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Evidence-Based Use of Probiotics, Prebiotics and Fermented Foods for Digestive Health
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Probiotics, prebiotics, and fermented foods have surged in popularity in recent years. But clarity is needed about what these substances are and how they can be incorporated into healthy eating patterns or used in an evidence-based manner in clinical interventions. The interest in this group of substances is likely due, at least in part, to the convergence of several scientific and personal factors, including science on the importance of the microbiome to human health, consumer concerns about suboptimal gut health, and the rise of evidence pointing to health benefits of these substances. A critical review of the existing science is essential, however, so that these substances are used in a manner consistent with the evidence. Disparate messages about these substances can be gleaned from popular press reports, product promotions, regulatory actions, scientific journals, and conclusions from medical organizations. We hope this course will provide clarity and practical information about probiotics, prebiotics, and fermented foods for human use, including the science behind their definitions, their role in diet and health, and some useful resources to guide your use of them in your practice.

Probiotics
Probiotics are live microorganisms that, when administered in adequate amounts, confer a health benefit on the host.[1] Live microorganisms may be present in many foods and supplements, but only characterized strains with a scientifically demonstrated effect on health should be called probiotics. See **Box 1** for the characteristics of a probiotic. It is worth noting that some traits thought to be essential to a probiotic, such as acid resistance, bile tolerance, adherence to epithelial cells, being of human origin, or being able to survive through the gut, may be useful traits in certain circumstances, but none of these is a *required* trait for a probiotic. Probiotics may function very well, for example, in oral applications, without any of these traits.

Importance of strain and dose. Probiotics are known by their genus, species, and strain. For example, consider *Lactobacillus acidophilus* NCFM, a widely consumed probiotic. *Lactobacillus* refers to the genus, *acidophilus* is the species, and NCFM is the strain. In some cases, a subspecies is also part of the correct nomenclature of the probiotic, as is the case for *Bifidobacterium animalis* subsp. lactis and for *Bifidobacterium longum* subsp. *infantis*. Genus names are abbreviated with the first letter when it can be done so without ambiguity. Strain designations are important, as different strains of the same species may have different health effects. For example, *B. animalis* subsp. *lactis* strain CNCM I-2494 has studies showing it can help normalize intestinal transit time[2] while *B. animalis* subsp. *lactis* strain BB12 can help with immunity in infants,[3] and *B. lactis* strain HN019 supports immunity in elderly adults.[4] So be sure to look for the designation that identifies the specific strain showing the desired health benefits. Some strain designations refer to listings in international culture collections, such as CNCM (a

French collection, Collection Nationale de Cultures de Microorganismes), ATCC (American Type Culture Collection), or DSM or DSMZ (a German collection, Deutsche Sammlung von Mikroorganismen und Zellkulturen). Other strain designations are chosen by a researcher or are copyrighted descriptors.

Probiotics should be named according to current nomenclature, which can be challenging because accepted names can change as the science evolves. For example, the *Lactobacillus* genus has undergone recent changes and many well-studied species are now known by a different name (**Table 1**). The probiotic dose, which is typically expressed as CFU (colony forming units), also needs to be considered when recommending a probiotic. A probiotic should be used at the dose found to confer the targeted health benefit in studies; a higher dose is not needed and a lower dose may not be effective. Similarly, probiotics that provide many different strains in a blend may not be more effective than a single-strain preparation; in fact, the converse could be true. In both cases, consider available evidence.

Safety. Probiotic foods are required to have a safety profile equivalent to other food products, which in the United States is reasonable certainty of no harm for the general population. Safety for probiotics sold as dietary supplements are required to meet the standard of no unreasonable risk of illness or injury under conditions of use, again for the general population. To the extent probiotics are used in patient populations or for clinical conditions, safety must be considered further. Many clinical trials for common probiotic strains, such as those belonging to species of the *Lactobacillaceae* family and of the *Bifidobacterium* genus have been conducted and suggest they can be used safely in many patient populations, for example, premature infants[5] and those undergoing chemotherapy.[6] However, caution is advised for use in certain populations, including patients with short bowel syndrome, immunocompromised individuals, such as cancer patients with low white blood cell count, and those with serious underlying illness.[7] For such populations, evidence-based use under the care of relevant medical specialists is imperative, and product quality must match the needs of the patient. In the United States, few probiotic products have undergone safety testing as drugs, and products sold as dietary supplements are likely not manufactured to meet drug specifications.

