Review Article

Minor millets – Miracle grain of South India: A review

Abstract

Minor millets are important traditional food crops for dry land farmers in India. Minor millets such as ~~Finger~~ finger millet, ~~Foxtail~~ foxtail millet, ~~Proso~~ prosomillet, ~~Kodo~~ kodomillet, ~~Little~~ little millet and ~~Barnyard~~ barnyard millet are considered as a climate-smart crop. They are tagged as nutri- ~~cereals~~ -cerealsand are the source of food, feed and fodder. All these crops have superior nutritional properties, including high macro, micronutrients, dietaryfib~~e~~re content and low glycemic index with potential health benefits. This review aims to document the production status, demand, varietal diversity, processing, nutrient composition, and therapeutic potential of minor millets for further research on various aspects.~~This review is focused to documentthe production status, demand, varietal wealth, processing, nutrient composition and therapeutic potential of minor millets for further research on various aspects.~~

Keywords: Minor millets, Nutrients, Phytochemicals, Antioxidant

Introduction

Millets are a group of cereal food grain crops that are small-seeded, adapted to cultivation over a range of tropical and subtropical climates, and can be grown with very low inputs. They are the staple food of the millions inhabiting the arid and semiarid tropics of the world.According to FAO, the world production of millets is 89.17 million metric tons from an area of 74 million ha~~during~~ in2020.Major and minor millets are the two varieties grown in India. Sorghum, pearl millet, and maize are some of the major millets grown in larger quantities in India compared to minor or small millets, despite the fact that minor millets have higher nutritional value. In India, minor millets, which consist of six species, are cultivated over approximately 2 million hectares, mainly in semi-arid, hilly, and mountainous regions.~~Sorghum, pearl millet and maize are among the major millets. Major millets are grown in greater quantities in India than minor/small millets, although minormillets have a higher nutritional value. Minor millets comprising six species are grown in India overca 2 million ha, mostly in semi arid, hilly and mountainous regions~~ **[1].**The

six minor millet species grown are ~~Finger~~ finger millet, ~~Little~~ little millet, ~~Italian~~ italianor foxtail millet, ~~Barnyard~~ barnyard millet, ~~Proso~~ prosomillet and~~Kodo~~ kodomillet. Among these, finger millet occupies about 60% of the area and contributes 70% to the overall minor millet production.

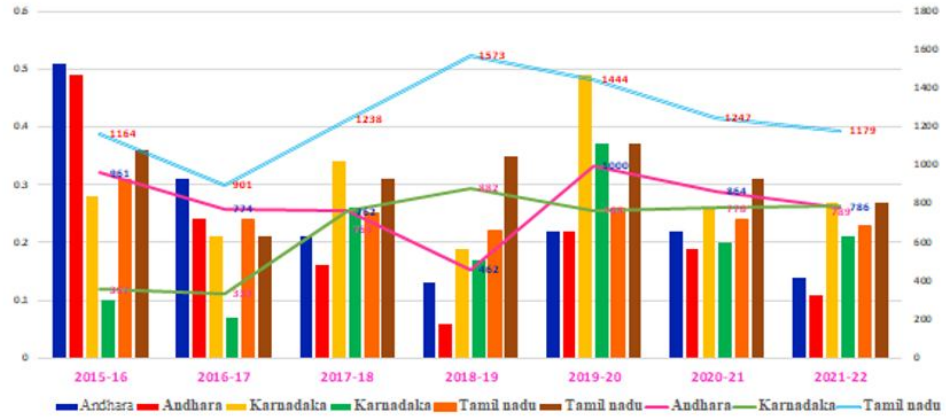
Minor millets are nutritious, climate-resilient, hardy and dry land crops, hence tagged as Nutri-cereals, contribute substantially ~~for~~ tofood and nutritional security. Recently, minor millets have gained the attention ~~by~~ ofthe masses due to ~~its~~ theirnon-gluten tendency. Nutritionally, minor millets are rich in minerals, polyphenols, antioxidants, and fibers that are important for healthy body functioning. Minor millets are a common food source for the people of Manipur, Meghalaya, and Nagaland, located in northeastern India. Although these grains were once referred to as coarse cereals, their nutrient richness has led the Government of India to officially categorize them as "Nutri cereals."~~Nutrition wise, minor millets are rich in minerals, polyphenols, antioxidants and fibers that are important for healthy body functioning. Further, minor millets are a common food source for the people of Manipur, Meghalaya and Nagaland, who are located in northeastern India. These were often referred to as coarse cereals but realizing the nutrient richness of the grains they are now gazetted as "Nutri cereals" by Government of India.~~

