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Millets in India: exploring historical significance, cultural heritage and ethnic foods

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Abstract

This review paper offers a comprehensive exploration of the historical significance of millets in India, their role in preserving cultural heritage and embodiment in a diverse array of ethnic foods. In-depth online literature searches were conducted to assess the data, and the information was retrieved from official government reports, journals and books. The study explores the archaeological evidence and historical records of millet cultivation in India, highlighting their importance in Vedic era, ancient civilizations and Mughal rule. Studies showed a diversity of cultures in India and the importance of millets in religious ceremonies, festivals, literature, and folklore, showcasing their deep-rooted presence in Indian traditions. Further, the inclusion of millets in various ethnic dishes of different states demonstrates the diverse culinary applications of millets in India. Recent processing technologies for millet need to be studied for producing various millet-based food products. Additionally, the paper briefly discusses the challenges of millet consumption and promotion in India along with its future prospects. The study suggests that promoting millets and reviving traditional millet-based ethnic food and cultural practices can help preserve India's rich heritage.

Keywords Millets, Historical significance, Ethnic foods, Cultural heritage, Processing technologies

Introduction

Millet is an ancient cereal grain that evolved in semi-arid tropical regions of Asia and Africa and expanded to other parts of the world. It is a member of the Poaceae grass family. Millets are an important staple crop with the capacity to withstand the harsh circumstances common in these areas because of their historical relevance in these places [1]. Millets are regarded as resilient crops, thriving in harsh climatic conditions characterized by unpredictability and nutrient-depleted soils. As a result, they have emerged as a resilient and suitable option for cultivation in such challenging environments [2]. Millets are small seeded cereal grains comprising of major millets like pearl millet and sorghum; minor millets such as foxtail millet, finger millet, little millet, kodo millet, barnyard millet and proso millet and pseudo-millets buckwheat and amaranth that are a potential source of food, feed and fodder in different countries [3, 4].

India is a major millet growing hub, because of its diverse agricultural practices and rich cultural tapestry, it considerably contributes to the food security and nutritional well-being of its population [5]. Millets, including finger millet (ragi), pearl millet (bajra), sorghum (jowar), and foxtail millet, are essential parts of the Indian diet, particularly in areas with difficult agricultural conditions [6]. India is the world's largest producer of millets. In the year 2021–22 pearl millet generated 58% of the total millet production, followed by sorghum (29%) and finger millet (10%). Figure 1 represents the millet growing states in India. The principal millet-producing states in India include Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Uttarakhand. Currently, these ten states account for around 98% of millets output

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Fig. 1 Geographical distribution of millets in Indian States [7]

in India over the 2020–21 decade. Millet cultivation and production are observed to be more prevalent in western India. Rajasthan provided 36% (4300 K hectares) of India's total millet farming area [7].

Millets are among the first domesticated crops in human history, having been grown for thousands of years. Ancient civilizations have a significant historical presence in the Indian subcontinent, as evidenced by archaeological discoveries from places like the Indus Valley [8]. Because millets are so adaptable to a wide range of typically difficult climatic conditions, they were formerly a mainstay of agricultural operations and were essential to ancient food systems. The popularity of millet cultivation and eating across India is attested to both historical writings like the Yajurveda and mentions in mediaeval narratives like Abul Fazl's Ain-i-Akbari [9]. These historical narratives emphasize the significance of millets in maintaining agricultural communities prior to the introduction of high-yielding grains such as wheat and rice. In India, millet has a rich cultural history and

Table 1 Nutrient composition of millets [12/8]

Grain	Carbohydrates (g)	Protein (g)	Fat (g)	Energy (Kcal)	Dietary fibre (g)	Ca (mg)	Zn (mg)	Fe (mg)	Thiamin (mg)	Folic acid (µg)
Sorghum	67.7	09.9	1.73	334	10.2	27.6	1.9	3.9	0.35	39.4
Pearl Millet	61.8	10.9	5.43	347	11.5	27.4	2.7	6.4	0.25	36.1
Finger millet	66.8	07.2	1.92	320	11.2	364.0	2.5	4.6	0.37	34.7
Kodo millet	66.2	08.9	2.55	331	06.4	15.3	1.6	2.3	0.29	39.5
Proso millet	70.4	12.5	1.10	341	–	14.0	1.4	0.8	0.41	–
Foxtail millet	60.1	12.3	4.30	331	–	31.0	2.4	2.8	0.59	15.0
Little millet	65.5	10.1	3.89	346	7.7	16.1	1.8	1.2	0.26	36.2
Barnyard millet	65.5	06.2	2.20	307	–	20.0	3.0	5.0	0.33	–
Amaranth	61	13.3	5.6	356	7.5	162.0	2.8	8.0	0.04	24.7
Wheat	71.2	11.8	1.5	339	10.7	38	2.7	3.5	0.41	–
Rice	78.2	6.8	0.5	370	2.8	10	1.4	0.7	0.41	–

is interwoven with several religious and social customs. These grains have always played a significant role in celebrations, customs, and traditional diets—particularly in rural and tribal societies [10]. The traditional knowledge and biodiversity connected to millets, as well as the grains themselves, have been conserved via ethnic rituals. Millet-based meals are still utilized in ceremonies and festivities in places like Rajasthan, Karnataka, and Nagaland, where they represent community togetherness, fertility, and wealth. Millet-based meals are a common element of tribal festivities and festivals like Makar Sankranti, which help to preserve the cultural history of these areas. Studying historical evidences and traditional cultural practices is of utmost importance as these are the foundations that helped in preserving millets in India [11].

Protein-energy malnutrition and micronutrient deficiencies are significant factors contributing to elevated mortality rates among a substantial proportion of the current global population, which stands at 7.2 billion, particularly affecting children. The study also looks at millets' nutritional makeup and possible medical uses, adding to the expanding conversation on the inclusion of these grains in modern diets again because of their positive effects on the environment and human health [12]. While poverty and inadequate nutrition in diets are key factors behind the widespread prevalence of malnutrition, the introduction of nutritionally dense crops presents a cost-effective and sustainable solution to this pressing issue. Interestingly, millets have proven to be nutritionally superior to major non-millet cereals as described in Table 1 [12], making them a promising candidate for addressing malnutrition-related challenges [13]. There is a renewed interest in reintroducing these nutritious grains into the mainstream, recognizing their potential benefits for both health and the environment [14]. This review paper offers a comprehensive exploration of the historical importance of millets in India, their role in preserving cultural heritage, and their embodiment in a diverse array of ethnic foods.

