JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Impact of Ragi Consumption on Gut Microbiota and Metabolic Health: A Review

Nishad Swati[1], Dubey P. Ritu[2], Gupta Alka[3]
[1]Research Scholar, Department of Food Nutrition and Public, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India
[2]Professor, Department of Food Nutrition and Public Health Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India
[3]Associate Professor, Department of Food Nutrition and Public Health Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Abstract

Finger millet (*Eleusine coracana* L.), commonly known as ragi, is a nutritionally dense ancient grain with emerging relevance for gut microbiota modulation and metabolic health. This review synthesizes recent evidence on ragi's nutritional and bioactive composition, prebiotic potential, and metabolic effects. Ragi is rich in dietary fiber, resistant starch, calcium, iron, zinc, polyphenols, and flavonoids. Its fiber and resistant starch fractions escape small intestinal digestion and undergo colonic fermentation, promoting short-chain fatty acid production and beneficial microbial taxa including *Lactobacillus*, *Bifidobacterium*, *Faecalibacterium*, *Eubacterium*, *Roseburia*, and *Akkermansia muciniphila*. Animal and in vitro studies report glucose-lowering, cholesterol-lowering, antioxidant, and anti-glycation effects. Human clinical evidence, though limited, indicates improvements in glycemic control and lipid profiles. However, methodological heterogeneity and small sample sizes constrain definitive conclusions. Rigorous randomized controlled trials with microbiome and metabolic endpoints are needed before evidence-based dietary recommendations can be established.

Keywords: *Ragi; finger millet*; *gut microbiota; metabolic health; short-chain fatty acids; prebiotics; type 2 diabetes; glycemic index*

1. Introduction

The rising global burden of type 2 diabetes mellitus (T2DM), obesity, and cardiovascular disease has intensified interest in whole-grain and millet-based dietary strategies (Sarao et al., 2026). Millets are small-seeded cereals of the Poaceae family, gaining recognition as functional foods with significant health-promoting properties (Singh et al., 2023). Among these, finger millet (*Eleusine coracana* L.), commonly known as ragi, is a nutrient-dense cereal traditionally cultivated in India and parts of Africa.

Ragi is rich in polyphenols, flavonoids, tannins, dietary fiber, essential amino acids, vitamins, and minerals, which contribute to its antioxidant, antidiabetic, antimicrobial, and anticancer activities (Shaikh and Uzgare, 2026). Emerging evidence suggests that ragi's health effects may be mediated partly through modulation of the gut microbiota, including prebiotic fiber fermentation and SCFA production. The prebiotic content of finger millet is utilized by gut microbiota such as *Faecalibacterium*, *Eubacterium*, and *Roseburia* to generate colonic SCFAs, while probiotic *Bifidobacterium* and *Lactobacillus* are known to be anti-diabetic in nature (Singh et al., 2022).

2. Nutritional and Bioactive Composition of Ragi

2.1 Macronutrient Profile

Ragi contains carbohydrates, protein, and fat, with micronutrients including calcium (0.38%) and dietary fiber (18%) (Gaikwad et al., 2025). Finger millet contains numerous bioactive compounds, including polyphenol (10.2 mg/g TAE), flavonoid (5.54 mg/g CE), phytic acid (0.48%), and dietary fiber (15–20%) (Singh et al., 2022). The grain is naturally gluten-free, making it suitable for individuals with gluten sensitivity or celiac disease (Kaur et al., 2024).

Finger millet starch constitutes about 70% of the grain and is highly valued for its slow-release properties, contributing to metabolic health and improved digestion (Dhanushkodi et al., 2024). The starch fraction contains amylose and amylopectin, with resistant starch formation contributing to its prebiotic potential. Studies have reported that fermentation of resistant starch in the colon produces SCFAs such as propionate and butyrate, which are associated with inducing satiety-related hormones like GLP-1 and peptide YY (Tawde and Jha, 2026).