Scenario of minor millets in India

India has the third largest area under minor millets cultivation in the world.Over the last eleven years, the area under minor millet has decreased considerably from 2011-12 to 2021-22.The area of minor millet shrunk from 7.99 lakh hectares (2011-2012) to 4.23 lakh hectares (2021-2022). Likewise, production under minor millet also reduced from 4.52 lakh tons to 3.75 lakh tons for the same period. However, the marginal gain in the productivity of minor millets from 565 q/ha to 885 q/ha was observed, but it was very minimal as compared to other crops like cereals, pulses, groundnut and cotton in India **[2].**The declining trend in area and production was also reported in recently published studies **[3]**. Them~~M~~ajor reason for the reduction of area and production was~~ere~~ the tradeoff between rice and wheat with minor millet**[4].**

In India, the major states involved in minor millet cultivation are Madhya Pradesh (32.4%,89000 hectares) followed by Chhattisgarh (19.5%,52000 hectares), Uttarakhand (8.0%,47000 hectares~~,~~), Maharashtra (7.8%), Gujarat (5.3%), and Tamil Nadu (3.9%) for the past seven years from 2015 – 2016 to 2021- 2022**[5 -6].**

Fig.1.Minor millet production status in south India – Area (A) in lakh ha, Production (P) in lakh tons and Yield (Y) in kg/ha



In south India, the growth rate ofarea under minor millet cultivation (from 0.51 to 0.14 lakh ha in Andhra Pradesh, from 0.28 to 0.27 in Karnataka, from0.31 to 0.23 lakh ha in Tamil Nadu)has declined over time(from 2015-16 to 2021-22)which was shown in Fig.1.In Karnataka, the increased trend of productionwas noticed during 2017-18 (0.26 lakh tons), then decreased during 2018-19 (0.17 lakh tons) and again increased (0.37) during 2019-20.The decreased ~~trend of~~ production trend was observed in Andhra Pradesh for the past seven years (from 0.49 to 0.11 lakh tons), whereas in Tamil Nadu sustained growth of production and productivity was recorded during the same years.

Among the South Indian states, Karnataka state is well known for cultivating minor millets in India, with finger millet (Karnataka awarded with Geographical Indication (GI) tag for finger millet by the central government) serving as a staple meal in the southern portion of the state **[7]**and its accounting 65% of area and production followed by Uttarakhand and Tamil Nadu. But Tamil Nadu has the highest productivity (3246 kg/ha) of finger millet, followed by Karnataka (1726 kg/ha), which is above the national average yield (1697 kg/ha). The state that produces the most small millets is Karnataka, accounting for 56% of the total production, followed by Tamil Nadu at 14.0% and Uttarakhand at 9.3%. All the other states put together contribute about one-fifth of the total production. Finger millet covers nearly 68% of the area under small millets, followed by little and kodo millets at about 10%, and the remaining area is occupied by barnyard, foxtail, and proso millets.~~The biggest small milletsproducing state is Karnataka (56% of total production) followed distantly by Tamil Nadu (14.0%) and Uttarakhand (9.3%). Rest of~~

~~the states together contribute about one-fifth of the total production. Nearly 68% of area under small millets is occupied by finger millet, followed by little and kodo millets (about 10%) and rest by barnyard, foxtail and proso millets.~~

Origin and distribution of minor millets

Comment [RR1]: The whole section should come before the section"scenario of minor millets in india"

