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Crop Biofortification of Finger Millet Through Agronomic Approaches to Enhance Bioactive Compounds for Human Health and Nutrition

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ABSTRACT

Finger millet (*Eleusine coracana* L.) is a gluten-free cereal crop widely grown in Africa and Asia, recognized for its rich bioactive compounds and health benefits. It contains high levels of polyphenols, flavonoids, and tannins with potent antioxidant properties, which help neutralize free radicals and reduce oxidative damage. These compounds also have anti-inflammatory effects, potentially lowering the risk of chronic diseases like cancer and cardiovascular diseases. Additionally, finger millet is a valuable source of essential minerals such as iron, zinc, calcium and magnesium, crucial for bone health, cognitive function, and body immune. Its high dietary fiber content aids gastrointestinal health, regulates blood sugar and reduces the risk of type 2 diabetes, obesity and heart disease. Finger millet is particularly high in essential amino acids, making it an excellent protein choice for vegetarians. Agronomic biofortification, which involves adding zinc, calcium, and iron to the soil and leaves of plants can increase the mineral content of the grain. This review investigates different approaches of agronomic biofortification of finger millet and explore the health and nutritional benefits of bioactive components with a focus on their role as a functional diet in the prevention and management of chronic diseases.

Keywords: Bioactive compounds, finger millet, nutrition, health, polyphenol

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INTRODUCTION

The finger millet (*Eleusine coracana* L.) is widely consumed as food, forage, and in various industrial applications. It is a gluten-free cereal crop widely grown in Africa and Asia, however, it is an underutilized crop in tropical and semi-arid regions worldwide. Finger millet can be grown as drought tolerant crops. Its grains are spherical and have a diameter of 1.0 to 1.5 mm (Siwela 2009, Gull et al 2014). It's a coarse grain with multiple culinary uses, including baking, roasting, steaming, frying, boiling, fermentation, and producing alcoholic beverages. Finger millet makes unleavened flatbreads like roti or chapatti, muddle (dumplings), and ambali (thin porridge) for human consumption. Malting is a feature of finger millet that improves vitamin bioavailability and overall nutritional content. It outperforms other cereal crops in terms of nutrition, and millions of economically marginalized people in Africa and Asia consume finger millet as their source of dietary nutrients. Finger millet is a good source of micronutrients such as calcium, zinc, phosphorus, magnesium, iron, carbohydrates, protein, dietary fiber, and vitamin B (Udeh et al 2017). Finger millet contains more dietary fiber and minerals than wheat or rice (Ramashia 2018). It has 5–8% protein, 1–2% ether extractives, 65–75% carbohydrates, 15–20% dietary fiber and 2.5–3.5% minerals. Finger millet has the greatest calcium (344 mg 100 g^{-1}) and potassium content (408 mg 100 g^{-1}) of all the grains and millets (Kumar et al 2016, Reddy et al 2008, Radchuk et al 2012, Gupta et al 2017). This cereal is low-fat (1.3%) and is mainly unsaturated fat. Finger millet has an average calorie content of 336 Kcal per 100 grams and contains several bioactive chemicals. Ferulic acid, quercetin, and ferulic-rich arabinoxylans or feraxans are bioactive substances with significant therapeutic effects (Udeh et al 2017). These mineral contributes various health benefits of finger millet. The Figure 1 indicates the health benefits and bioactive compounds of finger millet.

Agronomic biofortification is required for optimizing and ensuring the success of genetic biofortification of cereal grains with zinc. In case of greater bioavailability of the grain zinc derived from foliar applications than from soil, agronomic biofortification would be a very attractive and useful strategy in solving zinc deficiency related health problems globally and effectively. Agronomic biofortification adds mineral contents in grains of finger millet. As the value of nutrition has been more apparent over time, agronomic techniques have been broadened to enhance the nutritional qualities of crops (Wakeel et al 2018, Malik and Magbool 2020, De Valença et al 2017). The need to enhance and broaden agronomic techniques to enhance crop nutritional properties as indicated by climate changes and the quick depletion of soil nutrients (Siwela et al 2020). Finger millet contains ten times more calcium than brown rice, wheat, or maize, and three times more calcium than milk (Kumar et al 2016). Thus, incorporating finger millet, a grain that is naturally high in calcium, into international biofortification initiatives can be a smart place to start to reduce calcium deficiencies (Sharma et al 2017). There are two ways to achieve biofortification in finger millet; (1) by increasing the amount of nutrients accumulated in milled grains, and (2) by lowering the amount of antinutrients to boost the minerals bioavailability. The phosphorus, calcium, and magnesium contents of finger millet grains were improved by applying Ca + Fe fortified Urea-DAP briquettes. A substantial amount of calcium may be supplied to cereal plants through liming in soil, which can also be used to fortify them. The calcium content of grain was further enhanced by foliar application of Ca in finger millet. Applying foliar spray promotes quick and effective uptake of nutrients and other positively charged particles. The data clearly show that the sulphur content of finger millet was not considerably affected by the soil or foliar application of Ca or Fe from diverse sources. According to Reddy et al (2018), the pores in the cuticles of leaves are capable of absorbing nutrients because they are lined with molecules that are negatively charged. Consequently, these cations absorb relatively more quickly than anions.

