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Research Paper

Finger Millet: A powerhouse of nutrients its amino acid, micronutrient profile, bioactive compounds, health benefits, and value-added products.

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ABSTRACT: *In recent years, finger millet (Eleusine coracana L.) has gained popularity as healthy food due to its nutritional and phytochemical properties. The finger millet is known for several health benefits due to its polyphenol content and dietary fiber. Therefore, it does not need to be identified as a new source of nutraceuticals or other natural and nutritional materials with desirable functional characteristics. Using finger millet to make value-added foods and evaluating its nutritional and health characteristics is the focus of this review. It has much higher protein levels, fats, calcium, and dietary fiber than rice and wheat. Several amino acids are found in this millet, including isoleucine, leucine, methionine, and phenylalanine, which are all lacking in other starchy foods. This review focuses on finger millet's nutrient profile, amino acid profile, micronutrient profile, and value-added product as well as their role in health benefits.*

KEYWORDS: *Eleusine coracana L, Bioactive comupounds, amino-acid profile, isoleucine, methionine, and calcium.*

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I. INTRODUCTION

From a nutritional perspective, the quantity and quality of protein majorly affect how helpful or functional a grain is as food for humans. One significant class of bio-macromolecules that is engaged in physiological processes is the protein family. Natural vegetable proteins are valuable materials because they are secure, highly biocompatible, nutritive, and inexpensive. Therefore, the food and pharmaceutical industries must discover new vegetable proteins that are rich in critical amino acids [1, 2]. One such plant-based crop is the millet crop which includes grasses such as finger millet and Eleusine coracana (L.) Gaertn; pearl millet, Setaria italica (L.) P. Beauvois; Kodo millet, proso millet, and Panicum miliaceum L., belong to the monocotyledon family Poaceae. A total of 762,712 metric tons of millet grain were produced worldwide in 2013 [3]. Millets are one of the oldest crops, having been cultivated some 10000 years ago [4, 5]. According to several fossils from the Stone Age, they were significant grains in the region of Hungary at that time [5]. The cultivation of millets is particularly important in semi-arid and tropical regions because they are resistant to pests and diseases, have a short growing season, and are productive under hardy and drought conditions when major cereals are not reliable. Many industrialized nations underuse millets. Processing millet grains into foods and beverages with additional value has enormous promise in underdeveloped nations. Millets are also recommended for celiac patients because they don't contain gluten [6, 7]. According to the Food and Agriculture Organization (FAO), 850 million people worldwide suffer from chronic hunger [8]. Between 10 and 30 percent of children in Central Africa and South Asia suffer from protein malnutrition, and over 1 billion individuals worldwide consume insufficient quantities of dietary protein [8, 9, 10]. There is broad agreement that it is necessary to address the current and predicted food insecurity while also taking into account the sustainability of food production. An essential component of achieving this goal is supplying high-quality dietary proteins [11]. Additionally, it has lately been proposed that additional plant proteins should be included in diets [12]. Therefore, this review reveals the finger millet's amino acid and micronutrient profile.

I. Finger millet

E coracana L, occasionally called finger millet, is a staple food in parts of eastern and central Africa and India, commonly known as ragi and mandua in India, kaddo in Nepal, fingerhirse in Germany, and dagussa, tokuso, and barankiya in Ethiopia [13]. After sorghum, pearl millet, and foxtail millet, finger millet is the fourth most significant millet in the world. An estimated 10% of the 30 million tons of millet produced worldwide is finger millet [3]. In many Asian regions, finger millet is a significant subsistence and staple grain [14]. It can enhance dietary intake, increase food security, promote rural development, and aid in environmentally friendly land upkeep [15]. The millet seed is a component that may be eaten and is particularly high in calcium as well as phytochemicals, dietary fibers, and polyphenols [16,17]. Despite the availability of numerous varieties, only red-colored ones are commonly cultivated worldwide. In contrast to other millets such as sorghum, pearl millet, proso millet, and foxtail millet, finger millet has a five-layered seed coat, which could be attributed to its higher fiber content [18].

In terms of nutrition, finger millet is a good source of vitamins, minerals, and fiber, particularly calcium. According to reports, finger millet has a total of 72 to 79.5 percent carbohydrates. Among the carbs, starch makes up about 59.4 to 70.2 percent of the total [13]. The Finger millet's kernel comprises the endosperm, embryo, and seed coat. It contains a five-layer seed coat that is rich in nutritional fiber and antioxidants [19]. It is a crucial cereal crop because of its enormous nutritional value, which is equal to or greater than wheat and rice [20].

