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Review of Finger millet (*Eleusine coracana* (L.) Gaertn): A power house of health benefiting nutrients

Dinesh Chandra*, Satish Chandra, Pallavi, A.K. Sharma

Department of Biological Sciences, Govind Ballabh Pant University of Agriculture and Technology Pantnagar, 263145, Uttarakhand, India

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Abstract

The bulk of the world's millet crop is produced by India, Nigeria, Niger, Mali, Burkina Faso, Chad, and China. Finger millet (*Eleusine coracana* (L.) Gaertn), little millet (*Panicum sumatrense* Roth ex Roem. & Schult.), foxtail millet (*Setaria italica* (L.) P. Beauvois) and proso millet (*Panicum miliaceum* L.) are most commonly found species among various millet varieties. In India, finger millet occupy the largest area under cultivation among the small millets. Finger millet stands unique among the cereals such as barley, rye and oats with higher nutritional contents and has outstanding properties as a subsistence food crop. It is rich in calcium (0.34%), dietary fiber (18%), phytates (0.48%), protein (6%–13%) minerals (2.5%–3.5%), and phenolics (0.3%–3%). Moreover, it is also a rich source of thiamine, riboflavin, iron, methionine, isoleucine, leucine, phenylalanine and other essential amino acids. The abundance of these phytochemicals enhances the nutraceutical potential of finger millet, making it a powerhouse of health benefiting nutrients. It has distinguished health beneficial properties, such as anti-diabetic (type 2 diabetes mellitus), anti-diarrheal, antiulcer, anti-inflammatory, antitumerogenic (K562 chronic myeloid leukemia), atherosclerogenic effects, antimicrobial and antioxidant properties.

Keywords: Finger millet; Dietary fiber; Antioxidant; Diabetes; Health benefit

1. Introduction

A millet crop includes grasses like finger millet, (*Eleusine coracana* (L.) Gaertn), pearl millet (*Pennisetum glaucm* (L.) R.Br), foxtail millet (*Setaria italica* (L.) P. Beauvois), kodo millet (*Paspalum scorbiculatum* L.), bahiagrass (*Paspalum notatum* Flugge), little millet (*Panicum sumatrense* Roth ex Roem. & Schult.), proso millet (*Panicum miliaceum* L.), barnyard millet (*Echinochola crusgalli* (L.) P. Beauv), guinea grass (*Panicum maximum* Jacq), elephant grass (*Pennisetum purpurium* Schumach.) that belong to the family Poaceae of the monocotyledon group. India is considered as pivot for these minor crops. The world total production of millet grains in year 2013 was 762,712 metric tons and the top producer was India with an annual output of 334,500 tons contributing 43.85% [1]. Finger millet commonly known as ragi and mandua in India is one of the minor cereals a native of Ethiopia, but grown extensively in various regions of India and Africa, constitutes as a staple food that supply a major portion of calories and protein to large segments of the population in these countries especially for people of low income groups [2]. In India, Karnataka is the leading producer of finger millet accounting to 58% of its global production, yet only a few Indians are aware about its health benefits and nutritional value. The production area of finger millet in India stands sixth after wheat, rice, maize, sorghum and bajra.

In world, finger millet ranks fourth in importance among millets after sorghum, pearl millet and foxtail millet [3]. It is widely cultivated in Africa and South Asia under varied agro-climatic conditions and it is estimated that some 10% of the world's 30 million tons of millet produced is finger millet [4]. The crop

* Corresponding author at: Govind Ballabh Pant University of Agriculture and Technology Pantnagar, 263145, Uttarakhand, India.

E-mail addresses: dchandra.009@gmail.com (D. Chandra), satishchandrasemwal07@gmail.com (S. Chandra), meghsabhi@gmail.com (Pallavi), anilksharma_99@yahoo.com (A.K. Sharma).

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was domesticated around 5000 years BC. It is an allopolyploid with chromosome number $2n = 4x = 36$ and evolved from a cross between two diploid species, *Eleusine indica* (AA) and *Eleusine floccifolia* or *E. tristachya* (BB) as genome donors [5–9].

Millets are important but underutilized crops in tropical and semiarid regions of the world due to their greater resistance to pests and diseases, good adaption to a wide range of environment and their good yield of production, can withstand significant levels of salinity, short growing season, resistant to water logging, drought tolerant, requires little inputs during growth and with increasing world population and decreasing water supplies represents important crops for future human use. The drought tolerance of finger millet may be attributed to an efficient antioxidant potential and increased signal perception. Being as hardy crop it is relatively easy to grow finger millet under stressful regimes, without hampering the net productivity. There is vast potential to process millet grains into value-added foods and beverages in developing countries. Furthermore, millets, as they do not contain gluten and therefore it is advisable for stomach (abdominal) patients [10]. In current review attempt has been made to collect the available information from existing literature either online or offline related to the nutraceutical importance and health benefiting properties of finger millet and trying to present the collected data in a easily-documented pattern.