This review paper aims to explore the various approaches and the importance of agronomic biofortification to enhance bioactive compounds in finger millet and this study also evaluates the role of these bioactive compounds for human health and nutritional benefits.

Figure 1. Health benefits and bioactive compounds of finger millet

Agronomic biofortification

Agronomic biofortification is a quick and easy way to improve crop nutrition. Agronomic biofortification is performed by applying nutrients to crops to improve their nutrition (Gulave and Kshirsagar 2020, Nanja Reddy et al 2024) either through soil or leaves (Hanumanthappa et al 2018, Mugenzi et al 2018, Kanwal et al 2020) and seed priming (Rehman et al 2011, Haider et al 2018). The goal of agronomic biofortification is to counteract dietary deficits by increasing the micronutrient content of food crops (Panwar et al 2024). The mineral content of grains and fruits may be greatly boosted by adding fertilizers at various phases of crop growth. This strategy focuses on starchy staple crops such as rice, wheat, maize, sorghum, millet, sweet potatoes, and legumes. These crops represent an important element of worldwide diets, especially for communities at risk of micronutrient deficiencies making biofortification an effective strategy to reach malnourished people who have limited access to diversified meals, supplements, or commercially fortified foods (Saltzman et al 2013, Bouis et al 2011).

With the development of several types of specialty fertilizers, such as nano-fertilizers, chelated fertilizers, biofertilizers, and water-soluble fertilizers, which have better nutrient translocation to consumable plant parts and higher plant nutrient use efficiency, the efficacy of agronomic biofortification has increased recently. Agronomic biofortification has little impact on the nutritional value of crops, but they do help to increase crop development and production (Sheoran et al 2022, De Valença et al 2017). There are several research reports being conducted on agronomic biofortification of finger millet using different micronutrients like Iron (Fe) (Y Rani et al 2022, Nanja Reddy et al 2024), Zinc (Zn) (Yamunarani et al 2016, Kaur and Singh 2022, Nanja Reddy et al 2023) and Calcium (Ca) (Sharma et al 2017, Khobragade et al 2022). Zn, Fe, and Ca are crucial for human health and plant growth, and deficiencies can lead to disease, especially in poorer populations. Biofortifying crops with these minerals offers a fast and effective way to enhance their nutritional value (Kaur and Singh 2022). For the country to achieve nutritional security, biofortified varieties are very important. CFMV 2 is one of biofortified variety of finger millet which is rich in calcium (454 mg/100g), iron (39.0 ppm), and zinc (25.0 ppm) (Yadava et al 2017).

In the short run, agronomic biofortification is easy to use and produces results quickly (Wakeel et al 2018, Galić et al 2021). However, the high cost of the mineral fertilizers employed in agronomic biofortification drives up the price of biofortified crops, prohibiting lower-class communities from purchasing them (Cakmak and Kutman 2018). Furthermore, farmers play a major role in agronomic biofortification. Since the application of mineral fertilizers is a routine task, farmers may choose not to undertake it if the process does not yield a profit (Singh et al 2016, Umar et al 2019, DeValença et al 2017). Toxic buildup might also result from the frequent application of mineral fertilizers (Jha and Warkentin 2020 De Valença et al 2017). Furthermore, a rise in the demand for extracted minerals like selenium could lead to environmental harm (Umar et al 2019, De Valença et al 2017).

Approaches of Agronomic Biofortification

Soil application

The application of nutrient rich fertilizers in soil enhance the mineral contents of grains in finger millet. According to a greenhouse experiment, applying 10 mg of $FeSO_4$ kg^{-1} of soil (Aciksoz et al 2011) or 75 $FeSO_4$ kg ha^{-1} (Narwal et al 2010), respectively, to the soil resulted in a 19.4% rise in grain Fe content. When 1% of $FeSO_4$ was applied on leaves during the stem elongation and flowering stages, Pahlavan-Rad and Pessarakli (2009) found a rise in grain Fe concentration of 36%. Zn treatment through the soil increases crop grain production, and foliar spray increases Zn concentration in grains (Haider et al 2018, Nanja Reddy et al 2023).

