PLANT SCIENCE TODAY
Vol 12(sp1): 1-14
https://doi.org/10.14719/pst.9971

eISSN 2348-1900

REVIEW ARTICLE

Usage and consumption pattern of millets among different ethnicities- A review

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Received: 10 June 2025; Accepted: 17 July 2025; Available online: Version 1.0: 07 October 2025

Cite this article: Asholin DA, Veeranan AGV, Karthikeyan S, Kalaiselvan A, Umamaheswari T, Vennila MA. Usage and consumption pattern of millets among different ethnicities- A review. Plant Science Today. 2025; 12(sp1): 1-14. https://doi.org/10.14719/pst.9971

Abstract

Millets, known for their nutritional benefits and adaptability, are integral to the diets of various cultures across Asia, Africa and beyond. However, the preparation, flavouring and serving methods of millet vary greatly depending on regional tastes, available ingredients and cultural preferences. By examining the role of millet in different ethnic cuisines, it is possible to identify regional differences in millet intake and its function in traditional cuisines. This diversity in millet-based dishes underscores food's role as a key marker of identity and tradition, while also emphasizing the grain's potential for promoting sustainable and nutritious diets worldwide. Interestingly, because of their historical and cultural connections, several ethnic groups have a strong affinity for millet varieties. This study explores the diverse ways in which different ethnic groups utilize millet, a versatile and ancient grain, to create distinct culinary traditions and flavours.

Keywords: Africa; Asia; ethnicity; millet consumption; traditional

Introduction

Millet is a categorization name for small-seeded grains that belong to the Poaceae family but are classified into several tribes and genera (1). For millions of people worldwide, particularly those who reside in hot, arid regions, millet is a staple diet (2). This could be attributed to their efficient photosynthetic system, as they are C_4cereals and their seeds mature in only 6-8 weeks (3). Millet has been processed for ages to create various food products with improved sensory qualities, acceptability, aesthetic value and palatability (4). Millets are exceptional because of their abundance in proteins, dietary fibre, antioxidants, minerals, phytochemicals and polyphenols, which work as an elixir to combat illnesses (5).

Millets, sometimes referred to as "orphan crops" or "smart foods", have gotten less attention than other grains, such as maize, rice or wheat. Millets are referred as “orphan crops” since it is orphaned researchers, policy makers and food industry besides their climatic resilience, nutritional significance and cultural importance. They are also referred as “smart crops” because of their adaptive advantages such as drought-tolerant, requirement of less water and heat resistant, high nutritional profile compared to other food crops and sustainability benefits. However, millions of smallholder farmers and consumers rely heavily on these resilient grains for their food and economic well-being. They are traditionally farmed around the world, particularly in semi-arid tropical regions of Africa and Asia (6).

Globally 131 countries cultivate millets. The area under millets worldwide was 71.70 million hectares in 2022, barely changing from 71.88 million hectares under millets in 2012. According to 2024 ICAR-IIMR data India accounts for 41 % of global millet production covering 83 % of Asia’s cultivation area. Niger comes second with 11.5 % production. Significant differences in the cultivation of millets are shown by the fact that Niger's share is 2.6 times greater than Sudan's. Nigeria, Chad and Mali are the other nations that cultivate the most millets. India also leads in terms of production share, with 4.8 times the output of Niger, the second-largest producer. The other major producers of millets worldwide are China, Nigeria, Mali and Ethiopia; production levels in Nepal, Pakistan and the United States are comparable. Although it is not a significant millet-growing region, Azerbaijan is the most productive country in the world. In terms of productivity, the other top nations are China, Mexico, Switzerland and Turkey. Even though India is a leader in the production and cultivation of millet, it still falls short of ranking in the top 20 in terms of productivity (7). The global millet production and area under harvest is depicted in Fig. 1.

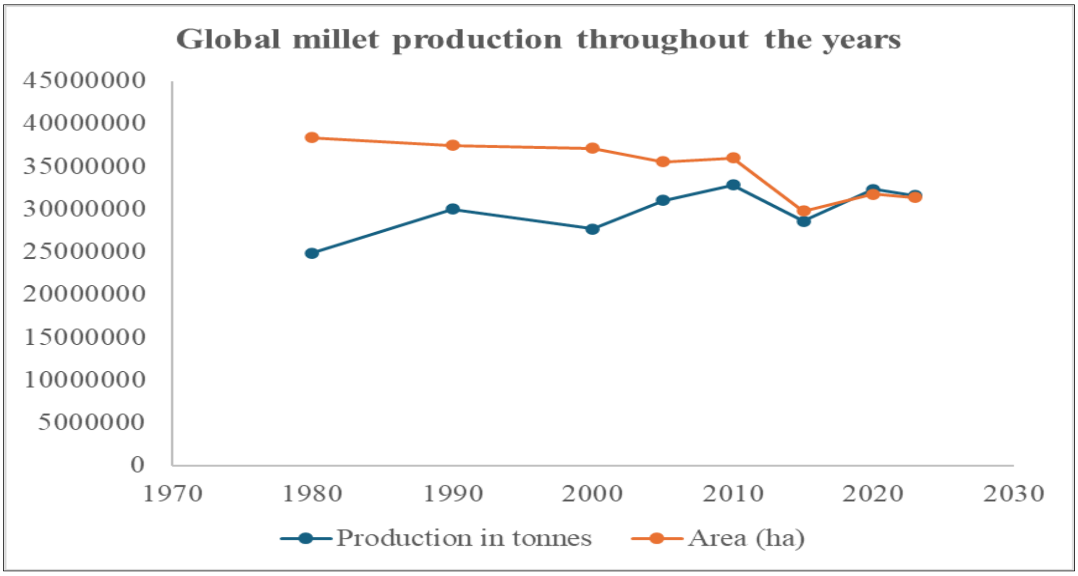

Fig. 1. Global millet production scenario.

In 2022, the total amount of millets consumed worldwide was 90.43 million metric tonnes. India consumed the most millets (17.75 million metric tonnes), followed by China (13.70 million metric tonnes) and Nigeria (8.80 million metric tonnes). *Sorghum* was the most common millet used for food, seeds, animal feed and other industrial applications. Approximately 65 % of the entire amount of millet used in 2022 came from the consumption of 59.55 million metric tonnes of *Sorghum* (8). But since then, the consumption trend of millets has been increased possibly due to the awareness among the public. The millet market is anticipated to grow at a Compound Annual Growth Rate (CAGR) of 4.6 % from 2025 to 2030, from an estimated $12.06 billion in 2025 to $15.10 billion by 2030 (9).

Classification of millets

Minor millets and major millets are the two categories of millets. While proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), finger millet (*Eleusine coracana*), barnyard millet (*Echinochloa esculenta*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scorbiculatum*), tef millet (*Eargrostis tef*) and fonio millet (*Digitaria exilis*) are classified as minor millets. Sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) are classified as major millets (10).

Nutrient profile of millets

Millets can provide a substantial contribution to a balanced diet due to their nutritionally well-rounded nature particularly in areas with a high prevalence of micronutrient deficits. Many health advantages have been linked to millet consumption (11). Millets include 60-70 % carbohydrates, 1.5-5 % fat, 7-11 % protein and 2-7 % crude fibre, vitamins and minerals. Including 100 g of millets in the daily diet can fulfil approximately 46 % to 54 % of the carbohydrate, 6 % to 20 % of the fat, 13 % to 20 % of the protein and 6 % to 25 % of the fibre requirements of the Recommended Dietary Allowance (RDA) for a sedentary adult man weighing 60 kg (12). Millet has been termed as “nutri-cereals”, because they are rich in vitamins and sulphur containing amino acids. Millets stand out from other cereals for their high calcium, fibre, polyphenol and protein content (13). The nutritional value of millets comparing to that of other cereals like rice and wheat is given in Table 1.