Methodology

In-depth literature searches were conducted on official government websites as well as four databases: PubMed, Scopus, Google Scholar, and Web of Science. Keywords and search terms utilized for the search encompassed variations and combinations of "millets", "history", "culture OR traditions OR stories", "therapeutic use", "ethnic foods OR cuisine", "tribal foods", and "India OR South India OR North India OR North East India OR Western India". The search was not confined to any specific time frame, aiming to capture the extensive history and diverse practices associated with millets in India.

Figure 2 depicts the selection process of the articles for the present study. The papers considered for inclusion in this review were subjected to a set of predefined criteria to ensure relevance and quality: (1) Peer-reviewed articles and journals; (2) Articles published in English; (3) Studies that specifically addressed millets in India; (4) Open access articles; (5) Articles that provided insights into the history, cultural significance, therapeutic use, or ethnic foods associated with millets.

Exclusion Criteria: (1) Non-peer-reviewed articles and grey literature; (2) Articles not accessible in full; (3) Studies that did not focus specifically on the context of India; and (4) Articles that did not contribute significantly to the themes of history, culture, therapeutic use, or ethnic foods of millets.

Following the literature search, all identified papers were subjected to an initial screening on the basis of their titles and abstracts. All the papers that did not meet the inclusion criteria were excluded. The remaining papers underwent a full-text review by the reviewers to assess their relevance and contribution to the themes of the review. The screening of data and assessment for eligibility was done by the primary reviewer. Both the reviewers independently reviewed all the papers that are included in the study. After the full-text review and data extraction, a total of 65 articles were selected for inclusion in this review.

Historical background of Indian millets

According to E. M. Forster, India is distinct and mysterious, remaining a fascinating subject [15]. The idea that Indian culture can be grasped through its cuisine is reinforced by its rich history of millet cultivation, dating back to ancient times. Millets, initially found in Asia and Africa, played a pivotal role in shaping India's agricultural practices and food habits before spreading globally. Table 2 describes the origin of different millets. Millet holds great historical importance in India. Through trade routes and human migration, millets have spread throughout the world. Archaeological evidence and historical records have provided insights into the prominence of these grains in India's agrarian landscape.

Archaeological evidence

Archaeological excavations at sites of ancient civilizations such as the Indus Valley Civilization (circa 3300–1300 BC) have revealed remnants of millet grains, indicating their cultivation and utilization during that period [8]. Millets, evident at Harappan sites, were among India's earliest cultivated crops. Archaeological data indicate Kashmir as a millet exchange hub in South and Central Asia (3000–2000 BC). Sorghum cultivation in Punjab can be traced to the pre-Harappan

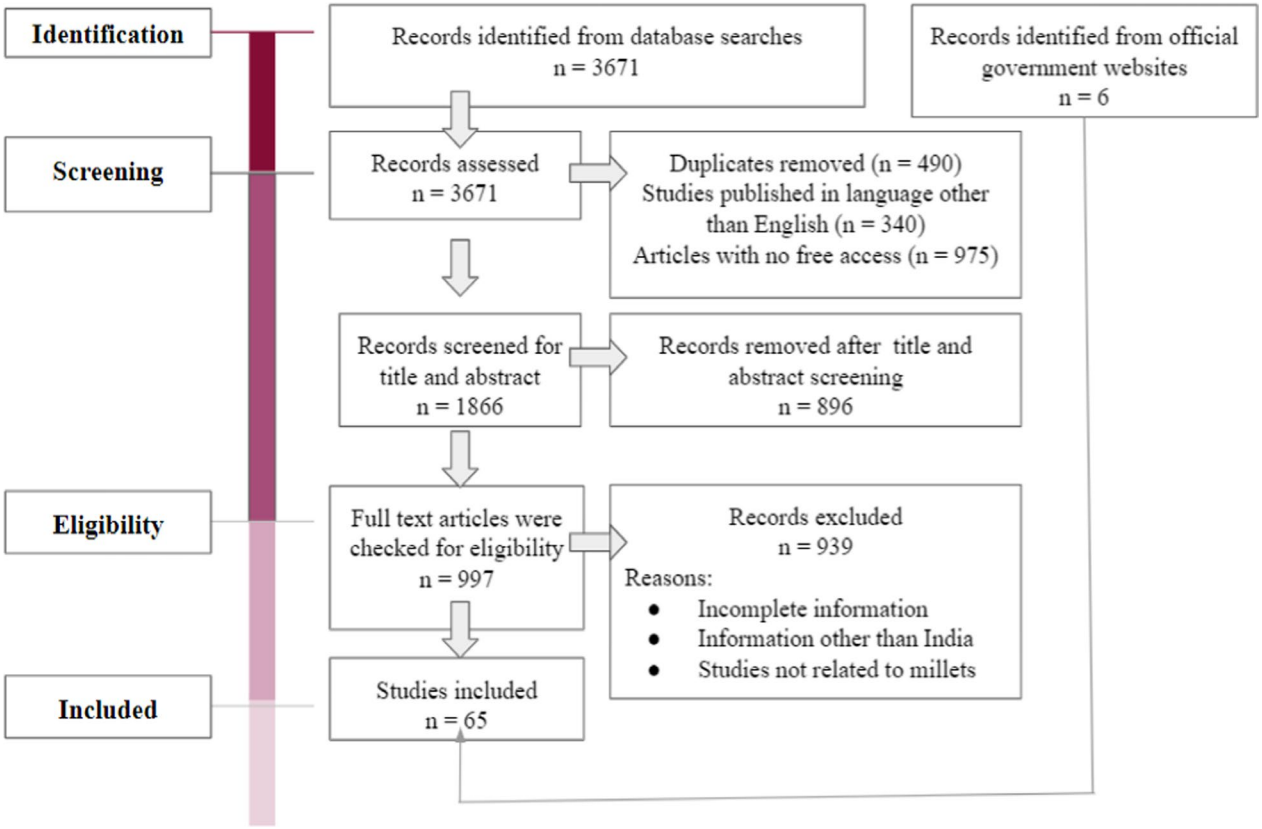

Fig. 2 Diagram describing the methodology for paper selection and data extraction for review

