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Fermented Millet Foods: Nutritional Enhancement, Bioactive Transformation and Gut Health Potential

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Abstract

Millets are nutrient-dense, climate-resilient cereals that have traditionally been consumed in fermented foods and beverages in several regions of Asia and Africa. Fermentation provides an effective biological approach for improving the nutritional and functional characteristics of millet-based foods. Microorganisms such as lactic acid bacteria, yeasts, and selected fungi can modify carbohydrates, proteins, phenolic compounds, and antinutritional factors during fermentation. These transformations may improve digestibility, mineral bioavailability, protein utilization, and the accessibility of bioactive compounds. Fermentation can also generate organic acids, peptides, vitamins, and other metabolites with potential physiological effects. Increasing evidence suggests that fermented millet products may interact with the intestinal microbiota through their dietary fibre, resistant carbohydrates, polyphenols, and microbial metabolites, thereby contributing to gastrointestinal health.

Keywords: *Millets, fermentation, lactic acid bacteria, bioactive compounds, gut microbiota, functional foods, nutritional enhancement.*

1. Introduction

Millets have gained renewed scientific and commercial interest because of their nutritional value, environmental adaptability, and potential contribution to sustainable food systems. Finger millet, pearl millet, foxtail millet, little millet, proso millet, and barnyard millet provide carbohydrates, proteins, dietary fibre, minerals, vitamins, phenolic compounds, and other phytochemicals [1]. Traditional fermentation has long been used to improve the quality and shelf stability of cereal-based foods. Fermentation is particularly relevant to millets because microbial activity can modify the cereal matrix and improve the availability of nutrients and bioactive compounds. Lactic acid bacteria and yeasts are among the most frequently involved microorganisms, either naturally or through the use of selected starter cultures [2]. Beyond nutritional improvement, fermentation may influence the interaction between millet-derived components and the gastrointestinal microbiota. This has created interest in fermented millet foods as potential functional foods capable of combining cereal nutrition with microbial and metabolite-mediated health benefits.

2. Fermentation of Millet Foods

Millet fermentation may be carried out through spontaneous fermentation or controlled fermentation using selected microorganisms. Spontaneous fermentation depends on the microorganisms naturally present on the grain or in the processing environment, whereas controlled fermentation uses defined starter cultures. Lactic acid bacteria, including species belonging to *Lactiplantibacillus*, *Lacticaseibacillus*, *Levilactobacillus*, and *Streptococcus*, can produce organic acids and modify the chemical environment of the food. Yeasts may contribute to carbohydrate metabolism, flavour development, and gas production in certain fermented products. Common processing steps include soaking, milling, fermentation, cooking, drying, and formulation. The final nutritional and sensory properties depend on millet species, water-to-grain ratio, fermentation time, temperature, pH, and microbial composition.

Table 1. Major effects of fermentation on millet-based foods

Component	Effect of fermentation	Potential benefit
Phytate	Partial degradation	Improved mineral availability
Phenolics	Transformation/release	Greater accessibility of bioactive compounds
Proteins	Partial hydrolysis	Improved digestibility and peptide formation
Starch	Structural modification	Altered digestibility
Dietary fibre	Microbial modification	Potential prebiotic effects
Carbohydrates	Conversion to organic acids/metabolites	Improved flavour and preservation
Vitamins	Potential microbial synthesis or increased availability	Improved nutritional profile

3. Nutritional Enhancement

One of the principal benefits of millet fermentation is the reduction of selected antinutritional factors. Phytate can bind minerals such as iron, zinc, calcium, and magnesium and reduce their absorption. Fermentation activates microbial and endogenous phytases, which can hydrolyse phytate and potentially increase mineral bioavailability [3].

Fermentation may also improve protein digestibility. Microbial proteolytic enzymes can partially hydrolyse storage proteins and produce smaller peptides and amino acids. This may improve the accessibility of proteins during gastrointestinal digestion. Starch is another important component affected by fermentation. Microbial metabolism and associated processing can alter starch structure and carbohydrate availability. Depending on the fermentation conditions, this may modify the rate of starch digestion and potentially influence postprandial glucose responses. The nutritional effect of fermentation is not universally positive, however. Certain nutrients may be lost during soaking, filtration, heating, or prolonged fermentation. Consequently, process optimization is necessary to maximize nutritional improvements while minimizing nutrient losses.

4. Bioactive Transformation During Fermentation

Millets contain phenolic acids, flavonoids, tannins, and other phytochemicals. Many of these compounds occur in bound forms associated with cell-wall components and may have limited bio-accessibility. Microbial enzymes can modify these structures and release or transform phenolic compounds during fermentation [4]. This transformation may increase the measurable antioxidant capacity of fermented millet products. Fermentation can also generate new metabolites with potential biological activity. However, increased antioxidant activity in chemical assays should not automatically be interpreted as evidence of clinical health benefits. Protein fermentation and enzymatic hydrolysis may additionally generate bioactive peptides. Some cereal-derived peptides have demonstrated antioxidant, antihypertensive, antimicrobial, or enzyme-inhibitory activities in experimental systems [5]. Further human studies are required to determine whether these activities translate into meaningful physiological effects.

