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Fact vs. Fiction: Fermented Foods and Gut Health

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Despite their long history of use, there is a renewed interest in the consumption of fermented foods. The use of fermented foods is rapidly gaining popularity, garnering attention for purported digestive health benefits. While fermented foods have some evidence of benefit to human health, including improving digestive tolerance, enhancing nutrient bioavailability, and improving food safety and accessibility, many claims are overstated. Additional research is needed prior to making generalized health claims across all products of fermented foods. This review aims to explore the role of fermented foods in digestive health and wellness, and current available evidence for encouraging consumption in an individual's diet.

Ancient Roots to Modern Science

While fermented foods have been consumed for thousands of years, recent advances in understanding the gut microbiome - the make-up of bacteria, viruses, and fungi in the gut - has renewed interest in their consumption. Traditionally, foods were fermented as a means of preservation to improve shelf life, food safety, and accessibility. Fermentation was also used to improve digestive tolerance, taste, and texture of foods. Their prominence in cultural dietary patterns and long history of use has led both consumers and researchers to wonder how fermented foods can fit into current dietary recommendations, how often an individual should consume them, and for what benefit.

Definition of Fermented Foods

To best understand their health benefits, it is important to first understand what constitutes a fermented food. The International Scientific Association for Probiotics and Prebiotics (ISAPP) expert consensus defines fermented foods and beverages as "*foods made through desired microbial growth and enzymatic conversions of food components*".[1]

Microbes, although essential to the fermentation

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process, may or may not be present at time of consumption due to heating and processing (see Table 1). It is important to note that while some foods require fermentation to be identified by their common name (e.g., yogurt), others may not. Sauerkraut, for example, may be pickled or fermented, therefore not all sauerkraut can be considered a ferment (also referred to as a fermented food). Pickled foods are typically produced through submersion in vinegar, and do not require microbes or meet the definition of a fermented food.

It is important to also note that very few fermented foods meet the accepted definition of probiotics. Probiotics, as defined by the ISAPP expert consensus, are "*live microbes, when consumed in adequate amounts; infer a benefit to the host*".[1] Probiotics are strain-specific and have a demonstrated health benefit in a well-designed research study to be classified as such. Most fermented foods do not meet the definition of a probiotic because their strains have not been defined, and adequate colony forming units (CFUs) are not guaranteed to sustain throughout shelf-life. For example, while sauerkraut undergoes fermentation with lactic acid bacteria (LAB), the strains used here are not defined, nor are counts guaranteed throughout shelf life.

Production of Fermented Foods

Fermented foods are produced via spontaneous fermentation or a starter culture. Spontaneous fermentation utilizes microbes that happen to be present in the air or are on the ingredients to ferment upon, whereas a starter culture is used to initially inoculate the food to initiate fermentation.[2] In using a starter culture, microbes may potentially go through a selection process for standardization of the product. While both a science and an art, when it comes to researching the health benefits of a fermented food, the variation in a food's composition and microbes present due to methods of production leads to significant heterogeneity in the literature. A ferment can differ greatly from one to the next in numbers of strains, types of strains, and total CFUs, making it challenging to generalize results from studies. In addition, the foods each have their own nutritive benefits independent of production method, its microbes, and their metabolites.

Table 1. Presence of Live Microbes in Fermented Foods[1]

Fermented Dairy Products	Live Microbes Present Upon Consumption (of unheated product)
Yogurt	Yes
Cheese	Yes
Kefir	Yes
Fermented Soy Products	
Miso	Yes
Natto	Yes
Tempeh	Yes
Soy sauce	Dependent*
Fermented Grain Products	
Dosa (lentils & rice)	No
Idli (rice)	No
Injera (teff)	No
Sourdough bread	No
Fermented Vegetables	
Kimchi	Yes
Sauerkraut	Yes
Fermented Meats	
Salami	No
Fish	Yes
Fermented Beverages	
Buttermilk	Yes
Kombucha	Dependent*
Boza	Yes
Wine	No
Beer	Dependent*
Other	
Cocoa	No
Fish sauce	No

*Dependent on processing techniques

Influence of Fermented Foods on Human Health

Health claims of fermented foods are often overstated. While fermented foods do have associated health benefits, other claims like the ability to treat 'leaky gut' or to replace antibiotic therapies is with minimal evidence. Current research suggests that microbes from ferments are transient.[2] An individual's microbiome is established and resistant to colonization; there is no niche to colonize and therefore exert their benefits transiently. Due to the transient nature of these microbes, it can be inferred that the benefits of fermented foods may only persist for the duration an individual consumes them.

