



## REVIEW ARTICLE

# A Comprehensive Review of the Nutritional Composition, Bioactive Compounds, and Health-Promoting Potential of *Eleusine coracana* (L.) Gaertn (Finger Millet)

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## Abstract

*Eleusine coracana* (L.) Gaertn (finger millet), is a traditional cereal extensively cultivated in India and parts of Africa, is gaining attention as a nutrient-dense food with multiple health-promoting properties. It is rich in polyphenols, flavonoids, tannins, dietary fiber, essential amino acids, vitamins, and minerals, which contribute to its antioxidant, antidiabetic, antimicrobial, and anticancer activities. Processing methods such as germination, fermentation, malting, and roasting have been shown to enhance the bioavailability and efficacy of these bioactive compounds, further improving the nutritional and functional quality of finger millet-based foods. Scientific studies indicate that finger millet regulates oxidative stress, improves enzymatic antioxidant defenses, lowers postprandial glucose, modulates gut microbiota, inhibits pathogenic bacteria and fungi, and exhibits cytotoxic and chemopreventive effects against various cancer cell lines. Its prebiotic properties also support beneficial gut microbes, contributing to overall metabolic and immune health. This review consolidates current research on the phytochemical composition, biological activities, and therapeutic potential of *E. coracana*, emphasizing its role as a functional food and a natural source of health-promoting compounds. Future research should focus on detailed characterization of bioactive constituents, optimization of processing techniques, and the development of nutraceuticals to fully harness the functional, therapeutic, and disease-preventive potential of finger millet.

**Keywords:** Anticancer, Antimicrobial, Antioxidant, Polyphenols, Finger millet

**Citation:** Shaikh, F. M. R., and Uzgare, A. S. (2026) A Comprehensive Review of the Nutritional Composition, Bioactive Compounds, and Health-Promoting Potential of *Eleusine coracana* (L.) Gaertn (Finger Millet). Integrated Health Research Journal 3(1-Supp), 107-113. [https://doi.org/10.47963/ihrj.v3i\(1-Supp\).2097](https://doi.org/10.47963/ihrj.v3i(1-Supp).2097)  
**Received** 11<sup>th</sup> January, 2026; **Accepted** 9<sup>th</sup> April, 2026; **Published** 1<sup>st</sup> June 2026.

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## Introduction

*E. coracana*, commonly known as ragi, is a highly nutritious cereal renowned for its diverse health-promoting properties<sup>1</sup>. India is the leading global producer of finger millet, with an annual production of approximately 1.8 million tons, followed by Ethiopia, Nepal, Uganda, and Tanzania, with production levels ranging from approximately 1.2 million tons to 0.10 million tons<sup>2</sup>. *E. coracana* is an important traditional Indian millet mainly cultivated under rainfed conditions in peninsular regions, and is valued for its stress tolerance, high nutritional content, and health benefits<sup>3</sup>. The grain of finger millet consists mainly of starch (about 70%), supplemented by proteins, lipids, vitamins, and minerals, while bioactive compounds contribute substantially to the nutritional

value and quality of finger millet-based foods<sup>4</sup>. Finger millet is traditionally malted, yielding a malt that is a good source of  $\alpha$ - and  $\beta$ -amylases, proteases, and phytase, and that offers readily digestible carbohydrates and proteins with enhanced mineral bio-accessibility<sup>1</sup>. It is also a rich source of thiamine, riboflavin, iron, methionine, isoleucine, leucine, phenylalanine, and other essential amino acids. The high content of these phytochemicals enhances its nutraceutical value, establishing finger millet as a nutrient-dense, health-promoting grain<sup>5</sup>. Renowned for its health-promoting properties, *E. coracana* derives these benefits from its rich polyphenol content, dietary fiber, and calcium, contributing to antidiabetic, antitumor, antiatherogenic, antioxidant, and antimicrobial activities<sup>6</sup>.

This review aims to provide a comprehensive overview of

*Eleusine coracana*, emphasizing its bioactive constituents and associated health-promoting properties. It critically examines the relationship between its phytochemical profile and reported therapeutic potential, highlighting its value as a nutrient-dense functional food and a promising natural resource for disease prevention. Furthermore, the review addresses current limitations, including variability in phytochemical composition, bioavailability challenges, and gaps in clinical validation. It also explores future prospects for the integration of finger millet into the food industry, with particular focus on product development, functional food innovation, and strategies to enhance its nutritional and commercial value.

