

The Superfood Finger Millet (*Eleusine coracana*) and its Therapeutic Activities - A Review

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ABSTRACT

This comprehensive review article delves into the multifaceted aspects of the superfood finger millet (*Eleusine coracana*) and its therapeutic activities, with an emphasis on preclinical studies. Finger millet, commonly known as ragi, has a rich history of consumption across diverse regions, notably Africa and Asia, owing to its exceptional nutritional profile and associated health benefits. The paper meticulously examines the intricate nutritional composition of finger millet, elucidating its notable concentrations of essential nutrients such as dietary fiber, proteins, vitamins, and minerals. Moreover, it meticulously scrutinizes the therapeutic properties of finger millet, including its documented antioxidant, anti-diabetic, anti-inflammatory, and anti-cancer attributes, with an in-depth exploration of findings from preclinical investigations supporting these claims.

Throughout the review, special attention is devoted to dissecting the mechanisms underlying finger millet's therapeutic effects, drawing on insights garnered from preclinical studies. These investigations shed light on the molecular pathways and biological processes through which finger millet exerts its health-promoting actions, providing valuable mechanistic understanding. Additionally, the

review assesses the potential applications of finger millet in preventing and managing various health conditions, based on the robust evidence gleaned from preclinical research endeavors.

In essence, this review underscores the pivotal role of finger millet as a functional food endowed with substantial potential for enhancing human health and well-being. By synthesizing and analyzing the wealth of data from preclinical studies, the paper not only accentuates the nutritional prowess of finger millet but also delineates its therapeutic prowess, thereby advocating for its integration into dietary regimes and health interventions.

Keywords: Finger millet, *Eleusine coracana*, superfood, therapeutic activities, preclinical studies, nutritional composition, antioxidant, anti-diabetic, anti-inflammatory, anti-cancer, functional food.

INTRODUCTION

Millets are cultivated as minor seeded grasses and are known as cereal grains or crops around the globe. Finger millet (Ragi), Pearl millet (Bajra), Foxtail millet (Kakum), Proso millet (Chena), sorghum (Jowar), Kodo millet (Kodon), Little millet (Kutkki), Barnyard millet (Sanwa) and brown top millet are examples of different types of millet and each are having different nutritional composition.

They are treated as significant crops and an important staple food in different parts of eastern and central Africa and India. 2023 is considered as International Year of Millets and has widely gained global attention toward millets and their health benefits to the body. Millets are nutraceuticals and are a vital part of Indian foods. Finger Millet is a prime millet crop with nutritional, therapeutic, and commercial importance, is a gluten-free grain, and it is most commonly named Mandua or Ragi. ⁽¹⁾

Ragi or finger millet is one of the common millets in several regions of India. ⁽²⁾ India is the largest producer of various kinds of millet. Out of the total minor millet produced, finger millet accounts for about 85% of production in India. ⁽³⁾ Its annual production is at 4.5 million tons where 2.5 million and 1.2 million tons are produced in Africa and India, respectively. ⁽⁴⁾ Finger Millet consists of different varieties like black, reddish-brown, and white. As it is a rich source of calcium, it strengthens bones and teeth. It has potential health benefits in all age groups and people with chronic diseases, the grains contain zinc (Zn), amino acids, and vitamin B complex. Finger Millet contains antioxidant properties such as polyphenols that protect the body against degenerative diseases. ⁽⁵⁾

ABOUT THE PLANT *Eleusine coracana* (Finger Millet)

Scientific classification of *Eleusine coracana*

KINGDOM – Plantae

ORDER – Poales

FAMILY - Poaceae / grass family

GENUS – *Eleusine*

SPECIES - *Eleusine coracana*

MORPHOLOGICAL CHARACTERISTICS OF PLANT

***Eleusine coracana*:**

Leaves: Leaves are narrow, grass-like. Leaf blades are linear to linear-lanceolate, up to 70 cm long and 20 mm wide. ⁽⁶⁾

Flowers: The flowers consist of a group of digitally arranged spikes referred to as a finger. ⁽⁷⁾ Flowers are digitate, sometimes with one or more racemes some distance below the main cluster of 4-19 branches. Inflorescence shape is variable. ⁽⁶⁾

Stems: It is an annual herbaceous cereal crop, growing to 30-150 cm in height and maturation starts in 75-160 days. ⁽⁷⁾ Plants are tufted, erect, or with geniculately ascending culms that are up to 165 cm high. ⁽⁶⁾