As a whole grain, millets' high fibre content lowers the risk of conditions including colorectal cancer, prevents constipation and maintains gut health. Millet proteins aid to maintain a normal blood lipid profile, restore blood glucose homeostasis and change the composition of gut flora. Numerous clinical and animal research have demonstrated the effectiveness of millets in lowering insulin resistance, improving and maintaining normal blood glucose levels and lowering the level of glycosylated haemoglobin (HbA1c) (22). Millets contain flavonoids, which function as antioxidants and boost the immune system. Regular eating of millet decreases diabetic risk. Phenolic substances such as ferulic acid, cinnamic acid, coumaric acid present in millets can prevent postprandial hyperglycemia by partially blocking the enzymatic degradation of complex carbs. Fiber, magnesium and tannins in millets aid in slow release of glucose in blood thereby effectively controlling diabetes (23). Antioxidants such as curcumin, quercetin and ellagic acid in millets have radical scavenging activity and neutralize free radicals (24). High fibre content, resistant starch, phenols and tryptophan in millets improves satiety and controls hunger by modifying serotonin levels in brain which can prevent obesity (25). Due to their high

Table 1. Nutritional composition of millets compared to rice and wheat

Millet	Carbohydrates (g)	Energy (Kcal)	Protein (g)	Fat (g)	Fibre (g)	Reference
Sorghum	70.7	329	10.4	3.1	2.0	14
Finger millet	72. 6	336	7.7	1.5	3.6	15
Foxtail millet	69.95	349	10.29	3.06	4.25	16
Kodo millet	65.9	353	8.3	1.4	9	17
Pearl millet	67	363	11.8	4.8	2.3	18
Barnyard millet	70	333.3	6.8	2.9	4.9	19
Proso millet	70.4	341	12.5	1.1	-	20
Little millet	69.7	374	6.87	4.64	3.20	21
Rice	77.16	345	6.4	0.5	0.3	8
Wheat	64.7	306	11.8	1.47	2	8

magnesium content, millets can help reduce blood pressure and the risk of heart attacks, especially in cases of atherosclerosis. Additionally, millets include potassium that can help decrease blood pressure and cardiovascular problems. Millets have a lot of fibre, which is important for lowering cholesterol, eliminating Low Density Lipoprotein (LDL) from the body and increases High Density Lipoprotein (HDL). Tannins, fibre and polyphenols in millets reduces melanoma, breast and stomach cancer. Consuming 30 g of fibre daily reduces breast cancer by 50 % (26). Gluten consumption causes celiac disease, an immune-mediated enteropathy that makes it difficult for those who are genetically predisposed to tolerate even trace amounts of gluten in their diet. Since millets are gluten-free, they are a great option for those with celiac disease and gluten sensitivity, who frequently suffer from consuming wheat and other common cereal grains' gluten content (14).

Factors contributing to the decline in global millet consumption

Besides the high productivity and availability of millets its consumption has decreased overtime. The decreased consumption of millets can be attributed to a few limiting reasons. The change in dietary habits is one of the main causes of the fall in millets. People are more likely to choose grains like rice and wheat over traditional millets as economies grow and their access to a wider variety of foods increases. Commercially available decorticating procedures have not yet been successfully used on millets due to their tiny size and distinctive grain morphological traits like hard texture, coarse grits and tough husks. The consumption of millet has been limited to traditional meals due to the lack of processing technology to produce millet products on a commercial scale. Unsaturated fatty acids such as oleic acid, linoleic acid and linolenic acids are abundant in millets. Therefore, millet grains that are stored for extended periods of time in hot, humid circumstances develop rancidity and unpleasant odours. Significant levels of phytates, phenols, tannins and enzyme inhibitors may restrict millets' ability to fully utilize their nutritional potential (27–30). The Green Revolution, which was implemented in India in the 1960s to combat poverty and hunger, increased the production of food grains, especially wheat and rice, making them more widely available and reasonably priced for consumers. Over-reliance on these two crops has led to a gradual decrease in millet consumption, making millets underutilized and neglected crops because of a lack of public awareness as well as several limitations, including lack of cooking methods, taste, texture and affordability (31).

Methodology

Comprehensive literature searches were carried out using four databases: PubMed, Scopus, Google Scholar and Web of Science, in addition to official government websites. The search terms and keywords used were permutations and combinations of “millets”, “traditional OR millet OR consumption”, “ethnic OR millet OR foods”, “African OR millet OR foods” and “Asian OR millet OR foods”. The search included the documents after the year of 2000. The inclusion criteria are 1. Peer-reviewed articles and journals; 2. Articles published in English; 3. Studies that specifically addressed millets. All publications that were found after the literature search were first screened based on their abstracts and titles. Every paper that didn't fit the above-mentioned requirements was eliminated.

Bibliometric analyses

The bibliometric analysis was done using VOSviewer software. The documents were collected from Scopus and Dimensions database using the keywords “traditional AND millets AND consumption” under the full data category.

For co-author network analysis Dimensions API database was used. Based on the given keywords “traditional AND millets AND consumption”, with the inclusion criteria of “English” and the publication years ranging from 1984 to 2025, a total of 135 documents were retrieved. All the documents were further processed without any exclusion. The analytical results obtained from the database were processed using Microsoft Excel and VOSviewer software. The network show seven distinct clusters with a total link strength of 583600 and 3171 links. United States depicted higher link strength of 92488 which is followed by India and China with link strength of 89055 and 68402 respectively. While China and India also appear as significant contributors with broad intra- and inter-regional interactions, the United States serves as a crucial bridge connecting varied nations across clusters. All things considered, the map depicts a highly networked research environment with prominent centres of intellectual collaboration. Total link strength of Dimension API database is given in Fig. 2.

From the Scopus database, data were curated using the search title “traditional”, “millets”, “consumption” for keyword co-occurrence analysis. Out of documents 42 keywords meeting the minimum threshold of 5 co-occurrences were identified. There were 4 distinct clusters with central nodes highlighting the keywords “millet”, “millets”, “human” and “nutrition”. One cluster highlight link between millet intake and their health outcome between genders such as “bio-fortification”, “nutritional status”, “iron”. Another cluster indicates the keywords related to cereal science highlighting comparative studies between “sorghum”, “rice”, “maize”. Meanwhile another cluster addresses broader food systems and dietary patterns, emphasizing public awareness and traditional dietary practices involving millets. Hence the map emphasizes the importance of millets in tackling global issues in sustainability, agriculture and nutrition, with close ties across scientific fields. The network of keywords co-occurrence from Scopus database is given in Fig. 3.

Millet cuisine around the world

African millet cuisine

A wide range of millet species are found throughout Africa. Millet production accounts for roughly 19 % of cereal-cultivated land. The most important millet is pearl millet, which accounts for about 87 % of millet production in Africa (32). Fig. 4 depicts the different types of millet food found in different parts of Africa.

Fig. 5 demonstrates the area under millet cultivation in Africa and the percentage of world crop area. The area under millet cultivation gradually grew from about 19.5 million to little over 21 million hectares between 2000 and 2010. The farmed area decreased to over 18 million hectares between

