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Ethnobotanical study of small millets from India: Prodigious grain for nutritional and industrial aspects

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Abstract
India is the largest grower of minor millets and the cultivation of these small-seeded millets has declined steadily over the past few decades due to their lower economic competitiveness with major commodity like cereals, pulses etc. Finger millet, foxtail millet, barnyard millet, kodo millet, little millet and proso millet have a wide genetic adaptation and are able to grow successfully in diverse soils and climatic conditions and can withstand severe climatic stresses thus being the best candidates to substitute commodities like wheat and rice in areas where diversified agriculture is required. Minor millets have also excellent nutritional value having good protein content and better amino acid profile along with vitamin A, minerals, fibre, starch composition and low glycemic index. It constitutes a major source of carbohydrates and proteins for people living in semi-arid areas. So, it contributes to national food security and potential health benefits also, therefore millet grain is now receiving increasing interest from scientists, technologists, and nutritionists. They are doing innovative research on processing and value addition to millets to provide ready to eat and ready to cook items so that great masses can take the advantages. Value-addition to millet grain also offers good opportunity to rural and tribal farmers for income generation and promoting production and marketing leads to the food and nutritional security, employment and revenue generation etc.

Keywords: Millets, nutritional quality, food security, climate change, value addition

1. Introduction

Advancement in science has resulted in enhanced productivity of crops like maize, wheat, rice and other dominant crops which resulted in replacement of numerous other important crops. Development of specialized and intensive agriculture for increase productivity and profitability resulted in shrinking of diversity in number of cultivated crops and available varieties as diverse genotypes. Today, our food security is depended on less than ten crops. The impact of narrowing down of species base for food security is likely to be felt most by the rural and hill people as they have restricted livelihood opportunities. The underutilized crops of today were the major crops in the past. Both historical records of cropping pattern and the evidence of dietary habits of people of tribal and hilly areas of the country indicates that present under-utilized crops have a distinct position and a well-defined role in providing food and nutritional security at house hold level in the past. Sustainable agricultural development and food security depend on our ability to broaden the range of cultivated crops in an effective and sustainable way and must include the underutilized crops. According to Riley *et al.* (1992) [1] finger millet has the potential to improve resource management in the hills of Nepal and serve as a staple food, weaning food, or a cash crop which provides income generating opportunities. Research and improvement efforts are needed to explore the potential of finger millet to increase agricultural production, crop diversification and a better nutritional environment.Millets are very much important crop for food security because of their sustainability in adverse agro-climatic conditions and their nutritional composition (Ushakumari *et al.*, 2004) [2]. It is nutrient rich food for large population particularly pregnant women, lactating mothers as well as children and more importantly for more than 50 % the low income marginal people (Shobana *et al.*, 2009) [3]. It grown mainly for its grains which having high proteins, vitamins, minerals, fibre content and energy and better than or at par with other cereals/millets (Vadivoo *et al.*, 1998) [4].

The nutritional composition of finger millet comprises protein, fat, carbohydrate, minerals, calcium, fibre and energy 328 kCal per 100g (Gupta *et al.*, 2011 [5]; Kumar *et al.*, 2014 [6]). Among the millets, finger millet is considerably rich in the amino acid content (Devi *et al.*, 2011) [7] and the high calcium, high soluble fibre, low fat and low glycemic index of grains indicate that it could be used by patients suffering from diabetic patients (Seetharam and Rao, 2007) [8]. These crops have substantive potential in broadening the diversity in the food basket and ensuring improved food and nutrition security (Mal *et al.* 2010) [9]. Along with nutrition, millets offer health benefits if taken in daily diet and help in the management of several diseases/disorders like diabetes, obesity, hyperlipidemia, etc. (Veena, 2003) [10]. Millets offer unique advantage for health being rich in minerals and vitamins as well as nutraceuticals. Though millets are not the important ingredients in daily diet of American and European people, however, now these countries have recognized the importance of millets as ingredient in multigrain and gluten-free cereal products. In many Asian and African countries millet is also the staple food of the people in millet producing areas and used to prepare various traditional foods and beverages like *Idli*, *Dosa*, *Papad*, *Chakli*, *Porridges*, breads, infant and snack foods (Chandrasekara and Shahidi, 2011) [11].