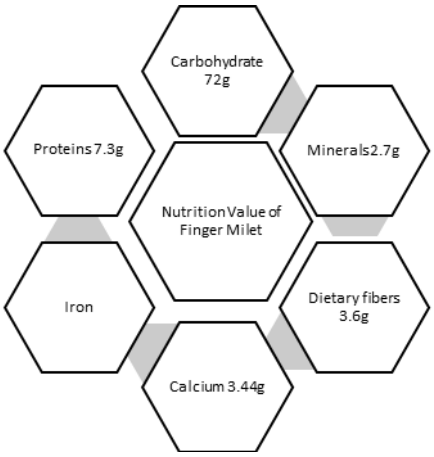


Figure 2.1.a: Nutritive value of ragi/100 g [3]

a. Amino acid:

Polished rice, maize, and refined wheat—the three grains that are most frequently consumed—cannot offer complete protein because they contain very little of all the essential amino acids. Legumes contain low quantities of the amino acid methionine and cysteine and different degrees of protein digestibility; therefore, they do not offer complete protein even when paired with other legumes that are well-known to be rich sources of protein. However, when paired with millets, legumes can offer complete protein that is highly digestible and more widely available [21]. Millets, which are coarse cereals and naturally high in methionine and cysteine, can be used to supplement the amino acid deficiency in pigeon peas and chickpeas. The average protein content of finger millet is 7.3 percent, compared to 11.6 percent for pearl millet [18]. A study on the influence of malting on the nutritional content of finger millet and mungbean reported a substantial increase ($p<0.05$) in free amino acid content from 12 to 24 hours of germination [22].

Table 2.a: Essential amino acid profile of finger millet (100g/g)

Variety	Arg	His	Lys	Tryp	Phenyl	Tyro	Met	Cys	Three	Leu	iso	Val	Reference
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	[3]
VR847	-	2.93	4.57	0.55	5.30	-	1.83	0.64	4.39	9.14	4.39	6.45	[21]
GPU28	-	2.85	4.00	0.70	5.31	-	1.77	0.46	4.15	9.77	4.62	6.69	[21]
Black finger millet	0.284	0.225	0.221		0.447	1.01	0.337	0.185	0.330	0.881	0.402	0.573	[23]
Finger millet	4.33	2.47	2.58	1.45	5.37	4.28	2.62	1.13	4.15	10.24	4.17	6.20	[24]
Finger millet	-	1.30	0.44	1.32	1.0	0.53	1.0	0.50	1.22	1.55	1.49	1.77	[25]

Ragi/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	[18]

Ar* Arginine, His* Histidine, Lys* Lysine, Tryp* Tryptophan, Phenyl* Phenylalanine, Tyro* Tyrosine, Met* Methionine, Cys* Cysteine, Threo* Threonine, Leu* Leucine, Iso* Isoleucine and Val* Valine.

Protein is the second important ingredient in millet. With 24.6 to 36.2 percent of the total protein in finger millet, prolamin is the predominant protein component. Compared to the 33.9 percent necessary amino acids in the FAO reference protein, finger millet has 44.7 percent of the total amino acids. The amino acid composition of finger millet also provides a favorable essential to the total amino acid ratio. The amino acid tryptophan is typically the second most lacking in cereals. However, finger millet is not lacking. Also, finger millet contains more lysine, threonine, and valine than other millets, it has a comparatively better balance of essential amino acids [26]

Proteins have nutritional quality if they contain essential amino acids that cannot be synthesized by the body. A lack of one of these amino acids will lead to poor growth in livestock and humans and nitrogen loss in the diet. From a nutritional standpoint, the most important aspect of protein is its essential amino acids (EAA). The carbon skeleton prevents the human body from synthesizing EAA, so these must be obtained from the diet [27]. Due to this, essential amino acids are more essential for growth and metabolic maintenance than remaining non-essential amino acids [2]. A protein's composition of amino acids and the ability of the essential amino acids to be digested by the body greatly influence the protein's quality [28]. The combination of millets and other sources of protein could compensate for the lack of certain amino acids, such as lysine, in millets [26].

b. Micronutrient profile

Finding sources of high quality and quantity of protein and major micronutrients for a plant-based diet is crucial because vegetarian and vegan diets are becoming more popular in the West while protein and micronutrient deficiencies are still widespread in Asia and Africa. Healthy eating is essential for human development, health, and function. Millets provide a larger range of micronutrients and complete protein when combined with legumes [21]. The finger millet contains a variety of important micronutrients [22]. The high content of calcium (0.38 percent), protein (6–13 percent), dietary fiber (18 percent), carbohydrates (65–75 percent), minerals (2.5–3.5 percent), phytates (0.48 percent), tannins (0.61 percent), phenolic compounds (0.3–3 percent), and trypsin inhibitory factors are what give finger millet its nutraceutical importance. It is also known for its positive effects on health [3].

