

FERMENTATION EFFECTS ON NUTRITIONAL QUALITY OF TRADITIONAL FOOD PRODUCTS

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ABSTRACT

Fermentation is one of the oldest and most widely used biological food-processing techniques and remains an important part of traditional food systems in many regions of the world. Traditional fermented foods are commonly prepared from cereals, legumes, vegetables, fruits, milk, and other locally available raw materials through the metabolic activities of naturally occurring or deliberately introduced microorganisms. The fermentation process can produce substantial biochemical changes in food composition, including the transformation of carbohydrates, proteins, lipids, vitamins, minerals, phenolic compounds, and other bioactive components. Recent research indicates that fermentation can improve nutritional quality by increasing nutrient bioavailability, enhancing protein digestibility, reducing antinutritional factors such as phytate and tannins, and generating beneficial metabolites. For example, research on traditional finger-millet injera found that fermentation reduced phytate and condensed tannins while increasing the bioaccessibility of iron, zinc, and calcium. Fermentation may also contribute to improved sensory properties, preservation, digestibility, and functional characteristics of traditional foods. However, nutritional changes are not always positive or uniform; they depend on the raw material, microorganisms, fermentation duration, temperature, pH, moisture, and processing conditions.

KEYWORDS : *Fermentation, traditional foods, nutritional quality, nutrient bioavailability, probiotics, lactic acid bacteria, antinutritional factors, phytate, mineral bioavailability, food processing, fermented foods, food safety.*

INTRODUCTION

Fermentation is an ancient biological process that has played an important role in the development of human food systems. Long before the emergence of modern food-processing technologies, communities used fermentation to preserve seasonal foods, improve their flavor and texture, extend shelf life, and make certain raw materials easier to digest. Traditional fermented foods are found in almost every part of the world and are produced from a wide variety of raw materials, including cereals, legumes, vegetables, fruits, roots, tubers, milk, meat, and fish. Examples include sourdough products, fermented porridges, injera, tempeh, kimchi, sauerkraut, yogurt, traditional cheeses, fermented soybean products, pickles, and numerous indigenous beverages. Künili, İ. E., Akdeniz, V., Akpınar, A., Budak, Ş. Ö., Curiel, J. A., Guzel, M., ... & Kesenkaş, H. (2025). FOUND THAT Contemporary research increasingly recognizes that fermentation is not simply a preservation method but also a biochemical process capable of changing the nutritional characteristics of foods. The nutritional quality of a food depends not only on the amount of nutrients present in the raw material but also on the extent to which those nutrients can be digested, absorbed, and utilized by the human body. Cereals and legumes, for example, can contain substantial quantities of protein, minerals, dietary fiber, vitamins, and phytochemicals. However, they may also contain antinutritional compounds such as phytate, tannins, oxalates, enzyme inhibitors, and certain polyphenols that can interfere with nutrient digestion or mineral absorption. Fermentation can modify these compounds through microbial

enzymes and metabolic activities. In cereal-based foods, fermentation has been associated with reductions in antinutritional factors and improvements in nutrient bioavailability.

