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The Superiority of Fermented Millets: Nutritional and Functional Advantages

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Millet is an ancient grain that has been cultivated for more than 7,000 years in Asia and Africa and has long served as both a staple food and a health-promoting crop. These small-grained, multipurpose cereals possess medicinal value owing to their rich content of vitamins, minerals, and bioactive compounds that support human health and recovery. Because of their exceptional nutritional profile, millets are often referred to as nutri-cereals (Jacob *et al.*, 2024). Millets are grouped into major millets like sorghum, pearl millet, and finger millet and minor millets, which include foxtail millet, little millet, kodo millet, proso millet, browntop millet, fonio, teff, and barnyard millet. Their corresponding Indian names are provided in Table 1. Millet-based fermented food products are foods and beverages produced through microbial fermentation involving bacteria, yeasts, or fungi. Fermentation breaks down complex carbohydrates into organic acids, gases, or alcohol, improving flavor, texture, shelf life, digestibility, and nutritional value. These products may contain probiotics that support gut health, though their presence depends on the fermentation process and microbial strains used. Common lactic acid bacteria involved include *Lactobacillus*, *Pediococcus*, and *Leuconostoc* species, which influence the sensory and nutritional properties of the final product. Traditional fermented millet foods consumed worldwide include ogi, koko, fura, uji, jandh, mangisi, pito, burukutu, and kunu-zaki, highlighting the cultural, nutritional, and economic importance of fermented millets.

Table 1: Millets Name

English Name	Hindi Name
Amaranth	Rajgira/ Ramdana
Barnyard	Sanwa/ Samvat ke Chawal
Buckwheat	Kuttu
Finger millet	Ragi/ Nachni
Foxtail millet	Kangni / Kakum
Kodu	Kodon
Little millet	Moraiyo/ Kutki/ Shavan/ Sama
Pearl millet	Bajra
Proso millet (broomcorn millet)	Chena
Sorghum	Jowar

Therapeutic potentiality of millets

- ✓ Millets support digestive health by improving bowel movements and promoting gut microbiota due to their prebiotic content.
- ✓ They enhance gut health and immune function by stimulating the growth of beneficial probiotics.
- ✓ Millets are inherently gluten-free, which makes them a suitable dietary option for people with celiac disease or gluten intolerance.

- ✓ They are nutrient-dense, rich in protein and dietary fiber, and do not cause gastrointestinal discomfort.
- ✓ Millets support cardiovascular health by providing essential minerals such as iron, zinc, magnesium, manganese, and copper.
- ✓ Consumption of millets may increase adiponectin levels, improving lipid metabolism and insulin sensitivity.
- ✓ Millets help reduce cholesterol and triglyceride levels, lowering the risk of heart diseases.
- ✓ They contribute to mood regulation due to the presence of tryptophan and essential amino acids.
- ✓ Regular millet intake helps manage type 2 diabetes by maintaining blood glucose levels.
- ✓ Millets aid in obesity management by reducing BMI and controlling body weight.
- ✓ They are rich in antioxidants, which reduce oxidative stress linked to chronic diseases.
- ✓ Antioxidant activity of millets may lower the risk of neurodegenerative disorders, diabetes, and cardiovascular diseases.

How Fermented Millets May Support Mental Well-Being

Fermented millets provide more than basic nutrition they can promote gut health, which is closely linked to brain function and emotional balance through the gut-brain axis.

- Better digestion and lower inflammation: Fermentation improves nutrient availability and supports beneficial gut microbes. A healthy gut barrier and balanced microbiota may help reduce systemic inflammation, which is associated with mood disorders and cognitive decline.
- Support for brain chemistry: Some probiotic microorganisms involved in fermentation can influence the gut–brain axis and are linked with the regulation of neurotransmitters such as GABA (gamma-aminobutyric acid), which plays a role in relaxation and stress modulation.
- A complementary dietary approach: Alongside medical care and a healthy lifestyle, including fermented foods like fermented millets in the diet may contribute to improved mood regulation, mental clarity, and emotional resilience over time.