In India, six minor millets viz., finger millet, foxtail millet, proso millet, kodo millet, little millet and barnyard millet are being cultivated in different regions (Fig 1). Among all finger millet (*ragi*) is the most popular millet across the country and it is cultivated in around 1.6 million ha, with an annual production of 2.4 million tones and a productivity of approximately 1, 534 kg/ha (Government of India, 2009) [12]. Rest of the other five small millets only cultivated in area of 1.1 m ha with a production of 0.7 million tonnes. In India prospects of production and cultivation of millets is high, since they can be grown under moisture stress and low soil fertility condition, and also has ability to respond to favourable conditions. Kodo millet and little millet are more popular in central and southern India, while the other four minor millets grown in Himalayan region. The prospects of different types of millets have been discussed in the following sections.

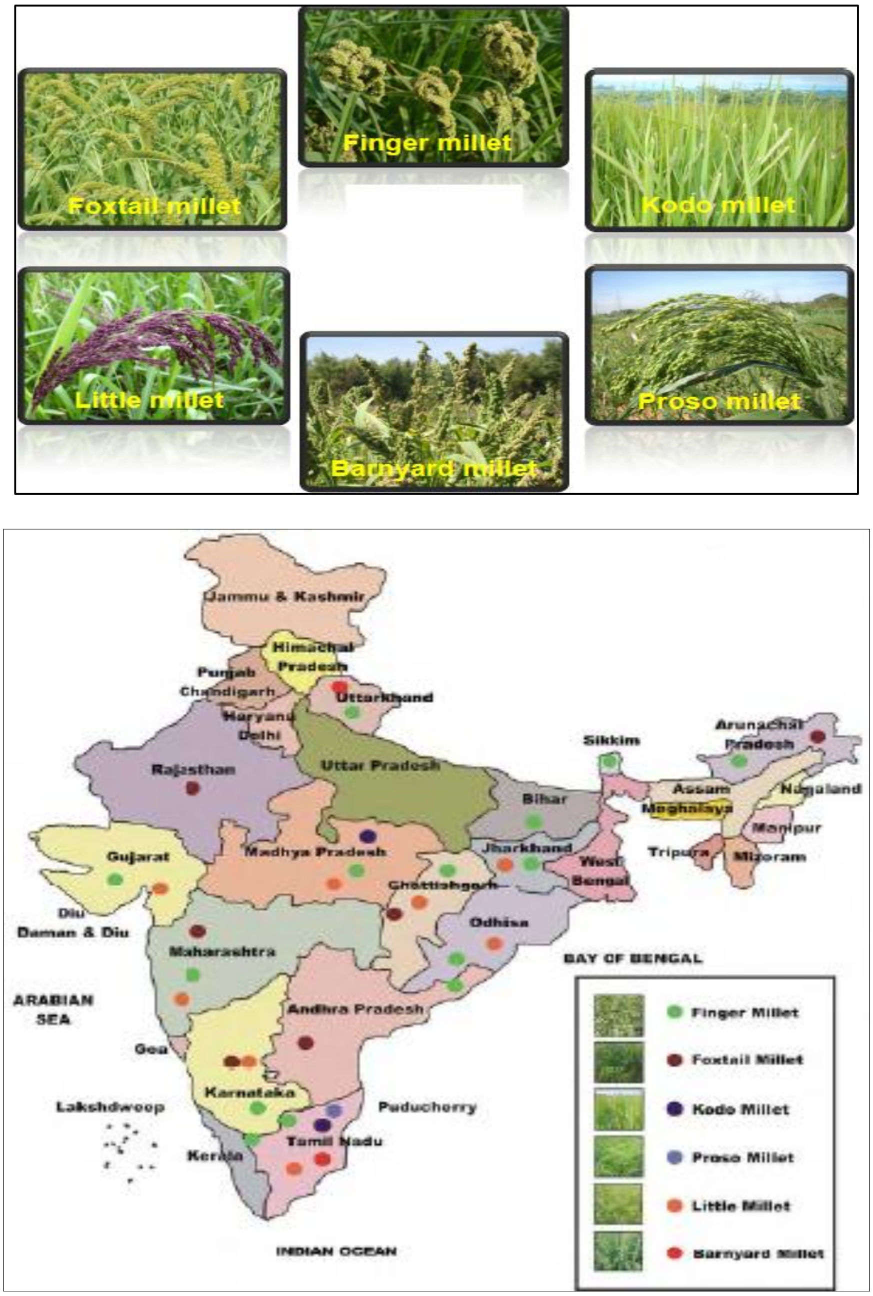

Fig 1: Distribution of small millets in India

2. Origin and Distribution

Among minor millets, finger millet ranks first in India. *Eleusine*means "Goddess of cereals" in Greek. The name finger millet is derived from the finger like structure of the panicle. Finger millet, also known as *ragi*, is valued as staple food in south India (Karnataka, Tamil Nadu and Andhra Pradesh) and hilly regions of the country. It is highly adaptable to higher elevations and is grown in the Himalayas up to an altitude of 2300 m. The straw has immense utility as fodder. Silage is also made from *ragi* forages at flowering stage. It is a rich source of calcium (0.344%) for growing children and aged people. It is usually converted into flour, which is used for preparation of cake/puddings/porridge. Straw makes valuable fodder for both draught and milch animals. It is wholesome food for diabetics (Mathanghi and Sudha, 2012) [13]. Finger millet grains can be stored for years without infested by storage pest, which makes it a prefect food grain commodity for famine prone areas (National Research Council, 1996) [14]. Finger millet's domestication has been traced back to 5,000 years ago in Ethiopia (Hilu, 1977) [15] while India is considered as a secondary centre of its origin.