2. Nutritional significance of finger millet

The main constituents of the millet kernel are seed coat (testa), embryo and endosperm. Among several varieties of finger millets such as yellow, white, tan, red, brown, or violet color, only the red-colored are cultivated extensively throughout world. The presence of five layered testa in finger millet makes it unique compared to other millets such as foxtail millet, pearl millet, kodo millet and proso millet. This could be one of the possible reasons for the higher dietary fiber content in finger millet [11]. A comparative nutritional (Table 1), mineral and vitamin (Table 2), and amino acid (Table 3) profile of finger millet with other minor millets, cereals and pseudo-cereals are summarized in said table.

The nutraceutical importance of finger millet lies in its high content of calcium (0.38%), protein (6%–13%), dietary fiber (18%), carbohydrates (65%–75%), minerals (2.5%–3.5%), phytates (0.48%), tannins (0.61%), phenolic compounds (0.3–3%) and trypsin inhibitory factors, and is recognized for its health beneficial effects, such as anti-diabetic, antitumerogenic, anti-diarrheal, antiulcer, anti-inflammatory, atherosclerogenic effects, antioxidant and antimicrobial properties [15,23,24]. Earlier it was believed that polyphenols, phytates, tannins and dietary fiber contents of finger millet act as anti-nutrients because of their metal chelating and enzyme inhibition activities but now it has been confirmed that these constituents can contribute to antioxidant activity, which is an important factor in resisting aging and metabolic diseases [25,26]. Morevoer, finger millet is also useful in management of various physiological disorders such as diabetes mellitus, hypertension, vascular fragility, hypercholesterolemia, prevention of oxidation of low-density lipoproteins (LDLs) and also improves gastrointestinal health [27].

Finger millet is milled with the testa which is generally rich in dietary fiber and micronutrients to prepare flour and the whole meal is utilized in the preparation of traditional foods, such as roti (unleavened breads), ambali (thin porridge) and mudde (dumpling) [15]. On daily consumption of whole grain of finger millet and its products can protect against the risk of cardiovascular diseases, type II diabetes, and gastrointestinal cancers and other health issues [28]. The dietary fiber, minerals, phenolics and vitamins concentrated in the outer layer of the

Table 1
Nutrient composition of finger millet with other minor millets, pseudo-cereals and cereals grain.

		Protein (%)	Fat (%)	Starch (%)	Ash (%)	Crude fiber (%)	Total dietary fiber/100 g	Total phenol (mg/100 g)	Carbohydrates (g)
Minor millets	Finger millet	7.3	1.3	59.0	3	3.6	19.1	102	72.6
	Pearl millet	14.5	5.1	60.5	2	2	7	51.4	67.5
	Proso millet	11	3.5	56.1	3.6	9	8.5	0.10	70.4
	Foxtail millet	11.7	3.9	59.1	3	7	19.11	106	60.9
	Kodo millet	8.3	1.4	72.0	3.6	9	37.8	368	65.9
	Little millet	7.7	4.7	60.9	6.9	7.6	–	21.2	67
	Barnyard millet	6.2	4.8	60.3	4	13.6	13	26.7	65.5
Pseudo-cereals	Amarath	15.2	8	67.3	3.2	4.1	20.6	2.71	59.2
	Quinoa	13.3	7.5	69	2.6	3.8	14.2	2.8	69
	Buckwheat	10.9	2.7	67.2	1.59	10.1	29.5	7.25	66
Cereals	Wheat	14.4	2.3	64	1.8	2.9	12.1	20.5	71.2
	Rice	7.5	2.4	77.2	4.7	10.2	3.7	2.51	78.2
	Maize	12.1	4.6	62.3	1.8	2.3	12.8	2.91	66.2
	Sorghum	11	3.2	73.8	1.8	2.7	11.8	43.1	72.6
	Barley	11.5	2.2	58.5	2.9	5.6	15.4	16.4	80.7
	Oats	17.1	6.4	52.8	3.2	11.3	12.5	1.2	69.8
	Rye	13.4	1.8	68.3	2	2.1	16.1	13.2	80.1

Sources [12–20].

Table 2
Mineral and vitamin composition of finger millet with other minor millets, pseudo-cereals and cereal grains (mg/100 g).