Table 2 Origin of millets

Common name	Scientific name	Place of origin	References
Sorghum/jowar millet	*Sorghum bicolor* (L.) *Moench.*	African Savannah	[16, 17]
Pearl/bajra millet	*Pennisetum glaucum* (L.) *R. Br.*	West African Savannah	[18]
Finger/ragi millet/Mandua/Nachani	*Eleusine coracana* (L.) *Gaertn.*	East African highlands	[19]
Green/Yellow/Bristley Foxtail millet/Kangni/Kakum	*Setaria* sp. *Beauv.* (cf. *viridis Beauv., glaucaauct.* Pl., *verticillata* (L.) *P. Beauv.*)	India	[20]
Kodo millet/Kodra/Koden	*Paspalum scrobiculatum* (L.)	India	[21]
Broomcorn/Proso millet/Barri/Chena	*Panicum miliaceum* (L.)	China and South East Europe	[19]
Little millet/Kutki/Shavan	*Panicum sumatrense Roth. Ex Roem. & Schult.* (syn. *P. miliareauct.* Pl.)	India	[18]
Italian millet/Barnyard millet/Sanwa	*Setaria italica* (L.) *P. Beauv*	China and SE Europe	[22]
Browntop millet/sama	*Brachiaria ramosa (L.) Stapf*	South India	[8]
Amaranth	*Amaranthus caudatus* L	South America	[23]
Buckwheat	*Fagopyrum esculentum*	China	[24]

period (2300–2000 BC). In the peripheral regions of the Harappan civilization, the prevalence of finger millet is evident, as observed in the archaeological findings at Rojdi during the Mature Harappan period (2500–2000 BC) and subsequently at Rojdi and Oriyo Timbo during the Late Harappan period (2000–1800 BC) [21, 25]. Additionally, Italian millet, sorghum millet, and pearl millet cultivation were identified during the Late Harappan phase (2000–1700 BC) at various sites including Rojdi, Kanmer, Oriyo Timbo, and Babar Kot, where little millet and foxtail millet were also cultivated concurrently [16, 20].

Foxtail millet, originating in China, was domesticated in India, with archaeological remains found in Bihar, Maharashtra, and Punjab. Pearl millet traces were discovered in Neolithic South India (2000–1200 BC) and the Narhan culture (1300–800 BC) [26]. Subsequent archaeological findings from the Iron Age and Early Historic periods in regions such as Gujarat, Maharashtra, and the Deccan Plateau further affirm the continuous cultivation of millets, showcasing their adaptability to varied climatic conditions [27]. Neolithic seeds like brown top millet, bristly foxtail, and pearl millet date back to 2000–1200 BC, while finger and kodo millets from Africa belong to the Early Iron period (1200–1000 BC). In the Chalcolithic Deccan era (1400–1000 BC), Jorwe farmers in Malwa practised kharif and rabi crop rotation, cultivating sorghum, finger millet, wheat, barley, and rice. Chalcolithic findings (1800–1200 BC) revealed kodo millet in Northern and eastern India, while its first report in South India is from the megalithic age (1000–300 BC) in Maharashtra and Andhra Pradesh [28]. Amaranths have a common occurrence in India. It has the Sanskrit name Rajagiri [23] and has also been found in archaeological remains dated to before 800 BC [25]. Buckwheat was transferred from China to India through Himalayan region and later became the site of domestication. It has neither Sanskrit name nor archeological evidence [24].

Historical records

Millet has been described in early Indian literature such as the Yajurveda, including foxtail millet (priyangava), barnyard millet (aanava), and black finger millet (shyaamaka). These references indicate that millet consumption dates back to ancient times, even preceding the Indian Bronze Age around 4500 BC [9]. Kalidasa (4–5th AD) depicts in his legendary literary masterpiece 'Abhijnana Shakuntalam', that sage Kanva pouring foxtail millet to Shakuntala in the Dushyanta's court while bidding farewell, which indicates the auspicious nature attributed to this millet [29]. In the third millennium BC, pearl millet gained prominence in Saurashtra, reaching South India around 1800 BC, but its mention in Ayurvedic texts as "Nali" occurs only in the fourteenth century AD, first appearing in Madanapala Nighantu (1374 AD) under the Truna Dhanya category [30]. The text delineates the characteristics of millets, highlighting their taste as Madhura (sweet) and Kashaya (astringent), nature as Laghu (light) and Ruksha (dry), Vipaka as Katu (pungent), and their propensity to elevate Vata and Pitta. Furthermore, millets exhibit qualities such as Baddhamalakara (tightening tools), Lekhanam (scraping), and Kledashoshana (moisture absorption) [30]. Within the Kautilya Arthashastra, the discourse on millets revolves around their cultivation and utilization as sustenance. Specifically, the text notes that Kodrava, Varaka, and Priyangu, when subjected to the cooking process, exhibit a noteworthy expansion, tripling their original volume. This implies an inherent quality of these millets to increase in quantity upon cooking [31].

During Satavahanas (1st to third century AD) and Vataka dynasty (250–270 AD), sorghum was abundantly used over rice in the Deccan region, which changed gradually. The term 'yavanaala' mentioned in Indian text Charaka Samhita (100–200 AD) is attributed to sorghum [21]. Cereals, such as priyangu (foxtail millet), hyudarsa (sorghum), korusa (kodo), and yajgnausadhis, such as priyangu (foxtail millet), syamaka (barnyard), and gavedhu (coix), are included in the gramausadhi group of plants in the Vishnu purana (450 AD). In the Arthashastra of Mauryan age (200–300 AD), kodo millet has been referred to as *kodrava*, grown along with other crops. Ibn Batuta from Morocco who visited India during the times of Muhammad-bin-Tughlak (1325–1351 AD) recorded that kodo millet was the commonest grain [28].