Millets were~~are~~ the first crops to be domesticated by ~~the~~ mankind in Asia and Africa, which later spread across the globe as critical food sources to the evolving civilizations. Minor millets are small coarse ~~of~~ grains belonging to the group of forage grass called millet**[8]** belonging~~s~~ to the family *Poaceae*; most of the genera belong~~s~~ to the sub-family *Panicoideae*, ~~that~~ whichcan grow in extreme ecological conditions**[9]**. The word millet comes from the French word "Mille" which means "thousand", meaning that a handful of millet can hold up to a thousand grains **[10]**. The minor millets include foxtail millet, little millet, kodo millet, proso millet and barnyard millet (Fig.2.). There are ~~other~~ four other types of minor millets namely browntop millet, ~~,~~fonio, tef, and job's tear millet (*Coixlaeryma*), which are of minor importance in India because they are grown mostly in Africa **[11].**

Finger millet [*Eleusine coracana* (L.) Gaertn.] is an allotetraploid evolved from its wild progenitor, *E. africana*. Domestication of cultivated finger millet started around 5,000 years ago in Western Uganda and Ethiopian highlands and the crop has extended to Western Ghats of India around 3,000 BC **[12]**. Foxtail millet *[Setariaitalica (L.)* P. Beauv.] is a member of the subfamily Panicoideae and the tribe Paniceae. The green foxtail (*S. viridis*) is a wild ancestor of cultivated foxtail millet. Foxtail millet is grown since >10,500 years ago in China **[13]**. Proso millet or common millet (*Panicum miliaceum* L.) is the true millet of ~~the~~ history, and it is one of the oldest human foods and believed to be the first domesticated cereal grain. Recent studiessuggested that Proso millet probably was domesticated in China and Europe **[14]**.

Little millet (*Panicum sumatrense* Roth. ex. Roem. & Schult.) was domesticated in India particularly important in the Eastern Ghats of India, where it forms an important part of tribal agriculture**[15]**. In barnyard millet, two species, namely *Echinochloa crus-galli* and *E. colona* are cultivated as cereals. *E. crus-galli* is native to temperate Eurasia and was domesticated in Japan some 4000 years ago, while *E. colona* is widely distributed in the tropics and subtropics of the Old ~~world,~~World and was domesticated in India**[16]**. Kodo millet belongs to the genus Paspalum, a diverse genus comprising about 400 species, most of which are native to the tropical and subtropical regions of the Americas, and the main center of origin and diversity of the genus is considered to be South American tropics and subtropics **[17]**. Kodo millet, also known as cow grass, rice grass, ditch millet, Native Paspalum, or Indian Crown Grass, and it is estimated to have been domesticated in India 3000 years ago. It is cultivated by tribal people in small areas

throughout India, from Kerala and Tamil Nadu in the south~~,~~ to Rajasthan, Uttar Pradesh and West Bengal in the North**[18]**.

Remember the following text:

Teff (Eragrostis tef) is the most important minor millet in Ethiopia, especially in the poorly drained, heavy soils that predominate in the Central Plateau. However, the crop has not become important outside Ethiopia. Fonio (Digitariaexilis), also known as hungry rice, is grown as a minor millet crop throughout the savanna zone of West Africa.~~Teff *(Eragrostis tef)* is the most important minor millet in Ethiopia, particularly in the poorly drained, heavy soils that predominate in the Central Plateau. Nevertheless, the crop has not become important outside Ethiopia. Fonio *(Digitaria exilis)* also known as hungry rice is grown as a minor millet crop throughout the savanna zone of West Africa.~~ In parts of Guinea and Nigeria, it is the staple crop and is considered to be the oldest West African cereal and its cultivation is thought to date back to 5000 B.C**[19]**.