		Ca	P	Fe	Mg	Na	K	Cu	Mn	Zn	Thaimine	Riboflavin	Niacin
Minor millets	Finger millet	344	283	3.9	137	11	408	0.47	5.49	2.3	0.42	0.19	1.1
	Pearl millet	42	240	11	137	10	390	1.06	1.15	3.1	0.38	0.21	2.8
	Proso millet	8	206	2.9	114	5	195	0.8	1.6	1.7	0.41	0.28	4.5
	Foxtail millet	31	290	2.8	143	1.3	364	0.59	1.16	3.51	0.59	0.11	3.2
	Kodo millet	35	188	1.7	110	4.8	141	1.60	1.10	0.7	0.15	0.09	2
	Little millet	17	220	9.3	61	7.9	126	0.05	0.68	3.7	0.30	0.09	3.2
	Barnyard millet	22	280	18.6	82	-	-	0.60	0.96	3	0.33	0.1	4.2
Pseudo-cereals	Amarath	180	557	9.2	279.2	22	532	0.86	2.9	1.6	0.116	0.2	0.923
	Quinoa	32.9	152	5.5	206.8	7	172	1.09	0.631	1.8	0.107	0.11	0.412
	Buckwheat	60.9	347	4.7	203.4	1	460	1.1	1.3	1.0	0.101	0.425	1.02
Cereals	Wheat	41	306	3.9	120	3	363	0.9	13.3	1	0.41	5.46	5.5
	Rice	10	160	0.5	32	6	130	0.25	1.1	1.2	0.41	0.0149	1.62
	Maize	10	89	2.3	0.163	37	270	0.22	0.163	0.46	0.155	0.055	1.77
	Sorghum	13	289	3.4	165	2	363	1.7	1.6	1.7	0.33	0.1	3.7
	Barley	29	221	2.5	79	9	280	2.13	1.32	2.13	0.191	0.114	4.6
	Oats	54	523	5	177	2	429	4	4.9	4	0.763	0.139	0.961
	Rye	33	374	2.67	110	6	264	0.45	2.6	3.73	0.3	0.3	4.3

Sources (USDA database [12–14,21,22]).

seed coat form the part of the food and offer their nutritional and health benefits [29]. Some of the health related functional attributes of finger millet are summarized in Table 4.

2.1. Polyphenols and dietary fiber

The growing public awareness toward nutritional and health benefits of finger millet are attributed to its polyphenols and dietary fiber content. Among cereals such as rice, wheat, barley and maize, finger millet grain has higher contents of polyphenols. These phenolics compound are not stored in the grain but their location is mainly in the outer aleurone layer, testa and pericarp of fruit which form the main components of the bran fraction and exist as free, soluble conjugates and insoluble bound forms [32,35]. Finger millet grain genotypes have varied total tannin and phenolic contents. The major bound phenolics present in finger millets are ferulic acid (64%–96%) and p-coumaric acid (50%–99%). Varieties of finger millets also contain proanthocyanidins (condensed tannin), a high-molecular weight polyphenols that consist of polymerized flavan-3-ol and/or flavan-3, 4-diol units [50]. Three classes of phenolic found in finger millet-hydroxybenzoic acid derivatives, hydroxycinnamic acid derivatives and flavonoids. These derivative compounds identified as p-hydroxybenzoic acid, proanthocyanidins, ferulic acid, gallic acid, protocatechuic acid, vanillic acid, syringic acid, trans cinnamic acid–coumaric acid,

Table 3
Essential amino acid profile of finger millet with minor millets, pseudocereals and cereals grains (g/100 g).

		Arginine	Histidine	Lysine	Tryptophan	Phenylalanine	Tyrosine	Methionine	Cystine	Threonine	Leucine	Isoleucine	Valine
Minor millets	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	–	–	–	–	–	–	–	–	–	–	–	–
Pseudo-cereals	Amarath	1.470	0.380	0.830	0.181	0.610	0.540	0.340	0.190	0.430	0.860	0.550	0.600
	Quinoa	1.200	0.360	0.700	0.052	0.500	0.410	0.310	0.150	0.370	0.840	0.480	0.570
	Buckwheat	0.982	0.309	0.672	0.192	0.520	0.241	0.172	0.229	0.506	0.832	0.498	0.678
Cereals	Wheat	0.480	0.130	0.230	0.080	0.280	0.290	0.150	0.090	0.230	0.500	0.300	0.380
	Rice	0.290	0.130	0.170	0.070	0.280	0.180	0.090	0.140	0.180	0.410	0.220	0.280
	Maize	0.131	0.089	0.137	0.023	0.150	0.123	0.067	0.026	0.129	0.348	0.129	0.185
	Sorghum	0.355	0.246	0.229	0.124	0.546	0.321	0.169	0.127	0.346	1.491	0.433	0.561
	Barley	0.496	0.223	0.369	0.165	0.556	0.284	0.190	0.219	0.337	0.673	0.362	0.486
	Oats	1.192	0.405	0.701	0.234	0.895	0.573	0.312	0.408	0.575	1.284	0.694	0.937
	Rye	0.500	0.400	0.600	0.100	0.400	0.200	0.200	–	0.300	0.600	0.200	0.300

Source (USDA database [12,13]).

