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Research Article

Finger Millet as a Sustainable Nutritional Source: Health Benefits and Agronomic Potential

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ABSTRACT

Finger millet (*Eleusine coracana*) is a nutrient-dense cereal grain that has been cultivated for centuries, particularly in semi-arid regions of Africa and Asia. As the global population grows and climate change intensifies, there is an urgent need for sustainable agricultural practices and nutritious food sources. This research investigates finger millet as a viable solution, emphasizing its health benefits and agronomic potential. Nutritionally, finger millet is an excellent source of essential nutrients, including high levels of calcium, iron, and dietary fiber, making it particularly beneficial for addressing malnutrition and promoting health. Its low glycemic index and high antioxidant content contribute to its role in managing diabetes, cardiovascular diseases, and digestive health. Additionally, finger millet's gluten-free nature makes it suitable for individuals with celiac disease or gluten sensitivity, expanding its market potential. From an agronomic perspective, finger millet exhibits remarkable resilience, requiring minimal water and thriving in poor soil conditions. This adaptability positions it as an important crop in sustainable agriculture, especially in areas prone to drought and food insecurity. The crop's short growth cycle allows for multiple harvests per year, maximizing yield and ensuring food availability.

Keywords – Ayurveda, Finger millet, Nutrition, Agronomic potential, Malnutrition,

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1. Introduction

Finger millet (*Eleusine coracana* L.) is a significant grain widely cultivated in various regions of India and Africa, where it serves as a staple food for a large portion of the population. In India, it ranks sixth in production, following wheat, rice, maize, sorghum, and bajra. Known as *ragi* in South India, finger millet is highly valued for its exceptional nutritional content, surpassing other cereals like barley and rye. It is particularly rich in minerals, dietary fiber, and essential amino acids.ⁱ In rural areas, especially in South India, *ragi* is a primary food source due to its nutritional benefits. Among all cereals, finger millet stands out for its high calcium content, along with its abundance of antioxidants and phytochemicals. The grain is also noted for its significant dietary fiber content, which plays a crucial role in regulating blood sugar levels, making it beneficial for diabetic patients. Additionally, finger millet is advantageous for those suffering from cardiovascular diseases, cancer, and cognitive disorders.ⁱⁱ

Climate change and population growth pose challenges to food security. Major crops such as maize, wheat, and rice are expected to face yield reductions due to warming in the coming years, highlighting the need for incorporating climate-resilient crops in agricultural production systems. Finger millet (*Eleusine coracana* (L.) Gaertn) is a nutritious cereal crop adapted to arid regions that could serve as an alternative crop for sustaining the food supply in low rainfall environments where other crops routinely fail.ⁱⁱⁱ

As a small-seeded crop, finger millet belongs to a group of cereals used for both human consumption and fodder. It thrives in the semi-arid tropical regions of Africa and Asia, particularly in countries like Nigeria and India, which together account for 97% of global millet production. These crops are well-suited to dry, high-temperature conditions and require minimal water, making them an ideal choice for regions with limited water resources.

Millet varieties vary in form, nutritional composition, and texture. Some of the well-known types include finger millet, pearl millet, foxtail millet, proso millet, sorghum, kodo millet, and brown top millet, each offering unique nutritional benefits. There is a belief that both India and Africa have a long history of cultivating millets, which have been an integral part of their diets for thousands of years. Millets have been grown for over 10,000 years in East Asia, and the term "millet" is derived from the French word *mille*, meaning "thousand," as a single handful of millet grains can contain up to 1,000 seeds.^{iv} The agricultural sector faces colossal challenges amid environmental changes and a burgeoning human

population. In this context, crops must adapt to evolving climatic conditions while meeting increasing production demands.^v

Millets belong to a group of small-seeded, annual cereal plants, and their cultivation has played an essential role in global food systems due to their resilience and nutritional value.^{vi}

2. Overview of ragi (*Eleusine coracana*)



Finger millet image^{vii} Finger millet (*Eleusine coracana*) belongs to the Poaceae family and is commonly known as *Mandua* or *Ragi* in India. The grain consists of an embryo and endosperm, encased in a seed coat called the testa. Finger millet is available in a range of colors, including white, tan, red, yellow, violet, and brown. The red variety is particularly widespread and is cultivated in various countries, including Sri Lanka, Nepal, Madagascar, Malaysia, Uganda, Japan, different parts of Africa, and India. Finger millet is grown in 25 countries across Asia and Africa, occupying around 12% of the area designated for millet cultivation. In India, finger millet is cultivated on approximately 1.19 million hectares, producing 1.98 million tons, with an average yield of around 1,661 kg per hectare. It is a vital food source in regions like South Karnataka.