The confirmed health benefits of fermented foods include food preservation, increased nutrient bioavailability, and enhanced digestive tolerance. Using fermentation as a means for food preservation can enhance food safety, accessibility, and retain nutrient values. Through the fermentation process, the transformation of food components can also increase the bioavailability of nutrients by reducing anti-nutritional factors (ANFs) such as phytates and tannins. In reducing these ANFs, micronutrients such as calcium, iron, and magnesium become more bioavailable for absorption.[2,3]

Many epidemiological studies have shown that the risk of chronic disease (e.g., diabetes and cardiovascular disease) often decline with increased consumption of fermented foods.[1,2] Future research is needed to determine the mechanisms of action between ferments and chronic disease. Current theories propose that administration of live cultures may positively interact with our own gut microbiome and innate immune system to help outcompete potential growth of pathogenic bacteria and provide a substrate for fermentation-derived metabolites that infer a benefit to our health. While some benefits have been extensively researched; others are theoretical and require further studies.

A recent study explored the role total fermented food intake had in modulating the human immune system. The randomized prospective study included 36 patients either to receive a diet high in dietary fiber, or to include fermented foods.[4] Patients were monitored 3 weeks pre-intervention, and then had 4 weeks of a 'ramp up' phase where participants worked their way up to a high fiber or high fermented food diet, 6 weeks maintenance of the diet, and a 4 week 'choice diet' where participants maintained the diet to their desired extent. Researchers found that those individuals in the fermented foods arm who were consuming ~6 servings on average of fermented foods a day (up from a baseline of ~0.4 servings of fermented foods a day) had a reduction in pro-inflammatory cytokines. In addition, an increase in microbial diversity was seen with an increase in intake of fermented foods. This is the first study of its kind to assess total fermented food intake and its impact on immune function. While further research is needed, it begins to explore how dietary advice may shift to include a total fermented food target to positively influence human health.

Safety of Fermented Foods

The primary purpose of food fermentation is to increase the shelf-life and thereby enhance the safety of a food or beverage for consumption. Fermentation achieves the purpose in many ways, including reducing water activity and pH via the production of organic acids.[2] The microbes used in fermentation are non-pathogenic and considered safe. While safe for most individuals, it should be noted that some by-products of fermentation may have a negative impact on health, most notably, alcohol and biogenic amines. The production of biogenic amines, like histamine and tyramine, can negatively influence patients diagnosed with mast cell disorders or placed on monoamine oxidase inhibitors (MAOIs).[5,6,7] Through fermentation, amino acids are decarboxylated to release biogenic amines and are found in high quantities in fermented meat and fish products, cheese, wine, and beer. It may be prudent for those on MAOIs, and helpful for those that have histamine intolerance or a mast cell activation disorder to limit intake of biogenic amines and therefore fermented foods.[5]

The Health Benefits of Common Fermented Foods

Healthcare providers are more frequently being asked by their patients "should I consume fermented foods for my health?" or running into patients attempting to utilize fermented foods to treat their digestive symptoms (see Table 2). Being aware of the current evidence for fermented foods in gut

health can ensure patients are receiving accurate information on the benefits of including fermented foods in their diet.

Yogurt

Yogurt is one of the most recognized ferments in North America. In epidemiological studies, yogurt consumption has been associated with a risk

Table 2. Frequently Asked Questions for Fermented Foods

1. How much should I consume and how often?

At this point, we do not have enough evidence to make specific recommendations for intake, however due to the transient nature of microbes (meaning, any microbes consumed like tourists in the gut and are just there for a 'visit') regular consumption is encouraged. Fermented foods are a way to add various nutrients and variety to the diet, in addition to the microbes they offer.

2. Can I cook fermented foods? Can I eat them as part of a hot meal?

In cooking fermented foods, the majority of the time live microbes are destroyed. While there may not be live microbes in the food you are consuming, it does not mean it does not have benefits. For example, sourdough bread does not have live microbes, however the fermentation process improves its digestive tolerance – offering benefit to those who struggle with IBS and are intolerant to FODMAPs*.

3. Are there any risks to consuming fermented foods or any patient populations who should not eat them?

Fermented foods are considered to be safe for the general population; however, there may be certain health conditions that would require a reduction in intake or avoidance such as those on MAOIs, those who are histamine intolerant, or those with mast cell activation disorders.

4. Are all fermented foods considered probiotics?

No, few fermented foods meet the definition of probiotic. While fermented foods can contain live microbes, the microbes are often not adequately characterized down to strain, nor are the microbes quantified, meaning the exact amount of live microbes is unclear. Probiotics require both to be defined, in addition to having research to support health benefits of the particular microbial strain at the specified dose. Just because a fermented food does not classify as a probiotic does not mean it doesn't have benefits – including fermented foods in the diet can have many benefits.