Roots: The shallow root system is fibrous and strong, difficult to pull out. Sometimes roots emerge from the lower nodes. ⁽⁸⁾

Seeds: Finger millet grain is essentially spherical in shape, about 1–2 mm diameter with an average 1000 kernel weight of 2.5 g. ⁽⁹⁾ The grain is white, red, brown, or black; more or less globose, with the surface finely striated. ⁽⁶⁾

GEOGRAPHICAL LOCATIONS:

The earliest report of finger millet comes from Hallur in Karnataka India dating approximately 2300 BC. ⁽⁸⁾ It is cultivated in various parts of India and the entire world. In India, finger millet is mostly produced in southern parts and hilly areas like Karnataka, Andhra Pradesh, Tamil Nadu, and mostly in Uttarakhand. In today's world, about 12% of the total millet area is under Finger millet cultivation, which mainly covers more than 25 countries in Asia and Africa. ⁽⁷⁾

Finger millet is grown in India, Sri Lanka, Nepal, and parts of Africa, Madagascar, Malaysia, Uganda, and Japan. In India, finger millet is produced in 1.98 million tones and is cultivated over an area of 1.19 million hectares. Karnataka accounts for 56.21 and 59.52% of the area of production. In Karnataka, finger millet is principally grown in Tumakuru, Chikkaballapura, Mandya, Chitradurga, Bengaluru Rural, Hassan, Ramanagara, Kolar, Chikkamagaluru, Mysuru, Chamarajnar, Bengaluru Urban and

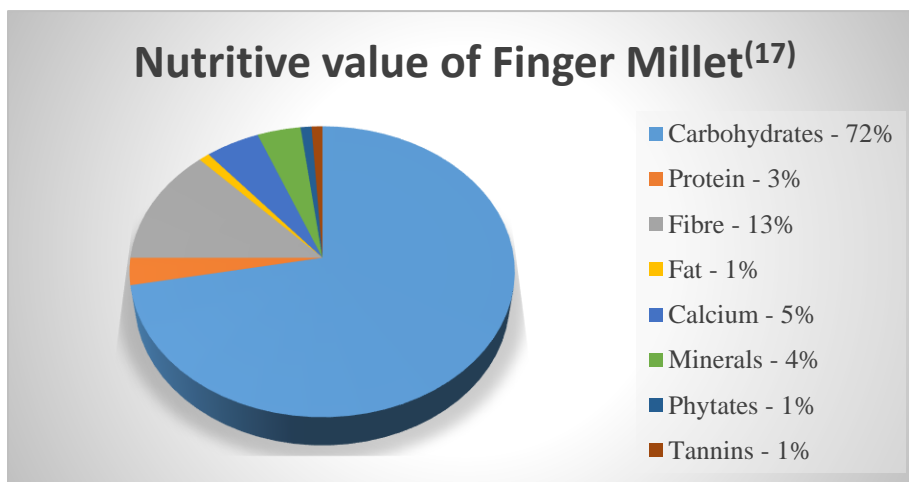
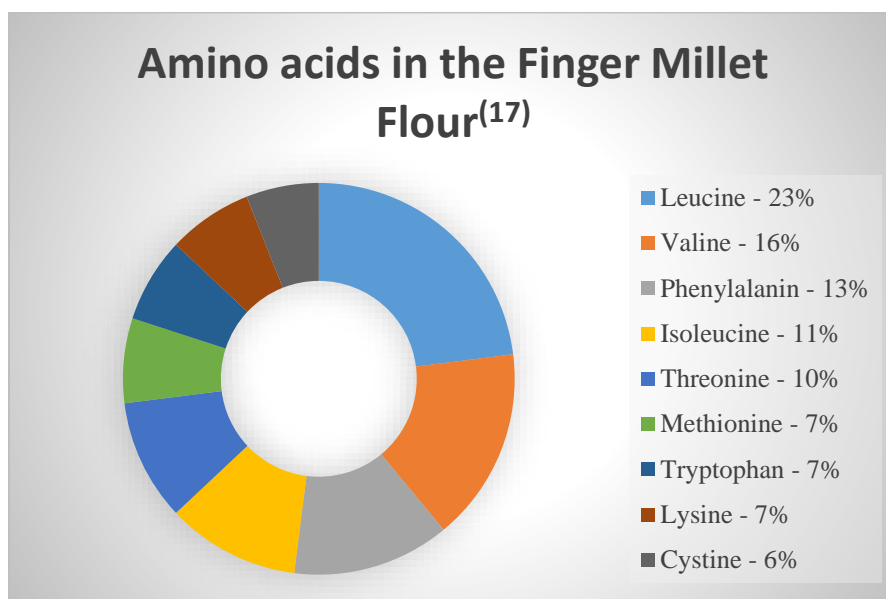
Davanagere districts. ⁽¹⁰⁾ There are more species of *Eleusine* in the south of Asia than in any other part of the world, also *E. coracana* is of Indian origin, and that it was later introduced into East Africa. ⁽¹¹⁾