	
a~~1~~.**Finger millet**	b~~2~~.**Proso millet**

c~~3~~.Foxtail millet

d4.Kodo millet

e~~5~~.Barnyard millet

f~~6~~.Little millet

Fig.2 (a-f): ~~.~~Minor millets of S~~s~~outh India

Minor millets - Climate resilient crop

~~In India, minor millets can be grown from June to November, and loamy, well- drained~~Minor millets can be grown in India from June to November, and loamy, well-drained soil works best for growth. These crops are widely divergent for thermo and photoperiods, and hence are known for their climatic resilience and are relatively less prone to biotic stress factors**[20]**.It needs very little input~~s~~ for ~~their~~ itssustenance.Millets may be cultivated with less rainfall since they are crops fed by the rain. Major millets require 450 mm of rainfall, whereas minor millets only need 350 mm**[21]**. Different minor millets can adapt well to the climatic conditions prevailing in a geographic location.For example, Proso millet can complete its life cycle in 60–80 days, while

Foxtail millet can mature in 70–90 days. Little millet and barnyard millet generally mature in 75–100 days, while ~~,k~~K~~K~~odo millet and f~~F~~inger millet~~s~~ take slightly longer duration of 95–130 days. Because of earliness compared to other crops, these are highly suitable for contingency crop planning and cropping system and have the exceptional feature of faster recovery and growth after ~~alleviation of stress specially~~stress alleviation, especially in finger millet and kodo millet.

Varietal wealth of minor millets in India

Indian Council of Agricultural Research, through the Indian Institute of Millets Research and AICRP Project on Millets, has succeeded in the development of more than 90 varieties for different agro-climatic regions so far. Till 2022, 302 varieties in different minor millets -142 in finger millet, 41 in kodo,38 in foxtail,32 in Little,27 in proso millet and 22 in barnyard millet were evolved and released for cultivation in different regions of the country**[23]**.

A number of varieties with high-yield potential have been released for different states. The list of i~~I~~mproved and popular varieties recommended for different states of S~~s~~outhIndia ~~are~~ isgiven below (Table.1).

Table.1. Improved and popular varieties of S~~s~~outh India

Minor millets	Karnataka	Tamil Nadu	Andhra Pradesh
Finger millet	GPU 28, GPU-45, GPU-48, PR 202, MR 1, MR 6, Indaf 7, ML-365, GPU 67, GPU 66, KMR 204, KMR 301, KMR 340, DHFM-78-3	GPU 28, CO 13, TNAU 946 (CO 14), CO 9, CO 12, CO 15	VR 847, PR 202, VR 708, VR 762, VR 900, VR 936, PPR-2700
Foxtail millet	SiA 3088, SiA 3156, SiA 3085, Lepakshi, SiA 326, Narasimharaya, Krishnadevaraya, PS-4	SiA 326, HMT 100-1 and PS 4,Narasimharaya, SiA 3088, SiA 3156, SiA 3085, DHFt-109-3, PS-4	TNAU 43, TNAU-186, TNAU 196, CO 1, CO 2, CO 4, CO 5, K2, K3, SiA 3088, SiA 3156, SiA 3085, PS-4
Kodo millet	GPUK 3, RBK 155, RK 390-25, TNAU-86	KMV 20 (Bamban), CO 3, TNAU 86, GPUK 3, RK 390-25	-
Little mille	OLM 203, JK 8, BL-6, DHLM-36-3	Paiyur 2, TNAU 63 and CO 3,C0-4,K1, OLM -203, OLM -20, BL-6, DHLM-36-3, DHLM-14-1	OLM 203, JK 8, BL-6, DHLM-36-3
Barnyard millet	VL 172, RAU 11, VL 181, DHBM-93-3, DHB-93-2	CO 1, CO 2, VL 181, VL 29, DHBM-93-3	-
Proso millet	GPUP 8, GPUP 21,	Co-5, TNAU 151,	Sagar, Nagarjuna, Co

	TNAU 145, TNAU-151, TNAU-164, TNAU-202, TNPm-230, DHP-2769	TNAU 164, TNAU 145, TNAU 202, Co 4, K2, Co 3, Co 2, GPUP 21, GPUP 8 , TNPm-230	4, Co 3, TNAU-151, TNAU-164, TNAU-202, TNPm-230