5. Are fermented foods a good alternative to commercial probiotics supplements?

No, fermented foods do not replace the appropriate use of probiotic supplements. While fermented foods are a great way to include variety in the diet, these foods do not have the same therapeutic benefits as certain strains of probiotics. Certain strains of probiotics, when taken in the right dose, have research to support their benefit in very specific health conditions, like prevention of antibiotic associated diarrhea, symptom management with IBS, or prevention of C. difficile.

*FODMAPs: Fermentable Oligosaccharides, Disaccharides, Monosaccharides, and Polyols.

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reduction for Type II diabetes mellitus, heart disease, and cancer. Additionally, it has been associated with improved bone health and weight management.[2,8] It is well established that the fermentation of milk improves digestibility of lactose by reducing the lactose content both in the production of yogurt, and throughout digestion via the live microbes ability to express B-galactosidase.[8] While some studies have shown benefit for yogurt consumption in reducing antibiotic associated diarrhea, results are inconsistent.[9]

While all yogurt is fermented, only some yogurts simultaneously meet the criteria of a fermented and a probiotic food – meaning their bacterial strains are adequately specific, has a therapeutic dose, and has been researched for a particular health benefit. Yogurts and other fermented milk products may include a specific probiotic strain to support specific therapeutic benefits, including improving constipation, reducing symptoms of irritable bowel syndrome (IBS), and reducing incidence of *Clostridioides difficile (C. difficile)* and antibiotic associated diarrhea.[10] It is important to note these findings cannot be generalized to yogurt itself, but refer to the probiotic strain present. Beyond lactose maldigestion and strain-specific therapeutic effects of yogurts with added probiotics, the research supporting yogurt consumption to improve specific digestive disorders is yet to be elucidated.

Kefir

While kefir is often considered to be similar to yogurt, its starter cultures, termed 'kefir grains' include both bacteria and yeast. Kefir has extensive research exploring its impact on human health. Like yogurt, kefir improves the digestibility of the milk by reducing lactose content.[8]

In management of constipation, one uncontrolled pilot study of 20 patients (10 with slow transit constipation and 10 with normal transit constipation) were administered 500 mL of kefir daily for 4 weeks.[11] In both groups of patients, improved stool frequency, stool consistency, and decreased laxative consumption was seen. In addition, a significant improvement was also seen in the group of patients with slow transit constipation. Kefir has shown promise as an adjunct in *Helicobacter Pylori* (*H. Pylori*) eradication. A randomized double blind control study of 82 patients with *H. Pylori* were randomized to receive either 250 mL kefir twice daily, or 250 mL milk containing placebo twice daily as an adjunct to triple antibiotic therapy.[12] In comparison to the patients in the milk group, the patients in the kefir group had a 78.2% eradication rate, whereas the patients in the milk group had a 50% eradication rate ($p=0.26$). The patients in the kefir group also experienced fewer antibiotic-related side effects including diarrhea, headache, nausea, and abdominal pain. Trials with probiotics as an adjunct to antibiotics also have shown similar results.[10] The use of kefir alongside antibiotic therapy for the treatment of *H. Pylori* could be considered.

Kombucha

With roots dating back to Northeast China during the Qin Dynasty in 220 BC, kombucha, a fermented tea drink, is produced with a starter culture of LAB, acetic acid bacteria, and yeast.[2] Acetic acid is produced through fermentation, and polyphenols and flavonoids from the tea increase. Despite its significant popularity in North America and purported benefits for digestive health, there are no human studies to date that explore these claims. While there are several in vitro animal studies that are promising for its antimicrobial and antioxidant effects, blood glucose control, and improving hypercholesterolemia, these cannot be generalized to humans.[2]

Sauerkraut

Produced from the spontaneous fermentation of cabbage via LAB, sauerkraut has been a cultural staple in food preservation for centuries. Very few studies have explored the health benefits of sauerkraut, however, one randomized double-blind pilot study compared the administration of 75 gram/day pasteurized or unpasteurized sauerkraut in 58 patients with IBS over 6 weeks.[13] Both groups showed a significant change in gut microbiota diversity and significant improvement of IBS Severity Scoring System (IBS-SSS). The researchers concluded that other properties of the sauerkraut, independent of pasteurization, including the prebiotic properties and the metabolic by-products of fermentation may have contributed to the favorable results. However,

without unfermented cabbage as an additional control, it is not possible to attribute the results to the fermentation process.