Table 4
Some of the health related functional attributes of finger millet.

Functional properties of finger millet	References
Antioxidant property- Higher antioxidant capacity of finger millet is attributed to the high total phenolic content as well as flavonoids such as catechin, gallocatechin, epicatechin, procyanidin dimmer, levels of enzymatic (catalase, superoxide dismutase, glutathione peroxidase, and glutathione reductase) and non-enzymatic antioxidants (glutathione, vitamin E and C).	[23,30–35]
Antiprotein (albumin) glycation property- Finger millet seed coat polyphenols are effective inhibitors of fructose induced albumin glycation.	[36,44]
Antimicrobial activity- Polyphenol extract from finger millet seed coat and whole flour active against *Bacillus cereus*, *Aspergillus niger* and Fermented finger millet extract- suppress growth of *Salmonella* sp., *Escherichia coli.*	[29,32]
Antiulcerative property- Finger millet incorporated diet prevents mucosal ulceration.	[37]
Aldose reductase (AR) enzyme inhibitory property- Finger millet seed coat polyphenols and quercitin inhibits AR activity which results in the prevention of AR induced cataractogenesis.	[38]
Blood glucose lowering effect, Nephroprotective properties, Cholesterol lowering,- Finger millet incorporated diets reduce serum cholesterol and phenolics from finger millet seed coat matter inhibit the intestinal α-glucosidase and pancreatic amylase thus helps in controlling postprandial hyperglycemia.	[39–42]
Inhibition of phospholipases (PL)- Gallic acid, quercitin and crude polyphenol extract from finger millet act as potent inhibitor of PLA2 from snake venom, it indicates the potential application of finger millet in treating inflammatory disorders.	[43]
Inhibition of pathogenic bacterial strains- Protocatechuic, caffeic, gallic, parahydroxy benzoic acid, polyphenols, and quercitin from finger millet inhibited the growth of several pathogenic bacteria.	[24,43]
Improvement on hemoglobin status in children- Excellent plant source of natural iron. Germinated finger millet based food showed a general improvement on hemoglobin status.	[45]
Natural probiotic treatment for diarrhea- Finger millet drink fermented by lactic acid bacteria used as a therapeutic agent against diarrhea.	[46]
Production of antihypercholestrolemic metabolites- Solid state fermentation of finger millet results in the production of metabolites like statin *viz.* pravastatin, lovastatin, monacolin J, pravastatin and mevastatin known as monacolins. These metabolites inhibit the enzymatic conversion of hydroxymethyl-glutarate to mevalonate by HMG- CoA reductase, which is the important step in the biosynthetic pathway of cholesterol.	[47,48]
Wound healing property- In diabetic patients, wound healing is impaired and studies have shown that finger millet extracts results in ameliorating this impairment by improving the nerve growth factor (NGF) production and improved antioxidant status.	[40,49]

caffeic acid, sinapic acid, quercetinin finger millets. Tannin content in outer layer of finger millets may act as a physical barrier to fungal invasion and thus provides resistance to grain against fungal attack [51].

2.2. Glycemic response (GR) of finger millet

High dietary fiber and phenolic content makes finger millet very beneficial for diabetic patients. Apart from this it also has low glycemic index (GI) that makes it an ideal snack to prevent late night food thirst and help to maintain blood sugar at a constant ratio. A study on small sample size ($n = 6$) where finger millet preparations such as chapathi (unleavened flat bread), sevai (rice string hoppers), idli (fermented, steamed rice cake), dosai (fermented rice pan cake), and kozhukattai (steamed rice balls) to type 2 diabetes mellitus (formerly called NIDDM-non-insulin dependent diabetes mellitus) showed a significant decrease in the postprandial blood glucose levels after finger millet administration for a month [52]. Thus, regular consumption of finger millet product can decrease fasting glucose by 32% and can eliminate insulin resistance by 43%. Finger millet malting and fermentation processes improve the carbohydrate digestibility and attributed the higher glycemic response (GR) of finger millet dosa and roti compared to the normal whole finger millet dosa and roti. The reason of higher GR is due to the conversion of starch to dextrins and maltose during germination. The polished finger millet in grain form as a formulation with legumes gave a higher GI of 93.4 as compared to wheat-based formulations with legumes 55.4 [53,54]. The glycemic index for foxtail millet incorporated biscuit was 50.8 compared to 68.0 for both barnyard millet (dehulled) incorporated biscuits and control refined flour wheat biscuits and on the other hand, GI for the dehulled and heat-treated barnyard millet, were 50.0 and 41.7 respectively [55,56].