Foxtail millet is considered to be one of the oldest cultivated millets. It is an annual warm-season crop that grows 2-5 ft. (60-152 cm) tall. The stems of foxtail millet are course and leafy. The yellowish or purplish, 8-in (20-cm) nodding inflorescence is composed of a main stalk with many side branches. The seed heads are dense and bristly and the oval, convex seed grain can be a variety of colors. Foxtail millet is grown in cooler, drought prone regions compared to other millets (Koch, 2002) [16]. It is widely grown throughout China, India, Russia, Africa, and the United States. In the United States, foxtail millet is mainly grown in the northern and western Great Plains, Midwest, the Dakotas, Colorado, Kansas, Nebraska, and Wyoming (Baltensperger, 1996) [17]. It can adapt in sandy to loamy soils with pH from 5.5–7. It will grow rapidly in warm weather and can grow in semi-arid conditions; however, it has a shallow root system that does not easily recover from drought (Hancock Seed, 2014) [18]. It can produce one ton of forage on 2 ½ in of moisture and requires approximately 1/3 less water than corn (Koch, 2002) [16]. It has a high level of tolerance to salinity (Krishnamurthy *et al.*, 2014) [20]. It can grow at higher altitudes (1500 m) as well as in plains (Baltensperger, 1996) [17].

Barnyard millet (*Echinochloa* sp.) is one of the oldest domesticated millets in the semi-arid tropics of Asia and Africa. Barnyard millet is grown for human consumption as well as fodder. It is generally cultivated in areas where climatic and edaphic conditions are unsuitable for rice cultivation (Yabuno, 1987) [20]. In the Indian Himalayan region, the crop was traditionally used as a substitute for rice. It has been identified as a suitable choice for climate-resilient agriculture. High nutrient content and antioxidant effects make it to be considered as a functional food crop (Sood *et al.*, 2015) [21]. Barnyard millet showed parallel line of evolution both in India and Africa. It is annually cultivated in India, Central African Republic, Tanzania and Malawi (Doggett, 1989) [22]. This millet is annual in habit and is cultivated mostly in the temperate regions (De Wet *et al.*, 1983) [23] of Japan, Korea, China, Russia and Germany. Its wild ancestor is barnyard grass from which it was directly domesticated some 4000 years ago in Japan (Doggett, 1989) [22].

