

Nutraceutical Potential of Finger millet (*Eleusine Coracana*): Review

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ABSTRACT

Finger millet is gaining the status as an ingredient in the production of function food. It promotes eating enriched food that is closed to their natural state rather than taking dietary supplements. It is highly suitable as cereal grain in human diet. It has high nutritive values; it is non-glutinous, non-acidic and easy to digest. The contents like phytic acids and phytate makes it a versatile crop. Finger millet provides phosphorus which plays a vital role in the structural development of body cells and bones. It is also well balanced with Essential amino acids along with vitamin A and vitamin B. The utility of finger millet crop for food applications is set out. Its content of calcium and iron are also important from nutraceutical viewpoint. In addition the biotic properties of • Flavonoids, carotenoids, and polyphenols add worth to the formulation. In finger millets the polyphenols play an important role as an antioxidant. The important antioxidant which finger millet acquires are vitamin C, vitamin E and beta-carotene. Fermented finger millet food or ragi soups are a good source of nutrition. Patents filed for upheaval in products and operations have received popularity and gives assurance for the future of finger millet industry.

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Received: June 09, 2020; Accepted: June 17, 2020; Published: June 27, 2020

Keywords: Eleusine Coracana, Phytochemicals, Antioxidant, Nutraceutical, Vitamin.

Origin and History: Ragi (*Eleusine Coracana*) or finger millet, which is also known as birds foot, African millet, and ear(head of grain) because it radiates in a curving manner which consists of five spikes [1]. These plants are considered to be grown as a cereal crop in the arid and semiarid areas. Some of the general information of ragi is specified in (Table 1). *Eleusine Coracana* is mainly found in Africa and Asia [2]. Major countries that cultivate finger millets are; Uganda, Zimbabwe, Nigeria, Kenya, Mozambique, and southern Asia (India and Nepal) (Table 4). In India major states which grow finger millets are; Rajasthan, Maharashtra, Puducherry, Karnataka, Andhra Pradesh, Orissa, Tamil Nadu and Goa (Table 3). Different growing seasons are specified in (Table 2) [3]. Out of these states Karnataka and Tamil Nadu produce a bulk of finger millet in India. Finger millet adds a great value to nutritional and health benefits (Table 5) [3]. It is a rich source of fiber and calcium, which helps in lowering cholesterol levels, controlling body weight, diabetes, and cooling down the body temperature [4].

Table 1: General information of finger millet (Ragi)

Symbol:	ELCO3
Group:	Monocot
Family:	Poaceae
Duration:	Annual
Growth habit:	Graminoid

Source: USDA (United States Department of Agriculture)

Table 2: Finger millet is grown in all cropping seasons in different states of India

Name of state	Season
Andhra Pradesh	Early Kharif (May-August)
	Late Kharif (July-November)
	Late Rabi (November-March)
Karnataka	Kar or early Kharif (April-August)
	Kharif (July-November)
	Late Kharif (August-November)
	Rabi (October-September)
	Summer (January-May)
Tamil Nadu	Maghazipattam (December-April)
	Chitharaipattam (April-August)
	Adipattam (June-September)
	Purattasipattam (September-December)
Himachal Pradesh	Kharif (April-September)
Bihar	Kharif (June-September)
Uttar Pradesh	Kharif (June-September)

Source: IIMR (Indian Institute of millets Research)

Production of finger millet

Table 3: Different states and their production rate of ragi in different years

States	2001-2005	2005-2010	2010-2015	2015-2019
Andhra Pradesh	6.46%	6.77%	5.19%	6.78%
Karnataka	7.38%	8.86%	8.86%	8.86%
Puducherry	14.45%	11.63%	11.63%	11.63%

Source: USDA (United States Department of Agriculture)

Table 4: Different countries and their production rate of ragi in different years

Country	Unit of measure	2001-2005	2005-2010	2010-2015	2015-2019
China	1000 MT	-7.44%	-1.60%	28.90%	4.55%
Ethiopia	1000 MT	4.55%	19.22%	21.8%	10.0%
Sudan	1000 MT	16.77%	166.07%	-25.24%	50.0%
Nigeria	1000 MT	-9.34%	7.00%	4.87%	-5.52%
Niger	1000 MT	-25.38%	30.13%	43.54%	-1.22%
Mali	1000 MT	4.48%	18.77%	-1.2%	-21.20%
Senegal	1000 MT	20.0%	87.96%	0.37%	-5.24%

Source: USDA (United States Department of Agriculture)

MT: metric tons, (-): negative sign represents fall in the production, (+): positive sign represents rise in the production.

