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MINI REVIEW

Finger Millet [*Eleusine coracana* (L.) Gaertn.]: A Minor Crop for Sustainable Food and Nutritional Security

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Finger millet (*Eleusine coracana* L. Gaertn) is an orphan food grain crop grown in Africa and Asia for subsistence farming. The crop has wide adaptability, resilience to fragile ecosystems and has better tolerance to abiotic stresses in comparison to major cereals. The crop grains have excellent nutritional properties and medicinal importance. Grains are rich source of calcium, dietary fibre and essential amino acids particularly tryptophan and methionine. Polyphenols and tannins in the seed coat of grains although reduce the bioavailability of mineral nutrients but, has added advantage of providing antioxidant activity. Research in recent years has revealed its nutritional value and climate resilience, which has not only brought back the importance of this crop but it is now being designated as miracle grains, wonder grains and future crop.

Keywords: Small millet, Health benefits, Nutritional value, Antinutritional compounds.

INTRODUCTION

Finger millet (*Eleusine coracana* L. Gaertn) is highly self-fertilized allotetraploid (2n = 4x = 36) annual plant widely grown as small grain cereal in arid and semi-arid areas of Central Africa and India [1-3]. Its English common name comes from the growth form of its panicles which take the form of several fingers. Today, the crop is ranked fourth globally in importance among the millets, after sorghum, pearl millet and foxtail millet [4]. It is a member of poaceae family and chloridiodeae sub-family. Finger millet is the only millet belonging to the tribe chlorideae, all other belong to the tribe piniceae. It is believed to be one of the few special species that supports the world's food supplies [5]. It is a hardy crop that can be grown in very diverse environments and has an excellent food value. The crop is even grown in higher elevations up to 2400 m above mean sea level in the Himalayas [6-8]. It is important minor millet in the tropics, grown in more than 25 countries in Africa (eastern and southern) and Asia (from near east to far east) [9].

The crop serves as a subsistence and food security crop that is especially important for its nutritive and cultural value [10,11]. The grain of finger millet has a fine aroma when cooked or roasted and is known to have many health-promoting qualities.

Eleusine coracana grain nutritional analyses

Grain physical characteristics: Finger millet grains are generally globular to oval in shape, about 1-1.5 mm in diameter with an average thousand kernel weight of 2.64 g [12]. The grain colour can range from white to brown with intermediate shades in between. Finger millet is unique in its grain characteristics as it is a utricle instead of a true caryopsis like major cereals. The utricle characteristic means that the pericarp is not completely fused with the testa [12,13]. This allows the pericarp to be removed by simply rubbing the dry grain or rubbing it after soaking in water. Finger millet has five layered-testa, which can be red to purple. Multilayer testa has been attributed as one of the reasons for high dietary fibre content in its grains [14]. The colour is due to flavonoids and tannins [15]. The endosperm comprises most of the weight of the finger millet kernel and it has relatively small germ (270 × 980 μm) the endosperm contains protein bodies of about 2 μm in diameter and starch granules with a diameter varying 8-21 μm [12]. The starch granules in finger millet are compound, with the individual granules being spherical, polygonal as well as rhombic shaped [16].

White coloured grains are mostly preferred for porridge and the brown coloured varieties are used for traditional opaque beer brewing in Southern Africa [17]. In India and Nepal, brown coloured varieties only are predominantly grown and consumed either in the form of unleavened bread, ragi bolls (*mudde*), porridge, malt, popped grains and fermented beverage. In Uttarakhand hills of India, before crushing the finger millet grains to flour, mixed with dried bark pieces of gethi tree [18], to provide gluten characteristics in finger millet flour and enhance the roti making quality of finger millet flour. This tree is commonly found in Uttarakhand mid hills and its bark has medicinal value as well as rich in micronutrients along with high viscosity. We have tested the bark in different gluten lacking millets and pseudo-cereal crops and results were similar as observed with finger millet. This indigenous knowledge is prevalent in Uttarakhand hills from time immorial and still in

TABLE-1
NUTRITIONAL COMPOSITION OF FINGER MILLET IN COMPARISON TO MAJOR CEREALS (@ 12 % Moisture; per 100 g EDIBLE PORTION)