2.2 Micronutrient and Mineral Content

Finger millet is exceptionally rich in calcium, potassium, and magnesium, with all varieties containing high levels of these minerals (Ramashia et al., 2022). The grain is recognized for its high content of calcium, iron, dietary fiber, and essential amino acids. Calcium content is particularly notable, with values ranging from 344 to 380 mg%, significantly exceeding other cereals and millets (Gaikwad et al., 2025). The calcium content of finger millet seeds (350 mg/100 g) is reasonably higher than average cow's milk (112 mg/100 g), making it an alternative easily digestible source of calcium for lactose-intolerant patients and weaning babies (Kaur et al., 2024).

Processing methods such as germination, fermentation, malting, and roasting have been shown to enhance the bioavailability of these minerals, further improving the nutritional and functional quality of finger millet-based foods (Shaikh and Uzgare, 2026). Fermentation significantly increases the bioaccessibility of iron, zinc, and calcium in finger millet-based foods (Fentie et al., 2024).

2.3 Bioactive Compounds

Finger millet seed coat contains high levels of phenolic compounds, primarily derivatives of benzoic acid, which exhibit antioxidant properties. The grain contains the highest flavonoids compared with other millets. Ferulic acid, protocatechuic acid, catechin, epicatechin, epigallocatechin, taxifolin, vitexin, tricin, luteolin, myricetin, quercetin, kaempferol, and naringenin are the main phenolics in finger millet grain. Polyphenols are abundant in the bran (seed coat tissue), contributing up to 60% of total polyphenols.

Finger millet is a potent source of antioxidants and shows robust radical-scavenging activity compared to wheat, rice, and other millets. Brown or red-seeded varieties of finger millet show higher antioxidant activity compared with white-seeded varieties (Kaur et al., 2024). Polyphenols are known for their antioxidant and anti-diabetic role, and phytic acid, previously considered an anti-nutritive substance, is now regarded as a nutraceutical as it reduces carbohydrate digestibility and thus controls post-prandial glucose levels and obesity (Singh et al., 2022).

2.4 Antinutrients and Processing Implications

Millets contain antinutritional factors that may hinder nutrient absorption. However, processing methods including fermentation, soaking, and sprouting reduce anti-nutrients, boosting bioavailability (Maurya et al., 2025). Fermentation treatments have been found to be effective in enhancing the nutritional composition and bioactive properties of finger millet. Lactic acid fermentation of finger millet is an effective method for

enhancing the bioavailability of micronutrients and increasing their phenolic content and antioxidant activities (Ude et al., 2024).

3. Ragi as a Prebiotic Substrate: Mechanisms of Gut Microbiota Modulation

3.1 Dietary Fiber and Resistant Starch as Prebiotic Substrates

Ragi's dietary fiber content facilitates colonic fermentation, leading to the production of SCFAs. The dietary fiber content in millets facilitates colonic fermentation, leading to the production of SCFAs, which promote gut barrier function and reduce inflammation (Singh et al., 2023). Finger millet is rich in complex carbohydrates—specifically dietary fibers like arabinoxylan and resistant starch—and phenolic compounds such as ferulic acid, catechins, and tannins. Resistant starch from *Eleusine coracana* acts as a prebiotic by feeding beneficial gut bacteria, resulting in the production of SCFAs like butyrate, acetate, and propionate.

The high fiber and resistant starch content of millets serve as prebiotics. Upon reaching the colon, they are fermented by beneficial colonic bacteria, leading to the production of SCFAs, primarily acetate, propionate, and butyrate (Tawde and Jha, 2026). Studies have demonstrated that ragi's high fiber content of approximately 11 grams per 100 grams produced more butyrate than refined wheat (Rebalance Kitchen, 2026).

3.2 Selective Stimulation of Beneficial Microbial Taxa

Recent findings have revealed that the prebiotic content of finger millet is utilized by gut microbiota such as *Faecalibacterium*, *Eubacterium*, and *Roseburia* to generate colonic SCFAs, and probiotic *Bifidobacterium* and *Lactobacillus*, which are known to be anti-diabetic in nature (Singh et al., 2022). Consuming millet has been linked to higher relative abundances of beneficial microbes, especially *Faecalibacterium*, *Eubacterium*, *Roseburia*, *Akkermansia*, *Lactobacilli*, and *Bifidobacteria* (Nayak et al., 2024).