One of the key benefits of finger millet is that it is gluten-free, making it an excellent option for individuals with gluten allergies or those suffering from abdominal issues. In developing countries, there is significant potential to process and transform millet grains into value-added products, benefiting both local economies and public health, particularly in India.^{viii}

3. Nutritional Composition of Finger Millet

Finger millet is notably rich in micronutrients, particularly vitamins and minerals compared to other major cereals like wheat and rice. The nutritional composition of finger millet is as follows:^{ix}

Composition (per 100g grain) of nutrients in Finger millet.

Finger millet Nutrients	Amount
Protein (g)	7.3
Fat (g)	1.3
Carbohydrate (g)	72.6
Crude fiber (g)	3.6
Ash (g)	3
Calcium (mg)	344
Iron (mg)	3.9
Zinc (mg)	2.3
Thiamin (mg)	0.42
Riboflavin (mg)	0.19
Niacin (mg)	1.1

4. Agronomic potential

Finger millet is considered as a special food supplement because of its high nutritional contents in comparison to other important cereals. It mainly consists of minerals, dietary fiber, and important amino acids. In different parts of our country, especially in South India, the rural population uses finger millet (*Eleusine coracana*), popularly known as ragi, as their principal food. There is a belief that India and Africa have an evolutionary millet and include it as food staples. For the last 10,000 years, millets have been cultivated in East Asia. The term millet is derived from the French word Mille, which means thousand, with a handful of millet containing up to 1000 grains. Millet belongs to the group of small-seeded species of cereal crops or grains, which are annual plants.

Ragi, among all cereals, contains greater calcium antioxidants and phytochemicals. The finger millet grain

possesses a high content of total dietary fiber among other cereal grains that is extremely beneficial in controlling blood glucose levels in diabetic patients. Besides, it is also helpful to patients suffering from cardiovascular disease, cancer, and other cognitive diseases.^x

These small seeded crops form an agronomic functional group and are used as human food. Semi-arid tropical regions of Africa and Asia especially Nigeria and India are the producer of millets with 97% productivity. It is favorable under dry and high-temperature conditions and these crops require little amount of water. Millets are found in different forms and differ from each other by their unique nutritional value, traits, and texture. Finger millet, Pearl millet, Foxtail millet, Proso millet, sorghum, Kodo millet, and brown top millet are examples of different types of millet having different nutritional composition.^{xi}

5. Processing of Finger Millet

Processing Technique	Description	Key Benefits	Key Outcomes
Soaking	Soaking in water (1:10 ratio) for 1-2 days at room temperature to reduce anti-nutrients.	Reduces trypsin inhibitors, polyphenols, phytic acid, saponins, and oxalates.	Improves nutritional quality, bioavailability of minerals, reduces anti-nutrients (e.g., tannins).
Fermentation	Microbial conversion of complex molecules into simpler ones.	Reduces anti-nutrients (tannins, trypsin inhibitors, phytic acid). Improves amino acid composition and vitamin content.	Increased protein digestibility, enhanced mineral content (zinc, calcium, iron), improved vitamin B (e.g., riboflavin, niacin).
Decortication	Hydrothermal processing (hydrating, steaming, and drying) to remove seed coat and harden the endosperm.	Enables processing of millet into grains similar to rice.	rich in phenolic compounds, minerals, and fiber.
Malting	Germination process converting starch into simpler sugars.	Increases amylase activity, nutritional value, and reduces anti-nutrient content.	Improved bioavailability of amino acids, vitamins, and minerals. Increased energy density in malt flour.
Popping	High-temperature, short-time treatment using sand to burst the endosperm.	Produces ready-to-eat products with enhanced flavor and texture.	Popped millet is high in fiber, more digestible, and has a distinct flavor and aroma.
Milling	Removal of seed coat through dehusking and debranning, followed by grinding.	Makes grain consumable, retains nutrients, and reduces the fibrous husk.	Produces flour suitable for dietary products; increases calcium, polyphenols, and fiber content.
Roasting	Heating grains at a moderate temperature (e.g., 125°C for 10 minutes) to enhance flavor.	Reduces anti-nutrient factors, improves storage life, and enhances flavor.	Improved bioavailability of iron, calcium, and protein. Slight decrease in viscosity.