Why Fermented Millets Are Better Than Unfermented Millets

- ✓ **Improved nutrient bioavailability:** Fermentation reduces antinutritional factors like phytic acid and tannins, enhancing the absorption of minerals such as iron, zinc, and calcium. Fermented finger millet (ragi) shows higher calcium and iron bioavailability than raw ragi.
- ✓ **Enhanced digestibility:** Microbial enzymes partially break down proteins and starch, making fermented millets easier to digest. Fermented pearl millet batter used for dosa causes less gastric discomfort than unfermented flour.
- ✓ **Lower glycemic response:** Fermentation converts complex carbohydrates into organic acids, which slow glucose release and reduce postprandial blood sugar spikes. Fermented millet idli has a lower glycemic index than plain cooked millet.
- ✓ **Increase in bioactive compounds**

Fermentation releases and generates bioactive peptides and phenolic compounds with antioxidant activity. LAB-fermented foxtail millet shows higher antioxidant capacity.

- ✓ **Probiotic and gut health benefits:** Fermented millets support beneficial gut microbiota and improve intestinal health. Fermented millet beverages act as natural probiotic drinks.
- ✓ **Improved flavor and shelf life:** Organic acids produced during fermentation enhance taste and inhibit spoilage microorganisms. Fermented millet porridge has better flavor and longer shelf stability.
- ✓ **Better suitability for metabolic disorders:** Fermented millets help in managing diabetes, obesity, and cardiovascular risk factors. Regular intake of fermented ragi-based foods supports glycemic control in type 2 diabetes.

Millet fermentation: The secret to supercharged nutrition

Millets are small-seeded ancient grains traditionally consumed in Asia and Africa, including finger millet (ragi), pearl millet (bajra), foxtail millet, little millet, and sorghum (jowar). Fermentation through soaking, sprouting, or natural microbial activity enables lactic acid bacteria and yeasts to reduce antinutritional factors and enhance the formation of probiotics and bioactive compounds, thereby improving digestibility and nutrient absorption. Common fermented millet foods include idli, dosa, kodo millet kanji, ragi ambli, and fermented millet porridges. Although millets naturally contain antinutrients such as phytates, tannins, polyphenols, oxalates, and trypsin inhibitors, traditional processing methods like soaking, sprouting, fermentation, debranning, and steaming effectively lower their levels and improve nutrient bioavailability.

Key benefits of millet fermentation include:

• Breakdown of phytic acid, facilitating better nutrient absorption
• Generation of bioactive compounds such as antioxidants
• Increased bioavailability of essential minerals and vitamins, including iron, zinc, calcium, and b-vitamins; and
• A lower glycemic index due to starch breakdown, resulting in slower glucose release and improved blood sugar management, making fermented millets a nutritionally superior and gut-friendly dietary option.

Many different types of fermented millet products are consumed around the world, as reported by Ajagekar *et al.,* (2023). Those are :

Koko is a traditional West African fermented millet porridge commonly consumed as breakfast, lunch, or a snack. It is prepared by wet milling pearl millet with spices, followed by sieving, fermentation, sedimentation, and cooking. The process is usually completed within 24 hours. Koko is rich in fiber, protein, complex carbohydrates, vitamins, and minerals, and is more digestible than unfermented millet.

Fura is a traditional fermented millet-based food widely consumed in West African countries such as Nigeria, Ghana, and Burkina Faso. It is prepared mainly from pearl millet, a gluten-free and high-fiber grain rich in minerals like iron, magnesium, and phosphorus. Millet flour is mixed with spices, cooked, kneaded into balls, and later reconstituted with sour milk to a porridge-like consistency.

Mangisi is a traditional naturally fermented millet-based beverage widely consumed in rural sub-Saharan Africa, particularly in Zimbabwe and Uganda. It is prepared from malted finger millet flour mixed with water and cooked to form a mash (masvusvu), which is then cooled, diluted, and allowed to undergo spontaneous fermentation. Mangisi is commonly consumed during social gatherings, ceremonies, and as a weaning or household beverage.