The kodo millet *(Paspalumscrobiculatum)*, is grown in India, Pakistan, Philippines, Indonesia, Vietnam, Thailand and West Africa. It is major food source in the Deccan plateau of India (Gujarat, Karnataka and parts of Tamil Nadu), some regions of Maharashtra, Odisha, West Bengal, Rajasthan, Uttar Pradesh and Himalayas and consumed traditionally as health and vitality foods in rural India (Hegde and Chandra, 2005) [24]. An estimation says Kodo millet is grown in area of about 907,800 ha with annual production of about 310,710 tonnes (Yadav *et al.*, 2013) [25]. Madhya Pradesh and Tamil Nadu have the maximum share in the production and promotion of kodo millet. The phosphorus content in kodo millet is lower than any other millet and its antioxidant potential is much higher than any other millet and major cereals (Deshpande *et al.*, 2015) [26]. This crop is drought tolerant and usually grown in semi-arid regions without any intercultural operations. Kodo is monocot and the seeds are very small and ellipsoidal, being approximately 1.5mm in width and 2mm in length; they vary in colour from being light brown to a dark grey. Kodo millet has a shallow root system which may be ideal for intercropping. The grain is enclosed in hard, corneous, persistent husks (FAO, 1995) [27]. Kodo grain is usually referred to be poisonous tocattle and human. The poisoning of the grain isassociated with thetoxic substance cyclopiazonic acid and is believed tobe produced by *Aspergillusflavus*, *A. tamarii* and *Phomopsis paspalli* (Patwardhan *et al.*, 1974; Rao and Husain, 1985; Antony *et al.*, 2003) [28, 29, 30].

Proso millet is a warm-season annual grass that grows 1–3½ ft tall. Stems are light green, erect, sometimes branched at the base, and grow 20–60 in (0.5–1.5 m) tall (Baltensperger, 1996) [17]. Plants have shallow, fibrous root systems and produce few tillers. Proso millet has a drooping, branched, compact inflorescence 4–18 in (10–45 cm) long made of many stalked, ovoid spikelets. The panicles may be spreading, loose and one-sided, or erect depending on the variety (McDonald *et al.*, 2003) [31]. Proso millet is usually confused with young corn seedlings, fall panicum (*Panicum dichotomiflorum*), and witch grass (*Panicum capillare*). A distinguishing feature of the plant is that the seed husk (palea and lemma) remains attached to the roots of seedlings (Bough *et al.*, 1986) [32].

It is thought that proso millet was originally cultivated in eastern Asia, later spreading to India, Russia, the Middle East, and Europe. Today proso millet is produced in India, China, Russia, the Middle East (Baltensperger, 1996) [17]. In the United States, it is mainly grown in the Great Plains states of Nebraska, South Dakota, and Colorado, with limited production in Kansas, Wyoming, and Minnesota. US production has increased in the past 10 years (McDonald *et al.*, 2003) [31]. The weedier wild-proso millet is thought to have escaped from domesticated varieties, and can be found throughout the United States. Proso millet grows best in full sun, moist to dry conditions, and can perform well in many soil types. It is found in croplands, fallow fields, roadsides, waste sites, and disturbed soils. Proso millet is both heat and drought-tolerant and is widely grown in the tropics and sub-tropics. Proso millet is a C_4 plant with a low transpiration ratio. Its high water use efficiency allows it to grow in water-limited environments (Baltensperger, 1996; [17] Lyon *et al.*, 2008 [33]). However, due to its shallow root system, it does not grow well under water stress (Baltensperger, 1996) [17]. It is not frost-tolerant and does not grow well in soils with a pH greater than 7.8. It has poor tolerance to high salinity.