	Finger millet[a,b,c]	Barnyard millet (dehulled)[b,c]	Foxtail millet (dehulled)[a,b,c]	Proso millet (dehulled)[a,b,c]	Little millet (dehulled)[b,c]	Kodo millet (dehulled)[b,c]	Sorghum[b,c,d]
Proximate composition							
Protein	7.7	11	11.2	12.5	9.7	9.8	10.4
Fat	1.5	3.9	4	3.5	5.2	3.6	3.1
Crude fibre	3.6	13.6	6.7	5.2	7.6	5.2	2
Carbohydrate (g)	72.6	55	63.2	63.8	60.9	66.6	70.7
Energy (Kcal)	336	300	351	354	329	353	329
Total dietary fiber (%)	19.1	22	19.11	8.5	–	37.8	11.8
Minerals and trace elements							
Ca (mg/100 g)	350	22	10	10	17	10	40
P (mg/100 g)	283	267	310	150	220	320	350
K (mg/100 g)	408	–	270	210	–	170	380
Na (mg/100 g)	11	–	10	10	–	10	50
Mg (mg/100 g)	137	39	130	120	139	130	190
Fe (mg/100 g)	3.9	5	3.3	3.3	9.3	7	5
Mn (mg/100 g)	5.94	0.96	2.2	1.8	0.7	1.1	1.6
Mb (mg/100 g)	0.102	–	0.7	–	–	–	0.039
Zn (mg/100 g)	2.3	3	2.2	1.8	3.7	0.7	1.5
Vitamins							
Thiamine (mg)	0.42	0.33	0.48	0.63	0.3	0.32	0.46
Riboflavin (mg)	0.19	0.1	0.12	0.22	0.09	0.05	0.15
Niacin (mg)	1.1	–	3.2	2.3	–	–	3.7
Total folic acid (µg)	18.3	–	15	–	–	–	20
Vitamin E (mg)	22		–	–	–	–	0.5
Phenolic compounds							
Total phenol (mg/100 g)	102	–	106	–	–	368	43.1
	Pearl millet[a,b,c]	Maize[b,c]	Rice brown[b,c,d]	Wheat[a,b,c]	Barley[b,c]	Oat[b,c,d]	Rye[c]
Proximate composition							
Protein	11.6	9.2	7.9	11.6	11.5	17.1	13.4
Fat	5.0	4.6	2.7	2	2.2	6.4	1.8
Crude fibre	2.3	2.8	1	2	5.6	11.3	2.1
Carbohydrate (g)	67.5	73	76	71	58.5	52.8	68.3
Energy (Kcal)	361	358	362	348	352	389–	–
Total dietary fiber (%)	11.3	12.8	3.7	12.1	15.4	12.5	16.1
Minerals and trace elements							
Ca (mg/100 g)	10	30	20	40	40	110	50
P (mg/100 g)	350	290	120	350	560	380	360
K (mg/100 g)	440	370	100	360	500	470	470
Na (mg/100 g)	10	30	3	40	20	20	10
Mg (mg/100 g)	130	140	30	144	140	130	110
Fe (mg/100 g)	7.5	3	1.9	4	3.7	6.2	3.8
Mn (mg/100 g)	1.8	0.5	1.2	4	1.9	4.5	5.8
Mb (mg/100 g)	0.069	–	–	0.051	–	–	–
Zn (mg/100 g)	2.9	2	1	3.1	2.4	3.7	3.2
Vitamins							
Thiamine (mg)	0.38	0.38	0.07	0.57	0.44	0.77	0.69
Riboflavin (mg)	0.22	0.14	0.03	0.12	0.15	0.14	0.26
Niacin (mg)	2.3		4.3	5.5	4.6	0.96	–
Total folic acid (µg)	45.5	–	20	36.6	23	56	–
Vitamin E (mg)	–	1.9	0.90-2.50	–	0.02	–	–
Phenolic compounds							
Total phenol (mg/100 g)	51.4	2.91	2.51	20.5	16.4	1.2	13.2

[a]Gopalan *et al.* [20]; [b]FAO [50]; [c]Saldivar [51]; [d]USDA National Nutrient Database for Standard Reference, Release 28 [52]

use but with the reduction in usage of finger millet as food crop the young generation is unaware of this information.

Nutritional composition: Nutritional potential of finger millet in terms of protein, carbohydrate and energy values are comparable to the major cereals like rice, wheat, barley or bajra (Table-1). Finger millet contains about 5-8 % protein, 1-2 % ether extractives, 65-75 % carbohydrates, 15-20 % dietary fibre and 2.5-3.5 % minerals [14,19-21]. High protein content in the range of 10-14 % has also been reported in some genotypes [22]. However, most studies have reported low protein content in finger millet, but high essential amino acid methionine [6] (Table-2). Carbohydrates (starch) is the major component of finger millet grain with amylase making up the about 30 % of the starch [23]. Finger millet grains and malt are a good source of dietary fibre [24]. The dietary fibre content of finger millet (11.5 %) is much higher than the fibre content of brown rice, polished rice and all other millets such as foxtail, little, kodo and barnyard millet. However, the dietary fibre content of finger millet is comparable to that of pearl millet and wheat [14]. The fat content is low leading to good storability of the grains. In terms of fatty acid composition almost half is oleic acid present in finger millet grains.