Millets cultivation during Mughal rule and colonial period

Pearl millet was cultivated in the arid regions of the northwest and western zones during the Mughal era, which lasted from 16th to seventeenth centuries AD. The two principal millets were pearl millet and sorghum. Abul Fazl's Ain-i-Akbari (sixteenth century AD) describes how millets, such as sorghum, pearl millet, kodo millet, barnyard millet, and finger millet, were grown in Malwa, Gujarat, Ajmer, Khandesh, Lahore, Agra, Allahabad, Awadh, and Multan as kharif crops [31]. Additionally, accounts from Francisco Pelsaert (1621–1627 AD) and Mughal Emperor Jahangir's (1569–1627 AD) autobiography highlight the significance of millets in the diet of the poor, with dishes like laziza (pearl millet and peas khichdi) gaining popularity and even becoming a routine meal during days of abstinence. Francisco Pelsaert of Dutch East India Company at Agra writes that sorghum, pearl millet and foxtail millet were the food grains eaten by the poor in the seventeenth century [32]. Mughal emperor Jahangir, in his autobiography Tuzk-eJahangiri, talks about laziza (tasty), a kind of khichdi he encountered in Gujarat. Laziza was a concoction of boiled peas and bajra, or pearl millet. He writes that khichdi is tasty, rich in flavour and suits him very well. On the days of abstinence, he ordered that khichdi be routinely served to him. The dietary practices of Mughal nobleman Mahabat Khan further emphasize the integral role of millets. Mahabat Khan, serving under Jahangir and Shah Jahan, consumed only one meal every 24 h, featuring a table laden with two trays of pulao, ash-ha (broths), and trays of rice and millet khichdi [33].

During the colonial period when European nations controlled India, there was no emphasis on millets as the colonizers manipulated agricultural production to suit their needs of imports which included spices, cotton, indigo and other commercial crops. Evidence depicts that the productivity of food grains including millets did not rise from the seventeenth century to twentieth century. Wheat and rice gained popularity among upper-class consumers, who saw millet as the diet of the underprivileged and labourers. People who consumed millet were therefore considered to be lower class [20].

The historical journey of millets in India is a testament to their resilience, versatility, and integral role in the country's agricultural practices. From ancient civilizations to present times, millets have navigated changes in uses and cultivation practices, reflecting the decline in India's agrarian landscape.

Ethnic practices and cultural significance of millets

With a kaleidoscope variety and a rich cultural past, India boasts one of the oldest civilizations in the world. Millets managed to persist despite being ignored, owing to cultural organizations and celebrations that were essential in keeping them alive. Millets in India hold a profound cultural significance, being intricately woven into the fabric of religious ceremonies, festivals, traditional medicine, as well as art, literature, and folklore. Many scholars agree that strong affiliation of millets to the indigenous cultures and traditions may have played a vital role in preserving them and saving the valuable germplasm from local extinction [34, 35]. This section explores the multifaceted ways in which millets contribute to the rich tapestry of Indian culture.

Millets in religious ceremonies and festivals

Millets are deeply ingrained in our cultural history and have historically been important in tribal regions' temple celebrations. Millets are served in various functions such as wedding ceremonies, crop harvesting celebrations, offerings to traditional Gods, worshiping rituals, and death commemorations of loved ones to express togetherness, unity, joy, and sorrow. Millets are also related to the origin, habitat, religion, and overall life of locals; therefore, people of India regard these as their cultural heritage [36].

Millets have played an important role in the social and community life of many cultures. In some communities, the harvesting and processing of millets are a communal activity that brings people together and strengthens social bonds. The "Kuthiyottam" festival, which takes place in the Indian state of Kerala, is an illustration of a harvest celebration associated with millets. During the months of November or December, a celebration honoring Lord Vishnu is conducted. A traditional dance called "Kuthiyottam" is performed during the festival, and young boys are instructed to do it. It involves complex ceremonies and millets are offered to the god. Two celebrations, Metumniu in August and Tsungkamniu in January, are held by the Yimchunger ethnic tribe in Nagaland to commemorate the millets' harvest [37]. The Kolli Hill tribes protect the landraces of little, foxtail, and proso millets; the characteristics of these millets suggest the presence of novel alleles for future breeding programmes [38, 39]. Festivals like Makar Sankranti are mainly celebrated in North India (celebrated in Haryana, Rajasthan, Uttar Pradesh, Bihar, Punjab, Himachal Pradesh, Gujarat, Maharashtra, Tamil Nadu, Kerala and West Bengal) and highlight the relationship between millets' harvest and agricultural prosperity and abundance. In the Gaddi festival, finger millet is often offered as a prasad as a traditional practice. Additionally, finger millet is said to provide good energy in temples, and thick pastes made from this flour are used to cure fire burns [40]. Gangaur is celebrated as a harvest festival in the month of Chaitra or Vaisakha in Rajasthan and Indians worship Maa Gauri and cook pearl millet products [41].

During the wedding rituals, it is customary for several indigenous people in the state of Madhya Pradesh to cover the bride and groom with a paste made by combining turmeric and finger millet flour [34]. The offering of millet grains as a wedding gift to the groom was one typical millet grain custom in South India; the quantity of grains given was considered a sign of dignity. Millets grains were often cooked and prepared, especially for celebrations of puberty and delivery due to the presence of a good amount of folic acid [42]. In religious ceremonies/festivals, especially navratri, preparations of amaranth, buckwheat, proso, foxtail, and barnyard millet are permissible meals on fasting days. Because small millets are high in folic acid, they have been used specifically to cure anaemia in women [43]. The Malayali in the Eastern Ghats continue to plant and preserve local varieties of millet as part of India's efforts to preserve its cultural heritage [44]. The preparation of traditional millet-based beverages is not only a means of livelihood in the tribal regions of Indian hills but also an important household-cum-societal drink associated with religious ceremonies [45].

Millets in literature and folklore

Millet is also mentioned in oral traditions and folklore, where it frequently represents fertility, prosperity, and the connection between the society and agriculture. In Karnataka, the poem "Ragi thandheera" in the Kannada language, composed by the Indian poet Purandara Dasa in the fifteenth century, is widely honoured in order to

demonstrate the ragi (finger millet) historical popularity. In his poem "Ramadhanya Charithre", Kanakadasa, a Kannada poet from the sixteenth century, immortalized finger millet. It is a highly imaginative literary work with a strong social message that alludes to the conflict between socially powerful and weak castes and classes through an argument between rice and finger millet (ragi), two food grains [10]. Sorghum was cited by Fernao Nuniz, a Portuguese traveller who visited the Vijayanagara Empire in the sixteenth century AD, as the main food grain consumed in South India [46]. In southern India, women have been singing songs while performing various tasks related to agricultural work and food preparation for more than a thousand years. As a result, some farming folk song genres arose that were linked to certain foodways practices, such as songs about ragi-grinding [11].