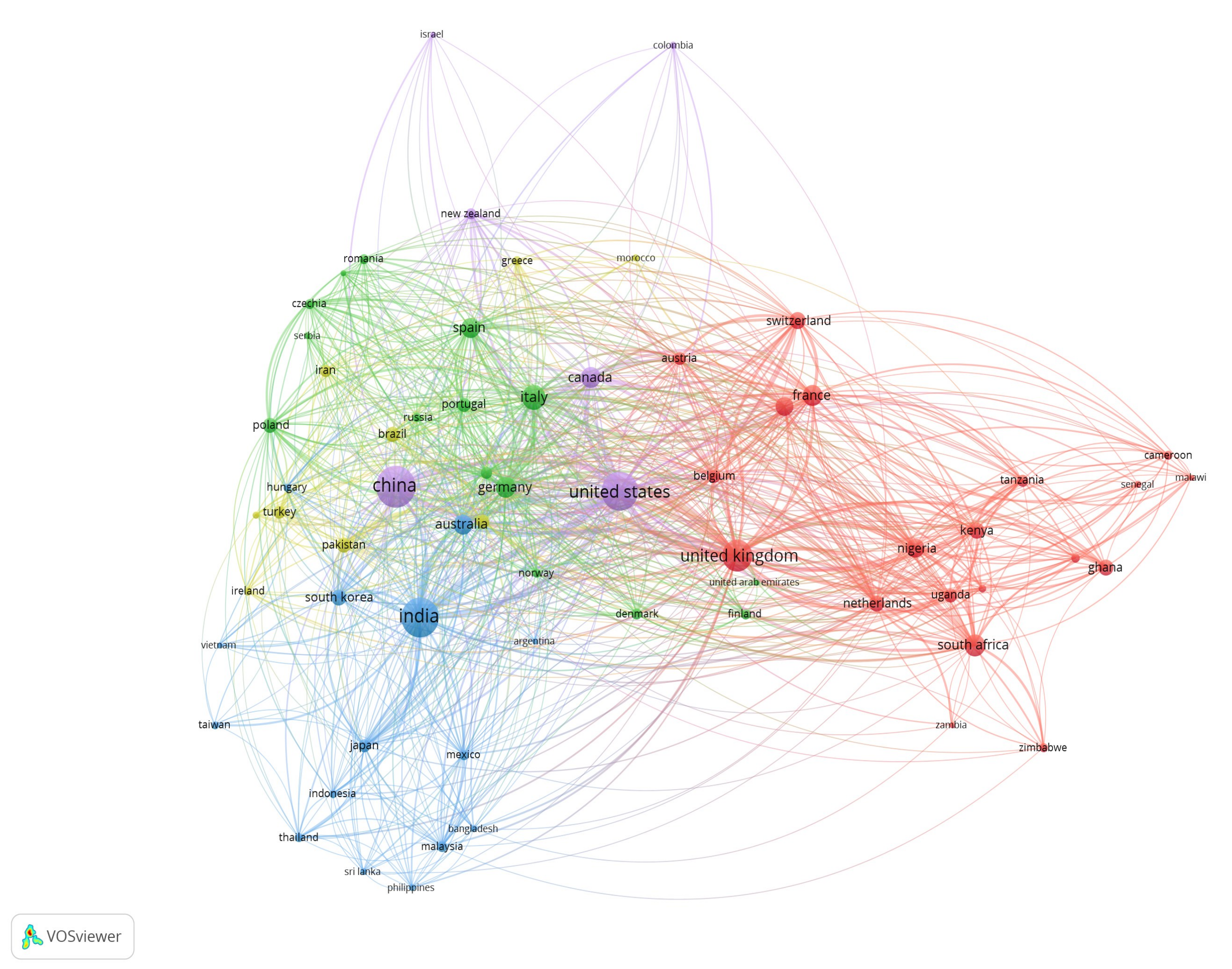

Fig. 2. Dimensions API database total link strength.

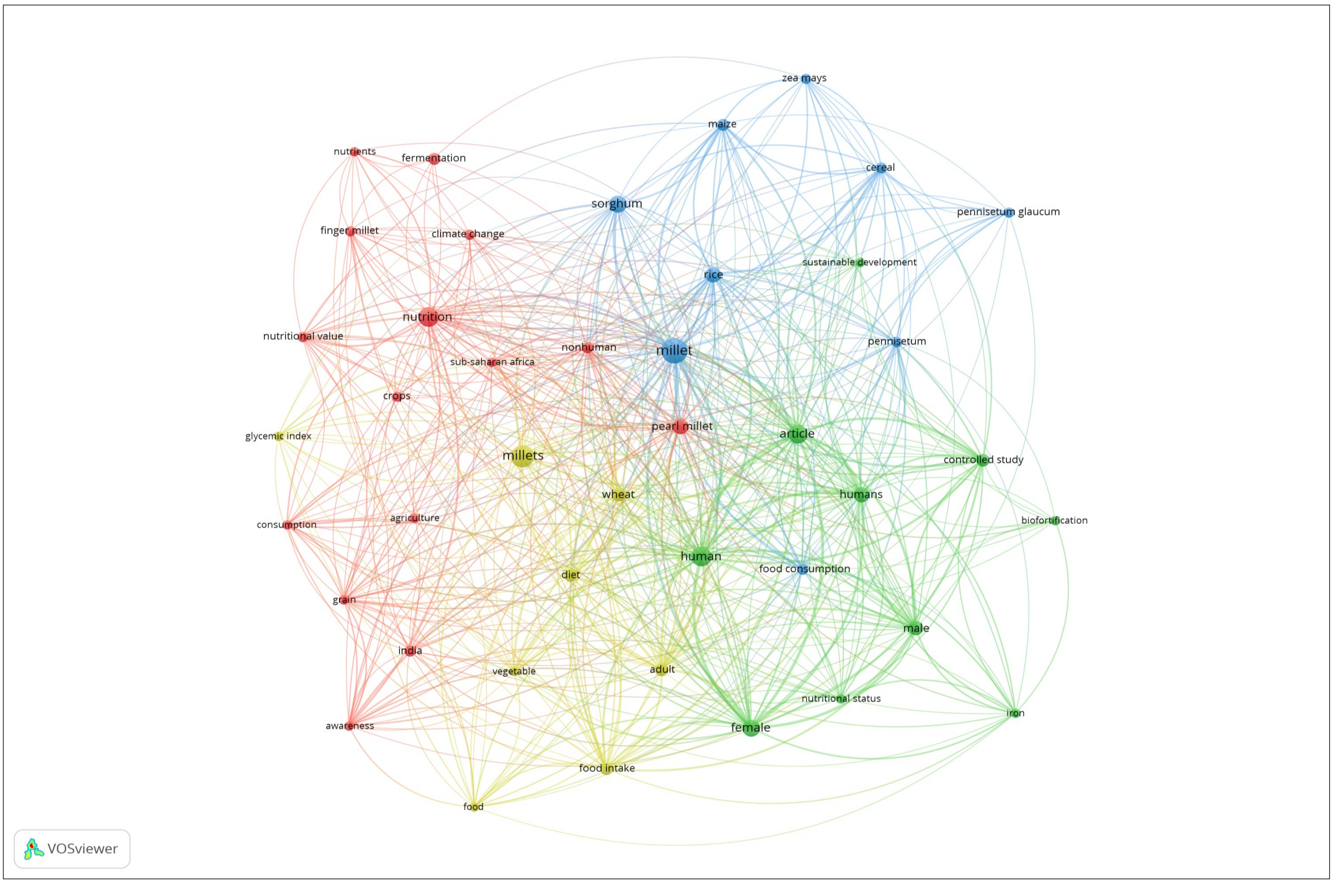

Fig. 3. Scopus database keywords co-occurrence.