3. Potential Uses

3.1 Food Industry

Finger millet is a cereal grass belongs to the family Poaceae and is more commonly known as ragi in India. It forms a predominant staple food for people living on marginal lands and with limited economic resources. An agronomically sustainable crop, it can grow on marginal lands, high altitudes and can easily withstand drought and saline conditions, requires little irrigation and other inputs and yet maintain optimum yields. Finger millet grains can be processed in several ways depending upon the ultimate utilization. The different processing techniques include milling, malting, popping, puffing, flaking, debraning etc. (Shobana *et al.*, 2013) [34].

Popping: It is a simple processing technique of cereals to prepare ready to eat products. Popped grain is crunchy, porous and a precooked product. Popping improves the nutritional value by inactivating some of the anti- nutritional factors and thereby enhancing the protein and carbohydrate digestibility (Nirmala *et al.,* 2000) [35].

Malting: Malted finger millet is considered superior to malted sorghum and malted maize. Studies have shown that finger millet develops higher amylase activity than sorghum and other millets (Malleshi and Desikachar, 1986[36]; Senappa, 1988[37]). Finger millet malt has improved digestibility, sensory and nutritional quality as well as has pronounced effect in lowering the antinutrients.

Noodles: Changes in food habits of present generation have created a good market of noodles in India and abroad. The demand for millet noodles particularly the noodles made out of finger millet is growing due to awareness of its nutritional properties. Noodles of different combinations are prepared such as noodles exclusively made of finger millet, finger millet and wheat in the ratio of 1:1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1. In case of exclusive millet-based noodles, pretreatment to the millet flour is given to facilitate extrusion and smooth texture which should retain while drying and cooking.

Roasting: Roasting and grinding processes render the grain digestible, without the loss of nutritious components (Krantz *et al.*, 1983) [38]. Roasting of cereals, pulses and oilseeds is a simpler and more commonly used household and village level technology which is reported to remove most anti nutritional or toxic effects such as trypsin inhibitor, hemagglutinin, gioterogenic agents, cyanogenic glycosides, alkaloids and saponins and increase storage life (Gopaldas *et al.,* 1982 [39]; Huffman and Martin, 1994 [40]).

Fermentation: Lactic acid fermentation has been found to affect the amount of amino acids in cereals and legumes. Fermentation increases the lysine and tryptophan content in millets (Hamad and Fields, 1979) [41]. Antony and Chandra (1998) [42] reported that fermentation of finger millet flour using endogenous grain microflora showed a significant reduction of phytates by 20% and tannins by 52% and trypsin inhibitor activity by 32% at the end of 24 h. There was a simultaneous increase in mineral availability (calcium-20, phosphorous-26, iron-27 and zinc-26%).

Extrusion: Extrusion technology is a new way of transforming ingredients into value added products. Extruded products prepared from different grains are very popular now days among the all age groups and their demand is growing, one such example is 'Kurkure' very popular among children. Finger millet flour or grits exhibit good extrusion characteristics. Like other preparations, the finger millet flour can be blended with other legume ingredient flours in appropriate proportion with further fortification of minerals and vitamins to design a balanced nutritional extruded food.

Bakery Products: The use of millets in bakery products will not only superior in terms of fiber content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products. In a recent study, attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fiber content by supplementing with malted finger millet flour (Desai *et al.*, 2010) [43]. In recent years, finger millet has received attention and efforts are under way to provide it to the consumer's inconvenient forms (Singh and Raghuvanshi, 2012) [44].