Millets-based ethnic Indian food

Indians have been using millets into a myriad of ethnic dishes for a very long time and were an integral part of traditional Indian diets for centuries. Until around 50 years ago, millets were a major grain crop grown in India and a staple food for many communities. Millets were valued for their resilience in diverse climatic conditions and their nutritional benefits. List of some millet-based ethnic Indian food is given in Table 3.

Gonds community of India consume *roti* (flat bread) and *gatka* (porridge) cooked out of Jowar flour as the staple food [47]. Amaranth, barnyard, kodo and proso millet are widely grown in the Himalayan region of India and were used widely in the staple diets of the locals. Popped and puffed seeds of amaranth are cooked as rice, used to prepare laddu after mixing with sugar syrup, or mixed with curd/buttermilk to prepare raita. Boiled amaranth leaves after sieving water are fried to prepare '*chaulai ka saag*'. Boiled amaranth and buckwheat leaves mixed in Bengal gram flour batter are fried to prepare pakora. Whole grains of amaranth, barnyard, kodo and proso millet grains are boiled and cooked with milk to prepare kheer. Kodo millet and Proso millet are cooked like rice, ground to flour for making *roti* and *chilra* which is a pancake prepared from these flour batter. Kodo flour is taken in the morning in Himachal Pradesh with milk to strengthen bone. Foxtail millet is widely used as nourishing gruel/soup for pregnant and nursing women in the hilly regions of Northern India [48]. Rajasthan and Haryana states of India consume pearl millet in the form of khichdi and roti (flatbread) known as *bajre ki khichdi* and *bajre ki roti* [48]. Figure 3 depicts various ethnic Indian dishes made from millets.

Ragi *hurihittu*, a meal prepared with popped finger millet, is rich in minerals and vitamins. In southern India, finger millet has been malted for use in food during all of recorded history. It has exceptional malting qualities, and the malt has a tolerable flavour, excellent fragrance, and a long shelf life [49]. *Ragi Mudde* (ragi and jaggery) is the ethnic dish consumed by the people in Karnataka for

Table 3 List of ethnic millet dishes from different regions of India

Ethnic food and beverage name	Type of millet used	Other ingredients used	Region	References
Bajre ki khichdi	Pearl millet	Pulses, rice	North India	[60]
Gatka (porridge)	Sorghum	Cornmeal, salt	South-central India (Gond community)	[48]
Kodo *roti* and *chilra*	Kodo millet	–	Himachal Pradesh	[48]
Soup	Foxtail millet	Foxtail millet flour	North India	[48]
Ragi *hurihittu*	Finger millet	Foxtail millet flour	Karnataka	[49]
Ragi Mudde	Finger millet	Foxtail millet flour	Karnataka	[49]
Chilra or *Iwar*	Buckwheat	–	Himachal Pradesh	[51]
Ambli	Finger millet	Rice, buttermilk	South India	[52]
Rabdi	Pearl millet	Bengal gram flour, buttermilk	Rajasthan, Haryana	[54]
Koozh	Finger millet; Pearl millet	Broken rice, buttermilk, onion, garlic	Tamil Nadu	[53]
Paleu or *chencha* (savoury porridge)	Barnyard millet	Onion, ginger, garlic, cumin seeds, peanuts	Uttarakhand	[42]
Zan (porridge)	Finger millet	Vegetables	Arunachal Pradesh—Monpa Tribe	[58]
Sargati (hard porridge)	Foxtail millet	–	South India	[51]
Kheer	Amaranth, Little millet	Milk, sugar	Himachal Pradesh, Uttarakhand	[48]
Roti	Pearl millet, Finger millet	–	North India, South India	[47]
Landa and *Pej*	Finger millet	Broken rice, maize	Gadaba tribe of Odisha	[57]

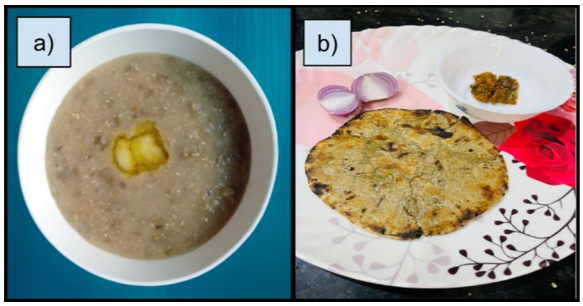

Fig. 3 Pearl millet-based ethnic Indian dishes consumed majorly by the people of Rajasthan, Haryana and Punjab: **a** *Bajre ki khichdi*—prepared by combining bajra (Pearl millet) with some lenti **b** *Bajre ki roti*—Flatbread made of pearl millet flour

Fig. 4 *Rabadi* is an indigenous natural pearl millet-based lactic fermented milk beverage popular in North Western Semi-arid regions of India mainly Rajasthan and Haryana. Traditionally *Rabadi* is prepared by mixing pearl millet flour with sour buttermilk and left in sunlight for hours for fermentation. Locals usually prefer this drink to save themselves from the high temperature and its high nutritive value

breakfast. Ragi, a staple crop in Karnataka, was prepared by women using *arka* (kodo millet), saame (little millet), and navne (foxtail millet). These dishes were delicious and were served with *sambhar* (vegetable stew), which was made from a variety of local beans, with avarekai (hyacinth beans) standing out for both its deep, rich scent and nutritional value. Women in the rural area thought this stew and millets combo was extremely nutritious and delicious [50]. *Chilra* or *lwar* is ethnic fermented buckwheat dish, which is traditionally prepared during marriage ceremonies and festivals in Himachal Pradesh [51]. *Ambali* is a traditional South Indian semi-liquid food made from fermented millet. It is made by combining finger millet flour with water to form a thick batter, which is then cooked and fermented [52]. *Koozh* is a traditional fermented millet-based food native to Tamil Nadu state of India which is best known for its flavour and nutritive value and is regularly used as breakfast meal [53]. *Rabadi* is an indigenous natural millet-based lactic fermented milk beverage (shown in Fig. 4) popular in North Western Semi-arid regions of India mainly Rajasthan and Haryana. Traditionally *Rabadi* is prepared by mixing pearl millet flour with sour buttermilk and left in sunlight for hours for fermentation. Locals usually prefer this drink to save themselves from the high temperature and its high nutritive value [54]. Assam's Kokrajhar district's Santali people have been consuming millet more regularly as a staple meal, snack, beverage, and sweet dish, among other uses. The main traditional millet-based foods that the Santali community eats are *Kode Dumbu*, *Belna Pitha*, *Sunum Pitha*, *Khapra Pitha*, *Kode Halwa*, *Kodu Pitha*, *Sukum Pitha*, *Ghula*, *Kodu Bhat*, and *Kodu Khichri* [55].