CHEMICAL CONSTITUENTS FOUND IN *Eleusine coracana*:

Finger millet is an excellent source of dietary fiber, micronutrients, and polyphenols, carbohydrates comprised of free sugars, starch, and non-starchy polysaccharides consisting of cellulose and hemicellulose. ⁽¹²⁾ According to previous studies, preliminary phytochemical screening and studies revealed the presence of carbohydrates, proteins, crude fiber and

minerals, polyphenolics (flavonoids and tannins), steroids, saponins, and triterpenes. ⁽¹³⁾ The seed coat of the millet is an edible component of the kernel and is a rich source of phytochemicals. ⁽¹⁴⁾ Finger millet contains 44.7% essential amino acids ⁽¹⁵⁾ of the amino acids. Among all of the cereals and millet, finger millet has the highest amount of calcium and potassium. ⁽⁷⁾

It is reported that finger millet is a very good source of a variety of polyphenols, they are phenolic acid and tannins while flavonoids are present in small quantities. Finger millet is considered one of the most nutritious cereals. ⁽¹⁶⁾



THERAPEUTIC ACTIVITIES:

Eleusine coracana helps for healthy bones and teeth and the prevention of osteoporosis, It Helps in Controlling Diabetes by activating insulin, reducing skin Aging, and making the skin tissues less prone to wrinkles and sagging. It's also one of the very few natural sources of Vitamin D, an excellent source of natural iron and thus treats anemic conditions, and helps in dealing with anxiety, depression, and insomnia. It is also useful for migraines. ⁽¹⁵⁾ Finger millet is a remedy for leprosy and liver disease. It also works in curing measles, pneumonia, and smallpox. It is also known for several health benefits such as anti-diabetic, anti-tumorigenic, and atherosclerogenic effects, antioxidant, and antimicrobial properties. As Finger millet does not contain gluten, it is highly recommended or advisable for celiac patients. ⁽⁷⁾

Natural Immunomodulator – Biological activities of purified arabinoxylans (AX) from the finger millet bran were evaluated for their immune-stimulatory activities using murine lymphocytes and peritoneal exudate macrophages. Arabinoxylans displayed significant p2 fold and macrophage phagocytosis. The results documented that the immunostimulatory activity of purified arabinoxylans is directly proportional to the amount of ferulic acid content. Thus, Purified arabinoxylans from the finger millet bran can be explored as a potent natural immunomodulator. ⁽¹⁸⁾

Antimicrobial activity – The polyphenols in finger millet showed the proliferation inhibitory activities on *Escherichia coli*, *Bacillus cereus*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Streptococcus pyogenes*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Serratia marcescens*, *Klebsiella pneumonia*, and *Yersinia enterocolitica*. Quercetin inhibited the growth of all the bacteria strains used whereas gallic, ferulic,

proto-catechuic, and p-hydroxy benzoic acids confined activity only to a few bacterial strains, namely *E. coli*, *B. cereus*, *S. aureus*, *Y. enterocolitica* and *L. monocytogenes*. The growth of these pathogenic bacteria was substantially inhibited by Quercetin revealing the potential nutraceutical properties of the polyphenols present in millets. From the study, it could be concluded that finger millet polyphenols could be used as a natural source of antioxidants, especially for minimizing the risk of diseases arising from oxidative deterioration. ⁽¹⁹⁾

Cataractogenesis – The accumulation of sorbitol mediated by the action of enzyme aldose reductase (AR) leads to the diabetes induced cataract. Finger millet was evaluated for AR-inhibiting activity because of the presence of Finger millet polyphenols (FMP) which is a major anti-diabetic and antioxidant component. Phenolic constituents in FMP such as gallic, p-hydroxy benzoic, protocatechuic, p-coumaric, syringic, vanillic, trans-cinnamic acids, ferulic, and quercetin inhibited cataract eye lens effectively, the aldose reductase was inhibited by Finger millet seed coat polyphenols (SCP) reversibly by non-competitive inhibition. This result provides stronger evidence for the potential of FMP in preventing cataractogenesis in humans. ⁽²⁰⁾