Barnyard millet has also been used to develop various bakery products such as biscuits, sweets, noodles, rusk, ready mix, popped products and some other speciality foods, but large-scale production needs industry involvement to commercialize the products globally. Barnyard millet is highly suitable for commercial foods for diabetics, infants and pregnant women because of high iron content. However, the non-availability of ready-to-use processed products has limited the usage and acceptability of barnyard millet, despite its nutritional superiority. There is a need to develop millet-based food products in the form of ready-to-use products and functional foods to meet the demands of the present-day consumers.

3.2 Pharmacological Importance's

Presently, it is consumed as a staple food only by a small section but its appealing nutritional traits have now created wide interest among the scientists to explore the nutraceutical properties of finger millet.Finger millet prevents constipation because of its high fibre content (Lata, 2015) [45]. Recent research has shown that diets rich in plant-based foods, particularly whole-grain cereals, are protective against several degenerative diseases (Fig 2). Sharma *et al.*, (2018) [46] reported that finger millet contain high antioxidant and phenolic compound known to offer several health benefits such as ant diabetic, antioxidant, hypercholesterolemia, antimicrobial effect and protection from diet related chronic diseases to its regular consumers. Finger millet is potentially a climate-resilient and nutritious crop with high nutraceutical, antioxidant properties and gluten-free, rich in calcium, fiber and iron, has excellent malting qualities, with low glycemic index (GI) and because of these properties, finger millet is a choice food for diabetics (Hittalmani *et al.*, 2017) [47]. The chemical constituents such as moisture, fat and protein tends to decrease slightly whereas total carbohydrate content, ash, fibre increases along with the increase in the bio-availability of minerals like calcium and iron on roasting (Singh *et al.*, 2018) [48]. Finger millet are good source of micronutrient which could alleviate the wide spread micronutrient malnutrition in India.Finger millet is good for diabetic and obese patients, as the digestion of finger millet takes place at a slow pace and hence glucose is released slowly into the blood (Shobana *et al.*, 2009) [3]. They also reported that roasted green finger millet is good for people suffering from liver damage, blood pressure, heart diseases and asthma. The millet is rich in calcium therefore helps in proper growth and development. Being a rich source of iron, finger millet is good for all those suffering from anaemia (Kumar *et al.*, 2016) [49]. The millet is should also be consumed by a lactating mother if she is not capable to produce sufficient milk to feed her infant (Panter, 1993) [50]. From the nutritional perspective, finger millet is considerably rich in minerals and its micronutrient density is higher than that of the world's major cereal grains; rice and wheat (Antony and Chandra, 1998 Table 1) [42]. Also small millets contain essential amino acids shown in table 2. It fights with malnutrition and degenerative diseases. It also works well as an anti-ageing agent. (National Research Council, 1996) [14].

Table 1: Nutritional composition of small millets

Minor millets	Protein (%)	Fat (%)	Starch (%)	Ash (%)	Crude fibre (%)	Total dietry fibre/100g	Total Phenol (mg/100g)	Carbohydrates (g)
Finger millet	7.3	13.0	59.0	3.0	3.6	19.1	102.0	72.6
Pearl millet	14.5	5.1	60.5	2.0	2.0	7.0	51.4	67.5
Proso millet	11.0	3.5	56.1	3.6	9.0	8.5	0.10	70.4
Foxtail millet	11.7	3.9	59.1	3.0	7.0	19.11	106.0	60.9
Kodo millet	8.3	1.4	72.0	3.6	9.0	37.8	368.0	65.9
Little millet	7.7	4.7	60.9	6.9	7.6	-	21.2	67.0
Barnyard millet	6.2	4.8	60.3	4.0	13.6	13.0	26.7	65.5

Source: (USDA database)

Table 2: Essential amino acid profile of minor millets (g/100 g).