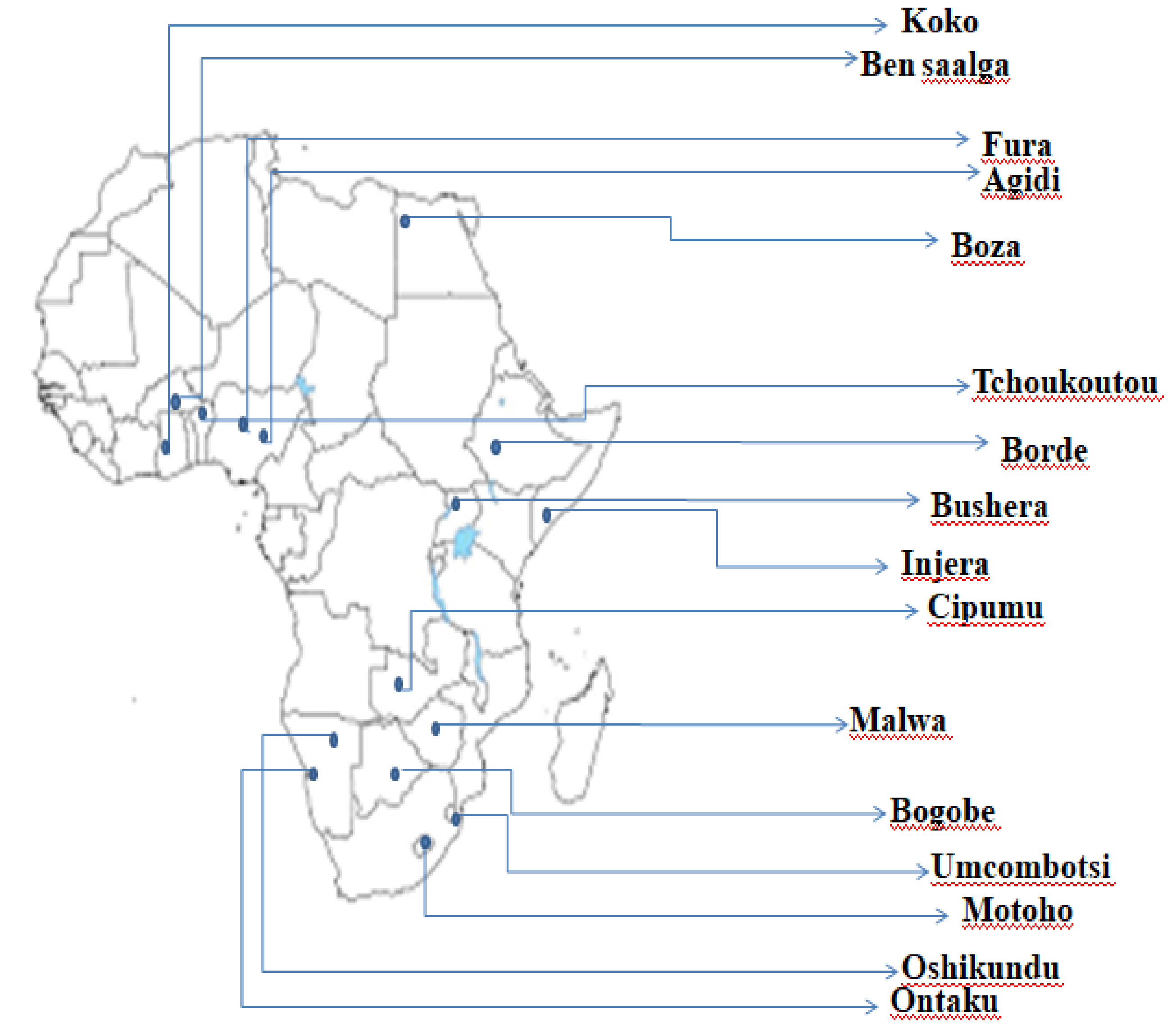

Fig. 4. Common millet dishes found in Africa.

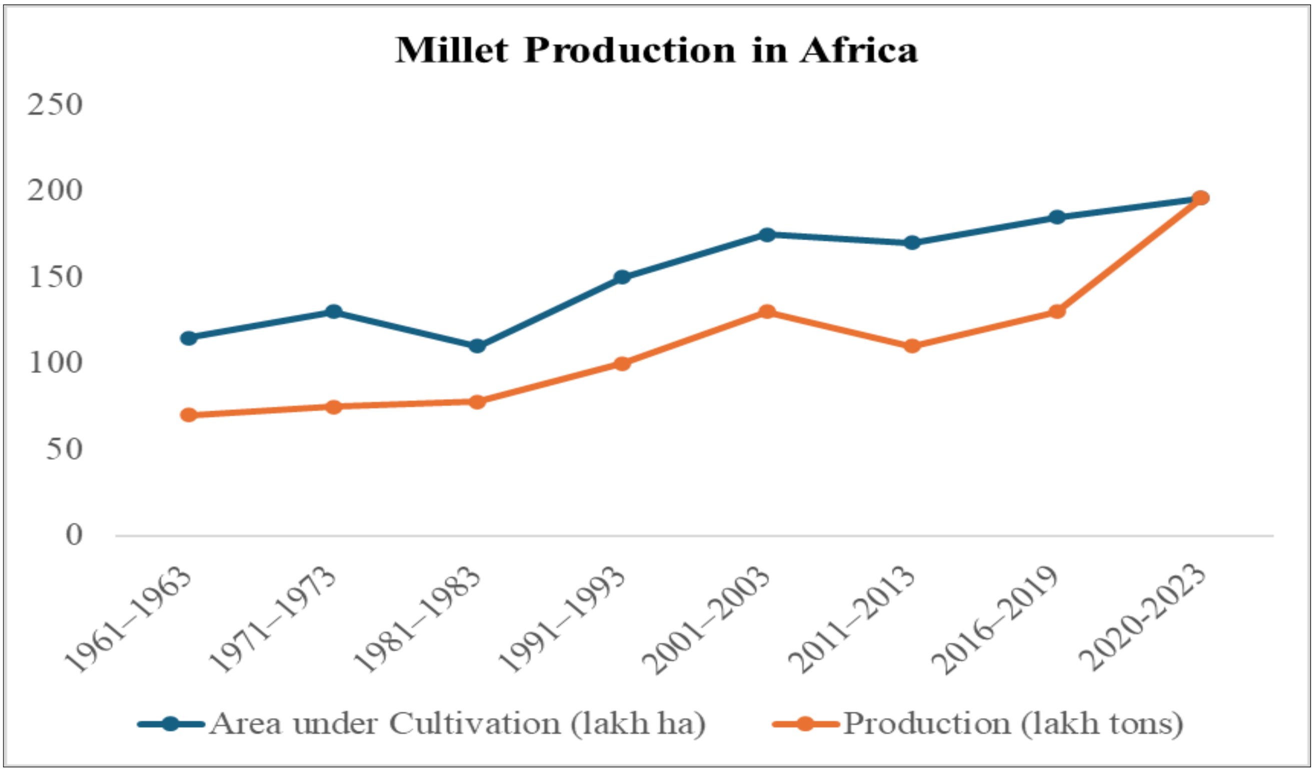

Fig. 5. Millet production in Africa.

2010 and 2015. From 18 to 21 million hectares after 2015, the area varied slightly but stayed mostly constant, reaching just under 20 million in 2023 (33).

Solid millet foods in Africa

Agidi is the traditional fermented starchy food product made mainly from maize (*Zea mays*), while sorghum and pearl millet can also be used as basic ingredients (34). Sorghum gives it a light brown hue, while pearl millet gives it a grey to greenish hue (35,36). Different localities refer to it by different names, such as *eko* in Yoruba, *akasan* in Benin, *komu* in Hausa and *Agidi* in Ibo. With acceptance spanning all socioeconomic strata and multiethnic communities, it is growing in popularity. It is quite popular among post-operative patients and other hospital patients due to its ease of ingestion, either by itself or in combination with soup, stew, bean cake (*akara*) or as a light meal (37).

A staple dish in North Africa, *couscous* is a globally well-known classic cereal product (38,39). It is a granulated and steamed food made from wheat, sorghum or pearl millet in West or North Africa. It is also called *wusu-wusu* (40).

Fura (*furah*) is a classic semi-solid dumpling made by steam boiling pearl millet balls of fermented, moist flour, then pounding and rolling them in a mortar. It is made by mixing millet with water and spices, compressing the mixture into a ball and then heating it. It is a staple cuisine in Nigeria, Ghana and Burkina Faso (41).

Injera is a leavened pancake that has a honeycomb-like structure and is prepared from teff (pseudo-millet), maize, finger millet, wheat rice or its combination (42). It is a staple cuisine in Somalia, Ethiopia and Eritrea (43). The main ingredient is teff, which is combined with water and fermented for 24 to 48 hr. A portion of the dough is cooked, blended and gelatinized. The purpose of gelatinizing the dough is to make it viscous so that the injera can rise (4).

Kisra is a flatbread made from sorghum popularly found in Sudan (44,45). Like *injera*, *kisra* is comparatively thin and lacks holes and has a spongy texture (4). *Masa* is a fried cake made in Nigeria from pearl millet (46).

Gruel foods from millet in Africa

Ben saalga is a popular dish in Burkina Faso, Africa (47). It is a semi -solid gruel made from pearl millet. Children frequently consume *ben saalga* as a complementary food (48). Processing methods include soaking, milling, sieving, settling (where fermentation takes place) and boiling (4). It contains approximately 40.3 % energy, 4.85 g of protein and 2.7 g lipids (49).

Bogobe (*ting*), which is produced from fermented maize, sorghum, or pearl millet, is native to Botswana and Southern Africa (4). Warm water (1:2, w/v) is added to cleaned or decorticated sorghum grain flour, which is then allowed to ferment for two days. Potatoes are chopped and added to the mixture to accelerate the fermenting process. In addition to providing starch and sugar as a substrate, potatoes can aid in the fermentation of microbes, which can be completed in as little as one day. *Ting* is the name of the intermediate fermented paste (50). For around 15 min, the fermented mixture is cooked to a porridge in hot water while being whisked to prevent lumps. This probiotic food provides fibre and proteins and is typically consumed with milk, sugar, *madila* (sour milk) or other relishes (41,51).