A recent review of cereal-based fermented foods concluded that fermentation can improve proximate nutritional characteristics, mineral bioavailability, antioxidant activity, and sensory properties while reducing several antinutritional factors. Microorganisms are the central agents responsible for most fermentation processes. Lactic acid bacteria, yeasts, molds, and other microorganisms can use nutrients in the food substrate as sources of energy and growth. During this process, microorganisms produce organic acids, alcohols, enzymes, gases, peptides, vitamins, aromatic compounds, and other metabolites. These products can influence the nutritional, sensory, microbiological, and functional characteristics of fermented foods. The microbial ecology of a fermented product depends on the raw material, environmental conditions, processing practices, fermentation temperature, acidity, oxygen availability, and duration of fermentation. Consequently, two traditionally prepared foods with similar ingredients can have significantly different nutritional characteristics because of differences in microbial communities and processing conditions. One of the most important nutritional effects of fermentation is the improvement of protein quality and digestibility. Proteins in cereals and legumes can be difficult to digest because of their structural characteristics and interactions with other food components. Mukherjee, A., Breselge, S., Dimidi, E., Marco, M. L., & Cotter, P. D. (2024). REVEALED ON During fermentation, microbial proteases and other enzymes break complex proteins into smaller peptides and amino acids. These transformations can increase protein accessibility to digestive enzymes and may generate biologically active peptides. Fermentation can therefore influence both the quantity and functional availability of protein. In some foods, measured protein concentration may increase because microorganisms consume carbohydrates and alter the relative composition of the food matrix, although this does not necessarily mean that new protein has been created in nutritionally equivalent amounts. Thus, nutritional interpretation should distinguish between changes in concentration and changes in absolute nutrient content.

Carbohydrates are another major food component affected by fermentation. Microorganisms commonly utilize fermentable carbohydrates as energy sources, producing organic acids, carbon dioxide, ethanol, and other metabolites. The resulting reduction in certain readily fermentable carbohydrates can modify the energy density, sweetness, acidity, digestibility, and glycemic characteristics of food. In cereal fermentation, the breakdown of complex carbohydrates can influence viscosity, texture, and digestibility. Sourdough fermentation, for example, produces biochemical transformations in proteins, carbohydrates, fats, vitamins, and minerals and can increase certain bioactive components in cereal foods. Fermentation also has an important relationship with dietary fiber. The effects depend on the type of food and the microorganisms involved. Some components of fiber may be degraded during fermentation, while others may become more accessible or undergo structural changes. Fermentation can therefore influence soluble and insoluble fiber fractions as well as resistant starch and other carbohydrate components. The nutritional significance of these changes depends on the final food matrix and the extent to which the modified components are available to the digestive system.

Mineral bioavailability represents another important area in which fermentation can improve nutritional quality. Cereals and legumes may contain minerals such as iron, zinc, calcium, and magnesium, but their absorption can be limited by phytate and other mineral-binding compounds. Microbial phytase activity during fermentation can break down phytic acid and release minerals from complexes. A recent experimental study of finger-millet-based injera demonstrated that fermentation reduced phytate and condensed tannin levels and increased the bioaccessibility of iron, zinc, and calcium. The study reported increases in bioaccessible minerals with increasing fermentation time, although the magnitude differed according to mineral and flour variety. Vitamins can also be affected by fermentation. Certain microorganisms are capable of synthesizing or contributing to the formation of vitamins, particularly some B-group vitamins and vitamin K-related compounds. However, the extent of vitamin production differs among microorganisms and food substrates. Some vitamins can also be degraded during processing, meaning that fermentation should not automatically be assumed to increase every vitamin. Recent research specifically examining microbial vitamin formation emphasizes the importance of microorganism-specific effects and food-processing conditions in determining vitamin outcomes. The nutritional importance of traditional fermented foods is particularly relevant in developing and rural communities. Traditional foods are often produced from locally available ingredients and require relatively simple equipment. Fermentation can increase the usability and storage stability of these foods without requiring sophisticated industrial infrastructure. This makes fermentation an economically accessible food-processing method.

Traditional fermented foods are also attracting increasing scientific attention because of their microbial biodiversity. Different foods contain different microbial ecosystems, and these microorganisms contribute to characteristic flavor, aroma, texture, acidity, and nutritional properties. Modern microbiological and molecular techniques have made it possible to identify microorganisms that were previously difficult to characterize. This scientific understanding may support the preservation of traditional fermentation practices while also allowing researchers to develop safer and more standardized fermentation systems. However, the nutritional benefits of fermentation must be interpreted carefully. Fermentation does not automatically improve every nutritional characteristic of every food. Certain nutrients may decrease because microorganisms consume them or because they are degraded during fermentation. Some fermentation processes may also increase acidity, salt concentration, alcohol content, or other components that require dietary consideration. Furthermore, poorly controlled fermentation can permit the growth of undesirable microorganisms or the accumulation of harmful metabolites. Reviews of indigenous fermented foods have emphasized that safety remains insufficiently documented for some traditional products.