2.3. Antitumerogenic effect of finger millet against K562 chronic myeloid leukemia (CML)

Chronic myeloid leukemia (CML) is a form of leukemia (virulent blood disease) characterized by increased and unregulated growth of myeloid cells in the bone marrow leading to their accumulation in the blood. The individual suffered from CML showing resistance toward available treatments has created a substantial need for developing new natural therapeutic options

[57]. Finger millet is a highly nutritive cereal and has long been used as a remedy for many infections including the leukemia. Recently seed purified extract of finger millet gained the importance of anti-proliferative activity on K562 chronic myeloid leukemia because finger millet seeds contain a bifunctional complex of α-amylase-trypsin inhibitor more commonly called RBI (ragi bifunctional inhibitor), that inhibits α-amylase and trypsin simultaneously. Basically, RBI is a monomeric protein made of 122 amino acid containing five intra-molecular disulfide bonds and the gene responsible for the encoding RBI has been cloned from finger millet seeds and expressed functionally in *Escherichia coli* [58–63]. Broadly speaking, the plant protease inhibitors (PIs) are multifunctional proteins required in diverse biological processes, such as redness, infection, extracellular matrix degradation, blood coagulation, apoptosis, tumor invasion and cancer metastasis and play very significant role in human health and disease management [64,65]. Consequently, plant protease inhibitors useful in inhibiting the different stages of carcinogenesis, including initiation, promotion and progression *in vitro* and *in vivo*.

Numerous study revealed that a trypsin–chymotrypsin inhibitor from buckwheat (*Fagopyrum esculentum*) also demonstrated anti-proliferative effect on T-acute lymphoblastic leukemia cells, Jurkat cells (immortalized line of human T lymphocyte) and solid tumor cells like hepatoma (HepG2), cervical carcinoma (HeLa) and esophageal squamouscell carcinoma (EC9706) cells [66,67]. The mechanism associated in the cytotoxic activity was found to be upregulation of Caspase-3, Caspase-9, disruption of mitochondrial membrane potential and increased DNA fragmentation. Thus, plant protease inhibitors are considered as nutraceuticals, providing both nutrition and pharmaceutics, specifically in the prevention and/or treatment of malignant neoplastic disease. It is also suggested that the ingestion of seeds containing protease inhibitors can lower the incidence of breast, colon, prostate, oral and pharyngeal cancers [68].

2.4. Other miscellaneous uses

From an Ayurvedic perspective finger millet promotes weight loss, healthy choice for vegans, mental relaxation, lowers triglycerides, reduced blood pressure, reverts skin aging, pregnancy, improves lactation, child growth and weaning, promotes hair growth, women friendly, geriatric tonic, gluten free food, lowers the risk of gall stones and fights diseases or prevent cancer.

3. Conclusion

The finger millet's dietary fiber and polyphenols have been recognized to offer several health benefits such as anti-diabetic, protection from diet related chronic diseases, hypocholesterolaemic, antioxidant, and antimicrobial effects to its regular consumers. Moreover, it is likewise rich in carbohydrate, energy and nutrition, making finger millet an important ingredient of dietary and nutritional balanced foods. The regular use of finger millet as a nutrient and its products helps in managing different disorders of body by maintaining blood glucose homeostasis. Also the whole meal-based finger millet products may be desirable due to the protective role of seed coat matter that have health enhancing benefits.