Gowe, a cooked paste produced from sorghum and/or maize flour that has been sweetened, fermented and malted, is a product of Benin. It is typically drunk as a beverage or as a porridge after being diluted with water and supplemented with sugar, ice and occasionally milk. It is the beverage of choice for young children, expectant mothers, the elderly and those who are ill (52).

Koko is a millet porridge that is eaten as an in-between meal or snack among Ghanians. Overnight steeping of pearl millet, wet grinding of the grain with spices, adding water to create a slurry, sifting, fermentation and sedimentation are the steps involved in production. To get the required consistency, the top water is then boiled and the sedimented bottom layer is added. *Koko* is a nutritious food that is rich in complex carbohydrates, fibre and protein. It is also a good source of B vitamins, calcium and iron, among other vitamins and minerals (53).

Motoho is a type of gruel that is typically made from sorghum. It is mostly consumed in Lesotho. To create a thin slurry, sorghum meal is combined with warm water (1 part sorghum meal to 3 parts water). A traditional starting culture known as *tomoso* is then added (1-part tomoso to 20 parts of the slurry) and the mixture is left to ferment. To make *tomoso*, a small amount of sorghum flour is combined with just enough warm water to cover the flour and the mixture is then allowed to ferment naturally for a day. It can also be acquired by back slopping from a prior successful fermentation. After the *tomoso* traditional starter culture is added, the fermentation process takes roughly 24 hr in the summer and 48-72 hr in the winter. Although it is optional and sometimes skipped, the fermented slurry may be pulverized using a wet milling procedure after fermentation. To cook and gelatinize the starch, the mixture is then cooked for 20 to 30 min. Before serving, it is let to cool to room temperature. *Motoho's* relatively long shelf life of approximately five days at 25 °C is said to be a contributing factor to its present successful commercial production, like that of *mahewu* (54).

Ogi is a classic porridge or gruel made from fermented maize or sorghum. *Ogi-baba* are the ones that are created especially from sorghum (55). It serves as a meal and weaning food for babies and is a staple cuisine for people living in West Africa. The traditional method for making *ogi* involves soaking the grains in water for 24 to 72 hr, then wet grinding and filtering them to get rid of the bran. *Ogi*, a sour starchy sediment, is produced by further fermenting the filtrate for two to three days. This product is typically sold as a wet cake in clear plastic bags or wrapped with leaves (4).

A common staple dish in sub-Saharan Africa is *ugali*. It is most frequently consumed in Tanzania's rural areas. In Burkina Faso and Cameroon, it is also referred to as *ikéille*. Grain or root crop flour is combined with boiling water and vigorously stirred to make *ugali*. *Ugali* is typically made from cereals including maize, rice (*Oryza sativa* and *Oryza glaberrima*), finger millet, sorghum and pearl millet, as well as root crops like cassava. In Bupigu village, *ugali* made from finger millet used to be the most significant staple meal (56,57).

Beverages found in Africa

Borde is an Ethiopian cereal beverage that ferments spontaneously with little to no alcohol and is used as a meal replacement (58). It is made using traditional methods using a range of locally accessible grain components. *Borde* has a thick viscosity, a sweet-sour flavour and an opaque, effervescent, whitish grey to brown colour (59). Its poor keeping quality means that it must be eaten within a day of actively fermenting. Adults and children in Ethiopia's Southern and Western regions consume it in large quantities (60).

Boza has a distinct acid-alcoholic scent and is thick and pale yellow. Because of its high alcohol level, it is akin to beer. *Boza* is also known as *bousa* or *bouza* in Nigeria and certain other African nations. Pearl millet is frequently used to make *boza* (*buza*, *bouza*) in Egypt (61). The primary components for making *boza* can include rice, millet, wheat or bulgur and maize. After being cleared of any extraneous objects, the chosen cereal or cereals are broken up into bits the size of semolina and sieved to get rid of the bran and hull. These cereals' flours are also favoured in various regions. The remaining ingredients are yeast (from a previous batch of *boza* or fermented bread dough), granulated sugar and drinking water (62).

Bushera is considered the most popular traditional fermented drink and is used as an energy drink, thirst quencher and social tool. *Bushera*, or *obushera*, is eaten by both young and elderly in Southwestern Uganda (60,63). It is typically made from sorghum and millet by low-income women in villages for both domestic use and sale (64). *Bushera* is made by mixing sorghum or millet malt flour with boiling water, letting it cool and then adding malted millet or sorghum or a batch that has already fermented to continue fermenting for one to six days. There are two primary ways that *bushera* is consumed: sour *bushera* for adults and sweet *bushera* for kids. A shorter fermentation time frame of one day is permitted for sweet *bushera*, whereas a longer fermentation period of twenty-four days produces sour *bushera* (63).

People of the Bemba ethnic group in northern Zambia make *cipumu*, an alcoholic beverage, from finger millet. In the community, brewing *cipumu* is a significant ritual, source of financial gain and incentive for collective labour (56).

Children and adults in Burkina Faso drink *Dégué* (*tchobal*), a spontaneously fermented and gelatinized pearl millet product (65). Following dehulling, the grains are ground with water and steam-cooked to create gelatinized balls that are then fermented for a whole day before being eaten with juice and dairy products (4).

Jnard is an opaque beer made from finger millet. An indigenous amylolytic starter called *murcha* acts on previously soaked and cooked finger millet paste to saccharify *jnard*. *Murcha* is a dried tablet made of rice that contains a variety of lactic acid bacteria, yeasts and filamentous fungus (66). The finger millet seeds are soaked overnight, ground into a crushed mass that is boiled and cooled to around 30 °C. Following the addition of ground *murcha* to the cooked mass, saccharification, lactic fermentation and alcoholic fermentation all occur at the same time during a one-to-three-day incubation period (67).

Commonly consumed in Nigeria, particularly in the Northern region, *kunu-zaki* (*kunu*) is a fermented beverage that is non-alcoholic and of high social and economic significance. It has a distinctively sweet-sour flavour, looks milky and creamy and is consumed by both adults and children while fermenting actively (67). The word "*kunun-zaki*" in Hausa means "sweet beverage." (68). It can be made from maize, sorghum or pearl millet by washing, drying and coarsely grinding the grains, then mixing the flour with hot water to create a paste that ferments spontaneously for days to produce the final product. Ginger is added to enhance its sensory qualities (4).

One of the most well-liked cereal-based drinks in Southern Africa and a few other Arabian Gulf nations is *mageu* (*mahewu*). It is a refreshing beverage that can also be used to wean infants. While maize flour is typically used to make it, certain ethnic groups substitute millets like sorghum. The first step in making it is to simmer maize meal in water until a thin porridge is formed. After cooling, sorghum malt is added for fermentation (4,69).

Malwa is a fermented, non-alcoholic beverage made from finger millet that is mostly consumed in households in Northern and Northeastern Uganda. The first step in making finger millet malt flour is to let the grains germinate for three to four days, then let them dry in the sun for one to two days before grinding them into flour. To make sourdough, a different batch of flour made from ungerminated finger millet grains is combined with water to create a stiff dough. It is then wrapped in plastic sheets and buried in the ground to undergo solid pit fermentation for 10-14 days. After that, it is roasted over an open flame on metal drums and allowed to dry in the sun for a day or two. One part malt is combined with two parts roasted sour dough, water is added and the mixture is blended by boiling. More malt is added once the mash has cooled to room temperature and the combination is allowed to ferment for two to four days at room temperature in plastic or metal drums. To speed up the fermentation process, extra malt may be added on the second day of fermentation. When the bubbling stops and a sour taste develops, the *malwa* beverage is deemed ready (63).

A naturally fermented millet mash is used to make *mangisi*, a sweet-sour beverage. In sub-Saharan Africa, preparations differ in places like Uganda and Zimbabwe. In one version, water is added to the flour after finger millet has been malted and ground. For almost 80 min, the mixture is heated gradually until it almost boils. After cooling, diluting, straining and letting it stand for a few hours, the result is a mash (*masvusvu*) that spontaneously ferments to produce *mangisi* (67).