Apart from the above varieties, nineteen different landraces from five millet crop species can be found in the Kolli Hills of Tamil Nadu. These include finger millet (Sundangikelvaragu, Perungelvaragu, Karunguliyankelvaagu, Arisikelvaragu, Sattaikelvaragu, Karakelvaragu), Italian millet (Perunthinai, Koranthinai, Senthinai, Mookanthinai, Palanthinai), little millet (Vellaperumsamai, Kattavettisamai, Karumsamai, Malliasamai, Thirigulasamai, Sadansamai), common or proso millet (panivaragu) and kodo millet (varagu). The latter two are cultivated only to a very limited extent **[24].**

Bio fortified varieties in minor millets

Bio fortification in minor millets is a feasible strategy to alleviate the micronutrient malnutrition among the rural poor. A few bio fortified cultivars with higher iron and zinc content along with high grain yield were released for farmers (Table 2)**[25].**

Table 2: List of released bio fortified minor millet varieties in India

Crop	Bio fortified varieties	Characteristics
Finger millet	VR 929 (Vegavathi)	Rich in iron (131.8 ppm). Grain yield:3110kg/ha
Finger millet	CFMV1 (Indravati)	Rich in calcium (428 mg/100g), iron (58.0 ppm) and zinc (44.0 ppm).Grain yield: 2950kg/ha
	CFMV 2 (Gira)	Rich in calcium (454 mg/100g), iron (39.0 ppm) and zinc (25.0 ppm). Grain yield:3200kg/ha
Little millet	CLMV1(Jaicar Sama-1)	Rich in iron (59.0 ppm) and zinc (35.0 ppm).Grain yield:1580kg/ha

Minor millets as source of fodder

Minor millets are also used as fodder crops due to their higher biomass. Kodo millet, little millet and proso millet are the most preferred animal feeds due to their higher palatability and crude protein content.**[26].**The minor millet grains can also become good substitutes for other cereal grains in the preparation of concentrate mixture of livestock and poultry, thereby reducing the cost of feed as well. Stover from millets is a valued fodder, especially if cut and dried immediately after the heads have been harvested for grain**[27]**. The nutritive value in terms of nitrogen and soluble nutrients is better in minor millet stover as compared to slender straws of paddy and wheat. Improved varieties and hybrids of the minor millets yield higher, both grain and stover (Table.3).

Minor millets produce 3–8 tons of fodder depending on cultural conditions. Finger millet stover is considered a good feed in India and Nepal. Under rain fed conditions, finger millet stover yield is about 2–3 t/ha and may reach up to 6–10 t/ha under irrigation. Green forage from kodo millet is readily eaten by cattle and is highly digestible up to flowering (70–75% dry matter digestibility).However, the stover obtained from the rain fed crop is relished more by cattle compared to an irrigated crop because stover of irrigated crop is tough and fibrous and hence is less palatable.

Finger millet stover can be used to feed crossbred dairy cows in diets supplemented with a concentrate mixture (energy and protein). Such diets allow 8 to 9 litres milk yield and a body weight gain of 200–300 g/day. It can be used for growing heifers when supplemented with wheat bran (25%) or groundnut cake. Dry matter intake of stover is about 3.5 kg/day and the daily weight gain is 310–350 g. It can also be made into silage with suitable supplements **[28]**.

Table 3. Stover yield of recent cultivars of minor millet in India

Crop	Variety / Hybrid	Grain yield (q/ha)	Fodder yield (q/ha)
Finger millet	ML-365	50-55	65
	Vegavathi (VR 929)	36	77
	CFMV 1 (Indravathi)	31.1	84.4
	CFMV 2	29.5	86.1
	CFMV 3	32	87
Barnyard millet	Pratap Sanwa 1	15-17	50-55
Kodo millet	CKMV 1 (ATL 2)	28	70
Proso millet	GPUP 21	15.7	42
	Pratap Cheena	15-17	48-50
	TNAU 202	19	37
Foxtail millet	Pratap Kangni-1	16-18	46-50
	CO-7	18.6	51
Little millet	Sabara	12-21	52
	CO-4	15.7	58
	DHLM -14-1	16	61
	CLMV 1	16	55

Minor Millets: A Power House of Nutrients

Minor millets are important due to their several nutritional and other useful characteristics.These crops are rich in protein, fat, crude fiber, iron and other minerals and vitamins in comparison to fine cereals like wheat and rice.