Fermentation enhances the growth of beneficial gut microorganisms, such as *Lactobacillus* and *Bifidobacterium*, which ferment fiber into SCFAs, such as butyrate and propionate. These SCFAs are crucial for enhancing glucose and lipid metabolism via pathways such as AMPK activation and GLUT4 translocation (Tawde and Jha, 2026).

3.3 Modulation of *Akkermansia muciniphila*

Notably, finger millet-induced mucus-degrading *Akkermansia muciniphila* can also help in alleviating diabetes by releasing propionate and Amuc_1100 protein. Decreased levels of *Akkermansia muciniphila* have been reported to correlate with increased energy intake and adiposity. Studies have shown significant increases in the abundance of *Akkermansia muciniphila* in high-fat-diet-induced obese rats fed millet grain diets (Singh et al., 2023).

3.4 Inhibition of Pathogenic Microbiota

Various millet bio-actives effectively controlled pathogenic gut microbiota, such as *Shigella* and *Clostridium histolyticum*, to lower gut inflammation and, thus, the risk of diabetes in the host (Singh et al., 2022). Finger millet polyphenols demonstrate antimicrobial activity against a range of pathogens including *E. coli*, *S. aureus*, *P. mirabilis*, and *Listeria monocytogenes* (Kaur et al., 2024). Finger millet modulates gut microbiota, inhibits pathogenic bacteria and fungi, and its prebiotic properties support beneficial gut microbes, contributing to overall metabolic and immune health (Shaikh and Uzgare, 2026).

3.5 Polyphenol–Microbiota Interactions

Recent findings have revealed that the antioxidant activity and bio-accessibility of finger millet polyphenols increased significantly ($P < 0.05$) in the colon, confirming the role of the gut microbiota (Singh et al., 2022). The polyphenol content of finger millet is utilized by gut microbiota to generate bioactive metabolites with enhanced antioxidant and anti-inflammatory properties. Fermentation processes increase the release of bound phenolics and reduce antinutritional factors such as phytic acid and tannins via microbial enzymes, including feruloyl esterases and tannases, thereby enhancing mineral bioavailability and the efficacy of bioactive compounds (Tawde and Jha, 2026).

Important Pathways to Discuss:

1. GPR41/FFAR3 → GPR43/FFAR2 → GLP-1/PYY → insulin sensitivity → glucose homeostasis:

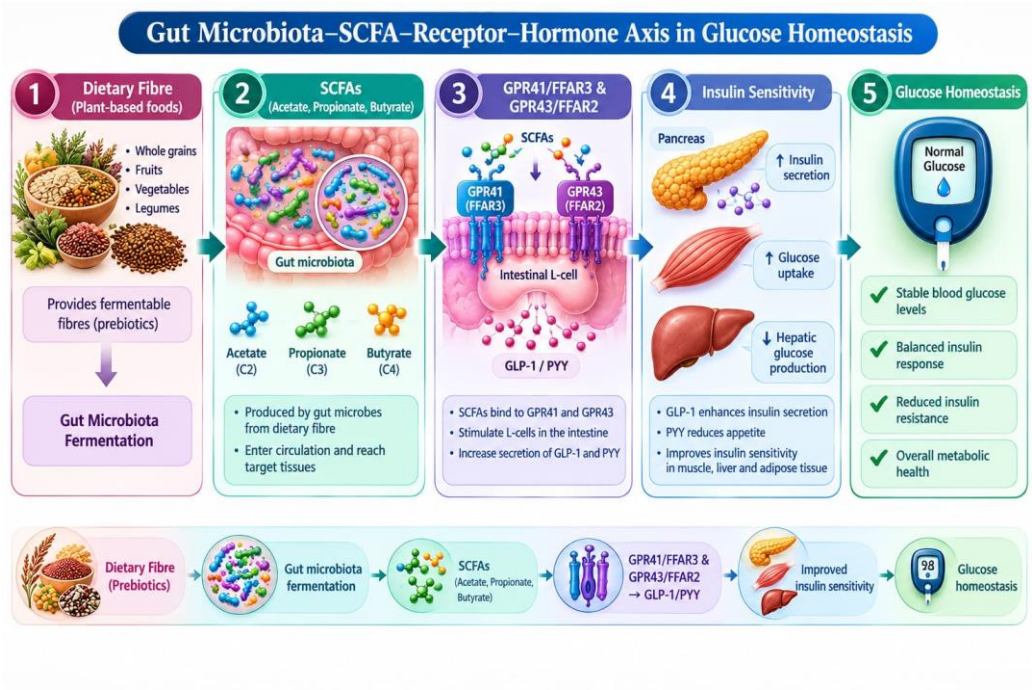

Figure 1. Proposed mechanistic pathway of GPR41/FFAR3 → GPR43/FFAR2 → GLP-1/PYY → insulin sensitivity → glucose homeostasis

Sources: **Tolhurst, G., et al. (2012).** *Short-chain fatty acids stimulate glucagon-like peptide-1 secretion via the G-protein-coupled receptor FFAR2.* **Diabetes, 61(2), 364–371.** DOI: 10.2337/db11-1019. The study specifically supports SCFA-mediated GLP-1 secretion through FFAR2 and discusses FFAR2/FFAR3 expression in GLP-1-secreting L-cells.

2. Ragi fibre/polyphenols → gut microbial fermentation → SCFAs → AMPK/GLP-1 pathways → improved metabolic health:

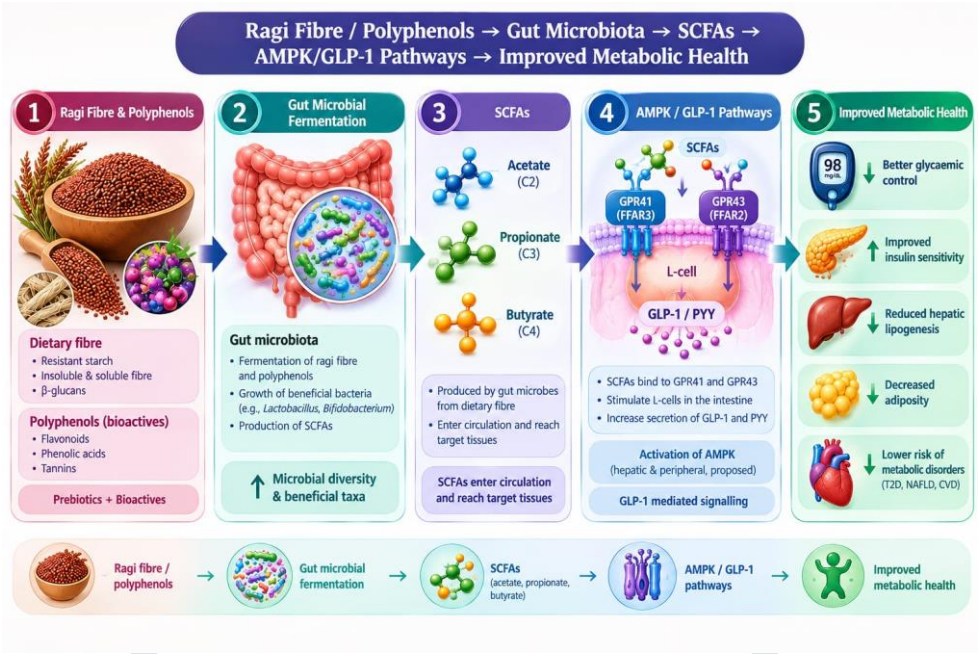

Figure 2. Proposed mechanistic pathway of finger millet (ragi) fibre and polyphenols–gut microbiota–SCFA–AMPK/GLP-1 axis in metabolic health.