Masvusvu is a traditional malted finger millet-based sweet beverage that is mostly consumed in Zimbabwe (70).

Merrisa is a traditional Sudanese alcoholic beverage made from malted sorghum. Its manufacturing has been characterized as a difficult process and it is most likely the most difficult brewing method of all the traditional African alcoholic beverages made from millet (4,71).

Made with pearl millet, *ontaku* is a fermented beverage that is particularly popular in Namibia. It is acidic, contains a live culture of fermenting microflora and has little to no alcohol (72).

Namibians traditionally drink *oshikundu*, a sour-sweet beverage made from cereal. Both alcoholic and non-alcoholic forms are expelled. Malted sorghum (*Sorghum bicolor*), bran, water and pearl millet (*Pennisetum glaucum*) meal, called locally as *mahangu*, are the ingredients used to make it. In several communities in Northern Namibia, peasant women frequently brew *oshikundu* for their own consumption as well as for sale in open marketplaces. In the manufacturing process, *mahangu* meal is combined with heated water and allowed to cool to room temperature while being stirred occasionally. The mixture is then supplemented with bran and malted sorghum meal. Adding bran to the brewing process is a choice based on availability and personal desire. A small amount of previously fermented *oshikundu* is added after the mixture has been prepared. Depending on the amount of starting material used and the desired volume of the finished product, water is then added to dilute the final mixture. *Oshikundu* is then ready to drink after the mixture has fermented for an average of one and a half hours at room temperature. Malt sorghum is fermented by yeast to generate the alcohol. It is a perishable beverage that is consumed the same day and has a shelf life of less than 6 hr (73).

Nigeria, Ghana and other West African countries drink *pito*, a light brown alcoholic beverage made from fermented sorghum or other millets. Nigerian tribes use it for cultural purposes and as a wholesome source of quick energy (4).

In West Africa, especially in Ghana, Togo and some regions of Benin, people drink *solom*, a relatively unknown grain beverage made from millet. This opaque, reddish-brown beverage is typically served cold, with chunks of ice. Both urban and rural communities utilize it for refreshment. Solom, like many other cereal-based drinks in Africa, is traditionally presented to guests as a sign of hospitality. It is also a component of the customary introduction of young girls into womanhood. According to oral tradition, *solom* is provided during regular social gatherings as well as at traditional marriages and other significant rituals. Sorghum or maize malt and water, or pearl millet meal, are the primary materials used to produce *solom*. It is optional to add millet bran. The unique nutritional and sensory features of *solom* are mostly derived from the ingredients, with varying qualities that rely heavily on the household's abilities. Fermentation is accomplished through random inoculation under uncontrolled environmental conditions. Local growers may use back slopping to improve fermentation and product quality (74).

Tchoukoutou is an "opaque beer," which refers to its turbidity produced by a lack of clarifying. Red sorghum is malted (soaked, germination and sun-dried), brewed (mashed, boiled, filtered) and fermented to create the beer. With a pH of 3.2 and a sour taste, the beer features a comparatively large but fluctuating number of particulates and crude protein. Lactic acid bacteria and yeasts (*S. cerevisiae*) dominate the fermentation process (66).

East Africans traditionally drink *togwa*, made of finger millet. *Togwa* is described as a non-alcoholic beverage that is both sweet and sour. Although *togwa* is made in East Africa as a native non-alcoholic beverage, a soft drink, it appears to refer to the intermediate product during the creation of alcohol from cereal, tuber crop flour and malt flour (75).

Uji is another well-known non-alcoholic beverage in East Africa, particularly in Uganda. Sorghum, maize or finger millet can be used to make it and it can be either fermented or left unfermented. The spontaneous or back-slop fermentation technique is used to make the fermented one, which is then boiled, sweetened and heated for consumption. *Leuconostoc mesenterodes* is the microorganism involved (66,76). Although the ratio of water to flour varies, the preparation process and components for *uji* and *ugali* is nearly identical. When making uji, extra water is added. Other components are rice, cassava, finger millet, sorghum, pearl millet and maize. Sugar is typically added when *uji* is consumed. Usually consumed for breakfast, *uji* also serves as a weaning food for babies (56).

Asian millet cuisine

Asia has long been a major consumer of millet, particularly in South Asia, East Asia and portions of Southeast and Central Asia, where millet varieties such finger millet, pearl millet, foxtail millet and proso millet were part of traditional diets. The three main Asian countries that produce the most millet are China, India and Nepal. India continues to be the world's greatest producer and consumer of millet, which is utilized in a variety of culinary and cultural staples. While millet continues to play a significant role in rural and highland cuisines in Nepal and Sri Lanka, it is still consumed in China as porridge and is used in traditional medicine. During the Green Revolution in Asia, millet consumption decreased as rice and wheat became more popular, but in recent years, it has increased again as people have become more conscious of the nutritional value, health advantages and climate resistance of millet (77).

Fig. 6 shows a notable and steady drop in millet production overall as well as in the area under cultivation between 1961 and 2023. Around 260 lakh hectares of millet were grown in the early 1960s, yielding more than 400 lakh tonnes. Although production reached a record of over 450 lakh tonnes in 1971-1973, both area and yield then started to gradually decrease. Production declined drastically to over 175 lakh tonnes during the 2020-2023 timeframe, while the cultivated area shrank to almost 100 lakh hectares. This trend points to both a declining millet farming landscape and a diminished emphasis on millet-based agriculture, which may be brought on by changes in dietary habits, governmental preferences for primary grains like wheat and rice and a lack of market support. Additionally, the statistics show that previous yield gains were not maintained over time, highlighting the necessity of refocusing efforts on millet promotion, productivity improvement and farmer incentives.

South Asian millet cuisine

Solid millet foods: *Ambali* is a fermented food from Tamil Nadu and Karnataka made from finger millet. Because it has a high calcium content and a low resistant starch content, it is regarded as a healthy diet for the elderly (78). Fig. 7 mentions the different kinds of millet foods found in South Asia.

Bengal gram flour and pearl millet flour are combined to make *appalu.* The dough is kneaded with spices as salt, sesame seeds, carom seeds and chilli powder. The dough is then formed into round shapes by flattening it into little balls. After being fried, these are served hot (73).

The flour of popped finger millet, known as *ragi hurihittu,* is high in minerals and dietary fibre. Popping is a straightforward processing method that involves intense heat treatment. Due to gelatinization, it enhances the taste and aroma, reduces antinutritional components and makes starch more soluble and digestible. Finger millets add more dietary

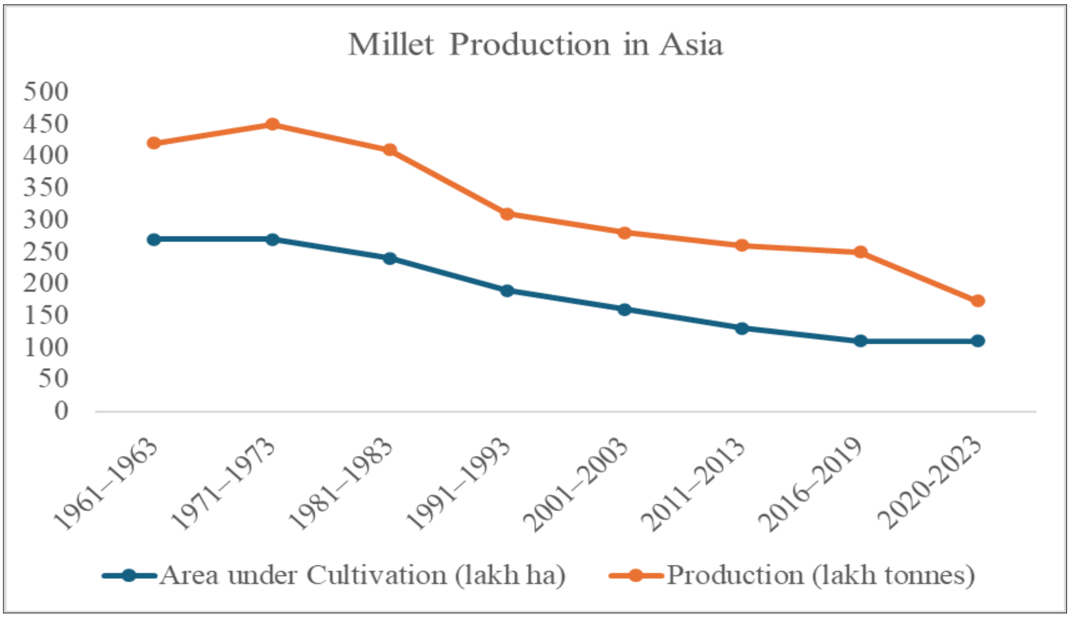

Fig. 6. Millet production in Asia.