5. Fermented Millet Foods and Gut Health

The gastrointestinal tract provides an important interface between fermented foods, dietary components, and the intestinal microbiota. Fermented millet foods contain dietary fibre, resistant carbohydrates, phenolic compounds, organic acids, and, depending on processing and product type, live microorganisms. Dietary fibre and resistant carbohydrates can reach the colon and serve as substrates for microbial fermentation. Their metabolism may generate short-chain fatty acids such as acetate, propionate, and butyrate. These metabolites have important roles in intestinal barrier function, immune regulation, and host energy metabolism [6].

Polyphenols from millet may also interact with gut microorganisms. Some poorly absorbed phenolic compounds can be metabolized by intestinal bacteria into smaller molecules that may possess different biological properties. Thus, the health effects of millet-based foods may depend partly on reciprocal interactions between plant compounds and the gut microbiota. When fermented millet products contain viable beneficial microorganisms, they may provide additional microbial functionality. Nevertheless, survival of microorganisms during processing and storage must be demonstrated, and probiotic claims require appropriate strain-specific scientific evidence.

6. Potential Functional Applications

Fermented millet can be incorporated into a variety of traditional and modern food products. Fermented porridges and beverages remain important applications, while contemporary product development includes fermented plant-based drinks, yoghurt-like foods, snacks, bakery products, and complementary foods.

Table 2. Potential applications of fermented millet foods

Product category	Fermentation-related advantage	Development opportunity
Fermented beverages	Organic acid production and flavour development	Functional drinks
Fermented porridge	Improved digestibility	Complementary and nutritional foods
Fermented dough products	Improved texture and flavour	Bakery applications
Millet yoghurt alternatives	Microbial fermentation	Dairy-free functional foods
Fermented snacks	Improved nutritional characteristics	Convenient health foods
Fermented millet flour	Improved functional properties	Ingredient for food formulations

Fermented millet foods may be particularly valuable in regions where millet is locally available, and traditional fermentation knowledge already exists. Modern processing can standardize these products while retaining culturally relevant characteristics.

7. Challenges and Future Perspectives

Several challenges must be addressed before fermented millet foods can achieve wider functional-food applications. Fermentation outcomes can vary considerably depending on raw material composition and microbial populations. Standardization of starter cultures, fermentation time, temperature, and endpoint pH is therefore important. Sensory quality is another consideration. Fermentation can produce desirable acidity and flavour but may also generate strong or unfamiliar sensory characteristics. Consumer acceptance studies should accompany product development. The relationship between fermented millet consumption and gut health also requires more rigorous investigation. In vitro microbiota studies and animal experiments provide useful mechanistic information, but well-designed human intervention studies are needed to establish effects on microbiome composition, short-chain fatty acid production, gastrointestinal function, and metabolic health. Future research should combine metabolomics, microbiome analysis, food chemistry, and clinical nutrition to identify specific fermentation-derived compounds responsible for potential health effects. The use of selected starter cultures and controlled fermentation could enable the development of standardized fermented millet products with predictable nutritional and functional characteristics.

8. Conclusion

Fermentation provides a promising biological strategy for improving the nutritional and functional characteristics of millet-based foods. Microbial activity can reduce selected antinutritional factors, modify proteins and carbohydrates, release or transform phenolic compounds, and generate potentially beneficial metabolites. These changes may improve nutrient bioavailability and contribute to the functional properties of fermented millet products. The presence of dietary fibre, resistant carbohydrates, polyphenols, organic acids, and potentially beneficial microorganisms also provides a basis for investigating their relationship with gut health. However, stronger clinical evidence is required before specific health claims can be established. Future integration of controlled fermentation, advanced analytical methods, microbiome research, and sustainable food processing could strengthen the role of fermented millet foods in modern functional nutrition.

References

1. Saleh, A. S. M., Zhang, Q., Chen, J., & Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety, 12*(3), 281–295.
2. Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., & Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Research International, 36*(6), 527–543.
3. Nkhata, S. G., Ayua, E., Kamau, E. H., & Shingiro, J. B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science & Nutrition, 6*(8), 2446–2458.
4. Chandrasekara, A., & Shahidi, F. (2012). Bioaccessibility and antioxidant potential of millet grain phenolics as affected by simulated in vitro digestion and microbial fermentation. *Journal of Functional Foods, 4*(1), 226–237.
5. Udenigwe, C. C., & Aluko, R. E. (2012). Food protein-derived bioactive peptides: Production, processing, and potential health benefits. *Journal of Food Science, 77*(1), R11–R24.
6. Koh, A., De Vadder, F., Kovatcheva-Datchary, P., & Bäckhed, F. (2016). From dietary fibre to host physiology: Short-chain fatty acids as key bacterial metabolites. *Cell, 165*(6), 1332–1345.
7. Taylor, J. R. N., & Duodu, K. G. (2015). Effects of processing sorghum and millets on their phenolic phytochemicals and the implications for health. *Molecules, 20*(1), 1041–1062.
8. Marco, M. L., Heeney, D., Binda, S., Cifelli, C. J., Cotter, P. D., Foligné, B., Gänzle, M., Kort, R., Pasin, G., Pihlanto, A., Smid, E. J., & Hutkins, R. (2017). Health benefits of fermented foods: Microbiota and beyond. *Current Opinion in Biotechnology, 44*, 94–102.
9. Parvez, S., Malik, K. A., Ah Kang, S., & Kim, H. Y. (2006). Probiotics and their fermented food products are beneficial for health. *Journal of Applied Microbiology, 100*(6), 1171–1185.