The protein content in minor millets like foxtail millet (11.2-15.0), little millet (10.0-15.0) and proso millet (10.0-13.0) is comparable with wheat (11.8) and much higher than rice (6.8). Though the finger millet contains lesser protein (7.0-10.0), but it is rich in mineral matter and calcium in comparison to wheat and rice. All the millets contain more fiber than fine cereals. Particularly, the minor millets namely barnyard millet (9.5-14.0), kodo millet (5.0-9.0) little millet (4.0-8.0) and foxtail millet (4.5-7.0) are the richest source of fibre in comparison to wheat (1.0) and rice (1.0). The fat content of the minor millets ranges from 1 to 7g, lowest in finger (1.3-1.8),proso (1-3.5) and kodo millet (1.4 -3.6) and highest in foxtail, and little millets (4 -7). Therefore, millets are now being pronounced as "Miracle grains and nutria-cereals"

The minor millets are rich sources of Vitamin E and B-complex vitamins (except Vitamin B 12). Total niacin content present is 10.88 mg. Matured grains of millets have shown low levels of Vitamin C. Finger millet contains over >10 fold higher calcium (240-410 mg per 100g),little and barnyard millets are rich in iron (13 to 20 mg per 100g) compared to other major cereals **[29]**.

Minor millet as Miracle grain - Nutritional composition and its uses

1. Finger millet

The grains area good source of natural calcium (240-410mg) which helps for bone strengthening and helps in reducing the risk of bone fractures. On daily consumption of whole grain of finger millet and its productscan protect against the risk of cardiovascular diseases, Type II diabetes and gastrointestinal cancers and other health issues**[30]**. It is milled with the testa which is generally rich in dietary fiber and micronutrients to prepare flour**[31]**. The dietary fiber, minerals, phenolics and vitamins concentrated in the outer layer of the seed coat form the part of the food and offer their nutritional and health benefits **[32]**. In addition, it helps to increase the hemoglobin level and also helps to fight malnutrition and degenerative diseases **[33].** Fibers of finger millet gives fullness feeling thus controlling the excessive food consumption**[8]**.

2. Barnyard Millet

It is a good source of protein, which is highly digestible and is an excellent source of dietary fiber with good amount of soluble and insoluble fractions**[34]**. Barnyard millet is known for its low glycemic index and high phosphorous (280 mg) and magnesium content. Among minor millets, barnyard millet has the highest dietary fiber (9.5-14.0g) and niacin content**[35]**. The carbohydrate content of barnyard millet (55.0 – 65.0 g) is low and slowly digestible, which

makes the barnyard millet a nature's gift for the modern mankind who is engaged in sedentary activities**[36]**. Barnyard millet is most effective in reducing blood glucose and lipid levels.

3. Little Millet

Little millet is known for its magnesium (120-133mg), phosphorous (251-260mg), and protein content (10.0-15.0g).The unique feature of little millet is that it is rich in Poly Unsaturated Fatty Acids (PUFA) and flavonoids **[37]**. It is a rich source of sulphur-containing amino acids (cysteine and methionine) and lysine, which is lacking in most cereals **[38].** It is generally considered to induce a lower glycemic response due to the presence of abundant dietary fiber, resistant starch, and slowly digestible starch **[39].** It is wonderful millet which is suitable for people of all age groups. It helps to prevent constipation and heals all the problems related to stomach. It improves the semen counts of men and also helps for women with irregular periods problems. Its high fiber helps to reduce the fat depositions in the body. Little millet is rich in cholesterol, when consumed increases good cholesterol in the body, suitable for growing kids and strengthens the body. Its complex carbohydrate digests slowly which is very helpful for diabetic patients **[40]**. It contains high phosphorous (251-260mg) and iron (13-20mg). It is especially good for people who have low body mass **[41]**.