In Tamil Nadu, pearl millet is cooked to create the Indian porridge known as *Kambam Choru*. In Uttarakhand, barnyard millet is used to make *chencha*, a delicious porridge cooked in buttermilk, while finger millet is used to make *rotis*. The most well-known porridge dish created by the Monpa tribes of Arunachal Pradesh is called *Zan* and is made with finger millet and veggies. Small millets' dehusked grains are cooked and consumed like rice. The processing of the grain is akin to parboiling rice in certain regions of South India. Porridge and roti are prepared and eaten often. It may also be ground into flour and used to bake cakes or puddings. Another method is to cook broken grains with veggies and spices to make a meal similar to curried rice. Protein quality and nutrition are improved by lysine fortification and heat processing. Foxtail millet is typically used as a meal or cooked whole like rice (millet rice). *Sargati*, a hard porridge, is another way to eat it [55]. Amaranth Grains cooked in water as kheer are used in curing chicken pox and measles [48].

Since pre-Vedic times, alcoholic beverages have been commonly drunk in India, and the Ramayana (written between 300 and 75 BC) makes particular mention of tribal people drinking them [56]. *Landa* and *Pej* are two commonly drank fermented finger millet (*Eleusine coracana* L) drinks that are regarded as staples by the Gadaba tribe of Odisha. *Landa* involves a germination and bursting process and is especially taken in the evening for refreshment. It has been demonstrated to be a nutrient-dense diet through the germination and popping process, which improves the availability of nutrients including protein and carbs. Made from finger millet flour, *pej* is eaten for lunch and dinner with other foods like curries and rice. It is a common beverage that is required to be served during lunch and supper [57].

Fermented millet-based ethnic beverages in the Indian Himalayas

The Indian Himalayan Region is spread across thirteen Indian States and Union Territories, namely Jammu & Kashmir, Ladakh, Uttarakhand, Himachal Pradesh, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Assam and West Bengal [58]. Figure 5 represents States/Union Territories under Indian Himalayan Region. The Indian Himalayan region is known for the production of traditional fermented beverages both alcoholic and non-alcoholic by the indigenous tribal communities who have developed their own starter cultures with native natural ingredients which facilitates the fermentation process. Tribal people in the Indian Himalayan Region prefer to consume pre-digested foods that are easy to digest and high in nutrients because the temperature there is typically chilly throughout the year [59, 60]. Tribal communities residing in the states/union territories of the Indian Himalayan Region represent the ethnic group and are mainly concentrated in the rural areas. It is well known that these tribes use locally accessible materials and methods that have been passed down from their ancestors to make fermented alcoholic beverages [61].

The oldest and most profitable way to biologically enhance food items through the manipulation of various microbial populations is through indigenous fermented foods, which are an essential component of the diets of the ethnic communities in India's Himalayan region. List of some millet-based fermented ethnic beverages of Indian Himalayan Region is given in Table 4. Himachal Pradesh and Uttarakhand are the part of the Western Indian Himalayas. *Sura*/ *Sur* is a millet-based fermented beverage prepared from finger millet/ kodra/kached (*Eleusine coracana*) and is mostly produced in Lug valley of Kullu district, Himachal Pradesh. *Sura* is high in ethanol content having about 15% of ethanol [62]. This millet is known as the "famine grain" and has a long shelf life. To prepare sura, no particular inoculum is needed. During its creation, natural microflora performs the starch hydrolysis and fermentation processes. During fermentation *dhehli* is added, which is an herbal mix prepared by elderly people using 36 herbs. *Jann* or *jaanr* is a fermented finger millet or barley beverage with mild alcoholic content and commonly consumed by the Bhotiya communities of Uttarakhand [63].

Kodo ko jaanr, also known as *Chyang*, is the most widely consumed mild-alcoholic beverage in the Sikkim and Darjeeling hills. It is made by fermenting dried finger millet [*Eleusine coracana* (L.) *Gaertn.*] seeds, which the locals refer to as "kodo". In Nepali, a frequent term for an alcoholic beverage is kodo, which means finger millet [64]. Because of its high calorie content, vitamin content, and healthy lactic acid bacteria and yeast, the