Minor millets	Arginine	Histidine	Lysine	Tryptophan	Phenylalanine	Tyrosine	Methionine	Cysteine	Threonine	Leucine	Isoleucine	Valine
Finger millet	0.300	0.130	0.220	0.100	0.310	0.220	0.210	0.140	0.240	0.690	0.400	0.480
Pearl millet	0.300	0.140	0.190	0.110	0.290	0.200	0.150	0.110	0.240	0.750	0.260	0.330
Proso millet	0.290	0.110	0.190	0.050	0.310	-	0.160	-	0.150	0.760	0.410	0.410
Foxtail millet	0.220	0.130	0.140	0.060	0.420	-	0.180	0.100	0.190	1.040	0.480	0.430
Kodo millet	0.270	0.120	0.150	0.050	0.430	-	0.180	0.110	0.200	0.650	0.360	0.410
Little millet	0.250	0.120	0.110	0.060	0.330	-	0.180	0.090	0.190	0.760	0.370	0.350
Barnyard millet	-	-	-	-	-	-	-	-	-	-	-	-

Source: (USDA database)

Little millet is gluten free whole grain, which is also a vegan food. It is rich in phyto-chemicals and it has excellent antioxidant properties. Its dietary fiber protects against hyperglycemia. It reduces cholesterol and helps in digestion. Little millet has nearly 2.5 times minerals and nearly 38 times fiber and nearly 13 times iron than rice. It has nearly 6.3 times fiber and nearly 1.8 times iron than wheat. It has lesser amount of carbohydrates than wheat and rice and has abundant quantities of thiamin (Vitamin B1) which is not present in rice and wheat. Little millet is used in place of rice it is cooked in similar manner. Sometimes it is also milled and can be baked.

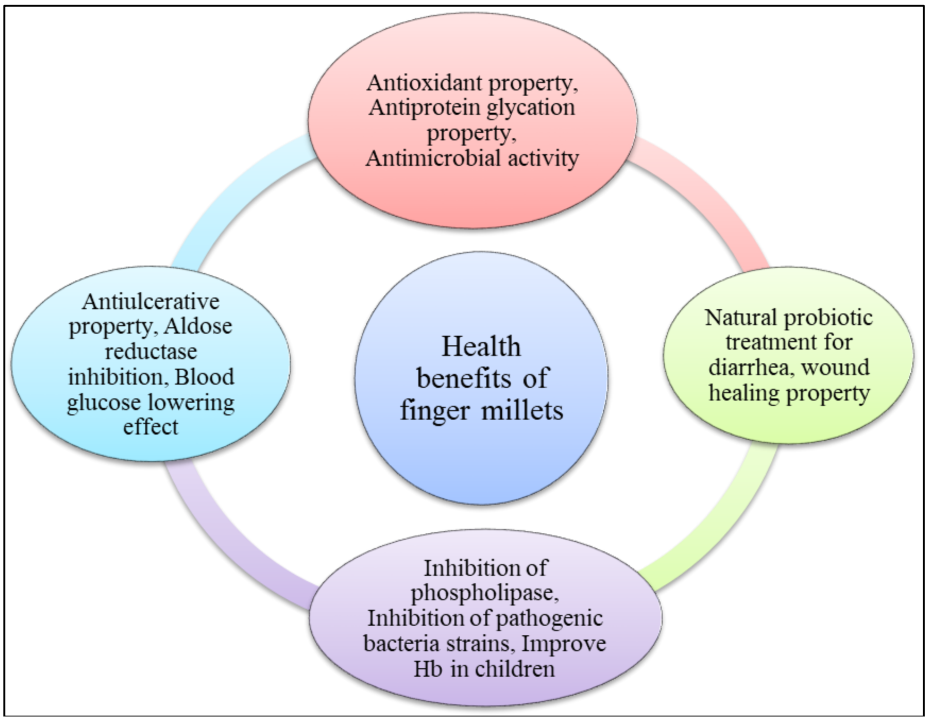

Fig 2: Nutraceutical properties of finger millet

3.3 Fuel and Fodder

Like all millets, foxtail millet species is fast-growing and produces relatively high yields with no danger of producing toxic levels of prussic acid (Lee and Henning, 2014) [51]. Foxtail millet can be harvested 75–90 days after planting (DAP). It is easy to harvest as hay because of its short, fine stems. Hay harvesting can begin at boot stage, when seed heads are beginning to emerge or from late boot to early bloom stage for optimum quality (Cash *et al.*, 2002) [52]. Foxtail millet has a C:N ratio of 44 and can produce 43 lb/ac