How do probiotics work? Multiple mechanisms have been uncovered that may mediate probiotic health benefits, and it is likely that several may be recruited to provide a single benefit.[8-10] Production of short-chain fatty acids (SCFAs) in the gut is a central mechanism underlying the functionality of many probiotics, resulting in a lower luminal pH, which can discourage pathogens. SCFAs also are known to have many systemic effects.[11] Mechanisms may also include production of small signaling molecules that may have neuroendocrine or antimicrobial activity, expression of structural molecules on the surface of probiotics that may improve binding to effector cells or mucin, up- or downregulation of immune activity via interactions with immune cells, and upregulation of mucin production or tight junction binding proteins on intestinal epithelial cells. Direct nutritional mechanisms may also be at play through synthesis of vitamins and improved nutrient absorption. Some benefits may be mediated by enzymes produced, such as lactase, which can improve the digestibility of lactose containing foods in lactose malabsorbers, and bile salt hydrolase, which plays an important role in bile salt metabolism and ultimately may lower total cholesterol. **Figure 1** summarizes some of these mechanistic activities. Probiotics may also interact with microbiota in different regions of the body. However, it is not essential that probiotics "alter the gut microbiota" or "change the balance the gut microbiota" to be effective. Most probiotics do not take up permanent residence in the gut, despite documented health benefits. Moreover, there is no evidence that in generally healthy people, probiotics function by widely reshaping microbial communities of the host. Instead, probiotics likely affect the microbiota in more indirect, less all-encompassing ways, such as outcompeting harmful microorganisms. Understanding probiotic mechanisms of action continues to be an active area of research.

Health benefits of probiotics. **Table 2** summarizes the health benefits of probiotics based on target physiological endpoints. Evidence that probiotics may affect different conditions or symptoms has been systematically reviewed under the auspices of different evidence-based organizations, including American Gastroenterological Association,[12] ***Journal of Family Practice***,[13] World Gastroenterology Organisation,[14] European Society for Pediatric Gastroenterology, Hepatology and Nutrition,[15-18] Cochrane,[19] and European Food Safety Authority.[20] In some cases, these systematic reviews have been transformed into evidence-based guidelines. However, not all have reached the same conclusions regarding actionable evidence. Different organizations utilize different evidence analysis and evaluation criteria, including the acceptable number and quality of studies, applicability of research conducted on populations in different global locations, and balance of safety and efficacy.

Most probiotic evidence focuses on different aspects of digestive or immune health. Many examples of digestive endpoints are provided in **Table 2**, including reducing antibiotic associated diarrhea, prevention of *C. difficile* diarrhea, managing some digestive symptoms and lactose maldigestion. Many human trials have also tracked probiotic effects on different expressions of immune activity. These include upregulation, which is thought to mediate anti-infection or anti-tumor activity, and downregulation, which is thought to mediate anti-inflammatory or anti-allergy effects. Studies that track cellular or humoral markers of immune function are informative regarding mechanisms behind probiotic activity. But alone, they are insufficient to inform on clinically meaningful activities, such as resistance to infection or vaccine response. Therefore, in **Table 2**, we only include examples of probiotics with evidence for clinically meaningful expressions of immune function.