TABLE-2
AMINO ACIDS AND PHENOLIC COMPOUNDS IN FINGER MILLET

Amino acids[a]	g/100 g protein	Phenolic compounds[a]	µg/mg as is
Essential amino acids		Phenolic acids	
Phe	6.2	Protocatechuic acid	23.1
His	2.6	Gentisic	61.5
Ile	5.1	*p*-Hydroxy benzoic acid	8.9
Leu	13.5	Vanillic	15.2
Lys	3.7	Caffeic	16.6
Met	2.6	Syringic	7.7
Thr	5.1	Coumaric	56.9
Val	7.9	Ferulic	387.0
Non essential amino acids		Cinnamic	35.1
Asp	7.9	Phenolic assay	mg/100 g catechin equivalent, dry weight basis
Glu	27.1		
Ala	8.0		
Arg	5.2		
Cys*	1.6		
Gly	4.8	Folin/Ciocalteu	0.55-0.59
Pro	6.7	Vanillin-HLC	0.17-0.32
Ser	6.9		
Tyr	3.6		
Trp*	1.3		

[a]McDonough *et al.* [12]

Among minerals, finger millet grains are exceptionally rich in calcium (350 mg/100 g) compared to all cereals and other millets and its grains also contain good amount of phosphorus, iron, potassium and many other trace elements and vitamins [20] (Table-1). High calcium content of 660 mg/100 g has been reported in finger millet [14,25]. Barbeau and Hilu [26] analyzed eight domesticated cultivars of finger millet to determine their proximate composition, calcium, iron and amino acid content and reported the content of calcium 376 to 515 mg/100 g and iron 3.72 to 6.8 mg/100 g. Wide variability for calcium content ranging from 184-489 mg/100 g in finger millet grains of 622 global core germplasm accessions was reported by Upadhyaya *et al.* [22].

Kadkol and Swaminathan [27] observed a range of 5.9 to 6.9 mg/100 g for iron content in six brown and two white grain finger millet varieties. A higher range of 12 mg/100 g (white seeded genotypes) to 17 mg/100 g (brown seeded genotypes) was observed by Kamalanathan *et al.* [28]. Similar values for iron content (13 mg/100 g by Indira and Naik [29]; 3-20 mg/100 g by Balakrishna Rao *et al.* [30]; 4.2-8.47 mg/100 g by Ramachandra *et al.* [15]; 2.70-5.57 mg/100 g by Maloo *et al.* [31]; 4-8 mg/100 g by Premavalli *et al.* [32]; 2.17-6.52 mg/100 g by Upadhyaya *et al.* [22]) were later reported. Genotypic variation for Zn content has also been reported in finger millet. Madibela and Modiakgolta [33] reported a mean of 20.5 ppm in forage finger millet. Yamunarani and Shankar [34] reported a wide range of Zn content varying from 1 mg/100 g to as high as 27 mg/100 g, in 333 genotypes of finger millet. Later, the Zn content range of 1.5-6.5 mg/100 g was observed in 35 finger millet genotypes [35], which further narrowed down to 1.7-2.5 mg/100 g in 622 global core germplasm accessions of ICRISAT [22].

Both environment and genetics affect the nutritional composition of finger millet grain [13]. There is an ample scope for the selection of nutrient-rich accessions due to substantial variability for micro-nutrients for use in the breeding programmes. Hybridization of nutrient rich accessions with agronomically superior accessions/adapted varieties will help in the development of nutritionally rich varieties to combat mal-nutrition in developing countries [22].

Finger millet grains are known to have high nutritional value, however, phytates (0.48 %), polyphenols (Table-2) and tannins (0.61 %) present in finger millet seed coat inhibits the bio-availability of the micro-nutrients. There are many studies, which report that simple processing methods like soaking, germination [36], steaming, fermentation [36], malting [37,38], decortication [39] and popping can improve the bio-availability of various abundant micro-nutrients of finger millet grains.

Further, polyphenols, phytates and tannins which were once considered as "anti-nutrients" due to their metal chelating and enzyme inhibition activities [40] are nowadays termed as neutraceuticals. It is now established that phytates, polyphenols and tannins can contribute to antioxidant activity of the millet foods, which is an important factor in health, aging and metabolic diseases [41-44].

Processing and value addition: Finger millet is generally used for the preparation of flour, pudding, porridge and roti [45]. With the changes in scenario of utilization pattern of processed products and awareness of the consumers about the health benefits, finger millet has gained importance because of its functional components, such as slowly digestible starch and resistant starch [46]. Food uses of finger millet has, however, been confined only to traditional consumers; limited especially to areas of their cultivation. A number of value added products of finger millet have been developed and demonstrated including multi-grain flour, papad, puffed or popped grains, puffed finger millet mix, weaning food (Malted), noodles, extruded products, bakery products, fermented foods and various local cuisines [47,48]. Large scale production and wide availability of these value added and convenience products of finger millet would certainly diversify its food uses. Their exploitation for preparation of ready-to-use or ready-to-cook products would help in increasing the consumption of millets among non-millet consumers and thereby nutritional security [49].

Conclusion

Finger millet is considered as wonderful millet because of its good storage quality, high nutritive value and therapeutic value. In spite of these advantages not much research work has been accomplished to harness the nutritional value of finger millet. However, recently with the increasing awareness of good nutrition, healthy living, value addition, consumption of finger millet has got a boost. Systematic characterization of the finger millet germplasm for various nutritional parameters, basic and strategic research to identify nutrition rich genotypes particularly high calcium content, limiting amino acids, post harvest processing and value addition may be future key areas of research.

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