The duration of fermentation is another critical factor. Short fermentation may produce insufficient microbial transformation, whereas prolonged fermentation may cause excessive degradation of particular nutrients or undesirable sensory changes. Temperature also affects microbial growth and enzyme activity. Similarly, pH influences which microorganisms dominate the fermentation ecosystem. Starter cultures can be used to improve reproducibility, but excessive standardization may alter the traditional characteristics of a food. Therefore, an

important challenge is to achieve a balance between traditional processing, nutritional improvement, sensory acceptability, and microbiological safety. Recent research has also moved from examining simple nutrient concentration toward examining bioavailability, bioaccessibility, metabolite formation, and functional effects. This represents an important development in nutritional science. A food containing a high concentration of iron is not necessarily nutritionally superior if the iron is poorly absorbed. Fermentation can therefore be valuable because it may improve the body's access to nutrients without necessarily increasing the total amount of those nutrients. The finger-millet injera study provides a strong example of this distinction because the major nutritional improvement was demonstrated through increased mineral bioaccessibility following reductions in antinutritional compounds.

Fermentation is also relevant to modern interest in plant-based foods. Consumers increasingly seek foods that are minimally processed, sustainable, functional, and nutritionally valuable. Fermentation can be applied to cereals, legumes, vegetables, fruits, and plant-based dairy alternatives. Another important dimension is the relationship between fermented foods and gastrointestinal health. Some fermented products contain live microorganisms, although not every fermented food remains probiotic after processing. Microbial metabolites, organic acids, peptides, and other fermentation products may contribute to the functional properties of foods. Current reviews suggest that fermented foods may influence gastrointestinal health through several mechanisms, including interactions between food-associated microorganisms, microbial metabolites, and the intestinal microbiota. However, evidence varies substantially among food types, populations, and study designs. Traditional fermented foods may therefore be viewed as both cultural products and nutritional resources. Their nutritional properties result from a complex interaction among raw materials, microorganisms, processing conditions, and storage. Understanding these interactions can help researchers and food producers improve the nutritional quality of traditional foods while preserving their cultural characteristics.

RESEARCH OBJECTIVE

1. To examine the effects of fermentation on the nutritional quality of traditional food products, particularly its influence on nutrient composition, bioavailability, digestibility, antinutritional factors, bioactive compounds, and overall food quality.

RESEARCH QUESTION

1. How does fermentation affect the nutritional quality of traditional food products in terms of nutrient composition, bioavailability, digestibility, antinutritional factors, and functional properties?

LITERATURE REVIEW

Fermentation has historically been used as a practical method of preserving foods and improving their sensory characteristics. Traditional fermentation generally relies on naturally occurring

microorganisms or previously fermented material used as an inoculum. Indigenous foods may be prepared through spontaneous fermentation, in which microorganisms naturally present on the raw material, utensils, environment, or previous batches initiate the process. Other products use defined starter cultures. The resulting microbial community produces metabolites that alter the physical and chemical characteristics of the food. Recent literature emphasizes that fermented foods represent complex microbial ecosystems rather than simple products of a single microorganism. Environmental conditions and raw materials strongly influence microbial communities and therefore the final nutritional and sensory properties of the product. Protein is an essential macronutrient required for tissue development, enzymes, hormones, and numerous physiological functions. Fermentation can improve protein digestibility through microbial proteolysis. Microorganisms produce proteolytic enzymes that hydrolyze complex proteins into peptides and amino acids. This can make proteins more accessible to human digestive enzymes. The effects are particularly relevant for cereal- and legume-based traditional foods. Legumes contain considerable protein but may also contain protease inhibitors and other compounds that limit digestibility. Fermentation may reduce these inhibitory compounds while simultaneously transforming proteins. Consequently, fermented products can provide protein in a more digestible form