Evidence for probiotic benefits extend to body sites beyond the gut and include oral care in children, liver health, bacterial vaginosis, urinary tract infections, brain function, and different expressions of metabolic health.[21,22] Further, studies on probiotics cover different population groups characterized by health status (patients or healthy subjects); age (infants, children, adults and elderly);[23,24] geographic region; and particular occupations (such as shift workers,[25,26] military,[27] athletes,[28] and astronauts[29]). Ultimately, recommendations for the use of probiotics should be dose- and strain-specific and targeted toward the particular needs of your client.

Fermented Foods

Fermented foods are foods made through desired microbial growth and enzymatic conversions of food components.[30] Throughout history, fermentation has served as a way to preserve and process foods, to change their nutritional profiles, and to give them desirable organoleptic properties.[31] Fermentation processes are classified by the microorganisms, the primary metabolites these microorganisms produce, and the type of food undergoing fermentation. These include alcohol and carbon dioxide (produced by yeasts), acetic acid (*Acetobacter*), lactic acid (lactic acid bacteria), propionic acid (*Propionibacterium freudenreichii*), and ammonia and fatty acids (*Bacillus*, molds). The food substrates vary as well, including meats, fish, milk, vegetables, soybeans and other legumes, cereals, starchy roots, and fruits. The transformation of the original food substrates through fermentation may lead to the formation of bioactive or bioavailable end-products. This can increase the concentrations of vitamins or bioactive compounds available to the host, and also may remove or reduce anti-nutritive compounds (such as phytate) present in some raw foods. Common examples of fermented foods are kimchi, sauerkraut, kombucha, kefir, yogurt, miso, and most cheeses and traditional salami.

Although all fermented foods require the action of live microorganisms, fermented foods in their final form may or may not contain live microorganisms (**Table 3**). This is one reason why fermented foods should not be automatically thought of as “probiotic” foods. Many processes, including different forms of heat treatment or filtering, effectively inactivate or remove live microorganisms. This is often done to improve the shelf stability of fermented foods, but in some cases it is inherent to the character of the food (for example, sourdough bread must be baked). Distinctions between probiotics, probiotic fermented foods, and fermented foods are shown in **Table 4**.

Live microorganisms present in traditional fermented foods and beverages such as kefir, kombucha, sauerkraut, and kimchi typically do not meet the required evidence level for probiotics, since their health effects have not been confirmed and the mixtures of microorganisms they contain are often uncharacterized and have not been studied for a health benefit.

Fermented foods are a part of most global cultures and have been consumed safely for millennia. However, it is worth noting that fermented foods and beverages that contain alcohol, high salt, or biogenic amines might not be appropriate for individuals with certain health conditions, including pregnancy, hypertension, or renal disease, respectively, or who engage in certain religious practices. Although fermented beverages such as bosa, busher, kefir, or kombucha generally contain low amounts of alcohol (<0.5%), this should be considered when making recommendations.

Recommending fermented foods. Although studies support that consumption of some fermented foods is associated with reduced risk of disease and better overall health, it is difficult to generalize regarding specific benefits for the many different types of fermented foods. In the case of fermented foods that contain known probiotics, randomized controlled trials have been conducted and reveal health benefits (see **Table 2**). However, most traditional fermented foods, such as kombucha or kimchi, to our knowledge, have not been studied in this manner. A complication for human trials with traditional fermented foods is reproducibility; the food should be made with well-defined cultures so that the microbiological makeup is consistent batch to batch. Some large cohort studies have found strong associations between consumption of fermented dairy products and reduced risk for type 2 diabetes,[32] less weight gain over time in a prospective study of >120,000 adults,[33] and reduced risk of overall mortality.[34] However, these studies are associative, not causal, and it is difficult to separate out confounding lifestyle factors that might contribute to these outcomes. More randomized, controlled trials are needed to measure the health benefits of fermented foods.[35]

As fermented foods may contribute to health, incorporating them into the diet as a means to meet the recommendations outlined within dietary guidance such as myPlate is reasonable. For example, sauerkraut and kimchi provide a serving of vegetables, yogurt and kefir are a source of dairy, and natto and tempeh are sources of protein. Fermented foods also fit into a variety of recommended dietary patterns, including the Mediterranean diet (e.g., olives) and the DASH (Dietary Approaches to Stop Hypertension) diet (e.g., yogurt). Notably, there are culturally accepted fermented foods for everyone.