## Methodology: Literature Search Strategy

A systematic literature search was conducted using Google Scholar, ScienceDirect, and PubMed to identify relevant studies published between 2002 to 2025. Keywords used included *Eleusine coracana*, finger millet, phytochemistry, antioxidant, antidiabetic, anticancer, antimicrobial, and pharmacological activities. Peer-reviewed systematic reviews, meta-analyses, and relevant experimental and observational studies published in English were included. Articles were screened based on title, abstract, and full text for relevance to the phytochemistry and therapeutic potential of *E. coracana*. Studies with insufficient data, duplicates, non-peer-reviewed sources, or those not directly relevant were excluded. This approach ensured the inclusion of reliable and scientifically relevant literature.

## Phytochemicals of *E. coracana* and Their Role in Antioxidant Activity

Phytochemicals derived from plants serve as potent anti-inflammatory agents, with studies demonstrating that both crude extracts and isolated compounds can effectively modulate inflammatory responses<sup>7</sup>. Rising awareness of nutrition underscores the health benefits of phytochemicals like polyphenols and dietary fiber. Finger millet, a minor cereal, is a promising source of such compounds, contributing to its multiple health-promoting properties<sup>8</sup>. Finger millet and kodo millet (*Paspalum scrobiculatum*), both rich in phenolic compounds and tannins<sup>9</sup>. Malting finger millet alters phenolic composition, increasing antioxidant activity of free phenolics (770 to 1686) while reducing that of bound phenolics (570 to 448), showing that malting modulates the grain's antioxidant potential<sup>10</sup>. In a study evaluated tannin and polyphenol content in finger millet germplasm and varieties KOPN-330, MR-6, and RAU-8. Polyphenols averaged 156.34 mg GAE/100 g and tannins 99.26 mgTAE/100 g. The phytic acid to iron molar ratio ranged from 16.18 to 20.01, suggesting low iron bioavailability, as ratios below 10:1 are preferred for higher absorption<sup>11</sup>. Finger millet is rich in phenolic compounds and antioxidants, but thermal processing affects their levels and activity. Roasting flour and foods

increased total phenolic content (21.58–28.63  $\mu\text{mol}$  FAE/g) and enhanced radical scavenging, reducing power, ferrous ion chelation, and  $\beta$ -carotene/linoleate emulsion antioxidant activity. Steaming reduced these effects, while adding spices like garlic and cinnamon boosted antioxidant activity in open-boiled porridges. These findings highlight finger millet's potential as a functional food ingredient for promoting health<sup>12</sup>. Fermentation of light and dark brown finger millet flours for 96 hours enhanced bioactive compounds and antioxidant activity. Total polyphenols and flavonoids increased 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging and lipid peroxide inhibition improved, while anthocyanins decreased. Protein and acidity rose, whereas fiber, fats, moisture, and carbohydrates declined. Porridges from 24 hours fermented flours showed the best sensory quality, highlighting fermentation as an effective way to boost antioxidant properties<sup>13</sup>. Finger millet seed coat and endosperm are rich in phytonutrients, and drum drying alters their composition. While catechin and DPPH activity decreased in the seed coat (30%), they increased in the endosperm (18%), with total antioxidant activity maintained, highlighting these fractions as potential functional foods with strong antioxidant properties<sup>14</sup>. Finger millet exhibits strong antioxidant properties. During 48 hours of germination, its total phenol content increased significantly from  $230.9 \pm 1.01$  to  $262.3 \pm 1.10$  mg/100 g, with ferric reducing antioxidant power (FRAP) also showing an increasing trend, highlighting its potential for promoting health<sup>15</sup>. Flavonoids from *E. coracana* (ECFs) were extracted and analyzed, revealing 82.6% total flavonoid content with 16 major components identified. ECFs demonstrated strong *in vitro* antioxidant activity ( $\text{IC}_{50}$ : 22.75  $\mu\text{g}/\text{mL}$  in the ABTS assay). This value is lower than that reported for vitamin E in comparable assays, suggesting a potentially higher radical scavenging capacity; however, such comparisons should be interpreted with caution, as they depend on consistent experimental conditions and must be supported by appropriate references. Furthermore, ECFs enhanced *in vivo* antioxidant defenses in *Caenorhabditis elegans*, increasing the activities of catalase, superoxide dismutase, and glutathione, while reducing malondialdehyde (MDA) and lipofuscin levels. These effects were associated with improved mobility and a 17.86% extension in lifespan, demonstrating significant antioxidant and anti-aging potential<sup>16</sup>. Further detailed information on phytochemicals and their reported mechanisms of action is provided in Table 1.