References

[1] FAO (2013). http://faostat.fao.org/site/339/default.aspx.
[2] M.M. O'Kennedy, A. Grootboom, P.R. Shewry, Harnessing sorghum and millet biotechnology for food and health, J. Cereal Sci. 44 (3) (2006) 224–235.
[3] H.D. Upadhyaya, C.L.L. Gowda, V.G. Reddy, Morphological diversity in finger millet germplasm introduced from Southern and Eastern Africa, J. SAT Agric. Res. 3 (1) (2007) 1–3.
[4] M.M. Dida, N. Wanyera, M.L.H. Dunn, J.L. Bennetzen, K.M. Devos, Population structure and diversity in finger millet (*Eleusine coracana*) germplasm, Trop. Plant Biol. 1 (2) (2008) 131–141.
[5] M.S. Chennaveeraiah, S.C. Hiremath, Genome relationship of *Eleusine tristachya* and *E. floccifolia*, J. Cytol. Genet. 8 (1973) 1–5.
[6] M.S. Chennaveeraiah, S.C. Hiremath, Genome analysis of *Eleusine coracana* (L.) Gaertn, Euphytica 23 (3) (1974) 489–495.
[7] K.W. Hilu, J.M.J. de Wet, Domestication of *Eleusine coracana*, Econ. Bot. 30 (3) (1976) 199–208.
[8] K.W. Hilu, J.M.J. de Wet, Racial evolution in *Eleusine coracana* ssp. *coracana* (finger millet), Am. J. Bot. (1976) 1311–1318.
[9] S.C. Hiremath, S.S. Salimath, The 'A'genome donor of *Eleusine coracana* (L.) Gaertn. (Gramineae), Theor. Appl. Genet. 84 (5–6) (1992) 747–754.
[10] A. Chandrasekara, F. Shahidi, Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity, J. Agric. Food Chem. 58 (11) (2010) 6706–6714.
[11] Food and Agricultural Organisation (FAO) of the United Nations, Sorghum and Millets in Human Nutrition (FAO Food and Nutrition Series, No. 27), 1995, ISBN 92-5-103381-1.
[12] C. Gopalan, B. Ramasastri, S.C. Balasubramanian, Nutritive Value of Indian Foods Hyderabad, India: National Institute of Nutrition, Indian Council for Medical Research, 1976.
[13] S. Shobana, K. Krishnaswamy, V. Sudha, N.G. Malleshi, R.M. Anjana, L. Palaniappan, V. Mohan, Finger millet (Ragi, *Eleusine coracana* L.): a review of its nutritional properties, processing, and plausible health benefits, Adv. Food Nutr. Res. 69 (2013) 1–39.
[14] L. Alvarez-Jubete, E.K. Arendt, E. Gallagher, Nutritive value and chemical composition of pseudocereals as gluten-free ingredients, Int. J. Food Sci. Nutr. 60 (2009) 240–257.
[15] P.B. Devi, R. Vijayabharathi, S. Sathyabama, N.G. Malleshi, V.B. Priyadarisini, Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: a review, J. Food Sci. Technol. 51 (6) (2014) 1021–1040.
[16] I. Leder, Sorghum and millets, in: Cultivated Plants, Primarily as Food Sources, 2004, pp. 66–84.
[17] C.M. McDonough, L.W. Rooney, S.O. Serna-Saldivar, in: K. Kurl, J.G. Ponte Jr. (Eds.), The Millets in Handbook of Cereal Science and Technology, 2nd ed., Revised and Expanded, Marcel Dekker Inc., NY, 2000.
[18] Z. Mlynekova, M. Chrenkova, Z. Formelova, Cereals and legumes in nutrition of people with celiac disease, Int. J. Celiac Dis. 2 (3) (2014) 105–109.
[19] S. Saldivar, Cereals: dietary importance, in: B. Caballero, L. Trugo, P. Finglas (Eds.), Encyclopedia of Food Sciences and Nutrition, Academic Press, Agosto, London, Reino Unido, 2003, pp. 1027–1033.
[20] S.W. Souci, W. Fachmann, H. Kraut, Food Composition and Nutrition Tables, Wissenschaft Verlags GmbH, Stuttgart, 2000.
[21] D.S. Sankara Rao, Y.G. Deosthale, Mineral composition, ionizable iron and soluble zinc in malted grains of pearl millet and *ragi*, Food Chem. 11 (1983) 217–223.
[22] S.R. Dangeti, S. Karthikeyan, G.R. Kumar, S. Desai, Proximate and phytochemical analysis of seed coat from *P. sumantranse* (Little Millet), Biochem. Anal. Biochem. 2 (2013).

[23] G. Sripriya, K. Chandrasekharan, V.S. Murty, T.S. Chandra, ESR spectroscopic studies on free radical quenching action of finger millet (*Eleusine coracana*), Food Chem. 57 (4) (1996) 537–540.

[24] S. Chethan, N.G. Malleshi, Finger millet polyphenols: characterization and their nutraceutical potential, Am. J. Food Technol. 2 (7) (2007) 582–592.

[25] L.U. Thompson, Potential health benefits and problems associated with antinutrients in foods, Food Res. Int. 26 (2) (1993) 131–149.

[26] L. Bravo, Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance, Nutr. Rev. 56 (11) (1998) 317–333.

[27] A. Scalbert, C. Manach, C. Morand, C. Remesy, L. Jimenez, Dietary polyphenols and the prevention of diseases, Crit. Rev. Food Sci. Nutr. 45 (4) (2005) 287–306.

[28] N.M. McKeown, J.B. Meigs, S. Liu, P.W. Wilson, P.F. Jacques, Whole-grain intake is favorably associated with metabolic risk factors for type 2 diabetes and cardiovascular disease in the Framingham Offspring Study, Am. J. Clin. Nutr. 76 (2) (2002) 390–398.

[29] U. Antony, L.G. Moses, T.S. Chandra, Inhibition of *Salmonella typhimurium* and *Escherichia coli* by fermented flour of finger millet (*Eleusine coracana*), World J. Microbiol. Biotechnol. 14 (6) (1998) 883–886.

[30] M.V.S.S.T. Subba Rao, G. Muralikrishna, Evaluation of the antioxidant properties of free and bound phenolic acids from native and malted finger millet (Ragi, *Eleusine coracana* Indaf-15), J. Agric. Food Chem. 50 (4) (2002) 889–892.