Table 5: Different varieties of finger millet found in India

States	Varieties
Karnataka	GPU-28,GPU-45,GPU-48,PR 202,MR 1,MR 6,ML- 365,GPU-67,GPU-66,KMR-340
Andhra Pradesh	VR 847,PR 202,VR 708,VR 762,VR 90
Tamil Nadu	GPU-28,CO 13,TNAU 946,CO 9,CO 12,CO 15
Maharashtra	Dapoli 1, PhuleNachani, KOPN 235, KOPLM 83
Jharkhand	A 404, BM 2
Orrisa	OEB 10,OUAT 2,BM 9-1,OEB 526
Chattisgarh	GPU 28,PR 202,VR 708,VL 149,VL 315,VL 324,VL 352
Uttarakhand	PAM-2,VL 315,VL 324,VL 352,VL 149,VL 146,VL 348

Source: IIMR (Indian Institute of millets Research)

Plant Characteristics

Finger millet is a very important food in the conventional cereal-based farming system [5]. The crop is also additionally extremely cultivated in Southern Asia in India, Myanmar, Sri Lanka, Bhutan, and China [6]. Two main pigmentations are present that are green pigment which is found on leaves and stem, the purple pigment is found only on the stem [7]. Finger millets are classified into three types of growth habits; decumbent, prostrate, and erect [7]. All the *Coracana* species have an erect growth pattern [7]. Finger millets might be characterized by spreading inflorescence, advanced cultivars have extremely proliferated inflorescence branches that are clumped along to make a fist-like structure [8]. Inflorescence compactness (panicle shape) can be classified into 4 groups; long-open inflorescences, fisty inflorescences, compact inflorescences,

and pendulous inflorescences [7]. Based on seed color, finger millets can be identified by 6 colors; white, light brown, brown, ragi brown, red-brown, and purple-brown [7]. Plant height, days to silking, and days to maturity are highly affiliated to yield the outcome of maize [9]. Variation in grain yield range from 15-144.4g per plant and grain size can range from 0.5-5.4g per 1000 grains [7]. Basal tillers range from 5-16, finger numbers range from 5-11, finger length range from 14.15-16.18 cm, finger width has a range of 1.35-14.30 cm and peduncle length is 4.35-14.3 cm [7]. It takes around 45-92 days to flower and around 65-139 days to mature respectively [7]. Growth characters show high variations that range from 6-19 leaves for leaf range, 15.95-47.78 cm for flag leaf length, 0.42-1.48 mm for flag leaf dimension (width), 19.08-59.47 cm for blade leaf length, 0.56-1.8 mm for blade leaf width and 25.3-128.01 cm for plant height respectively [7].

Finger Millet as Food Ingredient

Finger Millet as a food ingredient: Whole grains have to be included in the diet, recommended in dietary guidance around the world because it reduces the risk of obesity or weight gain, hypertension, and stroke [10]. Finger millet ranks sixth position in production rate after wheat, rice, maize, and sorghum in India. Finger millet is well recognized for its nutritional level, which consists of calcium (0.38%), dietary fibers (18%) and phenolic compounds (0.3-3%) [11]. Other than this, finger millet increases the health beneficial factors such as antimicrobial properties, antioxidant, and anti-tumorigenic. Diabetic based food formulation by finger millet contains 13.0-18.3% proteins, 11.3-11.8% fats, 59.9-67.5% starch, and 13.2-18.0% dietary fibers, and the glycemic index (GI) values were 55.4+/-9, 93.4+/-7, 105+/-6 and 109+/-8 [12]. Fortification of diets with phenolic acid was shown to relate anti-mutagenic, anti-glycemic, and antioxidants properties [13].

Protein

Finger millet consists of a good amount of protein in it. The protein in finger millet has fortunately not been reported as an allergen [14]. The protein content is about 7.3-7.7 g (5-8%) [15]. Prolamins are the major portions of protein [16]. The globulin and albumin fraction of protein contains major essential amino acids [3]. Protein digestibility of finger millet is mainly affected by the tannins [17]. Supplementing finger millet diets with lysine protein improved the nutritional status, apparent protein digestibility [18]. The nutraceutical property of protein in finger millet is that it maintains homeostasis [19]. Grain protein increases with increase in phosphorus rate, this is due to the significance of phosphorus in the synthesis of protein and it acts as an important building block in amino acids and generation of energy for the uptake and transfer of nitrogen in finger millet grains [20]. Finger millet's endosperm are important sinks of carbon and nitrogen compounds which further enhances the protein content [21].