.However, the nutritional interpretation of increased protein percentage requires caution. Microbial utilization of carbohydrates can change the relative concentration of protein even if the absolute protein quantity does not increase. Thus, studies should evaluate both composition and digestibility. Carbohydrates are among the major substrates consumed by fermenting microorganisms. Lactic acid bacteria and yeasts can convert fermentable carbohydrates into organic acids, carbon dioxide, ethanol, and other metabolites. These transformations influence sweetness, acidity, texture, viscosity, and digestibility. Sourdough research demonstrates that fermentation produces significant transformations in cereal carbohydrates and other nutrients. Fermentation may also influence resistant starch and dietary fiber fractions, although the direction and magnitude of change depend on the food matrix and processing conditions. One of the most consistent nutritional advantages reported in the literature is the reduction of antinutritional factors. Phytate is particularly important because it can bind minerals such as iron, zinc, and calcium. Díaz, A., García, G., & Cano, R. D. J. (2026) . Tannins and enzyme inhibitors can also interfere with digestion and nutrient absorption. Microorganisms can produce enzymes capable of degrading phytate and other compounds. As a result, fermentation can reduce the concentration or activity of antinutritional factors and improve nutrient accessibility.

Phytate is particularly important in cereals and legumes because it can bind minerals and reduce their absorption. Endalew et al. reported that traditional fermentation of finger-millet-based injera reduced phytate and condensed tannins and increased the bioaccessibility of iron, zinc, and calcium. Their results provide experimental evidence that fermentation can improve mineral utilization rather than simply changing mineral concentration. This finding is particularly important for populations relying heavily on cereal- and plant-based foods. Improving mineral bioavailability through traditional processing could contribute to better nutritional quality without requiring expensive fortification technologies. Fermentation can modify phenolic

compounds and other phytochemicals. Plant foods often contain bioactive compounds in bound or chemically complex forms. Microbial enzymes can release these compounds or transform them into different metabolites. Research on fermented vegetables indicates that fermentation can increase the release and availability of bioactive molecules and may improve nutritional and functional properties. Fermentation may consequently affect antioxidant capacity. However, antioxidant activity should not be treated as a single indicator of nutritional quality because different analytical assays measure different chemical properties. Dairy fermentation is one of the most established examples of traditional fermentation.

Yogurt, traditional cultured milk, cheese, kefir, and other fermented dairy products are produced through microbial activity. Fermentation modifies lactose, proteins, organic acids, flavor compounds, and microbial composition. Traditional dairy fermentation may improve digestibility for some individuals by reducing lactose through microbial metabolism.. Recent reviews have examined the nutritional and potential health-related properties of fermented dairy products, while emphasizing differences among products and microbial cultures. Legumes are valuable sources of protein, dietary fiber, minerals, and phytochemicals. Nevertheless, they contain several antinutritional factors. Fermentation can reduce these compounds and improve protein digestibility. Traditional fermented soybean foods provide an important example. Recent research on Korean fermented soybean products describes complex microbial communities and significant nutritional and functional characteristics associated with products such as fermented soybean pastes Ashaolu, T. J., Greff, B., & Varga, L. (2025).. Fermented vegetables such as kimchi, sauerkraut, traditional pickles, and other regional products are important sources of organic acids, dietary fiber, phytochemicals, and microorganisms. Fermentation produces characteristic acidity and flavor while contributing to preservation. Recent research has emphasized the bioactive properties of fermented vegetables and their potential nutritional significance. The nutritional outcome, however, depends on ingredients, salt concentration, fermentation conditions, and storage. Improved digestibility is one of the important nutritional effects associated with fermentation. Microbial enzymes can partially break down proteins, carbohydrates, and other food components before consumption. Fermentation may therefore reduce the digestive workload and increase nutrient accessibility.