Colorectal carcinoma and breast cancer – Finger Millet is a rich source of dietary fiber, tannins, phenolic compounds, and calcium. The effect of phenolic compounds present in Finger Millet on colorectal carcinoma and breast cancer cell lines was studied and was found that the phenolic fractions exhibited ferric ion reduction ability and DPPH radical scavenging potential. Finger millet-free phenolic compound exhibited better cytotoxic potential compared to finger millet-bound phenolic compound when tested against breast cancer cell lines. Hence the study indicated the strength of finger millet-free and bound

phenolic compounds for exhibiting antioxidant properties, and the potential to modulate the proliferative potential of breast and colorectal cancer cells. ⁽²¹⁾

Finger millets and antiaging – A balanced diet with nutritional supplements incorporated into daily routine helps in the facilitation of enhanced lifespan and health of a human being. So far numerous phytochemicals have been revealed for delaying aging and age-related diseases. Among all cereals, millets are an important source of proteins, carbohydrates, minerals, and low fat content which indicates their use in the regular diet for a healthy life. The anti-aging factor of millets is well recognized due to the presence of total phenolics, flavonoids, and other natural compounds in large amounts, which will aid in the slowdown of the aging process and combat age-related diseases. The exploration of millets for the identification, isolation, and characterization of bioactive molecules is critical for their future use in delaying the aging process. More studies on the influence of characterized bioactive compounds can be determined in in-vitro systems (cell- or tissue-specific manner) followed by animal models to rule out any possibility of safety concerns. Finally, the therapeutic potential of bioactive compounds will be evaluated for their future use in personalized medicine. ⁽²²⁾

Anti-inflammatory and antioxidant activities - The prevalence of inflammatory-mediated diseases and oxidative stress-associated diseases is increasing worldwide. Arachidonate 5-lipoxygenase (A5-LOX) is a key enzyme involved in the biosynthesis of potent mediators of inflammatory disorders and allergic reactions. The formation of leukotrienes is catalyzed by arachidonic acid. In a study, various varieties of ragi like Ravi, Rawana, and Oshadha finger millet were studied to determine invitro arachidonate 5-lipoxygenase (A5-LOX), hyaluronidase,

xanthine oxidase (XO), and oxidative burst inhibitory activities, and antioxidant properties using methanolic and ethanolic extracts. Among all the extracts, the highest A5-LOX and XO were exhibited by the methanolic extract of Oshadha. The findings indicated the potential of using these finger millet extracts as natural sources of anti-inflammatory agents. Additionally, it is indicated that the Ravi, Rawana, and Oshadha varieties are good sources of antioxidants. ⁽²³⁾

Anticancer – The body can be protected against cancer by incorporating healthier and protective food. By dietary measures, the frequency or degree of tumorigenesis and spread can be reduced. Finger millet possess a wide-range of anti-carcinogenic potential by acting as free radical terminators and ROS. The process of cancer initiation and progression can be terminated by the regular use of millets due to the presence of phenols, phytates and tannins. ⁽²⁴⁾

Cardiovascular disease (CVD) – Finger Millet provides valued protection against CVDs such as strokes or heart attacks by lowering lipid peroxidation, which decreases arteriosclerosis. Supportive evidence states that a multigrain-formulated diet including finger millet effectively controls lipids and exerts antioxidant mechanisms in high cholesterol-induced rat models. Oxidative stress can be inhibited by the phenolic compounds present in the finger millet. The reabsorption of the bile acids (biosynthesized by the cholesterol) can be reduced by the soluble dietary fibers that reduce the LDL cholesterol levels. The anti-hypercholesteremic metabolites namely statin block the pathway for synthesizing cholesterol in the liver and thus inhibiting cholesterol formation.

The bad cholesterol level can be lowered by the high diet of fiber and complex carbohydrates present in finger millet. The

ferulic acid present in the Finger millet is known to decrease cholesterol levels. Thus by incorporating finger millet in the diet will help to reduce the risk of hypertension, atherosclerosis, etc. ⁽²⁴⁾