Germination	Soaking and sprouting of millet to enhance nutritional value.	Reduces anti-nutrients (e.g., phytic acid, trypsin inhibitor), increases lysine, methionine.	Increased amino acid content, better mineral bio-accessibility, and reduced anti-nutrient levels.
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Chart - Processing of Finger Millet^{xii}

6. Potential Health Benefits of Finger Millet

6.1 Diabetes Management

The phytochemicals in finger millet help slow down the digestion process which helps to control the blood sugar level and enhance antioxidant levels in the body. Finger millet contains more fiber than wheat and rice and has a lower glycemic response, which means it has a reduced ability to increase blood sugar levels and absorb starch.^{xiii} Finger millet (ragi) can be a beneficial food for diabetes management due to its unique nutritional properties. It has a low glycaemic index, is rich in fiber, and contains essential nutrients that help regulate blood sugar levels.

6.2 Celiac diseases

Celiac disease is an immune-related condition triggered by the absorption of gluten in genetically predisposed individuals. Since finger millet is gluten-free, it serves as a suitable alternative for people with celiac disease or those sensitive to gluten, as well as individuals who avoid the gluten found in wheat and other cereal grains.^{xiv}

6.3 Anemia

Finger millet is high in iron and is commonly included in diets to help treat anemia and combat malnutrition.^{xv} Anemia, especially iron-deficiency anemia, occurs when there is a lack of iron in the body, resulting in reduced red blood cell production and poor oxygen transport to tissues.

Finger millet can help address iron-deficiency anemia for several reasons:

- **High Iron Content:** Finger millet is a good source of iron, which is crucial for the formation of hemoglobin in red blood cells.
- **Bioavailability:** Although the iron in plant-based foods is non-heme (which is less easily absorbed by the body compared to animal-based heme iron), pairing finger millet with vitamin C-rich foods (like citrus fruits, tomatoes, or leafy greens) can improve iron absorption.
- **Additional Nutrients:** Finger millet is also rich in other nutrients like calcium and fiber, which contribute to overall health and can support recovery from anemia.

6.4 Dietary fiber

Fiber Content: Finger millet contains around **3–5 grams of dietary fiber per 100 grams** of the grain (this can vary slightly based on preparation methods). Ragi (finger millet) is an excellent source of dietary fiber. It contains both soluble and insoluble fiber, which contribute to various health benefits.^{xvi}

Types of Fiber:

1. **Insoluble Fiber:** This type of fiber helps improve digestion by adding bulk to stool and promoting

regular bowel movements. It can also aid in preventing constipation and supporting gut health.

2. **Soluble Fiber:** Soluble fiber can help lower cholesterol levels and regulate blood sugar levels. It also aids in weight management by promoting a feeling of fullness and helping to control appetite.

6.5 Bone Health

Ragi (finger millet) is highly beneficial for bone health due to its rich calcium content. It is one of the best plant-based sources of calcium, which is essential for maintaining strong bones and preventing bone-related conditions like osteoporosis.^{xvii} Finger millet (ragi) is highly beneficial for bone health, thanks to its rich nutrient profile, especially its high content of calcium, magnesium, and phosphorus. These minerals are essential for maintaining strong bones and preventing conditions like osteoporosis. Here's how finger millet supports bone health:

1. High Calcium Content

- Calcium is one of the most important minerals for bone health, as it helps in the formation and maintenance of bone structure and density.
- Finger millet is an excellent plant-based source of calcium. 100 grams of finger millet contains about 350-370 mg of calcium, which is significant compared to other grains.
- Regular consumption of finger millet can help in meeting the body's calcium requirements, especially for those who avoid dairy products.

2. Magnesium

- Magnesium plays a vital role in bone formation, working alongside calcium to strengthen bones.
- Finger millet provides a good amount of magnesium, which helps maintain bone density and promotes the absorption of calcium.
- Magnesium also supports muscle function, which is important for overall mobility and preventing falls or injuries that can affect bone health.