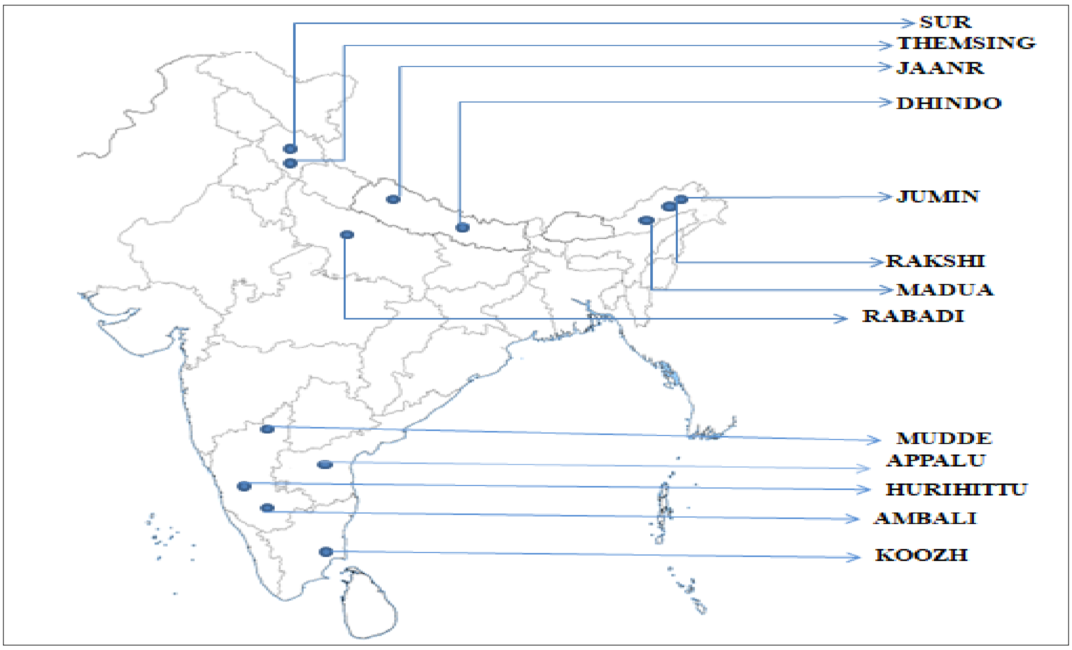

Fig. 7. Millet foods in South Asia.

fibre to the finished product because they are small and hard to de-bran when popped. The flour is used to make weaning foods, or ready-to-eat malts. Finger millet's high reducing sugar content and amylase enzyme activity are the main causes of *ragi hurihittu's* excellent nutritional value. Slow cell wall breakdown components found in *ragi hurihittu* are helpful for preparing foods high in fibre. Finger millet is germinated to increase the nutritional value of *hurihittu* by increasing the bioavailability of zinc and iron. It can be used to formulate geriatric diets and prepare dietetic foods for people with anaemia (79).

Warm milk and millet powder are combined to make *mirung gakir*, where *gakir* means milk and *mirung* means finger millet. This beverage is typically given to a nursing mother to ensure sufficient production of breast milk (80).

Millet beverages: A mainstay of Nepal's culinary tradition, millet *dhindo* is served on tables throughout the country's hilly and mountainous regions, particularly among Tamangs and in India's Sikkim and Darjeeling districts. Made with millet flour, water and ghee, this filling, thick and sticky porridge is typically served with beef gravy, lentil soup, vegetable curry or pickles. As a component of vegetarian and gluten-free cooking, millet *dhindo* has a high nutritional content. Enhanced with millet flour's fibre, iron and antioxidants. It blends health and flavour. Its ability to blend well with a variety of accompaniments adds to its allure (81).

A popular alcoholic beverage among the Nocte Tribe in the Tirap district in Arunachal Pradesh is *jumin*. Every tribal member drink *jumin* every day. This is also provided to greet every visitor (82).

The Gorka, Bhutia, Lepcha, Monpa and many other ethnic communities in Northeastern India produce and drink a moderate alcoholic beverage made from finger millet that has a sweet, sour and acidic flavour (83,84). A previous study reported *jaanr* contain 83.7 % carbohydrates, 9.3 % protein, 2 % fat (85).

Ethnic communities in Tamil Nadu, India mostly drink *koozh* which is a fermented beverage made with rice and millet flour. Pearl millet and finger millet are mainly used in its preparation. There are two fermentation phases in the *koozh* preparation process (86). The millet is first ground into flour, then combined with water to create a slurry, which is then allowed to ferment for the entire night. To form a thick porridge known as *noyee*, the overnight fermented millet slurry is combined with broken rice cooked in excess water on the second day. This porridge ferments for 24 hr, producing *kali*, a semi-solid porridge. To make *koozh*, the necessary amount of drinkable water (1:6 w/v) is added and the mixture is manually combined with salt (73).

Rabadi is a traditional, well-liked beverage from the Northwestern Indian states that is made by fermenting pearl millet (*Pennisetum typhoideum*) flour with buttermilk in various proportions. After three to four hours of fermentation in the sun, this prepared combination is boiled. Either the prepared product is taken straight away or it is diluted by adding buttermilk or milk (87).

The Monpa, Miji and Mishmi tribes, who live in the regions of Tawang and West Kameng, make *rakshi*, an alcoholic beverage. This beverage is made from finger millet, rice and barley grains. Following fermentation, a sizable vessel filled with fermented material is kept on fire while water is added to the fermented stock. To collect the distillate, a tiny metallic container is placed within the huge vessel above a triplet stand. Above the huge tank, a condenser is a wide vessel filled with cold water that is regularly replaced to maintain the water's constant coolness. The beverage made with this technique has a strong ethanol flavour and a pleasant alcoholic scent (88).

In every district of Arunachal Pradesh, nearly every tribe makes *madua*, one of the most well-liked and widespread fermented beverages made from millet. It's a classic alcoholic beverage made from finger millet. A sweet scent is released during saccharification, a sign that there has been enough fermentation. After that, the finger millet's fermented mass is moved into a bamboo basket with holes in it and warm water is fed to it drop by drop at a pace of 1 L/hr. The collected filtrate is stored in a container below. *Madua* of high grade has a bright yellow colour, a sweet flavour and a good alcoholic flavour (88).

Mirii is a slurry made from millet. In Apatani dialect, the processed flour is called *Mirii* and the entire finger millet grain is called *Sase*. An Apatani household's go-to breakfast is this slurry. Most of the millet's nutritional value, particularly its fibre content, is preserved in *Mirii* (80).

A stiff porridge is made from coarse ragi flour, which is then moulded into balls to form *mudde*. Ragi balls, also called ragi *mudde* in the local dialect, are a common food in Karnataka, India (89).

Sur is a fermented beverage made from finger millet that is mostly made in the region of Sirmour in Himachal Pradesh, India; Bhangal, Luharti in Kangra district, Balh valley, Barot valley in Mandi district and the Lug valley in Kullu (90). Fermentation is carried by using a mixture (inocula) of roasted barley and regional herbs called *dhaeli*. After kneading the millet flour with water to form a dough, it is placed in a container to ferment naturally for seven to eight days. After being partially baked into rotis, the fermented flour is sliced into pieces and allowed to cool. After that, the roti pieces and powdered *dhaeli* are combined with enough water and jaggery in earthen pots that have been smoke-treated and the pot is covered and left to ferment for ten days. Following the fermentation process, the liquid is filtered and kept in specially made earthen pots that are airtight from the top. The product contains 5–10 % alcohol (91).