Table 2.b: micronutrient with quantity from different sources

Ca (mg)	P (mg)	K (mg)	Na (mg)	Mg (mg)	Fe (mg)	Mn (mg)	Zn (mg)	Thiamine (mg)	Riboflavin (mg)	Nicotinic acid (mg)	Niacin (mg)	Reference
33	-	-	-	-	1.8	-	-	0.41	0.04	-	4.3	[20]
359.79	-	-	-	-	2.86	-	2.00	-	-	-	-	[21]
450.33	-	-	-	-	2.64	-	2.02	-	-	-	-	[21]
344 mg	283	408	11	137	3.9	5.49	2.3	0.42	0.19	-	1.1	[3]
0.33 %	0.24%	0.43%	0.02%	0.11%	46%	7.5%	15%	0.48 %	0.12 %	0.30 %	-	[7]

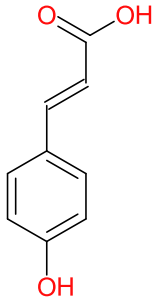
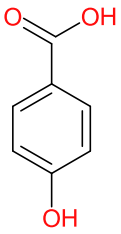
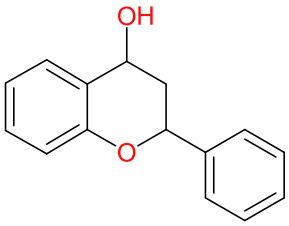
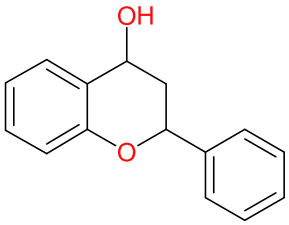
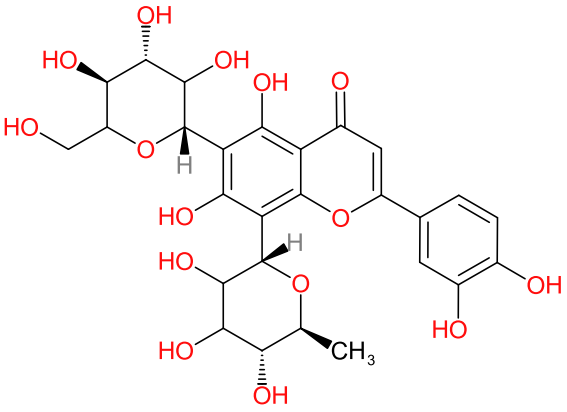
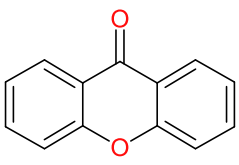
Nutritionally, finger millet is a good source of balance of essential amino acids and nutrients, especially calcium, other minerals, and fiber [26]. [29] reported that finger millet contains approximately ten times and thirty-five times higher calcium compared to wheat and rice. [30] also reported finger millet as a rich source of minerals that could mainly use to overcome some health issues like anemia, and bone and teeth disorders. Finger millet is the richest source of calcium and iron as well as other vital nutrients, which effectively tackle bone-related health issues [31]. Its crude fiber and mineral content is remarkably higher than those of wheat (1.2% fiber, 1.5% minerals) and rice (0.2% fiber, 0.6% minerals) [32]

c. Bioactive Compounds

The nutritional content of food and the availability of bioactive substances with beneficial effects on human health are used to determine food quality [33]. Wheat, rice, and maize have been extensively explored for their phenolic content and bioactive properties since the grains contain a variety of health-promoting components such as vitamins, minerals, and phytochemicals. Besides these cereals, millets are also important because their seed coat contains polyphenol with a chlorogenic equivalent of 0.09 to 2.44 mg per 100 grams [34]. Finger millets have hypoglycemic properties [35]. hypocholesterolemic [36] and anti-ulcerative properties [37]. Phenolic compounds are found in all types of millet and are connected to different parts of the cell wall by

glycosidic links, like arabinoxylans and protein. Bioactive phenolics are notably present in a wall-bound form in the finger millet seed coat [34].