Although applying micronutrients to crops through the soil is the most popular technique, crop production has been the main focus of testing rather than biofortification. This approach pollutes soil over time due to an excessive buildup of wasted micronutrients and has low micronutrient use efficiency and cost-effectiveness. When using fertilizers for agronomic biofortification, caution must be exercised because improper fertilizer application can have unforeseen, and occasionally severe, effects on crops and the environment. Conversely, a well-balanced fertilization approach yields greater economic and environmental benefits over time. Furthermore, soil microbes are extremely sensitive to fertilization and play a critical role in the soil ecology. A poor fertilization schedule causes a shortage of nutrients, which alters the microbial population in soil. Over time, uneven fertilization can negatively impact the soil's biological health (Sheoran et al 2022, Shahzad Aslam et al 2012). Most mineral fertilizers are sprayed directly onto crop leaves or added to the soil.

Foliar application

Foliar application is better to soil application since there is very little micronutrient loss with this method and the nutrients are absorbed by the plant tissue directly (Johnson et al 2005). Because it boosts micronutrient levels rather than merely increasing production, foliar application is typically more successful than soil application (Singh et al 2016, De Valença et al 2016, Melash et al 2016). Foliar treatment is more cost-effective and useful when crop indications of nutrient deficiencies are apparent (Singh et al 2016, De Valença et al 2017). Since foliar spray avoids soil immobilization, it is often more effective in promoting plant absorption of nutrients. On the other hand, the disadvantages include the potential for rain to wash fertilizers away, as well as increased costs and application complexity (Garcia-Banuelos et al 2014). According to Zou et al (2012), foliar application of zinc increased grain zinc concentration more effectively. Because it is easier to implement, more efficient in using fertilizer, requires less infrastructure, and doesn't require the technical know-how of techniques like nutri priming and soil-less cultivation—which are covered in later sections—foliar application is the most widely used method for micronutrient biofortification. The application of foliar Fe-EDTA during the vegetative growth and blooming stages of finger millet led to an approximately 83% rise in grain Fe concentration, as reported by Manzeke-Kangara et al (2021).

Foliar application is dependent upon a number of variables, such as fertilizer type, crop characteristics, application timing, and environmental conditions (Praharaj et al 2021, Alshaal and EI-Ramady 2017). The foliar treatments are expensive and are readily removed by rainfall (De Valença et al 2017, Galić et al 2021). The way that nutrients are absorbed by leaves during foliar treatments is significantly influenced by their properties. When applied topically, nutrients enter leaf cells through the cuticle and are then transferred by the plasmodesmata to different areas of the leaf. The leaf's permeability, age, and shape all influence how well nutrients are absorbed (Alshaal and El-Ramady 2017). When it comes to crop development, foliar spray works best during the flowering and early milk phases as opposed to the booting and elongation phases. Since foliar nutrition treatment during this time would considerably contribute to enhancing the micronutrient contents of the fruits, blooming and early milk stages are among the earliest phases where absorption of nutrients for fruit development begin (Melash et al 2016). The effectiveness of foliar sprays is influenced by environmental factors such temperature, wind speed, humidity, and time of day (Alshaal and El-Ramady 2017). Early morning and late evening temperatures that are warm and humid encourage the permeability of nutrients, whereas high temperatures and low relative humidity cause the water in sprayed solutions to evaporate, concentrating minerals on surfaces and decreasing their permeability (Alshaal and El-Ramady 2017).

Nutripriming

Soaking seeds in a nutrient-rich solution prior to planting is known as nutripriming or seed-priming. Nutripriming plays a crucial role by ensuring that seeds have a higher initial nutrient load, improving both plant health and nutritional quality of the grains. It boosts the concentration of essential micronutrients such as iron (Fe), zinc (Zn), and calcium (Ca) in finger millet grains, which are vital for addressing malnutrition.These nutrients can be absorbed by the seeds during priming and utilized during the plant's growth. Nutripriming techniques seldom ever lead to grains having more nutritional value (Duffner et al 2014).

The different types of agronomic biofortification of finger millet is given in Figure 2.