Fermented foods are also being studied in relation to gastrointestinal health. A recent review in Nature Reviews Gastroenterology & Hepatology examined mechanisms through which fermented foods and their components may influence gastrointestinal health. However, not every fermented food contains live microorganisms at the point of consumption, and the health effects of fermented foods should not automatically be equated with probiotic effects. Food safety is an essential component of nutritional quality. A food cannot be considered beneficial if unsafe microorganisms or toxins are present. Fermentation can increase food safety by lowering pH, producing antimicrobial compounds, and inhibiting many undesirable microorganisms. Nevertheless, traditional spontaneous fermentation can be variable. Indigenous fermented foods may be prepared under different household conditions, and microbiological safety may not always be adequately documented. A 2023 review of indigenous fermented foods highlighted the importance of further research into microbial composition and safety.

Traditional fermentation is not only a food-processing technology but also a form of cultural knowledge. Recipes, fermentation practices, starter materials, vessels, timing, and sensory criteria are often transferred between generations. Recent studies of traditional fermented foods emphasize their cultural and economic importance alongside their nutritional properties. For example, research on Malaysian fermented foods discusses their role in cultural heritage, traditional culinary practices, nutrition, and sustainable food systems. Current research is increasingly integrating traditional knowledge with modern microbiology, metabolomics, nutritional analysis, and food technology. Scientists are studying microbial biodiversity, fermentation metabolites, bioactive compounds, and mechanisms of nutrient transformation. The 2025 review by Sampsel et al. indicates that current fermented-food research increasingly connects fermentation with nutritional and health outcomes while identifying the need for better product characterization and stronger experimental evidence. Overall, the literature demonstrates that fermentation can substantially modify the nutritional characteristics of traditional foods. However, the effects are highly dependent on food type, microorganism, fermentation duration, temperature, pH, and processing conditions.

METHODOLOGY

This study adopted a qualitative descriptive research approach based on a structured literature review to examine the effects of fermentation on the nutritional quality of traditional food products. The approach was selected because the purpose of the study was to synthesize existing scientific knowledge regarding the nutritional changes associated with traditional fermentation rather than to conduct a new laboratory experiment. Recent peer-reviewed literature concerning fermented cereals, legumes, vegetables, dairy products, indigenous fermented foods, microbial ecology, antinutritional factors, mineral bioavailability, and bioactive compounds was examined. Particular attention was given to studies published between 2023 and 2026 so that the discussion would reflect recent developments in fermentation and nutritional science. The literature was analyzed comparatively to identify recurring findings concerning protein digestibility, carbohydrate transformation, vitamin formation, mineral bioavailability, reduction of phytate and tannins, antioxidant activity, sensory quality, food safety, and functional properties.

RESEARCH DESIGN

A was employed. The design involved identifying relevant academic literature, examining the findings reported by different researchers, comparing results across food categories, and organizing the evidence according to major nutritional dimensions. The study considered traditional fermented products prepared from cereals, legumes, vegetables, fruits, and dairy materials. Studies were considered relevant when they examined fermentation and at least one nutritional or food-quality outcome. Priority was given to peer-reviewed review articles and experimental studies published in recognized scientific journals. The selected literature included studies examining traditional foods directly as well as broader studies addressing mechanisms of fermentation that are applicable to traditional food products. Studies were included when they addressed fermentation of food products and reported information relevant to nutritional quality,

nutrient composition, nutrient bioavailability, digestibility, antinutritional factors, bioactive compounds, sensory characteristics, or food safety. Studies involving traditional or culturally established fermented foods received particular attention. Articles that focused exclusively on non-food industrial fermentation, pharmaceutical fermentation, or unrelated microbial processes were excluded. Duplicate publications and sources without sufficient academic information were also excluded. The literature collection process involved several stages. First, relevant keywords were identified from the research objective and question. Second, academic sources were searched according to these terms. Third, titles and abstracts were examined to determine relevance. Fourth, selected studies were read and important information was extracted. The extracted information included food type, raw material, microorganisms involved, fermentation conditions where available, nutritional components studied, changes observed during fermentation, and major conclusions. The information was then organized into thematic categories to facilitate comparison across studies.