[31] P.S. Hegde, N.S. Rajasekaran, T.S. Chandra, Effects of the antioxidant properties of millet species on oxidative stress and glycemic status in alloxan-induced rats, Nutr. Res. 25 (12) (2005) 1109–1120.

[32] V. Viswanath, A. Urooj, N.G. Malleshi, Evaluation of antioxidant and antimicrobial properties of finger millet polyphenols (*Eleusine coracana*), Food Chem. 114 (1) (2009) 340–346.

[33] A. Chandrasekara, F. Shahidi, Determination of antioxidant activity in free and hydrolyzed fractions of millet grains and characterization of their phenolic profiles by HPLC-DAD-ESI-MS, J. Funct. Foods 3 (3) (2011) 144–158.

[34] B.R. Veenashri, G. Muralikrishna, In vitro anti-oxidant activity of xylo-oligosaccharides derived from cereal and millet brans – a comparative study, Food Chem. 126 (3) (2011) 1475–1481.

[35] S. Shobana, Investigations on the carbohydrate digestibility of finger millet (*Eleusine Coracana*) with special reference to the influence of its seed coat constituents (Doctoral dissertation, University of Mysore), 2009.

[36] U. Antony, G. Sripriya, T.S. Chandra, Effect of fermentation on the primary nutrients in finger millet (*Eleusine coracana*), J. Agric. Food Chem. 44 (9) (1996) 2616–2618.

[37] F.I. Tovey, A.P. Jayaraj, C.G. Clark, The possibility of dietary protective factors in duodenal ulcer, Postgrad. Med. J. 51 (596) (1975) 366–372.

[38] S. Chethan, S.M. Dharmesh, N.G. Malleshi, Inhibition of aldose reductase from cataracted eye lenses by finger millet (*Eleusine coracana*) polyphenols, Bioorg. Med. Chem. 16 (23) (2008) 10085–10090.

[39] M.S. Pore, N.G. Magar, Effect of ragi feeding on serum cholesterol level, Indian J. Med. Res. 64 (6) (1976) 909–914.

[40] P.S. Hegde, B. Anitha, T.S. Chandra, In vivo effect of whole grain flour of finger millet (*Eleusine coracana*) and kodo millet (*Paspalum scrobiculatum*) on rat dermal wound healing, Indian J. Exp. Biol. 43 (3) (2005) 254–258.

[41] S. Shobana, M.R. Harsha, K. Platel, K. Srinivasan, N.G. Malleshi, Amelioration of hyperglycaemia and its associated complications by finger millet (*Eleusine coracana* L.) seed coat matter in streptozotocin-induced diabetic rats, Br. J. Nutr. 104 (12) (2010) 1787–1795.

[42] S. Shobana, Y.N. Sreerama, N.G. Malleshi, Composition and enzyme inhibitory properties of finger millet (*Eleusine coracana* L.) seed coat phenolics: mode of inhibition of α-glucosidase and α-amylase, Food Chem. 115 (4) (2009) 1268–1273.

[43] S. Chethan, Finger millet (*Eleusine coracana*) seed polyphenols and their nutraceutical potential (Ph.D. Thesis), University of Mysore, Mysore, India, 2008.

[44] P.S. Hegde, G. Chandrakasan, T.S. Chandra, Inhibition of collagen glycation and crosslinking in vitro by methanolic extracts of Finger millet (*Eleusine coracana*) and Kodo millet (*Paspalum scrobiculatum*), J. Nutr. Biochem. 13 (9) (2002) 517–521.

[45] S. Tatala, G. Ndossi, D. Ash, P. Mamiro, Effect of germination of finger millet on nutritional value of foods and effect of food supplement on nutrition and anaemia status in Tanzania children, Tanzan J. Health Res. 9 (2) (2007) 77–86.

[46] V. Lei, H. Friis, K.F. Michaelsen, Spontaneously fermented millet product as a natural probiotic treatment for diarrhoea in young children: an intervention study in Northern Ghana, Int. J. Food Microbiol. 110 (3) (2006) 246–253.

[47] M. Manzoni, S. Bergomi, M. Rollini, V. Cavazzoni, Production of statins by filamentous fungi, Biotechnol. Lett. 21 (3) (1999) 253–257.

[48] V. Venkateswaran, G. Vijayalakshmi, Finger millet (*Eleusine coracana*)—an economically viable source for antihypercholesterolemic metabolites production by *Monascus purpureus*, J. Food Sci. Technol. 47 (4) (2010) 426–431.

[49] N.S. Rajasekaran, M. Nithya, C. Rose, T.S. Chandra, The effect of finger millet feeding on the early responses during the process of wound healing in diabetic rats, BBA-Mol. Basis Dis. 1689 (3) (2004) 190–201.