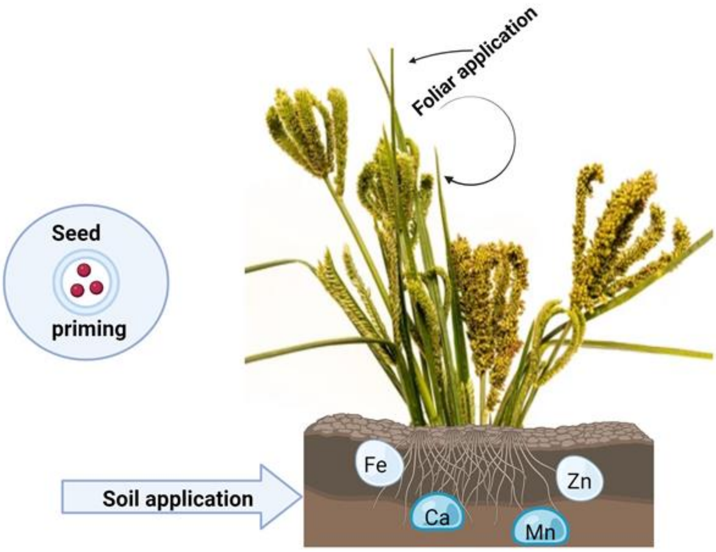


Figure 2: Different types of agronomic biofortification of finger millet.

Bioactive compounds

Minerals

The mineral composition of finger millet grains varies greatly and is influenced by genetic variables and environmental circumstances in the growing region. Regarding nutritional value, finger millet is a good source of nutrients, especially calcium, and iron.

Table 1. Vitamin and mineral composition of cereal grains

Cereals	Ca (%)	P (%)	Mg (%)	Fe (%)	Mn (%)	K (%)	Na (%)	Zn (%)	Thiamin (mg/100 g)	Riboflavin (mg/100gm)	Nicotinic acid (mg/100 g)
Rice	0.02	0.12	0.03	19	12	0.1	0	10	0.07	0.03	1.6
Wheat	0.04	0.35	0.14	40.1	40	0.36	0.04	30.9	0.57	0.12	7.4
Maize	0.03	0.29	0.14	30	5	0.37	0.03	20	0.38	0.14	2.8
Sorghum	0.04	0.35	0.19	50	16.3	0.38	0.05	15.4	0.46	0.15	4.84
Barley	0.04	0.56	0.14	36.7	18.9	0.5	0.02	23.6	0.44	0.15	7.2
Oats	0.11	0.38	0.13	62	45	0.47	0.02	37	0.77	0.14	0.97
Finger millet	0.33	0.24	0.11	46	7.5	0.43	0.02	15	0.48	0.12	0.3
Pearl millet	0.01	0.35	0.13	74.9	18	0.44	0.01	29.5	0.38	0.22	2.7
Proso millet	0.01	0.15	0.12	33.1	18.1	0.21	0.01	18.1	0.63	0.22	1.32
Foxtail millet	0.01	0.31	0.13	32.6	21.9	0.27	0.01	21.9	0.48	0.12	3.7

(Source: Serna-Saldivar 2003)

Finger millet has the highest calcium content among all cereals (344 mg/100 g) and is a good source of other minerals and fiber. The total ash level of finger millet is higher than that of regularly consumed cereal grains, with ash concentrations ranging from 1.7% (Rao 1994) to 4.13% (Rao et al 1973). The contents of minerals and vitamins of different cereal grains are summarized in Table 1. The mineral composition and polyphenol contents change during the finger millet grains' processing (Table 2).

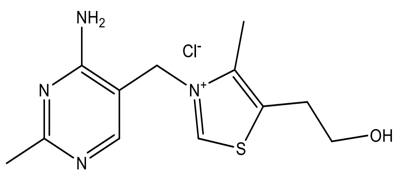
Table 2. Changes in polyphenol content and nutrient composition during the processing of finger millet (g/100 g)

Parameter	Whole flour	Husk	3% flour	5% flour	7% flour	Hyrdrothermally processed	Decorticated
Moisture	7.7	8.7	8.7	8.9	9.7	11.1	10.46
Calcium	0.34	0.64	0.28	0.24	0.14	0.31	0.18
Phosphorus	0.25	0.49	0.19	0.15	0.08	0.157	0.109
Iron	0.003	0.003	0.002	0.002	0.002	0.006	0.003
Protein	7.4	15.4	5.7	4.9	3.5	6.9	4.43
Starch	71.1	30.1	77.8	82.3	89.1	65	74
Phenolic content	7.3	12.6	4.3	3.6	3.3	1.19	0.52
Fat	1.2	3	1.1	1	0.9	1.4	0.9
Acid insoluble ash	0.3	0.5	0.1	0.1	0.1	0.08	0.07
Dietary fiber	22.5	53.3	9.9	6	4.2	21.1	14.7