## Exploring the Antidiabetic Potentials of *E. coracana*

The worldwide incidence of diabetes mellitus is increasing, posing serious health risks and higher mortality. Poor blood glucose regulation can lead to severe complications. While conventional antidiabetic drugs are effective, they often have side effects, highlighting medicinal plants as promising alternatives with potentially fewer adverse effects<sup>17</sup>. Finger millet, a nutrient-rich cereal, is a low glycemic index food (GI 54–60) that helps reduce blood glucose levels, making it beneficial for diabetic patients. Its consumption also offers

**Table I.** Chemical compounds therapeutic properties and mechanism of action of *E. coracana*

Class of Compounds	Specific Compounds	Chemical Type	Therapeutic Properties	Mechanism	Quantitative Data (examples)
Hydroxybenzoic acids	Gallic acid, Protocatechuic acid, Vanillic acid, Syringic acid	Polyphenols	Antioxidant, Antimicrobial, Anticancer	ROS scavenging, enzyme inhibition	Total phenolics: ~0.3–3 mg GAE/g <sup>39</sup>
Hydroxycinnamic acids	Ferulic acid, p-coumaric acid, Caffeic acid, Sinapic acid	Polyphenols	Antioxidant, Anticancer	Inhibits lipid peroxidation, chemoprevention	Ferulic acid (18.60 mg/100 g) <sup>40</sup>
Flavonoids	Quercetin	Flavonoid	Antioxidant, Antimicrobial, Anticancer	Apoptosis induction, anti-inflammatory	Low concentration (3µg/g) <sup>41</sup>
Tannins / Proanthocyanidins	Procyanidins	Condensed polyphenols	Strong antioxidant, Antimicrobial, Anticancer	Radical scavenging, microbial membrane disruption	Tannins: 0.04–3.74% <sup>42</sup>
Total Polyphenols	Seed coat phenolics	Polyphenol mixture	Antioxidant, Antimicrobial	Reducing power, DPPH scavenging	Up to 85% in seed coat fraction <sup>43</sup>
Tannins (general)	Catechin equivalents	Polyphenols	Antioxidant, Anticancer	ROS suppression	340–500 mg/100g <sup>44</sup>
Alkaloids, terpenoids, steroids	Various	Secondary metabolites	Antimicrobial, Antioxidant	Broad bioactivity	Qualitative presence <sup>45</sup>
Phytates and lignans	Phytic acid, lignans	Phytonutrients	Antioxidant, Anticancer	Metal chelation, DNA protection	Phytic acid ~571 mg/100 g <sup>46</sup>

antioxidant, hypocholesterolemic, and chronic disease-preventive effects, highlighting its potential as a functional food for diabetes management<sup>18</sup>. Seed coat matter (SCM) of black *E. coracana* demonstrated significant antidiabetic and antioxidant effects in streptozotocin-induced diabetic rats. Treatment with 20–40% SCM reduced blood glucose by up to 45%, improved liver enzyme profiles increased catalase and superoxide dismutase activities, lowered lipid peroxidation (TBARS), and protected pancreatic, liver, and kidney tissues from damage, highlighting its therapeutic potential<sup>19</sup>. *E. coracana* contains bioactives like polyphenols, phytic acid, and dietary fiber that reduce postprandial glucose and improve insulin sensitivity. Its prebiotics support gut microbes such as *Bifidobacterium*, *Lactobacillus*, and *Akkermansia muciniphila*, producing short-chain fatty acids and proteins that enhance anti-diabetic effects. Millet compounds also suppress harmful gut bacteria, lowering inflammation and diabetes risk<sup>20</sup>. Anti-diabetic potential of finger millet using *in vitro* absorption and intestinal permeability models. Finger millet extract showed superior absorption and permeability compared to Metformin, likely due to its high phenolic and flavonoid content, which inhibit carbohydrate-digesting enzymes. These results highlight finger millet as a promising natural alternative for diabetes management<sup>21</sup>. Reduced-sugar cookies formulated with Finger Millet, Jamun, and stevia showed high phenolic content and antioxidant activity. These cookies have potential as a functional food for managing diabetes and metabolic disorders<sup>22</sup>. Phenolic compounds extracted from Finger millet seed coats showed potent inhibition of  $\alpha$ -glucosidase and pancreatic amylase, key enzymes involved in postprandial hyperglycemia. The phenolics exhibited non-competitive inhibition with low IC<sub>50</sub> values, indicating strong therapeutic potential for natural diabetes management<sup>23</sup>.