4. Proso Millet

Proso millet has a high protein profile (10.0-13.0 g) following foxtail millet and alsohas a higher nutritional value when compared with staple cereals as it contains a higher concentration of minerals and dietary fibreer. Proso millet is a rich source of vitamins and minerals such as iron (4.0-5.2mg), calcium (20-23mg), potassium(250-320mg), phosphorus (230-281mg), zinc (1.4-2.4mg), magnesium (117-153mg),vitamin B-complex, niacin (4.5mg), and folic acid. Proso millet contains essential amino acids like lysine, leucine, isoleucine, and methionine in significantly higher quantities, unlike other crops.**[42].** However, proso millet has an almost 51% higher essential amino acid index than wheat **[43].** In grains, the quality of protein decreases after drying but the amount of protein increases **[44]**.Traditionally, it is used as recuperative food, especially post-pregnancy or illness **[35].**

5. Kodo Millet

Kodo millet is a highly drought-resistantee crop. It is the coarsest of all food grains. Kodo millet is a nutritious grain and a good alternative to rice and wheat. The grain is covered with a tough seed coat that must be removed before cooking.Kodo millet is nutritious grain and a good

~~substitute to rice and wheat. The grain is covered with a hardy seed coat which should be removed before cooking.~~

Kodo millet has the highest phosphorous content (215-310mg) and radical scavenging activity owing to its high phenol content. Consuming kodo millet reduces the risk of cardiovascular dysfunction **[45]**. The protein, fiber and mineral content are much higher than the major cereals like rice. The major protein fraction in kodo millet is gluten **[46]**. Kodo millet is traditional food which helps to use in weight loss. It is easily digestible and is rich in phytochemicals and antioxidants which help in preventing different lifestyle related diseases. Kodomillet helps in reducing the joints and knee pain and helps in regularizing the menstruation in woman **[36]**.

Apart from being a rich source of nutrients, Kodo millet contains high amounts of polyphenols, tannins, phosphorus and phytic acids. The antioxidant activity of kodo millet decreases when the whole grain is dehulled and cooked **[47]**. Kodo millets contains high amounts of vitamins and minerals, especially B-complex vitamins, B6, niacin and folic acid, Fe, Ca, Mg, K, and Zn. Kodo millet is very easy to digest and thus can be beneficial for infant and geriatric product formulation.

6. Foxtail millet

Foxtail is also known as Italian millet and German millet. Foxtail millet is good source of beta–carotene, which is the precursor of Vitamin A. Foxtail millet helps in steady release of glucose without affecting the metabolism of the body. When people consume foxtail millet, the prevalence of diabetes is reduced and it is also known as healthy heart food due to its good source of magnesium (100-130mg)**[48]**. Foxtail millet is well renowned for its grain and fodder.

Foxtail millet has a greater nutritional value compared to major cereals such as wheat and rice due to its copious dietary fiber content, resistant starch, vitamins, minerals, and essential amino acids, except for lysine and methionine, but it is richer than most cereals. Among the minor millets, foxtail millet contains the highest protein (11.2-15.0g). It also contains a higher amount of stearic and linoleic acids, which helps in maintaining a good lipid profile.

Phytochemicals in minor millets

Phyto-chemicals are the compounds that occur naturally in plants.Much of the health beneficial effects of minor millets have been attributed to the presence of abundant phytochemicals, including phenolic compounds, phytosterols etc. Phenolic compounds, *viz*. phenolic acids, flavonoids etc., which are present in millets impart bioactivities including anti-oxidant, anti-microbial, anti-diabetic, and anti-hypertensive properties. The3-deoxy anthocyanin, which is

found in milletsis known to exhibit several bioactivities including the ability to protect from certain types of cancers; they act as antioxidants and also play many roles in the body immune system.Lignans are a type of phytonutrient found in millet that is beneficial to the human body,which protest against hormone-dependent malignancies like breast cancer and reduce the risk of heart disease.