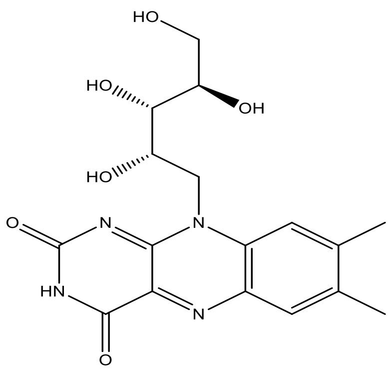
(Source: Shobana and Malleshi 2007, Viswanath et al 2009, Dharmaraj andMalleshi 2011, Devi et al 2014)

Vitamins

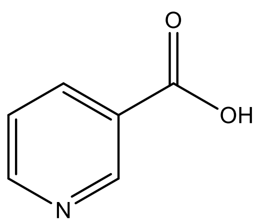
Finger millet is a rich source of thiamin, riboflavin, and nicotinic acid (Table 3). The finger millet grains contain various vitamins, including thiamine, riboflavin, niacin, folic acid, vitamin C, and vitamin A, as illustrated in Figure 3. In addition, finger millet grains are abundant in fat and water-soluble vitamins, particularly vitamins A and B complex. Vitamin B, which plays diverse physiological roles in brain function and proper cell development, is abundant in finger millet. Additionally, Vitamin B has even been linked to a decrease in fatigue.



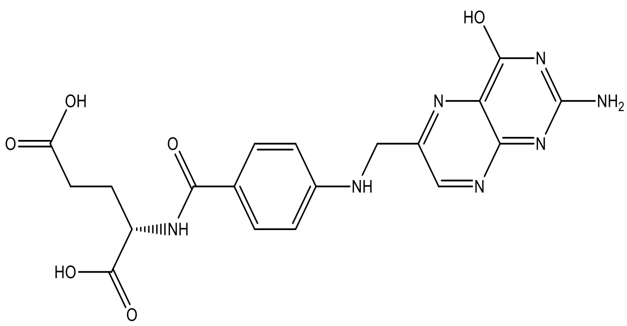
Thiamine



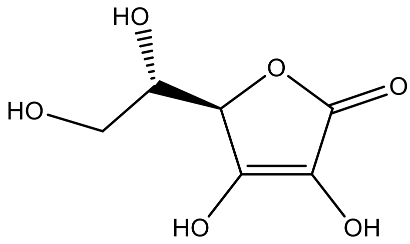
Riboflavin



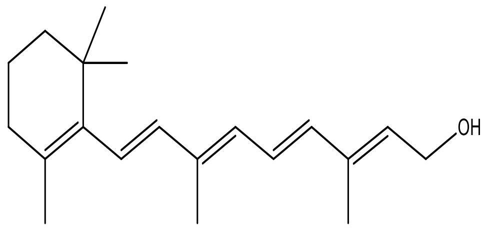
Niacin



Folic acid



Vitamin C



Vitamin A

Figure 3: Structure of vitamins present in finger millet.

Table 3. Major vitamin content and fatty acids of finger millet

Nutrients	mg/100 g	References
Vitamins		
Vit A (Retinol)	6.0	Siwela 2009, Ramashia 2018
Vit B1 (Thiamine)	0.2-0.48	Saleh et al 2013)
Vit B2 (Riboflavin)	0.12	Ramashia 2018, Devi et al 2014
Vit C (Ascorbic acid)	0.0-1.0	Siwela 2009
Niacin	1.0-1.30	Saleh et al 2013)
Fatty acids	g/100 g of total lipids	
Linoleic acid	24.2	Serna-Saldivar 2010)
Linolenic acid	1.3-4.40	Serna-Saldivar 2010, Fernandez et al 2003, Ramashia et al 2018
Palmitic	21.1-24.7	Fernandez et al 2003
Oleic acid	49.8	Serna-Saldivar 2010

Amino acids

Finger millet grains contain essential and non-essential amino acids (Table 4).