Improve bone health and prevent osteoporosis – Osteoporosis is a most common bone disorder that is chronic, metabolic, and progressive. It is characterized by a decrease in density of the bone and an increase in bone fragility which results in the risk of bone fracture. The study is conducted to reduce such conditions using dietary supplements like Finger millet. Various literature, and scientific materials like *Asthiikshaya*, *Ayurveda* literature, research papers, journals, and online databases regarding Osteoporosis, millet, and other relevant topics are reviewed for the study. In the result section it was mentioned that the supplements such as calcium and vitamin D are required to prevent osteoporosis and osteopenia. Finger millet is a rich source of calcium, vitamin D, phosphorous, vitamin B12, etc. and also it is easily digestible. *Kashaya rasa Madhur, tikta, Madhur vipak ushna virya, of ragi, kangani, and bajra* are also mentioned in the ayurvedic text which helps in balancing vata dosha which is helpful in asthiikshaya. Finger millets contribute to high bioavailability and high calcium retention of calcium and could be useful for bone health, growth, and a decrease in depletion of bone tissue. ⁽²⁵⁾

Wound Healing – The *Eleusine coracana* was investigated for its wound-healing properties. The crude extracted was prepared using ethanol as solvent by maceration and wound healing property was evaluated using the Chorioallantoic Membrane Model (CAM) at different concentrations like 50mg, 100mg, 150mg, and 200mg/ml with the basic Fibroblast Growth Factor (bFGF) as the positive control. Further fractionation of crude

extract was done into Hexane, Methanolic, and Aqueous fractions and then subjected to amino acid content analysis using the Amino Acid Analyzer. The good wound healing property is observed by the increase in percentage angiogenesis at all doses of the extract. The amino acid analysis revealed the presence of glycine, a proline that is important in wound healing. The *E. coracana* seeds, therefore, have wound-healing properties based on the CAM model. ⁽²⁶⁾

Control Diabetes – Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. A study investigated the role of finger millet-enriched probiotic fermented milk in reducing diabetes in streptozotocin-induced diabetic rats. The rats were divided into 6 groups each containing 6 Sprague Dawley rats, in which 2 were control groups and others were tested. The 4 test (diabetic) groups were fed with probiotic fermented milk, finger millet-enriched probiotic fermented milk, finger millet flour, or metformin (standard drug). (The probiotic strain used for fermentation was *Lactobacillus helveticus* MTCC 5463 orally) for four weeks. The results of this study concluded that the fasting blood glucose level of diabetic rats who received finger millet-enriched milk was significantly decreased (64.26%) compared to metformin (56.43%) and diabetic groups receiving the probiotic fermented milk (18.88 %) and finger millet flour (47.14 %) after four weeks of treatment. Also, the symptoms like polyphagia and polydipsia were significantly ameliorated in diabetic rats after 4 weeks of treatment. Histological observations of pancreatic tissues and liver showed that the enriched milk prevents more severe changes in the acinar cells and ameliorates the inflammation and alteration in the liver structure to some extent. Therefore, the finger millet-enriched probiotic fermented milk can be a potential functional

food in the management of diabetes. ⁽²⁷⁾

Hepatoprotective activity – The study was performed to evaluate the hepatoprotective activity of different extracts of grains of finger millet against Carbon tetrachloride (CCl₄) induced hepatotoxicity in rats. The extracts of finger millet were prepared using n-hexane, ethyl acetate, butanol, and ethanol as solvents. Finger millet reduced the CCl₄-induced changes in biochemical parameters which was evident by enzymatic examination, hence it is indicated that finger millet exhibited significant hepatoprotective activity. The extracts at an oral dose of 500 mg/kg lowered the serum glutamate pyruvate transaminase (SGPT), alkaline phosphatase (ALP), serum glutamate oxaloacetate transaminase (SGOT), and total protein exhibiting a significant hepatoprotective effect. The activity exhibited by the extract was comparable to the standard drug, Silymarin administered 100 mg/kg, p.o. Histopathological investigation revealed that the treatment with finger millet extracts protected the animal from liver damage induced by CCl₄. The results indicate that the different extracts of Finger millet grains possess hepatoprotective activity on CCL₄-induced hepatic injury in rats. ⁽¹³⁾

CONCLUSION

Finger millet is an ancient grain that offers a wealth of health benefits. Finger millet is not only a staple food but has a wide range of therapeutic activities ranging from diabetes management to heart health and beyond, such as hepatoprotective, anticancer, and wound healing, improved healthy growth, and prevention of osteoporosis, it is a natural immunomodulatory and helps in improving the skin and reduces aging as it has antioxidant and anti-inflammatory activity. Finger millet stands out as a nutrient-packed superfood that deserves a place in our daily diets, as it provides various vitamins, proteins, and amino acids to our body, improving our health.

Incorporating finger millet into our daily diets can pave the way for a healthier and more nourished future.

Declaration by Authors

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