Prebiotics

A prebiotic is a substrate that is selectively utilized by host microorganisms conferring a health benefit.[36] There are three essential components of this definition: a substance, a physiologically beneficial effect, and a mechanism, which entails selective utilization by the microbiota harbored by the host. Past definitions indicated that a prebiotic needed to be fermented in the gut. Although still true for most prebiotics, that stipulation has been broadened to include other types of mechanisms for selective utilization.[37] Numerous members of the microbiota may be targeted by a single prebiotic substrate. By definition, the prebiotic substance must affect a limited group of beneficial microorganisms in the host rather than supporting the growth of the microbial ecosystem more broadly.

Over the years, the concept of prebiotics has evolved. It has expanded beyond the gut to include beneficial microorganisms associated with other colonized body sites, even though the majority of current prebiotics focus solely on utilization in the gut. Although most commercially available prebiotics are fermentable carbohydrates, the definition is broad enough to include compounds such as polyphenols and phytochemicals.

The most commonly-studied prebiotics are the soluble fibers inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS), and more recently synthesized versions of human milk oligosaccharides (HMOs). Prebiotics may be present naturally in certain foods or in synthesized forms in foods or supplements. The majority of research into their health effects has focused on isolated substances, and less on prebiotics as part of whole plant foods (e.g., asparagus, onions, and wheat). However, recently a dietary interventions focusing on prebiotic-rich foods, including salsify, Jerusalem artichoke, artichoke, leek, onion, garlic, and scorzonera, demonstrated that consumption of these foods increased fecal *Bifidobacterium*, increased satiety, and reduced participants' desire to consume sweet and salty food.[38] Some formula and foods for infants deliver prebiotics.[39,40] Therefore, although prebiotic-rich foods are not as extensively researched as isolated prebiotics, their consumption is strongly recommended.

Prebiotics and fiber. Prebiotics are frequently likened to dietary fibers, but strictly speaking, only some dietary fibers also qualify as prebiotics (**Figure 2**). Unlike fiber, a prebiotic must be shown to act as a substrate for a subset of resident microorganisms that are beneficial to health. Further, a prebiotic's beneficial physiological effect on the host should depend (at least in part) on its utilization by host microorganisms. A fiber may provide a health benefit such as fecal bulking, but this would not be a prebiotic benefit because it is not facilitated by selective utilization by microorganisms.

How do prebiotics work? Prebiotics are not digested by human enzymes but rather are utilized by microorganisms. The chemistry of these carbohydrate substances, which can differ by monosaccharide units present, chain length, and chemical linkages between the monosaccharides, dictates their specificity and which resident microorganisms can selectively utilize them.[41] For example, inulin type fibers, which include fructooligosaccharides, oligofructose, and inulin, are generally linear fructose polymers linked by β-(2,1) bonds that escape digestion by human alimentary enzymes. Bifidobacteria metabolize these substrates and produce by-products, including acetate and lactate, which are linked to beneficial human health outcomes. While our understanding of the exact mechanisms by which prebiotics improve health is evolving, research has shown that prebiotics can bind certain pathogenic microorganisms and eliminate them from the body, and help maintain normal immune function. For example, SCFA production in the gut is considered to be related to health because SCFAs not only have direct effects, such as reducing the pH of the gut and thus inhibiting the growth of pathogenic bacteria, but SCFAs also have systemic effects that range from improving bone mineralization to helping facilitate weight loss and glycemic control.[11,42] Many experts agree that saccharolytic fermentation by microorganisms in the gut, which is encouraged by prebiotics and other non-digested fibers, results in healthier metabolic end-products than proteolytic metabolism.[43]

