining traditional processing technique with modern food science, its is possible to deliver healthful and convenient millets based products (*Mundassery et al, 2024*). Institutional interventions also play important role such as integrating millets into public food programs like school feeding or public distribution systems can create consistent demand while improving health.

A recent study demonstrated that when millets were introduced into India's Public Distribution System (PDS), consumption in participating states grew, showing the feasibility and effectiveness of institutional procurement (*Sasirekha et al., 2025)*. This kind of public-sector support helps build a stable market for millets, giving farmers an incentive to grow them and producers the scale needed to supply urban consumers. Behaviour change and consumer education are equally important, many urban consumers are aware of millet's health benefits, but barriers such as unfamiliarity, perceived taste challenges, and lengthy cooking times still limit regular consumption (*Kane-Potaka et al, 2021*). Educational campaigns, cooking demonstrations, celebrity endorsement and recipe innovation especially by combining millets with familiar foods can help overcome these perceptions *(Millet Recipe, IIMR, Lacey et al, 2025)*.

Rebranding millets as "smart foods" not just ancient grains can shift their image from niche or rural staples to modern, functional foods that support wellness and sustainability. 'Smart Food' refers to food that is good for you (nutritious and healthy); good for the planet (environmentally sustainable); and good for the farmer (climate smart with the potential to increase yields and have multiple uses).

Sorghum, pearl millet, finger millet and other small millets fulfills the criteria of environmentally sustainable and climate smart, nutritious, and healthy, low carbon footprints, multiple use such as food fodder and ready to used secondary products (ICRISAT). Overall, policies that improve supply chains and incentivize producer by giving them subsidies and good quality seeds are essential. Investment in small-scale processing infrastructure, storage and market linkages are critical for making millets food products affordable and widespread availability – further enhancing their suitability for sustainable agricultural development *(Kumar et al., 2024)*. With coordinated efforts across agriculture, food technology, and public health sectors, millets can evolve from underutilized "orphan crops" into core components of resilient and nutritious.

4.5 Conclusion

Millets provide a powerful and sustainable solution to modern challenges in nutrition and agriculture such as hunger, malnutrition, drought, rising temperature. Their rich nutrient content supports health, while their ability to grow in drought-prone environment with less inputs strengthen food security under challenging climatic conditions. So millets offer triple benefits**:**

1. Improve nutritional health and help to reduce undernourishment
2. Strengthen food security by helping in mitigation of malnutrition
3. Build climate resilience by having low input requirement

Integration of millets into modern diets require clear and coordinated strategies such as raising public awareness in general public through campaigns, nutritional education, developing attractive value-added millet products and implementing supportive policies and subsidies. These strategies help millets to position it as key component of healthy, climate-resilient food systems.

Conflict of interest

There is no conflicts of interest related to this work.

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