[50] L. Dykes, L.W. Rooney, Phenolic compounds in cereal grains and their health benefits, Cereal Foods World. 52 (3) (2007) 105–111.

[51] A. Gull, R. Jan, G.A. Nayik, K. Prasad, P. Kumar, Significance of finger millet in nutrition, health and value added products: a review, J. Environ. Sci. Comput. Sci. Eng. Technol. 3 (3) (2014) 1601–1608.

[52] C. Geetha, P. Parvathi, Hypoglycemic effect of millet incorporated breakfast items on selected non-insulin dependent diabetic patients, Indian J. Nutr. Diet. 27 (1990) 316–320.

[53] P.L. Kumari, S. Sumathi, Effect of consumption of finger millet on hyperglycemia in non-insulin dependent diabetes mellitus (NIDDM) subjects, Plant Food Hum. Nutr. 57 (3–4) (2002) 205–213.

[54] S. Shobana, R. Usha Kumari, N.G. Malleshi, S.Z. Ali, Glycemic response of rice, wheat and finger millet based diabetic food formulations in normoglycemic subjects, Int. J. Food Sci. Nutr. 58 (5) (2007) 363–372.

[55] T. Anju, S. Sarita, Suitability of foxtail millet (*Setaria italica*) and barnyard millet (*Echinochloa frumentacea*) for development of low glycemic index biscuits, Malays. J. Nutr. 16 (3) (2010) 361–368.

[56] R. Ugare, B. Chimmad, R. Naik, P. Bharati, S. Itagi, Glycemic index and significance of barnyard millet (*Echinochloa frumentacae*) in type II diabetics, J. Food Sci. Technol. 51 (2) (2014) 392–395.

[57] T.L. Holyoake, X. Jiang, M.W. Drummond, A.C. Eaves, C.J. Eaves, Elucidating critical mechanisms of deregulated stem cell turnover in the chronic phase of chronic myeloid leukemia, Leukemia 16 (2002) 549–558.

[58] B. Shivaraj, T.N. Pattabiraman, Natural plant enzyme inhibitors. Characterization of an unusual alpha-amylase/trypsin inhibitor from ragi (*Eleusine coracana* Geartn.), Biochem. J. 193 (1981) 29–36.

[59] F.A.P. Campos, M. Richardson, The complete amino acid sequence of the bifunctional α-amylase/trypsin inhibitor from seeds of ragi (Indian finger millet, *Eleusine coracana* Gaertn.), FEBS Lett. 152 (2) (1983) 300–304.

[60] K. Maskos, M. Huber-Wunderlich, R. Glockshuber, RBI, a one-domain α-amylase/trypsin inhibitor with completely independent binding sites, FEBS Lett. 397 (1) (1996) 11–16.

[61] S. Sen, S.K. Dutta, Evaluation of anti-cancer potential of ragi bifunctional inhibitor (RBI) from *Elusine coracana* on human chronic myeloid leukemia cells, Eur. J. Plant Sci. Biotechnol. 6 (2012) 103–108.

[62] S. Sen, S.K. Dutta, Cloning, expression and characterization of biotic stress inducible Ragi bifunctional inhibitor (RBI) gene from *Eleusine coracana* Gaertn, J. Plant Biochem. Biotechnol. 21 (1) (2012) 66–76.

[63] S. Sen, S.K. Dutta, S. Ghosh Dastidar, Development of a highly potent therapeutic regimen for chronic myeloid leukemia using the extract of *Eleusine coracana* seeds, Int. J. Biomed. Pharm. Sci. 5 (1) (2011) 7–11.

[64] V.V. Mosolov, L.I. Grigor'eva, T.A. Valueva, Plant protease inhibitors as multifunctional proteins (Review), Appl. Biochem. Microbiol. 37 (2001) 545–551.

[65] R. Pandey, N. Patil, M. Rao, Proteases and protease inhibitors: implications in antitumorigenesis and drug development, Int. J. Hum. Genet. 7 (2007) 67–82.

[66] S.S. Park, H. Obha, Suppressive activity of protease inhibitors from buckwheat seeds against human T-acute lymphoblastic leukemia cell lines, Appl. Biochem. Biotechnol. 117 (2004) 65–74.
[67] Y.Y. Li, Z. Zhang, Z.H. Wang, H.W. Wang, L. Zhang, L. Zhu, rBTI induces apoptosis in human solid tumor cell lines by loss in mitochondrial transmembrane potential and caspase activation, Toxicol. Lett. 189 (2009) 166–175.
[68] F.L. Meyskens Jr., E. Szabo, Diet and cancer. The disconnect between epidemiology and randomized clinical trials, Cancer Epidemiol. Biomarkers Prev. 14 (2005) 1366–1369.