Table 2. c: Phytochemical compounds with their structures

Phytochemical Compounds	Compounds	Structure	References
Phenolic Acid • Hydroxybenzoic acid • Hydroxycinnamic acid	protocatechuic, p-hydroxybenzoic p-coumaric, ferulic, syringic	 **Hydroxybenzoic**  **Hydroxycinnamic acid**	[34,35,36,37,38]
Flavonoids • Flavanols • Benzoic acid • proanthocyanidins	quercetin, apigenin, catechin, epicatechin gallic acid, protocatechuic acid, p-hydroxybenzoic acid, vanillic acid, syringic acid Tannin	**Flavanols**  **Anthocyanin**  **Flavonoids** 	[7,38] [37]
• Phytochemicals • Antioxidant	Polyphenol, terpenoids, alkaloids, phytoestrogens, phytocyanins DPPH (1,1-Diphenyl-2-picrylhydrazy, Radical scavenging activity	 **Xanthones**	[19; 29,39,40,41] [34,42]

Bioactive compounds	ferulic acid, quercetin, and ferulic-rich arabinoxylans or feraxans among		[35,37, 43, 44, 45]

The phytochemicals in finger millet, particularly phenolic compounds, are abundant and may help prevent chronic illnesses like diabetes, cancer, and cardiovascular diseases. Due to its nutritional qualities in terms of micro- and macronutrients, it has attained high importance. The polyphenols are made up of flavanols (catechin, epicatechin), flavonoid glycosides (catechin, epicatechin, quercetin, apigenin), and proanthocyanidins. Hydroxybenzoic (protocatechuic, p-hydroxybenzoic, and syringic) acids, hydroxycinnamic (caffeic, p-coumaric, and ferulic) acids, to a great extent, finger millet's antioxidant capabilities are derived from phenolic chemicals [38]. In comparison to rice, wheat, maize, and barley, finger millet grain has a dark brown seed coat and is high in polyphenols. These phenolic compounds exist as free, soluble conjugates, and insoluble bound forms in the outer layers, particularly the aleurone layer, testa, and pericarp, which compose the main components of the bran fraction. Ferulic acid (64-96 percent) and p-coumaric acid are the most abundant bound phenolics in finger millets (50-99 percent). Finger millets contain proanthocyanidins, commonly known as condensed tannins [26].

II. Utilization in industry

The term millet (A Nutritional Crop) refers to a variety of grass crops whose seeds are gathered for human use or animal feed. It is largely organic, highly digestible, naturally gluten-free, very nutrient-dense, and eaten as a whole grain [26]. With significant nutritional value, finger millet is becoming increasingly popular among dieting enthusiasts as a trendy meal to maintain a healthy lifestyle, avoid lifestyle problems, and treat chronic and non-communicable diseases [19, 31].

Figure 3.1.a: Finger millet product from [18]

Finger millet noodle

The popularity of finger millet noodles, in particular, is rising as people become more aware of their nutritious benefits. Many various combinations of noodles can be manufactured, including finger millet-only noodles, finger millet and wheat noodles that are blended 1:1, and finger millet noodles that are blended 5:4:1 with wheat and soy flour. When making exclusively millet-based noodles, millet flour is pretreated to help with extrusion and maintain its smooth texture throughout drying and cooking [26].

Weaning food

One of the abundant sources of calcium and amino acids containing sulfur is finger millet. Using composite malt flour, which also contains finger millet, Bengal gram, and green gram weaning meal is created. This mixture contains a lot of protein and calcium. The composite flour was soaked in water for 48 hours at 25ºC room temperature; however, 38 hours might suffice in the summer. To stop the germination process, soaking grains were mechanically or solar dried, keeping the temperature below 75 °C and the moisture content between 10 and 12 %. Malted grains were dried, then roasted, and ground into ready-to-eat (RTE) products using any size reduction equipment [20].

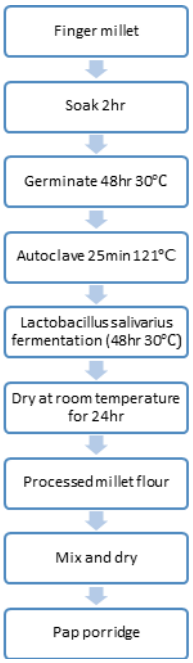
Puffing

Popping or puffing is a straightforward method of processing grains to create ready-to-eat foods. The whole finger millet grain is prepared for puffing by adding more water to bring its moisture level to between 18 and 20 percent, then tempering for roughly 4-6 hours under cover. Following the HTST (high temperature and short

time) method, the conditioned grains are puffed by agitation on the hot sand surface maintained at approximately 230–250º C for a brief period. By simply crushing puffed finger millet grains, one can create a powder that has more nutritional value by neutralizing some anti-nutritional elements and improving protein and carbohydrate digestibility [26].