Anti-nutrients: Challenges and solutions

Millets are nutritionally comparable and even superior to major cereals in terms of energy value, proteins, fat and minerals**.** However, due to the presence of anti-nutrients like phytate, polyphenols, oxalates and tannins, mineral bioavailability is affected. These anti-nutrients form complexes with dietary minerals, such as calcium, zinc and iron leading to a marked reduction in its bio-availability and make them biologically unavailable to human beings **[49].** However, the negative impact of these anti nutrients can be taken care by using common household food processing techniques like decortications, milling, soaking, malting, germination, fermentation, popping and cooking etc. These methods reduce the content of phytates, phenol, tannins and trypsin inhibitor activity, improve the digestibility of millets apart from enhancing bio-availability of minerals.

Shelf life of minor millets

The shelf-life of minor millet grain is normally above 6–8 months for fair and average quality grain, with 10–12% moisture. The shelf-life deterioration of processed products especially flour is a big challenge. Because minor millets are small grains, the separation of the oil rich germ from the endosperm might pose issues when millet flour is stored. Microorganisms also play an important role in determining the shelf life of the product.

Processing of minor millets

The harvesting process followed for minor millets is mostly carried in a traditional manner wherein a lot of refractions such as immature grains, chaffs, mud particles, stones, admixed grains as well as obnoxious material, dust, etc. will be mixed. For this, de-stoners, graders and aspirator systems suitable for millets are available and millet processors are using them effectively. Minor millets have good grain qualities suitable for processing.Being a staple and consumed at household levels, processing must be considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs**.**

Primary processing

The primary processing (wetting, dehulling, and milling) of minor millets is a vital step into converting the grain into edible form and thereby enhancing their quality and consumer acceptability. Among the minor millets, finger millet is naked grains as almost all the glumes get detached from the grains during harvesting.

On the other hand, the processing of little, proso, kodo, barnyard, browntop and foxtail millets are iscomplicated as they have an inedible husk that needs to be removed, followed by the de-branning to a desirable extent through primary processing. It was noticed that barnyard, little, brown top, and kodo millets need multiple passages, whereas foxtail and proso could be dehusked in a single stage.

2. Secondary processing

Secondary processing (fermentation, malting, extrusion, flaking, popping and roasting) and product development involves the conversion of the primary processed raw material into different Ready to-Eat (RTE) and Ready-to-Cook (RTC) minor millet products. Although the dehulled and de-branned minor millets are largely used for cooking and consumption similar to milled rice, they are pulverized into flour and suji and for use as roti and other foods similar to rice/wheat flour and semolina **[50]**.

During processing, some nutrient losses will also occur. To overcome this problem, fortified products (cookies, vermicelli, pasta, khichaidi mix and bread) are also developed by adding natural nutrient-rich ingredients like garden cress (rich in iron), gingelly seed (rich in zinc), spinach (rich in iron), etc., to enhance the iron and zinc content and thus enhance the iron and zinc proportions in them. Various processing methods such as germinationor malting, thermal processing, soaking and fermentation minimize the nutritional loss and increase the physiological and chemical accessibility of micronutrients in the body and also decrease the antinutrients like phytates**.**

Conclusion

Over the last few years, there is anhas been increasing recognition of their nutrient composition and benefits as healthy food. In addition, minor millets output has increased recently due to the availability of high-yielding varieties, pest and disease-resistant varieties, and improved cultivation techniques, rising by 1.05 percent annually. Therefore, dietary modification by increasing the consumption of a wide variety of fruits, vegetables and minor millet grains daily is a practical strategy for consumers to optimize their health and reduce the risk of chronic diseases.

Because of their health benefits, these grains do need a great promotion to reach the heights of the major cereals in terms of their production and utilization.

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