The Monpa tribe of Aunachal Pradesh's Tawang district makes an alcoholic beverage called *Themsing*. It can be made with barley (known locally as *Bong*) or finger millet (known locally as *Kongpu*) or a combination of the two (88).

Zan is a sort of porridge prepared from finger millet and vegetables. It is a Monpa tribal breakfast staple (92). Rich in dietary fibre, protein, calcium, iron and vital amino acids, *zan* is known for its remarkable nutritional benefits. The dish's nutritious value is further increased by the addition of vegetables (80).

East Asian millet cuisine

Awaokoshi or candied millet puffs, are a specialty of Osaka, Japan (93,94). *Noti* is a Korean pancake that is made with broomcorn millet (95). In Taiwan, foxtail millet is used to make *qohozi*, *tinuerau* wine. This traditional product category has an alcohol percentage of 10 % to 13 % (v/v). A fermented beverage made from millet and rice, *darassun* has its origins in Mongolia (96).

China's national beverage *baijiu* is a unique white liquor primarily derived from sorghum that some believe is good for health. Mostly made from sorghum fermented in pits or earthenware jars, it accounts for one-third of the world's total liquor production and is valued at an estimated $23 billion each year (97). Both volatile and non-volatile ingredients, which are mostly created by microbial metabolism during fermentation, give Chinese *baijiu* its flavour. Esters, acids, alcohols, aldehydes, chemicals containing sulphur and nitrogen and terpenes are examples of volatile substances. These substances have a significant impact on *baijiu's* quality and aromatic qualities. Since non-volatile ingredients are frequently employed as precursors to volatile ingredients, their quantity will influence the quantity of volatile ingredients in *baijiu*, which will impact the product's flavour and quality (98).

Another old mature-type vinegar prepared in the same process of *baijiu* is *shanxi*. The preparation of the *koji*, saccharification (the generation of sugar), alcoholic fermentation, acetic acid fermentation and maturation are the four steps of solid-state fermentation of *baijiu*. The fermentation of acetic acid takes less than 10 days. However, the basic production process takes over 18 months. By back slopping with an inoculum from a prior fermentation, known as *pei*, the acetic acid fermentation is accomplished. The primary yeasts in the fermentation of alcohol are *Saccharomyces cerevisiae* and *Hansenula anomala*, while the primary fungus in the saccharification process are *Aspergillus, Rhizopus* and *Monascus*. The fermentation of acetic acid involves several types of *Acetobacter bacteria* (54).

A Korean traditionally fermented alcoholic beverage, *omegisool* has a distinct flavour and taste, particularly being significantly sweeter and sourer than other alcoholic beverages. *Omegisool* is a beverage with a low alcohol content. The preparation of *omegisool*, which is mostly made in the Jeju region of Korea, involves combining water, *nuruk* and foxtail millet powder cakes (also known as *omegi* cake) and letting them ferment in a pot for three to five days. A variety of wild microorganisms, including molds, yeasts and LAB, thrive because of the spontaneous solid fermentation of barley grains at room temperature, which produces the *nuruk* required to manufacture *omegisool* (99).

During the harvest festival of the native Taiwanese people, *xiao mi jiao*, a foxtail millet-based alcoholic beverage made without distillation, is a significant customary offering (100).

Importance of traditional millet foods to modern millet foods

It is noted that modern millet-based culinary developments are greatly influenced and improved by traditional millet cuisines. Often the traditional recipes are minimally processed retaining the essential nutrients. Their preparation includes fermentation, germination, soaking and roasting which greatly enhances the bioavailability and bio accessibility of nutrients. The fermented millet foods are given in Table 2. Traditional millet foods reflect cultural and regional significance of the specific communities. In today's dietary landscape, traditional millet meals offer a foundational framework for innovation in the production of modern food products, integrating history with sustainability and health (77).

Challenges and future prospects

Despite its many health advantages and cultural significance, millet cultivation and promotion confront multiple challenges. Resolving these issues is essential to include millets into regular meals and agriculture. Customers' ignorance about millet's nutritional and health benefits is one of the main issues. To raise awareness and educate people about millets, national campaigns and educational initiatives are needed. Millets are typically grown by farmers who have limited access to markets, which lowers their income and deters them from selling. Promotion of millet was hampered by the gradual decline of traditional knowledge about millet farming methods and its application in local cuisines.

A fascinating paradox is the conflict between the comeback of millet in mainstream consumption and its preservation in ethnic diets. Future research should not only clarify this paradox but also try to close the gap between tradition and modernity. By eliminating the financial, technological and cultural barriers to millet use, we can unlock the potential of this ancient grain for contemporary diets and contribute to the development of a more robust, nutrient-dense and sustainable food system. Incorporating millets into the mainstream food chain while honouring their cultural significance in rural and tribal communities should be the focus of future research (77).

Conclusion

A staple in many parts of the world, millets show how various societies have tailored these adaptable grains to their own traditions and resources, producing a vast array of meals, textures and flavors. There are many different methods to prepare and eat millet, ranging from spicy porridge in India to sweet millet-based delicacies in China and Africa. This variety emphasizes how crucial food is as a vehicle for cultural expression and traditional preservation. In the end, even though millets are a common food among many ethnic groups, they are modified by local preferences, cooking techniques and ingredients, illustrating the diverse range of cuisines found throughout the world.

Table 2. Fermented millet foods

Food	Millet	Type	Microorganism involved	Major change due to fermentation	Reference
Agidi	Sorghum, pearl millet	Pudding	*Lactobacillus plantarum, Pediococccus acidolacti, L. acidophilus, Streptococcus, Bacillus, Leuconostoc*	Increased bioavailability of riboflavin, niacin and folate Increased protein and starch digestibility	(35)
Furah	Pearl millet	Dumpling	*Lactobacillus plantarum, Pedicoccus, Leuconostoc, Streptococus, Enterococcus, S. ccereviciae, Pichia anomala, Candida* spp.	Increased folate content	(35)
Koko	Pearl millet	Porridge	*Lactobacillus fermentum, Weisella, Lactobacillus salivarius*	Improved essential amino acids bioavailability	(53)
Ogi	Sorghum	Porridge	*Lactobacillus plantarum, Candida mycoderma, Saccharomyces cerevisiae, Corynebacterium*	Increased riboflavin and folate,	(35)
Boza	Pearl millet	Alcoholic beverage	*Lactobacillus plantarum, Lactobacillus paracasei, Lactobacillus rhamnosus* and *Lactobacillus pentosus*	Increased B-vitamins	(62)
Burukutu	sorghum	Beverage	*Acetobacter* spp., *Candida* spp., *Leuconostoc mesenteroides, Saccharomyces cerevisiae, S.chaveleri*	Increased lactic and acetic acid	(35)
Tchoukoutou	Sorghum	Alcoholic beverage	Lactic acid bacteria and yeasts	Improved energy, fat, protein and iron	(66)
Uji	Sorghum, finger millet	Beverage	*Leuconostoc mesenterodes*	Increased iron, zinc and calcium absorption	(76)
Ambali	Finger milet		*Lactobacillus fermentum, Leuconostoc mesenteroides, S. faecalis*	Improved bioavailability of iron, calcium, zinc	(79)
Jaanr	Finger millet	Alcoholic beverage	*Pichia anomala, Mucor circinelloides, Rhizopus chinensis, Pediococcus pentosaceus, Saccharomyces fibuligera, S.cerevisea, Candida glabarata, Lb. bifermentus*	Increased organic acids and bioactive compounds	(83,84)
Koozh	Finger millet, pearl millet	Porridge	Lactic acid bacteria	Increased free amino acids, phytochemicals, selenium	(79)

Acknowledgements

We would like to express our sincere gratitude to Tamil Nadu Agricultural University, Coimbatore and Community Science College and Research Institute, Madurai for their invaluable technical support and guidance.

Authors' contributions

ADA wrote the first draft of the manuscript. VAGV and KS provided guidance for overall correction and improvement. KA, UT, VMA assisted with literature collection and formatting. All authors contributed equally to the revision of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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