N in aboveground biomass. Mixing farming of foxtail millet and cowpea (*Vigna unguiculata*) is a good cover crop option. When foxtail millet was used in Maryland in a cover crop mixture with soybean prior to fall-planted broccoli, the soybean and millet mix suppressed more weeds than the millet alone, had a larger total Nitrogen, and had similar above-ground biomass (Abdul-Baki *et al.,* 1997) [53]. Foxtail millet residue is more persistent than other residue like soybean and buckwheat, probably because of its high C:N ratio (Morse, 1995) [54]. Agricultural residues such as finger millet straws are emerging sources of renewable fuel generation for domestic uses in developing countries. When compared with LPG, kerosene and other petroleum products, agricultural residues are cheaper and environment friendly (Jekayinfa and Scholz, 2009) [55]. Finger millet straws, are lignocellulosic biomass materials, they have high composition of organic constituents and energy. So, finger millet straws can be considered as potential source of renewable energy (OECD, 2010) [56]. Finger millet briquettes shows higher calorific value 4213-4662 Kcal/kg. This is comparable with other common agricultural residues such as rice, wheat, bagasse and wood (Hesborn *et al.*, 2009) [57].

In Himalayan region barnyard millet is used as the source of fodder. Barnyard millet leaves are broad, and the plant picks up good growth in short time and thus produces voluminous fodder. Barnyard fodder is highly appetizing and can be used for making hay or silage.

3.4 Food Source

In the Indian Himalayan region, millet is used as a substitute for staple cereals like rice and wheat. The grains are Dehulled, cooked and consumed like rice. Barnyard millet porridge (locally called Madira Ki Kheer) is a popular sweet dish in Uttarakhand. In southern India, barnyard millet is used in traditional preparations such as Idli, Dosa and Chakli. Mudde, a thick porridge of finger millet is consumed by rural and urban population of Southern Karnataka. In Maharashtra millet flour is consumed as flat thin cakes called roti. 50-75% of barnyard millet flour can be incorporated in preparation of rotis, idlies, dosa and chakli (Veena *et al.*, 2004) [58].

Kodo millet is ground to make flour and this flour can be used to make pudding. In tribal sectors, it is cooked as rice also and out of flour tribal population prepares different recipes. In Africa, it is cooked like rice. It is also a good choice of animal fodder for cattle, goats, pigs, sheep, and poultry. It has been noted that it makes a good cover crop. Though it is not been a major carbohydrate source in European countries; however it is gaining importance as a gluten free food and is a component in multigrain gluten free food products (Deshpande *et al.*, 2015) [59].

Now days commercial food products made from millets are emerging widely. Millet in combination with other cereals is utilized in commercial production of biscuits, beverages, weaning foods and beer. Millet, sorghum and corn are combined to form grits and flour. Fibre rich cookies are being made using combinations of cookies are being made using combinations of sorghum, maize and wheat (Charalampopoulos *et al.*, 2002 [60]; Lopez 2007 [61]).

4. Conclusion

From above discussion it is clear that millets being underutilized crop are being cultivated at various places. Millets are utilized in various forms; it can be utilized in raw form as well as processed form. Major forms of millets have great potential for food and industrial uses. There seems enough scope for the development of value added products from this underutilized crops. For increasing demand of under-utilized crops in near future there is need to create awareness among urban people regarding nutritive values of under-utilized crops and need to create remunerative market for it. Promoting utilization of millet grains especially finger millet in urban areas for creating new markets of farmers to improve their income and developing of value added, convenient and tasty food products by conventional as well as with modern techniques will increase its consumption and that will direct this to "the most loveable food" to the world.

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