Amino Acids

It has been experimentally proven that major portions of ragi/ragi flour are occupied by carbohydrates, followed by proteins and fats. Out of 100 gm of ragi flour, 80% is covered by carbohydrates [22]. The level of fat content in finger millet is comparatively low to that of other crops. Also finger millet is a good source of Essential amino acid (EAA), which are very essential for human body. Some of the EAA which finger millet contains in it are; Tryptophan, Valine, Methionine, Threonine, and Isoleucine (Table 6).

Table 6: Essential amino acid present in ragi with specific function

Essential amino acid present in ragi	Function	Amount (mg/g of protein)
Valine	Balances the nitrogen content in the body and to promote mental calmness, as well as repairing of tissues and muscle coordinates.	413
Isoleucine	Isoleucine amino acid is an EAA for the human body because it boosts up the energy level and promotes the body in recovering from strenuous physical activities. And essential for ensuring blood formation.	275
Threonine	Balances the level of protein in the human body, and helps in the formation of tooth enamel.	263
Tryptophan	One of the major EAA which helps in the treatment of psychiatric disorder by controlling / reducing the level of anxiety, insomnia, and depression . As well as treating migraine headaches.	191
Methionine	It is an sulfur-based amino acid, which is essential for many activities in the body, such as controlling the cholesterol level in the body.	194

Source: USDA (United States Department of Agriculture)

Carbohydrates

Finger millets are known for their high carbohydrate content (Table 7). It consists of 1.04% of free sugars, 65.5% starch, and 11.5% non-starchy polysaccharide [23]. The dietary fiber content of finger millet is much higher than that of brown rice, foxtail, barnyard millet, etc. Starch in finger millet consists of amylase and amylopectin with amylose content being less around 16%. Carbohydrate digestibility is slow and gradual and it is an anti-diabetic [19]. The starch granules give the grain the rhombic shape.

Table 7: Different carbohydrates present in ragi

Carbohydrate Component	Percentage
Starch	60-70%
Starch:amylose	15-20%
Starch:amylopectin	80-85%
Reducing sugar	1.2-1.8%
Non-reducing sugar	0.03-0.05%
Total dietary fiber	10-12%
Insoluble dietary fiber	9.0-11.0%
Soluble dietary fiber	1.0-2.0%

Crude fiber	3.0-3.6%
Non-starch Polysaccharide	20-30%

Source: USDA (United States Department of Agriculture)

Vitamins and Minerals

Nutritional statistics of finger millet crops are 5-8% proteins, 1-2% ether, 65-75% carbohydrates, 2.5-3.5% minerals, and 15-20% dietary fibers [24]. Out of all the millets, finger millet has the highest amount of calcium (0.38%), dietary fibers (18%), and phenolic compounds (0.3-3%) [11]. Extraction of polyphenols were carried out at different pH values and temperature. On analysis of seed coat and endosperm fractions of the finger millet for polyphenols, it revealed that nearly 90% of polyphenols were present in it [25].

Products of Finger Millet

India is the major producer of Ragi. There are a variety of products that are derived from ragi (Table 8). They are often used as an excellent substitute. Some of finger millet products are as follows:

Chapatti: Ragi chapattis not only improves that taste but also helps in maintaining the glucose level in diabetes patients. Due to the slow digestion rate and heaviness of the fibers it makes us feel fuller which further prevents excessive eating which is less calorie consumption [26].

Papad: The flour of finger millet is gelatinized to prepare the dough. It is then rolled out flat and baked or fried. It has a dark color due to that fact that pericarp isn't separated from starch [26].

Noodles: Ragi noodles are made to keep children and the teenage consumers in mind. Finger millet noodles are a good substitute for the traditional all-purpose flour noodles [26]. They are made by cold extrusion and drying making them brittle.

Fermented foods: Dosa and idli are staple fermented foods in India. Finger millet can be used to make these fermented foods which greatly enhance the nutritional value of the food [26].

Soup: Ragi soup is made by mixing powdered finger millets in water and heating it with constant stirring and simultaneously removing/dissolving the lumps. This soup is extremely beneficial for health and a better alternative for other conventional cornstarch and all-purpose flour soups [27].