Sources: *Devi et al. (2014); Chambers et al. (2018); Tolhurst et al. (2012); Singh et al. (2022).*

4. Metabolic Health Outcomes Associated with Ragi Consumption

4.1 Glycemic Control and Insulin Sensitivity

Millets are nutrient-dense functional cereals with potential for managing and preventing T2DM. The bioactive profile, dietary fiber, and resistant starch of millets may contribute to improving metabolic health and attenuating the postprandial glycemic response. Studies have shown that millet-derived constituents modulate glucose metabolism through multiple pathways, including inhibition of carbohydrate-hydrolyzing enzymes, improvement of insulin signaling, modulation of the gut microbiota, and suppression of oxidative stress and systemic inflammation (Sarao et al., 2026).

Clinical evidence supports these findings. In a single-blind randomised controlled crossover trial, finger millet muffins fed to 16 healthy and 14 prediabetic individuals resulted in reduced glycaemic and insulin responses in prediabetic individuals compared with wheat muffins. Finger millet-based muffins decreased insulin response in individuals with prediabetes in a randomised controlled trial (Almaski et al., 2023). A 90-day randomised controlled trial examining finger millet and barley-based diets with lifestyle modification in prediabetic adults demonstrated significant reductions in fasting plasma glucose ($P < .001$) and postprandial plasma glucose ($P < .05$) in the finger millet group compared with the standard diet group (Kumari et al., 2026). Multigrain rotis prepared from finger millet, foxtail millet, sorghum, jowar, oats, and maize reduced glycated hemoglobin (HbA1c) and LDL cholesterol levels.

4.2 Lipid Metabolism and Cardiovascular Health

Regular ingestion of finger millet products is associated with lower risks of cardiovascular disease, diabetes, and certain cancers. Additionally, it reduces blood pressure, cholesterol, and prevents constipation (Kaur et al., 2024). The intake of millet even in a single meal per day significantly improved glycemic control, especially fasting blood sugar and lipid profile. Studies have shown that high carbohydrate diet supplemented with finger millet flour led to reduced body weight gain, improved feed efficiency ratio, and enhanced serum lipid profile by lowering triglycerides, cholesterol, and LDL-c levels compared to high carbohydrate diet alone (Ibrahem and Sayed, 2023).

4.3 Obesity and Weight Management

The growing occurrence of overweight and obesity represents an urgent global health problem. Investigations have confirmed that millet consumption may promote the synthesis of leptin in the body that modulates neuropeptide Y and anandamide receptors and thereby regulates appetite. Studies have suggested that millet consumption may help in reduction of body weight, body mass index (BMI), and overall obesity. Fermented millet fiber increased the growth of beneficial gut microbiota (*Bacteroides* and *Prevotella*), propionic acid production, and stimulated release of gut hormones (GLP-1 and PYY) that contributed to improved lipid metabolism and fat loss measures (Tawde and Jha, 2026).

4.4 Gut Barrier Integrity and Endotoxemia

Millets' prebiotic properties and fermentation lead to the production of SCFAs, promoting gut barrier function and reducing inflammation (Singh et al., 2023). Additionally, millet consumption may impact gut hormones and exhibit antioxidant and anti-inflammatory effects (Singh et al., 2023). The prebiotic fiber and polyphenols in ragi are metabolized by gut microbiota into SCFAs such as butyrate and propionate, which improve insulin sensitivity and reduce systemic inflammation.

4.5 Clinical and Preclinical Evidence

The impact of millets on metabolic health is evident, with studies demonstrating improved glycemic control and lipid profiles (Singh et al., 2023). Studies on millet consumption conducted both in vivo and in vitro have demonstrated promising results for gut microbiota modulation, lipid metabolism, and glycemic control, confirming the potential of millet in treating diabetes and other illnesses (Maurya et al., 2025). However, the present state of evidence must be interpreted with caution as they require further validation through large-scale clinical studies (Tawde and Jha, 2026).