Jandh is a traditional mildly sweet and acidic fermented alcoholic beverage of Nepal, prepared mainly from finger millet (kodo or marua), sometimes blended with small amounts of wheat or maize. The millet grains are steamed, cooled, and inoculated with a traditional starter culture (much), then incubated at ambient temperature for initial fermentation. The fermenting grains are subsequently transferred to earthen pots or polyethylene bags, covered, and allowed to ferment further. Water is later added, and the beverage is extracted depending on seasonal practices.

Uji is a thin, lactic acid–fermented porridge widely consumed in East Africa, particularly in Kenya, Uganda, and Tanzania, where it is also known as Obusera and Iwawa. It is produced by fermenting mixtures of maize, sorghum, finger millet, and/or cassava flours using backslopping as the inoculation method. Uji is commonly consumed by both adults and children as a beverage and as a weaning food, with *Lactobacillus plantarum* being the dominant microorganism responsible for lactic acid production and the characteristic sour taste

Burukutu and Pito are traditional African alcoholic beverages in which millet is commonly used as a substitute for barley. Cereals such as finger millet play a major role in malt production in sub-Saharan Africa and parts of India. Unlike Western beers, African beers are

typically sour, lightly carbonated, unhopped, and often consumed unfiltered, containing residual substrates and microorganisms. Burukutu and Pito are brewed by fermenting malted or germinated millet, either alone or in combination with other cereals, resulting in a brownish suspension or liquor that is widely consumed in West Africa.
Ogi is a traditional fermented cereal porridge widely consumed in West Africa, prepared from millet, sorghum, or maize as a paste or moist cake wrapped in leaves or polyethylene bags. Gelatinized ogi is commonly used as a weaning food for infants from 4–6 months of age and is also consumed as a breakfast food by adults. Fermentation and malting modify starch properties, reducing excessive thickening and improving digestibility, while also enhancing microbiological safety. Studies have shown that *Lactobacillus plantarum* is the predominant bacterium responsible for lactic acid production and nutritional improvement, along with yeasts such as *Saccharomyces cerevisiae* and *Candida* spp. The characteristic sour taste and aroma of ogi are due to lactic, acetic, butyric, and formic acids, with consumers generally preferring lightly colored, mildly acidic ogi.
Ben-saalga is a traditional fermented millet gruel produced in Burkina Faso and commonly used as a complementary food for children. Its preparation involves cleaning, soaking, grinding, kneading, sifting, settling, and cooking pearl millet, often with small amounts of spices such as ginger and pepper. Although widely consumed, the cooked sour ben-saalga has been reported to have limited nutritional adequacy for infants and young children.
Bushera is a popular traditional fermented beverage from Uganda's western highlands, produced from germinated sorghum or millet flour. It is consumed by both children and adults and is prepared by mixing flour with boiling water, cooling, and fermenting for 1–6 days. The dominant microflora includes lactic acid bacteria, particularly *Lactobacillus brevis*, along with *Lactococcus*, *Leuconostoc*, *Enterococcus*, and *Streptococcus* species.
Togwa is a lactic acid–fermented traditional drink widely consumed in southern Tanzania, prepared from finger millet malt and maize flour. It is used both as a weaning food and a refreshing beverage. Fermentation occurs spontaneously after adding malted flour and a portion of previously fermented togwa, resulting in variable product quality.
Kunlun-zaki (also spelled *kunun-zaki*) is a popular non-alcoholic, cereal-based fermented beverage prepared from grains and widely consumed as a refreshing cold drink in the Sahel region, particularly in Chad, northern Nigeria, and Niger. At present, kunun-zaki production is largely a household-level activity, with little to no industrial-scale manufacturing.

Conclusion

Millets are ancient, nutrient-dense grains valued for their health-promoting properties and gluten-free nature. Fermentation further enhances their nutritional quality by improving digestibility, increasing mineral bioavailability, reducing antinutritional factors, and enriching bioactive compounds. Fermented millet foods also support gut health through beneficial microorganisms, which may positively influence immunity, metabolic health, and even mental well-being via the gut–brain axis. Traditional fermented millet products consumed worldwide highlight their cultural and functional importance. Overall, fermented millets represent a sustainable, affordable, and functional food choice with significant potential in promoting nutrition, preventing lifestyle disorders, and supporting overall health.

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