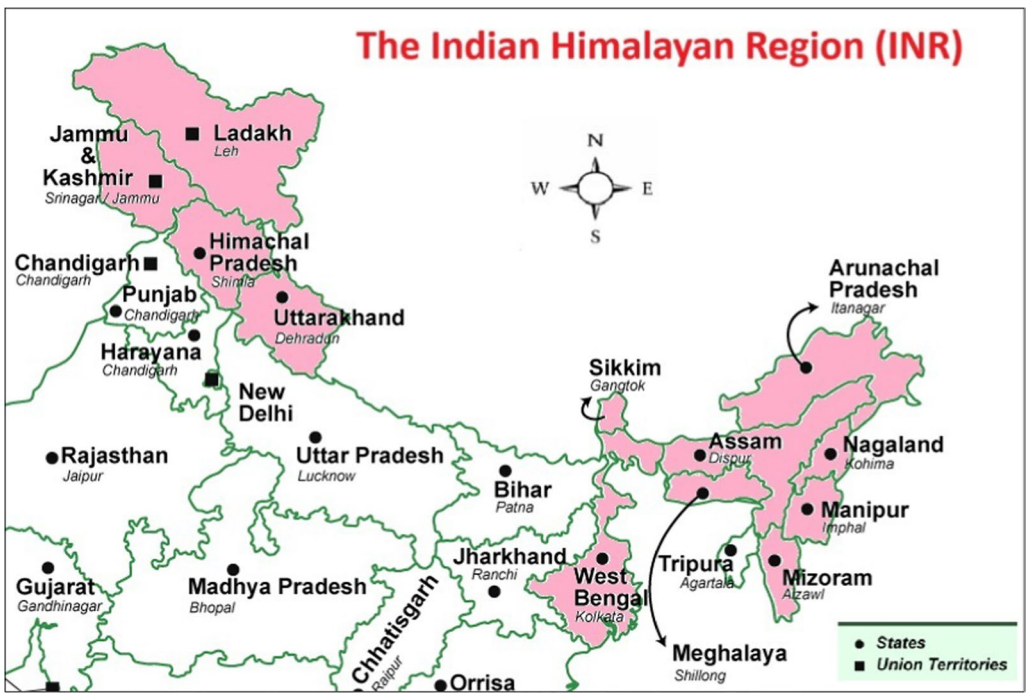

Fig. 5 States/Union Territories under Indian Himalayan Region (IHR). The IHR consists of 13 Indian States/Union Territories stretching across 2500 km [58]. The states and union territories in pink colour represent IHR

Table 4 List of fermented millet-based ethnic beverages in The Indian Himalayas

Fermented Beverages	Substrate for fermentation	State/Union Territory	References
Jaan	Cereals: rice/wheat/barley Millets: Foxtail millet, Proso millet	Uttarakhand	[64]
Sura/Sur	Finger millets and Jaggery	Uttarakhand, Himachal Pradesh-Lug valley	[62]
Madua apong	Millet, starter culture, Ektam leaves	Arunachal Pradesh-Almost all tribes	[65]
Themsing/Mingri	Millet or barley, starter culture	Arunachal Pradesh- Monpa tribe	[65, 66]
Rakshi	Millet or barley or rice	Arunachal Pradesh-Monpa, Sherdukpen and Idu-Mishmi tribes	[63, 65]
Mingri, lohpani and bhangchang	Finger millet/barley/rice/maize	Arunachal Pradesh-Monpa tribe	[65, 66]
Phaak	Finger millet/barley/rice	Arunachal Pradesh-Sherdukpen tribe	[66]
Poling	Madua (millet) + locally made starter yeast	Arunachal Pradesh-Nyishi tribe	[67]
O/oh and Sira-o	Rice mixed thoroughly with millet, rice beer starter	Arunachal Pradesh-Apatani tribe	[67]
Tongba	Finger millet	Sikkim	[68, 69]
Chyang (*Kodo ko jaanr*)	Kodo millet; Ragi millet	Sikkim	[64]

mildly alcoholic sweet-flavoured beverage is seen more as food than an alcoholic beverage [56]. *Madua apong* is also one of the most popular and commonly used traditional alcoholic beverages of different tribes of Arunachal Pradesh, India, prepared from finger millets. The best-quality *Madua Apong* is golden yellow in colour and sweet in taste and emits sweet alcoholic aroma during saccharification. This is a sign that the fermentation process has been completed. After that, the fermented finger millet mass is moved into a bamboo basket with holes in it, and lukewarm water is gradually added to it at a rate of one litre per hour. *Madua apong* is the name given to the filtrate that was so collected [65]. *Themsing* is an alcoholic beverage consumed by Monpa tribe of Tawang district of Arunachal Pradesh only. It is prepared either from finger millet (locally called kongpu) or from barley (locally known as bong) or from the mixture of both [65, 66]. *Rakshi*, *aara* and *aaro* are types of traditional distilled beverages prepared by the people of Monpa, Sherdukpen and Idu-Mishmi communities of Tawang and West Kameng districts of Arunachal Pradesh. Either finger millets, rice or barley grains are used to prepare it [63, 65, 66]. *Mingri* or *Niingri*, *Lohpani* and *Bhangchang* or Phaak are traditional alcoholic beverages highly peculiar to Monpa and Sherdukpen tribes dwelling predominantly in Tawang and West Kameng districts of Arunachal Pradesh. The finger millet is used to make these beverages. The identical raw material is fermented at three distinct phases to produce these three varieties of alcoholic drinks. After 4–5 days, the first lot of beer is collected called *Khajir* without adding any additional water. Monpas call this *mingri*, whereas Sherdukpen name it *niingri*. The remaining filtrate is fermented for an additional two to three days. Consequently, *lohpani*, a relatively darker yellowish beverage with a lower alcohol level and fragrance, is gathered. To produce *bhangchang* (in the Monpa tribe) or *Phaak* (in the Sherdukpen tribe), the leftover material is once again let to ferment for four to five days [65, 66]. The Nyishi tribe has a practice of making *poling*, an alcoholic beverage. Arunachal Pradesh's largest ethnic group is dispersed among seven districts. This product, which is made from *madua* (millets), is eaten frequently [67]. The Apatani people of Arunachal Pradesh make two traditional cereal-based drinks: *O and Sira-o*. These beverages main constituents are millet and rice. Sira-o is regarded as a unique beverage that is served during social events or ceremonies [64].

Tibetan, Nepalese, and other ethnic groups living in high-altitude regions of the Himalayas (Sikkim and Darjeeling hills) consider *tongba*, also known as *tumba*, to be a regular beverage. It is one of the locally fermented millet-based traditional alcoholic beverages of the Limbu community in eastern Nepal and is praised for its many ethnomedicinal properties, primarily its anti-inflammatory or pain-relieving effects [64]. The bamboo container that contains the fermented millet beverage, known historically as "*mandokpenaa thee*", is really what the name "*tongba*" refers to [68]. It is typically aged or held for around six months, during which time the fermentation culture develops and the tastes grow more subdued [69].