## Antimicrobial Properties of *E. coracana*

Many currently available drugs suffer from significant limitations, including adverse side effects, diminished efficacy against emerging or re-emerging fungal strains, and the rapid development of antimicrobial resistance<sup>24</sup>. Consequently, natural dietary products have gained attention as promising sources for the discovery of novel antibacterial agents<sup>25</sup>. In this context, natural products derived from medicinal plants, particularly *E. coracana*, represent a valuable and promising resource for the development of new antimicrobial agents<sup>26</sup>. Studies indicate that the seed coat of *E. coracana* is rich in polyphenols with strong antimicrobial activity. Methanol–acid extracts of the seed coat showed greater inhibition of *Bacillus cereus* and *Aspergillus flavus* than whole flour extracts, primarily due to phenolic acids such as daidzein, gallic, coumaric, syringic, and vanillic acids. These results highlight the potential of *E. coracana* seed coat as a natural antimicrobial agent for therapeutic and food preservation applications<sup>27</sup>. Finger millet from northern Nigeria exhibited concentration-dependent antibacterial activity against *E. coli*, *P. aeruginosa*, *S. aureus*, and *S. typhi*, with the highest inhibition (8 mm) observed against *P. aeruginosa* at 100 mg ml<sup>-1</sup>. Phytochemical analysis revealed the presence of tannins/phenols, flavonoids, alkaloids, saponins, glycosides, terpenoids, and steroids, with measurable phenolic and flavonoid contents. These results indicate that finger millet possesses notable *in vitro* antimicrobial potential along with nutritional benefits<sup>28</sup>. In a study, the incorporation of 20% finger millet into a fermented milk–millet composite product significantly enhanced its antimicrobial activity compared to the control

without finger millet ( $P < 0.05$ ). The composite product exhibited higher inhibitory effects against all tested pathogens, demonstrating that finger millet enrichment substantially improves the antimicrobial potential of fermented dairy-based functional foods<sup>29</sup>.  $\beta$ -Glucan (Ec- $\beta$  G) isolated from finger millet (*E. coracana*) demonstrated potent antimicrobial activity against both Gram-positive (*Lysinibacillus fusiformis*, *Enterococcus faecalis*) and Gram-negative (*Proteus vulgaris*, *Shigella sonnei*) bacteria, with minimum inhibitory concentrations below 70  $\mu\text{g/mL}$ . At 100  $\mu\text{g/mL}$ , Ec- $\beta$ G significantly reduced bacterial viability and inhibited biofilm formation, as confirmed by light and confocal microscopy, highlighting its potential as a natural antimicrobial agent<sup>30</sup>. *E. coracana* a nutrient-dense staple of arid and semi-arid regions, exhibits notable health-promoting properties. Extracts from 12-hours germinated seeds showed bactericidal activity against *Escherichia coli*, indicating potential applications in managing infectious diarrhea and as a natural food preservative. The study also reported antioxidant activity and high sensory acceptability, supporting the use of germinated finger millet as a functional food with antibacterial benefits<sup>31</sup>. Ethanolic and methanolic extracts of whole-grain flours from Ravi, Rawana, and Oshadha finger millet varieties were evaluated for antibacterial, antifungal, and  $\beta$ -lactamase inhibitory activities. The extracts exhibited dose-dependent antibacterial effects against both antibiotic-sensitive and antibiotic-resistant bacteria, with greater activity against Gram-positive strains, particularly *Staphylococcus aureus* and *Bacillus subtilis* (MICs: 2.1 and 1.8 mg/mL, respectively). However, the extracts showed limited antifungal and  $\beta$ -lactamase inhibitory activities and were less effective than standard drugs, indicating moderate antibacterial but minimal antifungal potential<sup>32</sup>. Five fungal endophytes were isolated from finger millet roots, three of which exhibited activity against *Fusarium* species. The most potent strain, WF4, was identified as *Phoma* sp. and produced four bioactive compounds viridicatol, tenuazonic acid, alternariol, and alternariol monomethyl ether that disrupted the hyphae of *Fusarium graminearum*. As reported by Mousa et al.<sup>33</sup>, except for tenuazonic acid, these compounds were newly reported from *Phoma* sp. WF4 (identified at the genus level) and were also newly associated with anti-*Fusarium* activity, highlighting finger millet as a promising source of natural antifungal agents<sup>33</sup>. Polyphenols extracted from the seed coat of finger millet demonstrate strong antimicrobial activity against several pathogenic bacteria, including *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*. Quercetin was identified as a major bioactive compound responsible for these antibacterial effects, underscoring the potential of finger millet polyphenols as natural antimicrobial agents<sup>34</sup>.