Prebiotic health benefits: what can be recommended to clients? **Table 2** shows indications where prebiotics can be considered for clients. Numerous reviews and meta-analyses have summarized human trials conducted on prebiotics.[36,44-50]

Although there is an adequate intake recommendation for fiber (14 g/1000 kcal), at present, there are no official dietary recommendations for adequate intake or recommended daily allowance for prebiotics in healthy individuals. Research has suggested that an oral dose of ≥3 g per day of prebiotics is needed to elicit a bifidogenic effect,[51] although even lower levels were effective in children with autism.[52] Typically, around 5 g is the target for FOS and GOS in the daily diet—and this includes plant sources of prebiotics. Larger doses of up to 20 g/day may be necessary to facilitate certain health outcomes such as weight loss or improved glycemic control.[53-57] Recommending that your clients consume diets high in fiber and in prebiotic-containing foods, such as onions, garlic, bananas, whole wheat, and asparagus, is a reasonable approach to helping promote gut health. However, since plant foods contain relatively low amounts of prebiotic, more specific recommendations and a supplemental prebiotic may be necessary to achieve a therapeutic benefit.[58] Furthermore, similar to recommendations to slowly increase fiber in the diet to allow time for adaptation, prebiotics must be consumed with dose in mind—gas, bloating, and diarrhea can result from too high a dose consumed without adaptation. Example clinical studies on a diversity of endpoints documenting prebiotic benefits can be found in **Table 5**.

Some consumers might be currently consuming or interested in starting certain restrictive eating patterns to help improve their gut health. For example, the low fermentable oligo-, di-, and mono-saccharides, and polyols (FODMAP) diet is an approach utilized for treating irritable bowel syndrome (IBS). Since prebiotics are typically fermentable carbohydrates, they would initially be eliminated as part of this eating pattern. However, if tolerated, reincorporating prebiotic foods back into the diet following the elimination period is recommended to not only support the gut microbiota but also to provide vitamins, minerals, and phytonutrients that would be present in foods that contain prebiotic fibers. Interestingly, a study in patients with functional bowel disorders, including flatulence showed that both a low FODMAP diet and also a Mediterranean diet supplemented with the proprietary prebiotic B-GOS reduced functional gastrointestinal symptoms.[59] Yet the prebioticsupplemented diet also increased fecal bifidobacteria. These results suggest that clients suffering from functional bowel symptoms can incorporate prebiotics into their diets.

Synbiotics. A synbiotic is an emerging formulation of substances that encompasses the probiotic and prebiotic concepts. A synbiotic is defined as a mixture comprising live microorganisms and substrate(s) selectively utilized by host microorganisms that confers a health benefit on the host.[60] In the context of synbiotics, a co-administered probiotic becomes, even transiently, a resident microorganism, and therefore can be considered part of the host microbiota. A common understanding of synbiotic has been that it is simply a combination of one or more probiotic strains along with prebiotics. However, the updated definition above recognizes that an innovative synbiotic could comprise a combination of a substrate that is utilized by the co-administered live microorganism. In this case, neither the live microorganism nor the substrate it utilizes need to meet the strict definitions of probiotic or prebiotic, respectively. Therefore, two types of synbiotics were recognized. A complementary synbiotic, comprising a probiotic plus a prebiotic, and a synergistic synbiotic, comprising a live microorganism and a substrate, designed to work in concert (**Figure 4**). Evidence to date for health benefits for synbiotics is almost exclusively for the complementary type; to our knowledge, selective utilization of the substrate by the co-administered live microorganism has not yet been demonstrated for a synbiotic, although they will surely be developed in the future. Evidence for complementary combination products has been recently summarized.[60] Briefly, several blinded, randomized, controlled trials have shown that oral consumptions of substrates (e.g., GOS, FOS, oligofructose, inulin, and polydextrose) in combination with live microorganisms (e.g., strains of *Bifidobacterium*, lactobacilli, *Streptococcus*, and *Bacillus*) provide health benefits. These benefits include treatment of inflammation;[61,62] metabolic diseases, such as dyslipidemia,[63-67] type 2 diabetes and glycemia,[65,66] overweight, obesity, and metabolic syndrome,[68-70] nonalcoholic fatty liver disease,[71-74] and polycystic ovarian syndrome[75]; gastrointestinal conditions, including IBS[76,77] and eradication of *Helicobacter pylori*[68,78]; prevention of sepsis[79] and surgical infections and complications[80-85]; and treatment of atopic dermatitis.[86] Taken together, this research supports the validity of the symbiotic concept, but most researched combinations are not available as such commercially, which limits evidence-based usage.