Table 8: Manufacturers and constituents of different products of ragi

Products	Company	Constituents	References
Chapatti	Soulful 24 mantra	7:3 wheat and finger millet	Gull et al.,2014
Papad	Areva	Finger millet,black gram, rice and spices	Veenu verma et al.,2013
Noodles	Naturally Yours	5:4:1 finger millet, wheat flour and soy flour	Veenu verma et al.,2013
Fermented food	ID batters Asal	Ragi flour or sprouted finger millet grains, rice and pulses	Gull et al.,2014
Soup	Manna health	Finger millet flour, yogurt and spices	Veenu verma et al.,2013

Finger Millet and its Health Benefits

The amount of nutrients and EAA present in the finger millet, it can be used as one of the major component responsible for maintaining good human health and growth. Finger millet is enriched in EAA (Essential Amino acid) like, valine, isoleucine, threonine, tryptophan, and methionine. In addition to this it contains some useful polyunsaturated fatty acids and vitamins, like linoleic acid and alpha-linolenic acid, which helps in the normal development of the central nervous system. Whereas vitamins: tocopherols, niacin, thiamin, and riboflavin are both water-soluble and liposoluble vitamins. Finger millet is a rich source of antioxidants like tannins, flavonoids, and phenolic acid which can be used for preventing cancer and aging [11]. The presence of high content of fibers in finger millet it slows down the pace of digestion which prevents lowering blood sugar level and avoids craving at late night. Finger millet is the richest source of calcium compared to other cereals [4] (Table 9). On comparison, it has three times more calcium content than milk and 10-fold higher calcium than brown rice, maize, or wheat [29]. Rather than nutritional properties, finger millet is considered to be excellent environmentally sustainable credentials. Whereas it can withstand high climatic conditions,

low soil fertility, requires very less inputs with a short growing season and has a great storage capacity [29].

Table 9: Calcium content in various cereals

Cereal	Calcium content (mg/100g)	References
Finger millet (<i>Eleusinecoracana</i>)	344	Shobana et al., 2013
Proso millet (<i>Panicummillaceum</i>)	14	Shobana et al., 2013
Barnyard millet (<i>Echinochloa crus-galli</i>)	20	Shobana et al., 2013
Pearl millet (<i>Pennisetumglaucum</i>)	42	Shobana et al., 2013

Patents of Finger Millet

Growing popularity of finger millet lead scientists to start researching more and more about finger millet to discover and invent new things, leading them to patent their findings and inventions (Table 10).

Table 10: Patents on finger millet

Title	Patent number	Inventor	Published
Finger millet bread formulation and a process for preparing the same	ZA200605351B	Indrani Dasappa Manohar Ragu Sai Rajif Jyotsna Rao Gandham Venkateswara	2007-12-27
Decorticated finger millet (<i>eleusinecoracana</i>) and process for its preparation	AU2002249506A1	Nagappa Gurusiddappa Malleshi	2003-10-08
Yi Zhong Finger-millet whole wheat and preparation method thereof	CN109527360A	Yang ZhixiangZuoShuyu	2019-03-29
Composition and process for making millet-based flour useable in formed food products	US20170188589A1	Kanika BhargavaKritika SHAKYA	2017-07-06
Treatment fluids comprising finger millet and methods of use	US10047269B2	Shoy George Chittattukara Ragi LohidakshanPoyyaraSaumitra Das	2018-08-14
Yi Zhong Finger- millet digesting Apparatus	CN208875326U	Li Yeppei Zhou Qijun	2019-05-21
It is a kind of to have effects that stomach invigorating finger millet paste and preparation method thereof	CN109527356A	Xie Jing, Lu Chao, He Cheng, Pan Mengzhan, Xiao Rong, Luo Yucui, Wu Fuping	2019-03-29
Yi Zhong Finger-millet bud health care yoghurt and preparation method thereof	CN110100894A	Wang ShuanghuiJinChenzhong Zhang Xuejiao Hu Yihong Wu Huijuan Li Yueyang	2019-08-09
Finger millet biscuit and process for preparing the same	JP2004298013A	Dasappa IndraniRagu Sai ManoharJyotsna RajivGandham Venkateswara Rao	2010-09-22

Conclusion

Ragi (*Eleusine Coracana*) is becoming an important crop for its health benefit application Whereas the United States National Academics had declared that finger millet as a potential “super cereal” being one of the most nutritious among all the major cereals. This added a number of newer applications in food technology developments. A brief nutrient description of Ragi crop is; 5-8% proteins, 1-2% ether, 65-75% carbohydrates, 2.5-3.5%minerals and 15-20% dietary fibers. Out of all the millets, finger millet had the highest amount of calcium, fibers and phenolic compounds. Compounds like Epigallocatechin, Alpha-amylase trypsin, and Feruloyl Arabinoxylans shows the anti-inflammatory, anti-cancer, and anti-oxidant activity respectively. Thus Ragi has a

great potential as a source of important nutrients and nutraceutical implication for human health.

Acknowledgment

The authors would like to express their sincere gratitude to Vice Chairman Dr. Premachandra Sagar and Principal Dr. CPS Prakash for their keen support and emboldening.

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