Porridges

In India and Africa, finger millet is the cereal of choice for making porridge for kids, the elderly, and those who are ill. It is regarded as more appetizing and has a higher mineral composition than sorghum or maize, particularly in terms of calcium content [25].



Flow chart 3.4.1: Porridge making from [25]

Fermented food

Fermented beverages from finger millet are also common. A traditional mild-alcoholic beverage prepared from finger millet (Kodo ko jand, raksi) is consumed in Eastern Himalayan areas of the Darjeeling hills and Sikkim in India, Nepal, and Bhutan [18]. Jandh is a somewhat sour and sweet alcoholic beverage fermented from finger millet (Eleusine- coracana) popularly known as Kodo or Marua. As part of the Jandh-making process, the millet seeds are steamed until they are soft and can be spread on leaves, preferably banana leaves. Marcha, the starter culture, is powdered and sprinkled on the boiled and cooled seeds. The mixture of seeds is piled in a heap and kept at ambient temperature for 24 hours. The seeds are then placed in a pot and covered with leaves and straw, and allowed to ferment, after which the seeds are kneaded to remove the seed coats. The grits are then poured into bamboo vessels (Toongba) with water (cold or hot depending on the season) After 10 minutes, the beverage is ready to drink (normally with a bamboo straw). This liquor is believed to be a good tonic, especially for those recovering from childbirth (Gajurel). Generally, millet is used for the preparation of Jandh. After fermentation, the mash is steam distilled in a traditional distillation apparatus, which has three sections-the bottom section, the middle section, and the top section. The mash ferments in the bottom section, and the apparatus is placed over a fire. In the middle section is a bucket that collects the distillate, and at the top is a pot to condense the alcohol vapor. During distillation, the cold-water pot is usually replenished three times with new cold water. This period is known as Tinpane Rakshi, and it contains a lot of alcohol. It could have a percentage of alcohol of 20–40% (v/v) [46].

III. Health benefits

Ragi (Eleusine coracana) is a good source of carbohydrates, proteins, dietary fiber, and minerals, making it an essential staple food for people from low socioeconomic groups and those with metabolic disorders such as diabetes and obesity [41]. It is significant due to its superior capacity for storage and nutritional value [47]. Due to their high fiber content, millets have a hypoglycemic effect. Reduced postprandial glucose is caused by delayed digestion and absorption of complex carbs and fiber [48]. One of the most diverse dietary supplements sold worldwide is phenolics, particularly phenols, which are abundant in plant diets ingested by humans and animals. There are many properties associated with these compounds, including antioxidants, anti-

mutagenic, anti-carcinogens, anti-inflammatory properties, anti-oestrogenic properties, and anti-viral properties [49]

Polyphenols are considered "life-span essential" due to their involvement in maintaining physiological functions and health into adulthood and the later stages of life [6]. Millet meal flour from whole grains reduces oxidative and hyperglycemic stress. Finger millet is beneficial and plays a significant role in maintaining human health, in particular, because its seed coat contains several phenolic chemicals, the majority of which are benzoic acid derivatives and have been linked to antioxidant activity [50]. To protect against oxidative damage and preserve a healthy physiological balance, reactive dietary antioxidants have been related to the oxidation of cellular components in severe chronic diseases like diabetes, heart disease, cancer, and several other basic human activities. Plant polyphenols have received significant attention in recent years from scientists, health professionals, and consumers for their multiple health advantages in lowering the risk of cancer, cardiovascular and neuro-degenerative illnesses, infections, aging, and diabetes [51,52]. As a trendy food for maintaining a healthy lifestyle and preventing lifestyle disorders, chronic illnesses, and non-communicable diseases, finger millet now has a profound nutritional value [19,31].

IV. Conclusion:

Increased nutritional awareness challenges the food industries in developing new food products with special health-enhancing characteristics. Its nutritional and functional properties have been reviewed and found best among all cereal grains. Vitamins, minerals, amino acid profiles, and antioxidant properties of this make a strong contribution to human nutrition. This Presence of dietary fiber and polyphenols inside the finger millet can offer various health advantages including anti-diabetic, hypocholesterolemia, Prevention of diet-associated chronic diseases, and antioxidant and antimicrobial effects. Finger millet may be applicable formulations of different value-added food products possibly attributed to its well-balanced protein profile and gluten-free nature. This study along with raising the profitability of its cultivators also speeds up the income and employment opportunities in rural areas.

V. Future scope

Our long-term goal is to develop an alternative plant-based protein that uses pulses that are deficient in some important amino acids and fortifies them with finger millet, so maximizing the utilization of the underutilized millet grain.

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