As synbiotics provide a source of both live microorganisms and selectively fermented substrates, the recommendations outlined above for recommending probiotics and prebiotics also apply to synbiotics.

What to Look for on a Product Label

Most products containing probiotics, prebiotics, or synbiotics are either supplements (typically capsules or powders) or foods (typically yogurt or fermented milk). Some probiotics are now being investigated as probiotic drugs, also known as live biotherapeutic agents.[87,88]

For probiotics, look for the following on the label:

- The genus, species, and strain designation for all strains in the product.
- CFU at end of shelf life—not at time of manufacture.

• Indication of what benefits the product has been shown to confer. However, regulatory requirements limit the types of statements that can be made on foods or dietary supplements.
• Storage instructions. Some, but not all, probiotics require refrigeration. Typically, store products under the conditions they were stored when purchased. Follow manufacturers' storage instructions.
• Although not required, it is a good sign if the label indicates that the product has been subjected to a valid, independent third party assessment of quality.

Two regional market surveys reviewed probiotic product labels, one on dietary supplements[89] and one on food products.[90] Labels were checked for strain designations, dose delivered at the end of shelf life, and statements of health benefits. Authors found that food products were labeled somewhat more completely than supplements, but still more than half of both types of products fell short of informative labeling (strain designations and dose delivered at the end of shelf life). Therefore, clients should be advised to limit probiotic purchases to products that are sufficiently labeled.

The word "prebiotic" is seldom used on a product label. Instead you may see GOS, FOS, oligofructose, chicory fiber, or inulin, which are accepted prebiotics. You may see HMOs, trans-GOS, xylo-oligosaccharides, resistant starch, polydextrose, and polyphenols featured in research publications and some products. Data on these substances are emerging and some compelling findings suggest they have prebiotic functionality as well. To meet the definition of "dietary fiber" and thereby be included in the fiber declaration in the Nutrition Facts panel, a prebiotic must have evidence of a health benefit.[91] Some prebiotics and candidate prebiotics have been recognized by the FDA as fibers, including arabinoxylan, alginate, inulin and inulin-type fructans, high amylose starch (resistant starch 2), GOS, polydextrose, and resistant maltodextrin/dextrin.

Not all fermented foods in their final form contain live microorganisms. Fermented foods may carry a label that states "live and active cultures" or "probiotic," indicating that live microorganisms are retained in the final form of the product. However, even if a fermented food does retain live microorganisms, the microorganisms might not meet the criteria required of a probiotic. If a fermented food claims it contains probiotics, look for the genus, species, and strain designation on the label—if it does not disclose this information, you cannot be sure it is a true source of probiotics. Since the term probiotic is not legally defined or enforced in the US, misuse of the term is not uncommon. Also, in some cases a food may be fermented, heat-treated to kill fermentation microorganisms, and then a probiotic or live microorganism may be added back. Such a product may state that it contains live cultures, but they are not the live cultures used in the fermentation process.