4.6 Processing, Fermentation, and Bioavailability

Processing and ingredient combinations affect the glycemic index (GI) of millet-based foods, providing opportunities for developing healthier food solutions (Maurya et al., 2025). Germination, fermentation, malting, and roasting have been shown to enhance the bioavailability and efficacy of bioactive compounds, further improving the nutritional and functional quality of finger millet-based foods (Shaikh and Uzgare, 2026). Fermentation enhances the growth of beneficial gut microorganisms and improves the prebiotic potential of finger millet (Tawde and Jha, 2026). Lactic acid fermentation of finger millet is an effective method for enhancing the bioavailability of micronutrients and increasing their phenolic content and antioxidant activities (Ude et al., 2024).

5. Knowledge Gaps and Future Directions

Despite promising findings, major gaps remain. Understanding the mechanisms provides valuable insights for personalized dietary recommendations, gut microbiota-targeted interventions, and integrating millets into public health initiatives (Singh et al., 2023). However, challenges persist in millet products' texture, shelf life, and consumer appeal. Overcoming these limitations through research and technical innovation is crucial for promoting millets as a modern dietary staple, boosting public health, and advancing sustainable food systems (Maurya et al., 2025).

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 (Shaikh and Uzgare, 2026). More robust long-term clinical evidence is still required to confirm the potential benefits of millet consumption (Tawde and Jha, 2026). Promoting millet cultivation aligns with sustainable food systems, making it a holistic approach to combat metabolic disorders and enhance overall human health (Singh et al., 2023).

6. Conclusion

Ragi is a nutritionally exceptional grain with significant potential for modulating gut microbiota and improving metabolic health. Its high calcium, dietary fiber, resistant starch, and polyphenol content position it as a functional food with prebiotic properties. Recent evidence demonstrates that ragi consumption promotes beneficial microbial taxa, enhances SCFA production, and improves glycemic control, lipid profiles, and gut barrier function. Animal and in vitro studies provide robust mechanistic evidence, and emerging human clinical trials support these findings. However, methodological heterogeneity, small sample sizes, and limited long-term trials constrain definitive conclusions. Rigorous randomized controlled trials with robust microbiome and metabolic endpoints are urgently needed to establish causal relationships and inform evidence-based dietary recommendations. Given the global burden of metabolic disorders and the sustainable nature of millet cultivation, ragi warrants prioritized research attention.

References

Almaski, A., Coe, S., Lightowler, H., Clegg, M. E., and Thondre, P. S. (2023). Finger millet-based muffin decreases insulin response in individuals with prediabetes in a randomised controlled trial. *British Journal of Nutrition*, 129(4), 650–659.

Dhanushkodi, A., et al. (2024). Review on finger millet (*Eleusine coracana* L.): Nutritional composition, modification, its effect on physicochemical, structural, functional properties, and its applications. *Journal of Food Composition and Analysis*, 133, 106–112.

Fentie, E. G., et al. (2024). Effect of fermentation on nutrient composition, antinutrients, and mineral bioaccessibility of finger millet based Injera: A traditional Ethiopian food. *Food Research International*, 190, 114635.

Gaikwad, V., et al. (2025). Nutritional significance of finger millet and its potential for using in functional products. *AGRIS*.

Ibrahem, E. S., and Sayed, R. S. (2023). Characteristics of finger millet (*Eleusine coracana* L.) flour and its effect on obese rats: A biological and applied study. *Egyptian Journal of Food Science*, 51(1), 113–125.

Kaur, S., Kumari, A., Seem, K., Kaur, G., Kumar, D., Verma, S., Singh, N., Kumar, A., Kumar, M., Jaiswal, S., Bhardwaj, R., Singh, B. K., and Riar, A. (2024). Finger millet (*Eleusine coracana* L.): From staple to superfood—A comprehensive review on nutritional, bioactive, industrial, and climate resilience potential. *Planta*, 260(4), 82.