Table 4. Essential and non-essential amino acids of finger millet

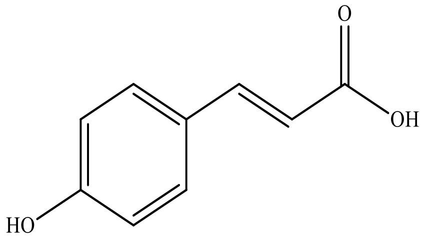
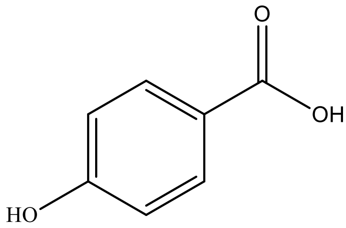
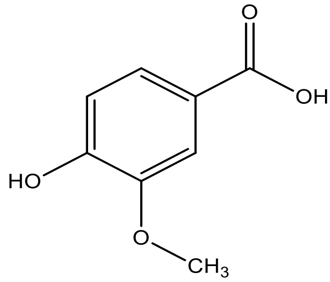
Amino acids	g/ 100 g protein	References
Essential		
Lysine	2.2	Thapliyal and Singh 2015, Ramashia 2018
Tryptophan	1.1-1.5	Serna-Saldivar 2010, Palanisamy et al 2012
Threonine	3.4-4.2	Serna-Saldivar 2010, Palanisamy et al 2012
Methionine	2.5-3.1	Serna-Saldivar 2010, Palanisamy et al 2012
Phenylalanine	4.1-5.2	Siwela 2009, Serna-Saldivar 2010, Amadou et al 2013
Histidine	2.2	Serna-Saldivar 2010
Isoleucine	4.3	Thapliyal and Singh 2015, Ramashia 2018
Leucine	6.6-9.5	Sarna-Saldivar 2010, Palanisamy et al 2012
Valine	4.9-6.6	Fernandez et al 2003, Serna-Salidivar 2010
Non-essential		
Glycine	2.14-4.0	Fernandez et al 2003, Serna-Salidivar 2010
Cystine	1.7-2.6	Siwela 2009, Serna-Saldivar 2010
Serine	3.6-5.1	Fernandez et al 2003, Serna-Salidivar 2010
Alanine	6.1-6.2	Serna-Saldivar 2010, Amadou et al 2013
Arginine	2.77-4.5	Fernandez et al 2003, Serna-Salidivar 2010
Tyrosine	2.79-3.6	Fernandez et al 2003, Serna-Salidivar 2010
Proline	7.0-9.9	Serna-Saldivar 2010, Amadou et al 2013
Aspartic acid	6.5-7.9	Fernandez et al 2003, Serna-Salidivar 2010
Glutamic acid	20.3-27.1	Fernandez et al 2003, Serna-Salidivar 2010

(Source: Ramashia et al 2019)

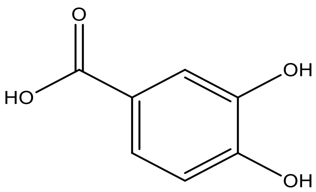
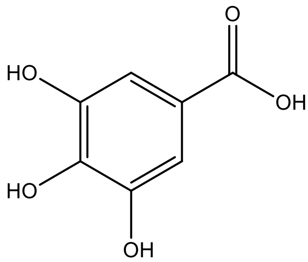
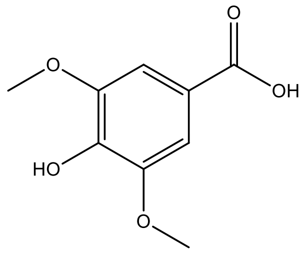
The grains are a rich source of methionine, cysteine, Tryptophan, lysine, isoleucine, leucine, phenylalanine, and threonine. Finger millets contain significant amounts of methionine and cysteine, as well as threonine, Tryptophan, isoleucine, and valine (Belton and Taylor 2002).

Phenolic compounds

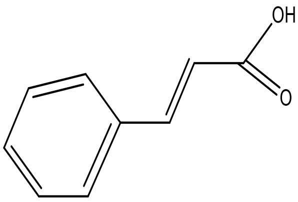
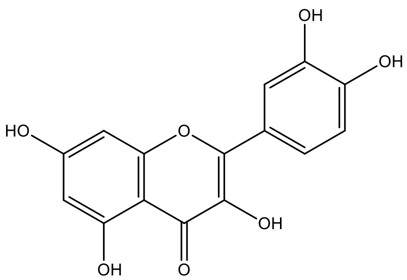
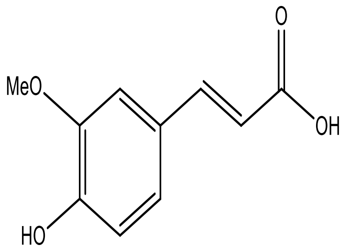
Phenolic compounds are among plants' most diverse groups of phytochemicals and play a significant role in human nutrition. This compound class includes hydroxybenzoic acids, hydroxycinnamic acids, flavonoids, stilbenes, and lignans (Chandrasekara and Shahidi 2012, Naczk and Shahidi 2004). Finger millet is a rich source of polyphenols and dietary fiber, contributing to its nutritional and health benefits. Phenolic compounds in finger millet grains are present in free, soluble conjugates and insoluble bound forms, with their distribution not being uniform throughout the grain. Instead, they are mainly concentrated in the outer layers, such as the aleurone layer, testa, and pericarp, which compromise the bulk of the bran. Figure 4 illustrates the chemical structure of phenolic compounds found in finger millet grains: p-coumaric acid, p-hydroxybenzoic acid, vanillic acid, protocatechuic acid, gallic acid, syringic acid, trans-cinnamic acid, quercetin, and ferulic acid. Finger millet grain genotypes have variable total tannin and phenolic contents. According to Hilu et al (1978), most of the phenolic compounds in millet grains are glycosides. In contrast, Subba Rao and Muralikrishna (2002) found ferulic acid to be the most abundant bound phenolic acid (18.60 mg 100 g^{-1}) and protocatechuic acid to be the most abundant free phenolic acid (45.0 mg 100 g^{-1}). Ferulic acid and p-coumaric acid are the two most abundant bound phenolic compounds in finger millets. The bound phenolics account for 64–96% and 50–99% of total ferulic acid p-coumaric acid levels, respectively (Devi et al 2014).