3. Phosphorus

- Phosphorus is another mineral that contributes to bone health by forming part of the bone matrix.
- Finger millet contains a reasonable amount of phosphorus, which works with calcium to build and repair bones.

4. Rich in Antioxidants

- Finger millet is rich in **antioxidants**, including phenolic compounds, which help combat oxidative stress and inflammation, both of which can negatively impact bone health over time.
- The antioxidants also support the body's ability to repair damaged bone tissue and prevent the breakdown of bone cells.

5. Vitamin D Support

While finger millet itself doesn't contain significant amounts of Vitamin D, it is often consumed with foods rich in this vitamin or through sunlight exposure, which helps in calcium absorption and bone health.

6.6 Weight Management

Ragi (finger millet) can be an effective part of a weight management plan due to its high fiber content, low glycemic index, and nutrient-dense profile. The fiber in ragi promotes a feeling of fullness, reducing overall calorie intake by preventing overeating.^{xviii}

6.7 Cardiovascular Health

The amino acids found in finger millet Methionine, threonine, and lecithin help eliminate excess fat from the liver, lower cholesterol levels, and prevent fat formation. Additionally, finger millet has a low concentration of serum triglycerides, reducing the risk of cardiovascular disease by lowering plasma triglyceride levels.^{xix}

6.8 Anti-aging

Finger millet (ragi) can play a significant role in promoting anti-aging benefits due to its rich nutrient profile, which includes antioxidants, minerals, and vitamins that help protect the skin and body from the effects of aging. Finger millets are rich in antioxidants and phenolic compounds, which are essential for maintaining good health, slowing aging, and managing metabolic syndrome.^{xx} They help prevent the cross-linking of collagen and glycation, both of which contribute to the aging process.^{xxi}

6.9 Anti-inflammatory Properties

Finger millet (ragi) has anti-inflammatory properties, which can help reduce inflammation in the body. This makes it beneficial for managing conditions associated with inflammation, such as arthritis and other inflammatory disorders.^{xxii} Chronic inflammation contributes to aging, as it accelerates the breakdown of tissues and leads to the development of age-related diseases. Finger millet contains anti-inflammatory compounds that can help reduce inflammation in the body, supporting overall health and preventing age-related deterioration.

6.10 Other health benefits

Consuming finger millet promotes natural body relaxation. Ragi is commonly used to help treat conditions such as depression, insomnia, migraines, and anxiety.^{xxiii} Finger millet (ragi) is a highly nutritious grain with several health benefits beyond those already mentioned and it also support heart health, Digestive health, Boosts immune system and improves skin health.

7. Conclusion

Finger millet (*Eleusine coracana*) holds significant promise as both a sustainable nutritional source and a crop with robust agronomic potential. Its high nutritional value, particularly in terms of essential minerals, fiber, and antioxidants, makes it an ideal food for addressing global malnutrition and dietary deficiencies. Additionally, finger millet's resilience to drought, pests, and poor soil conditions makes it an environmentally sustainable crop, especially in regions vulnerable to climate change. Its low environmental footprint, coupled with its adaptability to diverse agro-ecological zones, positions it as a key player in ensuring food security. The integration of finger millet into mainstream agricultural practices and dietary habits could enhance global nutrition while contributing to sustainable agricultural systems. Further research into improving yield, disease resistance, and post-harvest processing techniques will unlock its full potential and ensure its contribution to both health and environmental sustainability.

Ragi (finger millet) is a highly nutritious and beneficial grain that offers a wide range of health advantages. Despite finger millet's nutritional qualities and climate resilience, it is deemed an "orphan crop," neglected by researchers compared to major crops, which has hampered breeding efforts. However, in recent years, finger millet has entered the genomics era. Next-generation sequencing resources, including a chromosome-scale genome assembly, have been developed to support trait characterization. Finger Millet is Rich in fiber, antioxidants, essential amino acids, and minerals such as calcium and iron, ragi promotes overall health. It supports weight management, improves bone health, aids in digestion, and helps manage chronic conditions like diabetes and cardiovascular diseases. Its gluten-free nature makes it an ideal option for individuals with gluten sensitivity or celiac disease. Overall, ragi is a valuable addition to a balanced diet, offering both preventive and therapeutic health benefits.

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