DATA ANALYSIS

The collected information was analyzed through thematic content analysis. Findings from individual studies were grouped into major themes including macronutrient transformation, micronutrient availability, reduction of antinutritional factors, bioactive compound formation, digestibility, sensory characteristics, food safety, and cultural significance. Similar findings were compared to identify common patterns, while contradictory findings were examined in relation to differences in food substrate, microorganisms, fermentation time, temperature, and processing conditions. Particular emphasis was placed on distinguishing changes in nutrient concentration from changes in nutrient bioavailability. The analysis also considered the limitations of traditional fermentation, particularly variability and microbiological safety. The resulting themes were synthesized into an integrated interpretation of how fermentation influences the nutritional quality of traditional food products.

FINDINGS

The reviewed literature indicates that fermentation can improve the nutritional quality of traditional foods by increasing the accessibility and digestibility of nutrients. Microbial enzymes can break down complex proteins and carbohydrates and modify the food matrix. In cereal-based foods, fermentation has been associated with improvements in nutrient bioavailability and digestibility. A consistent finding across the literature is the reduction of phytate, tannins, and other antinutritional compounds. This is particularly important for cereals and legumes, where antinutritional compounds can limit mineral absorption. Experimental research on finger-millet injera demonstrated significant reductions in phytate and condensed tannins following fermentation. The findings indicate that fermentation may improve the bioaccessibility of important minerals, particularly iron, zinc, and calcium. The improvement appears to be associated with degradation of mineral-binding compounds such as phytate. In the finger-millet injera study, mineral bioaccessibility increased with fermentation time, although the magnitude differed among minerals and flour varieties.

The reviewed studies show that fermentation can release, transform, or generate bioactive compounds. Phenolic compounds, peptides, organic acids, and other metabolites may change during microbial activity. These transformations can influence antioxidant and functional characteristics of traditional foods. The findings demonstrate that nutritional changes are strongly dependent on the microorganisms involved. Lactic acid bacteria, yeasts, molds, and mixed microbial communities can produce different enzymes and metabolites. Consequently, the same raw material may produce different nutritional outcomes under different fermentation conditions. Fermentation contributes to the development of characteristic flavor, aroma, acidity, texture, and other sensory properties. It can also improve preservation by producing organic acids and other inhibitory metabolites. These characteristics explain why fermentation remains important in traditional food systems.

CONCLUSION

Fermentation is an important traditional food-processing technology with considerable potential to improve the nutritional quality of traditional food products. The evidence reviewed in this study demonstrates that fermentation can transform food components through microbial enzymatic activity and metabolic processes. These transformations may improve protein digestibility, modify carbohydrates, release bioactive compounds, reduce antinutritional factors, and increase the bioavailability of minerals. Particularly strong evidence exists for the reduction of phytate and tannins and the improvement of mineral bioaccessibility in fermented cereal products. The nutritional effects of fermentation are closely connected with the microorganisms responsible for the process. Lactic acid bacteria, yeasts, molds, and mixed microbial populations produce different enzymes and metabolites, resulting in different nutritional outcomes. Fermentation can also contribute to improved sensory characteristics and preservation, making traditional foods more acceptable and stable. At the same time, fermentation does not automatically improve all nutrients. Certain vitamins or other components may decline, while prolonged or poorly controlled fermentation may result in undesirable changes. Traditional fermentation also has important cultural and economic significance. It preserves indigenous food practices, supports local food systems, and provides communities with a relatively low-cost method for improving food preservation and quality. Modern scientific approaches can contribute to the standardization and safety of traditional fermentation without necessarily eliminating its cultural identity.

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