Kimchi

While the cabbage used in the production of kimchi is similar to sauerkraut, the fermentation of the cabbage differs. Kimchi is produced by brining a variety of vegetables, including cabbage, onion, garlic, chilies, and/or ginger, followed by seasoning and spontaneous fermentation. Interestingly, the variety of ingredients largely influences the microbial make-up of kimchi. In vitro and animal studies have found kimchi beneficial for weight control, improving hypercholesterolemia, and explored its anti-carcinogenic and anti-inflammatory enhancing properties.[2] Further studies in humans are indicated to learn of the potential benefits between kimchi and various chronic diseases, including its impact on digestive disorders as well as the gut microbiome.

Soy Products

Tempeh, miso, and nattō are staple fermented soy-based foods often consumed in Asian cultures. While their consumption has been associated with a risk reduction in various chronic diseases, like hypercholesterolemia, cancer, obesity, and diabetes, there is limited research related to digestive health.[2] Some observational studies have found association with miso intake and reduced occurrence of gastric cancer, albeit inconsistently. Nattō has been explored in a small, uncontrolled study of eight individuals for its impact on stool frequency, the gut microbiota, and its metabolites.[14] Results showed an increase in stool frequency in those with infrequent bowel movements, and in fecal samples, an increase in *Bacilli* and *Bifidobacteria* in the stool microbiota, and an increase in production of short chain fatty acids. Although the study size was small and uncontrolled, this supports the need for additional human studies on fermented soy products.

Sourdough Bread

While sourdough bread does not contain live microbes upon consumption, it is produced through the fermentation of flour (usually wheat-based) and a sourdough starter, or mother dough. Sourdough starters can include both bacteria and yeast, with microbial make-up influencing enzymatic activity and altering nutrient composition of the fermented end-product. Yeast and LAB work synergistically, with the metabolic by-products from yeast fermentation going on to act as metabolites for the LAB fermentation. It is through these actions sourdough bread has taken a spotlight in improved digestive tolerance of wheat products in both healthy populations, and those with digestive disorders. It is important to note that some commercially available sourdough bread has not undergone extensive fermentation, rather is flavored with a sourdough flavoring agent – research on sourdough bread has been done with traditionally prepared, fermented sourdough.

Through an intake reduction of fermentable carbohydrates (fructans, galactans, lactose, excess fructose, and sugar alcohols), the low FODMAP (Fermentable Oligosaccharides, Disaccharides, Monosaccharides, and Polyols) diet has been shown to reduce digestive symptoms, particularly of abdominal pain and bloating, in patients with IBS.[15] Fermentation of bread to make sourdough bread reduces fructan content, which renders certain sourdough breads to be suitable for intake on a low FODMAP diet in much larger quantities than non-fermented breads.[16] A double-blinded crossover randomized control study confirmed the impact of sourdough bread consumption had on IBS symptoms in comparison with regular bread.[17] Over two 4-week periods, 87 patients consumed either regular bread or sourdough rye bread, followed by a washout period prior to starting the next intervention group. Researchers assessed IBS symptoms using the validated IBS-SSS, and hydrogen breath excretion via breath test, with using the breads as the substrate. Results showed that during the intervention with the sourdough rye bread, patients showed a significant improvement in the total IBS-SSS as well as several symptoms including abdominal pain, flatulence, stomach rumbling, and intestinal cramping. In addition, during the sourdough rye bread intervention, a lower breath hydrogen excretion was seen via breath test, validating the reduced fermentation occurring in the gut compared to the unfermented bread product. In a small pilot study of 26 patients, who were randomized to receive wheat sourdough

or wheat bread for 7 days, no changes were seen in digestive symptoms with wheat sourdough.[18] However, with the sourdough consumption, the patients experienced significantly more tiredness, joint symptoms, and decreased alertness. This is difficult to interpret due to the small sample size and use of non-validated symptom assessment tools but does warrant further research.

Other Fermented Products

Independent of soy and wheat, research on the fermentation benefits of grains and legume products is limited. Fermented grain products like injera from Ethiopia, kvass from Europe, and dosa from India are staples in many cultures around the world. To the best of our knowledge, no specific research exists on fermented grain and legumes dishes and digestive health. However, it can be theorized that by way of enzymatic conversions, fermentation of grains and legumes may support digestive health. Additional research is indicated to explore these potential benefits.

CONCLUSION

While fermented foods do have evidence-based benefits for improving digestive tolerance, other claims are not supported in the literature. In addition to the long-realized benefits of food safety and accessibility, the fermentation process has also been shown to improve digestive tolerance and enhance nutrient profiles of some foods, benefiting certain patient populations like those with lactose intolerance or IBS. In addition, the cultural and nutritional relevance of fermented foods should not be overlooked. Further research is indicated to continue to explore the benefits of fermented foods on human health, especially as it pertains to our growing understanding of the gut microbiome. Although current research is inconclusive, many properties and known health benefits support the continued intake of fermented food and beverages. ■

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