Kumari, P., et al. (2026). Comparative efficacy of finger millet and barley-based diets with lifestyle modification in glycaemic control among prediabetic adults: A randomised controlled trial. *SAGE Open Medicine*, 14, 1–12.

Maurya, R., Boini, T., Misro, L., and Radhakrishna, T. (2025). Millets: A comprehensive review of nutritional, antinutritional, health, and processing aspects. *Journal of Drug Research in Ayurvedic Sciences*, 10(1), 1–15.

Nayak, N., Bhujle, R. R., Nanje-Gowda, N. A., Chakraborty, S., Siliveru, K., Subbiah, J., and Brennan, C. (2024). Deciphering the significance of millets as a superfood in promoting gut health: A review. *Heliyon*, 10(10), e30921.

Ramashia, S. E., et al. (2022). Varietal and processing influence on nutritional and phytochemical properties of finger millet: A review. *Heliyon*, 8(12), e12310.

Rebalance Kitchen. (2026, April 16). Gut microbiome and whole grains: What Indian research shows.

Singnale, P., Sasmal, D., Chukkala, S. G. S., Chilumula, M., Pandurangi, R., Singh, S. P., Mummadi, M. K., and Gondru, R. (2026). Role of functional foods and nutraceutical compounds in alleviating polycystic ovary syndrome: A narrative review. *Cureus*, 18(4), e106497.

Sarao, J., Kumar, A., Kumar, A., Prabhakar, P., Bishnoi, M., Godara, P., Soni, V., and Kumar, S. (2026). Millets as functional cereals for the management of type 2 diabetes mellitus: Nutritional composition, mechanistic pathways, and clinical evidence. *International Journal of Special Education*, 41(6s), 771–794.

Shaikh, F. M. R., and Uzgare, A. (2026). A comprehensive review of the nutritional composition, bioactive compounds, and health-promoting potential of *Eleusine coracana* (L.) Gaertn (finger millet). *International Health Research Journal*, 3(1-Supp).

Singh, S. B., Meena, A. K., Sisodia, B. S., Sharma, S., Sharma, M. M., and Mansoria, P. (2023). From farm to gut: Unraveling the role of millets in promoting metabolic well-being via gut microbiota. *Journal of Drug Research in Ayurvedic Sciences*, 8(Suppl 1), S50–S54.

Singh, V., Lee, G., Son, H., Amani, S., Baunthiyal, M., and Shin, J.-H. (2022). Anti-diabetic prospects of dietary bio-actives of millets and the significance of the gut microbiota: A case of finger millet. *Frontiers in Nutrition*, 9, 1056445.

Tawde, P., and Jha, P. (2026). Nutraceutical potential of fermented finger millet in type 2 diabetes mellitus. *Journal of Food Science*, 91(5), 1–18.

Ude, H. O., Dudoiu, K. G., and Jideani, A. I. O. (2024). Effect of lactic acid fermentation on the physico-chemical, functional, and antioxidant properties, and in vitro protein digestibility of malted ragi (*Eleusine coracana* L.). *Sustainable Food Technology*, 2(4), 1128–1138.

Naik, N. S., Nadiger, N., and Mukhopadhyay, A. (2026). Effects of millet consumption on metabolic homeostasis (glycemic control and lipid profiles) in adults: A systematic review. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews, 20(1*), 103359.

Grover, R., Khutan, H., Jain, A., Arora, H., Kushwaha, G., and Goyal, N. (2026). Impact of adding a millet diet on glycemic control and lipid profile in patients with type 2 diabetes mellitus. *Annals of African Medicine, 25(*1), 138–143.

Krishnan, H., Kaushik, D., Kumar, M., Oz, E., Brennan, C., Oz, F., Proestos, C., Hashem, A., Ibrahimova, U., and Abd Allah, E. F. (2024). Assessing the efficacy of pearl millet and finger millet enriched breakfast cereals to combat obesity. *Scientific Reports, 14*, Article 27752.