p-coumaric acid   p-hydroxy benzoic acid   Vanillic acid

Protocathechuic acid   Gallic acid   Syringic acid

Trans-cinnamic acid   Quercetin   Ferulic acid

Figure 4: Structure of major phenolic compounds present in finger millets

Nutritional benefits of finger millet

Finger millet has a protein, fat, and mineral content compared to other grains such as rice, corn, and sorghum (Reed 1976). According to Sankara Vadivoo et al (1998), finger millet contains a moisture content of 13.24%, protein of 7.6%, carbohydrate of 74.36%, fiber of 1.52%, minerals of 2.35%, fat of 1.35%, and provides energy 341.6 calories per 100 grams. It is a rich source of micronutrients such as calcium, phosphorus, magnesium, and iron. In addition, the finger millet protein contains beneficial amino acids such as cysteine, tyrosine, Tryptophan, and methionine (Rachie 1975). Climate change-induced erratic environmental conditions, including increased global temperature, directly impact crop production, leading to hunger and malnutrition worldwide. However, finger millet can greatly help alleviate hunger and malnutrition by withstanding adverse climatic conditions such as drought and contains a variety of macro and micronutrients, thereby saving food for the people. According to the latest Food and Agriculture (FAO) estimate, 925 million people have been undernourished since October 2010. Around 578 million people reside in Asia and the Pacific region, where most children suffer from malnutrition, leading to various diseases and fatalities. Undernutrition has been reported to be the underlying cause of mortality in diarrhea (61%), malaria (57%), pneumonia (52%, and measles (45% are essentially identical (Black et al 2003). Furthermore, in Nepal and many parts of Africa, finger millet grains are fermented into drinks or beers in many parts of Africa and Nepal and used for lunch in the central Terai region of Nepal as halwa, roti, and chokha. Due to the high iron and calcium content in finger millet, it is an ideal food for stimulating milk production and balancing hormonal activities in pregnant women and young mothers. Therefore, it is believed to be a beneficial dietary addition during pregnancy (ETimes 2021).

Health Benefits of finger millets

Finger millet has gained importance because of its high nutritional value, as it contains significant amounts of calcium (0.38%), dietary fiber (18%), and phenolic compounds (0.3-3%) content. These compounds provide the grain with anti-diabetic, anti-tumorogenic, anti-atherosclerogenic, antioxidant, and antibacterial properties (Devi et al 2014). In non-insulin-dependent diabetes mellitus (NIDDM), Laxmi Kumari and Sumathi (2002) investigated the effect of finger millet consumption on hyperglycemia. They found that finger millet's glycemic index was lower than rice and wheat. Including polyphenols in whole-finger millet flour could explain the reduced glycemic response. Epidemiological studies suggest that diabetes is less common among millet-eating communities (Saleh et al 2013). The high fiber content of finger millet delays digestion, which helps to reduce blood sugar levels. Regular consumption of finger millet has been reported to reduce the incidence of Diabetes Mellitus due to the presence of dietary fibers and polyphenols. The amino acids, Lecithin and Methionine, in finger millet help to lower cholesterol by extracting and cutting away excess fat from the liver, while threonine prevents fat production in the liver. Combining high dietary fiber and protein keeps the stomach full longer, preventing unpleasant cravings and reduced appetite and weight loss.

Additionally, finger millet, in its unripe, green form, can help regulate high blood pressure and hypertension. Its consumption stimulates insulin, which decreases blood sugar levels in the body, making it an excellent snack for avoiding late-night food cravings and helping to maintain healthy blood sugar levels. Furthermore, dietary fiber in finger millet aids in controlling "bad" cholesterol, which can lead to heart diseases such as atherosclerosis. Soluble fiber absorbs cholesterol before it enters the bloodstream, allowing people to maintain a healthy cholesterol level without medication (Webmed 2021). Drinking finger millet in the morning is believed to maximize its benefits and satisfy one throughout the day.