Recent innovation in millet processing

Millets are eaten as porridge, baked products like bread, boiled rice like products, steamed products like couscous, flaked and popped grains and various other health foods based on their gluten-free protein, low glycemic property, the presence of essential fatty acids, pigments and antioxidative property. But before taking shape into variety of commercial food products, millets undergo various processing operations [70]. Food processing is an

important operation, as it improves the bioavailability of nutrients and sensory properties and decreases antinutrients [71]. Primary processing includes cleaning, washing (soaking/germination), dehulling, milling (to make flour and semolina), and refining to get rid of antinutritional elements and the undesirable seed coat. Secondary processing is the process of flaking, popping, extrusion, and baking to transform primary processed raw materials into "ready-to-cook" (RTC) or "ready-to-eat" (RTE) products [71]. To enhance nutritional value and sensory characteristics, millets are dehulled or decorticated, which involves removing 10–12% of the grain's outer layer, or germ, using a rice mill or an abrasive disc mill. Nutrient digestibility is increased, and antinutritional content is decreased by the method. A roller mill or hammer is used to grind moistened millets into flour [72]. Germination is another mechanism that enhances the availability and digestion of nutrients. Grain is soaked and saturated in water throughout the germination process, and it takes two to three days for it to sprout. Malting is the controlled germination of millet. Amylase, protease, and protein quality are all improved by the process, which also lowers polyphenol, phytic acid, oxalates, and tannins and raises the vitamins riboflavin, thiamin, ascorbic acid, and vitamin A. However, for a longer shelf life, rootlets must be removed and antimicrobial must be applied [72]. In India, fermented millet products are traditionally eaten. In contrast to germination, fermentation involves the employment of microbial cultures to sour the product. During fermentation, nutrient levels, particularly iron and B vitamins, and their bioavailability, dramatically increase. Starch and protein become easier to digest. The concentration of tannin, polyphenols, and phytic acid is decreased via enzymatic modifications. Traditionally, millet is parboiled to produce soft-textured grains that may be used to make thick and dense gruels for babies, diabetic snack meals, and a variety of other rice-like products. Sorghum grains can be parboiled to produce suji, for instance. Extrusion is a method used to produce different kinds of food by gelatinizing and heating a foodstuff until it is thoroughly cooked. Pressure and heat, or steam, are used in this procedure. Grains are forced through an extruder, and because of the extruder's high temperature, by the time the grain exits (extrusion), the anti-nutritional components have been rendered inactive [1]. Various millet-based extruded products are available in Indian market such as pasta, noodles, breakfast cereals, and snacks.

Challenges and future prospects

Millet cultivation and its promotion face numerous challenges despite having various health benefits and cultural importance. For integrating millets into mainstream diets and Indian agriculture addressing these challenges is crucial. One of the major problems is that customers lack awareness of the nutritional and health importance of millet. Educational initiatives and national campaigns are required to educate and aware people regarding millets. Farmers that cultivate millets usually experience limited market access, which reduces their profits and discourages them from selling their products. Traditional knowledge about millet agricultural practices and its use in regional cuisines diminished slowly which hampered millet promotion. Government incentives and support for millet cultivation can promote millet farming and its integration into public food distribution system. Millet farmers can increase their market access and secure better prices by constructing infrastructure and provide logistical support. Indian government has increased minimum support price for jowar, bajra and ragi so as to encourage farmers to grow millets. Preserving knowledge regarding millets can be done by recording and disseminating traditional recipes and farming methods. Millets has been incorporated into government schemes like school mid-day meal programmes; it can serve as the catalyst to bring millets into the mainstream. Development of food processing technologies for millets so as to develop functional foods that will increase the demand for the crop.

Indian government has taken various initiatives to overcome challenges related to millet consumption and promotion. With the aim to create awareness and increase production and consumption of millets, United Nations, at the behest of the Government of India, declared 2023 the International Year Millets. The Production Linked Incentive Scheme for Food Processing Industry for Millet-based Products (PLISMBP) has been authorized by the Ministry of Food Processing Industries (MoFPI) and is implemented from 2022–2023 to 2026–2027. Currently being implemented in 35 States and Union Territories (UTs) is the Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) Scheme, which was introduced under the Atmanirbhar Bharat Abhiyan. Additionally, the government is promoting the Agri-Infrastructure Fund Scheme to encourage farmers, FPOs, and entrepreneurs to take advantage of interest-free financing for the establishment of primary millet processing plants. Indian government has increased minimum support price for jowar, bajra and ragi so as to encourage farmers to grow millets. To raise awareness on millets Government of India is organizing various conferences across the country that will help in spreading knowledge regarding millet consumption, processing, production, etc.

An interesting paradox is the contradiction between millet preservation in ethnic diets and their revival

in mainstream consumption. Future studies should attempt to bridge the gap between tradition and modernity in addition to elucidating this conundrum. We can unleash the promise of this ancient grain for modern diets and help create a more resilient, nutrient-dense, and sustainable food system by removing the cultural, technological, and financial obstacles to millet use. Future research should look on ways to respect the cultural relevance of millets in rural and tribal areas while incorporating them into the mainstream food chain.

Conclusion

Millets, with their entrenched historical importance, cultural significance, and exceptional health benefits, hold a unique place in shaping India's agricultural practices, food systems, and cultural heritage due to their resilience, nutritional richness, and deep cultural ties. Cultivation of millets can be traced from ancient times through archaeological evidence, historical texts, and cultural practices. Despite having great significance, millets faced marginalization during the colonial period and in the decades following, which resulted in a drop in both production and consumption. However, their resilience, adaptability to harsh environments, and high nutritional value have guaranteed their survival through various religious, social, and ethnic practices across India. A thorough historical chronology illustrating the evolution of millet farming in response to shifting socio-political situations spans from the Indus Valley Civilization to the Mughal and Colonial eras. This long-term perspective on millet agriculture in India deepens our knowledge of its ongoing significance. Millets, which stand for fertility, wealth, and the bond between society and agriculture, were a significant component of religious ceremonies and festivals in India and were also recorded in oral traditions and folklore. Millets were an integral part of traditional Indian diets and culinary practices for centuries. Millet-based ethnic foods and practices are still preserved among rural and tribal communities of India, offering potential for future revival in mainstream diets. Furthermore, the study offers insights into the challenges facing millet cultivation in contemporary India. The historical, cultural, and therapeutic dimensions explored in this paper open up new avenues for research, particularly in the areas of millet-based food innovation, cultural preservation, and health promotion. By positioning millets at the intersection of history, culture, and nutrition, this research advances a holistic understanding of their role in India's food heritage, providing a foundation for future studies to build upon.

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