## Chemopreventive and Anticancer Properties of *E. coracana*

Cancer represents a major global public health concern, affecting individuals across all socioeconomic groups. Medicinal plants offer potential in cancer prevention and

treatment, largely due to their antioxidant properties and ability to inhibit tumor growth<sup>35</sup>. Phenolic acids from finger millet were isolated and tested for anticancer activity. Cytotoxicity assays showed that millet polyphenols exhibited activity against HepG2 liver cancer cell lines, suggesting their potential as natural compounds for cancer prevention and therapy<sup>36</sup>. A finger millet (*E. coracana*) formulation was developed using *Levilactobacillus brevis* MTCC 4460 and optimized via response surface methodology and artificial neural networking. The optimized formulation (2% bacterial inoculum, 2% glucose, 3.3 days fermentation) yielded 5.98 mg/mL lactic acid and 3.38 log<sub>10</sub> CFU/mL viable bacteria. The fermented millet showed antiproliferative and antimigratory effects on MDA-MB-231 and HCT116 cancer cell lines, inducing apoptosis via Bcl-2 family proteins, while exhibiting no toxicity to normal HEK293 cells<sup>37</sup>. Finger millet (*E. coracana*) contains high levels of proteins, dietary fiber, and polyphenols, which are known for their various health benefits. This study comparatively evaluated the anticancer potential of its polyphenols through molecular docking against important cancer-related targets such as CDKN1A, FOXO1, FGFR2, CTNNB1, and GST-PI. The docking analysis revealed relatively strong binding affinities, ranging from -116.56 to -105.07 kcal/mol, indicating favorable interactions between millet polyphenols and these targets. In comparison, these results suggest that finger millet polyphenols demonstrate notable anticancer potential and may serve as promising compounds for further investigation in cancer therapy<sup>38</sup>.

## Conclusion and Future Scope

*E. coracana* is a nutrient-rich cereal with considerable health-promoting properties, attributed to its high content of polyphenols, flavonoids, tannins, dietary fiber, essential amino acids, and minerals. Its bioactive compounds exhibit strong antioxidant, antidiabetic, antimicrobial, and anticancer activities, which are further enhanced by processing methods such as germination, fermentation, malting, and roasting. Evidence from *in vitro*, *in vivo*, and computational studies highlights finger millet's potential as a functional food for managing oxidative stress, regulating blood glucose, combating microbial infections, and providing chemopreventive effects. These findings establish finger millet as a valuable natural resource for promoting health and preventing chronic diseases.

Future research should focus on validating the pharmacological effects of finger millet through human clinical trials to establish safe and effective dosages for therapeutic applications. Exploration of its bioactive compounds, particularly polyphenols and peptides, can lead to the development of novel nutraceuticals and functional foods. Studies on its prebiotic effects and modulation of gut microbiota may uncover additional mechanisms for disease prevention. Furthermore, breeding programs for nutritionally superior and stress-tolerant varieties, along with optimized processing techniques, can maximize both the health benefits and sensory quality of finger millet products. Integration of finger millet into functional diets and therapeutic interventions holds significant potential for sustainable nutrition-driven health promotion and

chronic disease management.

## Acknowledgements

There is none to acknowledge.

**Funding Source-** No particular grant from a governmental, private, or nonprofit funding organisation was obtained for this study.

## Authors' Contributions

Manuscript written by Fakeha Shaikh under the guidance of Ashish Uzgare.

## Conflict of Interest

Authors declare no competing or conflict of interest.

## Data Availability

None

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