It has been found to promote good health and prevent diseases while also delaying premature skin aging due to its high content of Methionine and Lysine amino acids, which help in the formation and maintenance of collagen. Collagen plays an important role in maintaining the elasticity and firmness of the skin, thereby reducing the risk of wrinkles and sagging. In addition, finger millet is a rich source of natural iron, making it an ideal choice for people with anemia and low hemoglobin levels. As a good iron source, finger millet can be considered a valuable cereal for anemic patients (Bala 2019). Regular consumption of finger millet is highly effective in treating anxiety, depression, and sleeplessness, owing to the presence of antioxidants, particularly Tryptophan and amino acids, which act as natural relaxants. In addition, sprouting finger millet can increase the body's Vitamin C levels, making iron absorption easier. Iron can be consumed in Dosa or Balls, with various vegetables and a generous sprinkle of sour cream to maximize absorption.

Finger millet is also a good source of calcium, aiding in bone formation and maintenance, making it a beneficial nutrient for developing children and the elderly. It can also help prevent diseases like osteoporosis and reduce the risk of fractures. Moreover, finger millet consumption provides a cooling effect during the summer and strengthens the body. Antioxidants, a buzzword in today's health books, are abundant in finger millet and protect cells from excessive oxidation, thus preventing cancer and premature aging due to cell damage. The seed coating of finger millet contains powerful antioxidants like phenolic acids, flavonoids, and tannins. Notably, esophageal cancer is less common in those who consume millet-based diets than in people who consume wheat or maize-based diets.

This cereal's high dietary fiber content improves digestive health by regulating bowel movements and preventing constipation. Finger millet contains insoluble fibers that help food movement through the intestines by retaining water and easing waste passage. Regularly including finger millet in the diet is recommended to preserve the digestive system and avoid constipation and other digestive issues. Finger millet is an excellent source of nutrients for new mothers and aids in maintaining hemoglobin levels in the blood. In addition, lactating mothers can enhance milk production by incorporating finger millet into their diet. Finger millet enriches the mother's milk with essential elements such as iron, calcium, and vital amino acids, which are crucial for both the child's and the mother's well-being. The potential health benefits of finger millet are summarized in Table 5.

Table 5. Potential health compounds of finger millet.

Compounds	Functions	References
Arabinoxylans	Antioxidant activity	Chandra et al 2016, Udeh et al 2017
Magnesium	Reduces the chances of having a heart attack	Chandra et al 2018
Phosphorus	Essential for body tissue development and energy metabolism.	Chandra et al 2018
Dietary fiber	Significant role in hypoglycemic and hypolipidemic effects and serum cholesterol reduction. Prevents atherosclerosis and has anti-toxin and anti-cancer properties.	Udeh et al 2017, Thilagavathi et al 2015
Ferulic acid	Prevents tissue damage and aids in the healing of wounds.	Sarita and Singh 2016
Phytic acid	Has a significant impact on lowering body cholesterol	Amadou et al 2013, Chandra et al 2018, Sarita and Singh 2016
Nutraceutical foods	Reduces the likelihood of chronic diseases like obesity, which promotes improved health. Blood hypertension, cancer, and diabetes are all reduced.	Sarita and Singh 2016
Phytates, phenols, and Tannins	Healing, aging, and metabolic syndrome all benefit from it. Prevents human health degradation, cancer, and cardiovascular disease. Blood pressure and diabetes are reduced. Reduces tumor size.	Siwela et al 2007, Thilagavathi et al 2015, Thilagavathi et al 2015, Siwela et al 2007

(Source: Ramashia et al 2019)

CONCLUSION

Agronomic biofortification through soil and foliar application is a potential method for increasing the iron, zinc, and calcium content in finger millet grains. Finger millet is an essential dietary staple in many developing countries, providing more nutritional advantages than rice. It is especially high in protein, healthy fats, and minerals like as zinc, calcium and iron. Furthermore, its high dietary fiber and polyphenol content provides several health benefits, including as anti-diabetic, antioxidant, cholesterol-lowering, antibacterial and anti-inflammatory properties, which assist to avoid chronic diet-related disorders. With increased recognition of its nutraceutical qualities, future study should focus on increasing its quality and commercializing its bioactive ingredients for health and nutrition.

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AUTHORS' CONTRIBUTION

All authors are responsible for conceptualization, literature review, initial and final drafting of this manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflicts of interest regarding publication of this manuscript.

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