The manufacturer is responsible for ensuring that product labels are accurate with regard to any health benefit statements or content, and that their products are safe. All food and dietary supplement products are required by the FDA to be produced using good manufacturing practices (GMPs), which focus on identity, purity, quality, strength, and composition of the product.[92] However, as reported by Natural Products Insider,[93] in 2019 violations of current GMPs were filed by the FDA for half of all dietary supplement firms, mostly for failure to specify final product specifications. Improved consumer and healthcare provider confidence in the quality of probiotic dietary supplements could be attained by manufacturers undergoing third party auditing of their process and final products.[94] Some auditors provide a quality seal for the product labels, which clearly indicates to the consumer that the product quality has been verified by a third party. Unfortunately, few if any probiotic or prebiotic products bear such a seal. Note that such audits generally focus on product quality and not verification of product claim substantiation. Regrettably, "quality marks" used by some companies to suggest their product has been verified are insubstantial and not based on actual quality measures.[95]

For foods and supplements, remember:

- There are no pre-market approvals required by the FDA for safety and efficacy.
- Companies are responsible for assuring safety for intended use (general population).
- Companies are responsible for assuring any label statements are truthful and not misleading.
- FDA enforcement can be limited due to limited agency resources.
- What you find in the marketplace may not be clearly or accurately labeled.

Bottom Line

Probiotics, prebiotics, and fermented foods have surged in popularity, at least in part due to the concurrence of developments in microbiome science, consumer concerns about suboptimal gut health, and the emerging evidence suggesting that these dietary components can make a real difference in health.

A strategy for recommending probiotics, prebiotics, synbiotics, or fermented foods should focus on an evidence-based approach to respond to specific conditions presented by your client. This is particularly true for probiotics where scientific evidence should drive recommendations and careful attention is paid to the strain designation and dose. Specific to fermented foods, some fermented milks and yogurts contain well-characterized probiotics that have been studied in control trials and demonstrate health benefits. However, most fermented foods have not been studied for health benefits and recommendations are limited to those based on nutritional properties of the foods and the hypothesis that increased consumption of live microbes in foods is beneficial. In the case of prebiotics, fewer studies have been published, but some clinical indications are compelling. Although research is mounting on synbiotics, currently it is challenging to match research to available commercial products. In the case of complementary synbiotics, which combine one or more probiotics with one or more prebiotics, rely on evidence available for the individual ingredients or contact the product manufacturer for studies conducted on the specific product formulation. Unstudied foods containing soluble fibers or live dietary microorganisms may be useful components of a healthy diet.

See **Table 2** for recommendations for probiotics and prebiotics for your clients. **Figure 3** makes some suggestions about how these recommendations might look as part of a healthy diet. See **Box 2** for some common questions on probiotics, prebiotics, and fermented foods.

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Quiz

1. _________ are live microorganisms that, when administered in adequate amounts, confer a health benefit on the host.
A. Fermented foods
B. Microbiota
C. Prebiotics
D. Probiotics
E. Synbiotics

2. Foods made through desired microbial growth and enzymatic conversions of food components are defined as _________ .
A. Fermented foods
B. Microbiota
C. Prebiotics
D. Probiotics
E. Synbiotics

3. A _________ is a substrate that is selectively utilized by host microorganisms conferring a health benefit.
A. Fermented food
B. Microbiota
C. Prebiotic
D. Probiotic
E. Synbiotic

4. _________ are defined as a mixture comprising live microorganisms and substrate(s) selectively utilized by host microorganisms that confers a health benefit on the host.
A. Fermented foods
B. Microbiota
C. Prebiotics
D. Probiotics
E. Synbiotics

5. Which of the following organizations provide evidence-based resources of probiotics and prebiotics?
A. American Gastroenterological Association
B. World Gastroenterology Organisation
C. European Society for Paediatric Gastroenterology Hepatology and Nutrition
D. International Scientific Association for Probiotics and Prebiotics
E. All of the above

6. The microorganisms in _________ are live, defined to the strain level, and are present in defined amounts, while _________ frequently contain uncharacterized microorganisms that may or may not be live in the final product.
A. Prebiotics; probiotics
B. Probiotics; prebiotics
C. Probiotics; fermented foods
D. Fermented foods; probiotics
E. Prebiotics; synbiotics

7. _________ is a fermented dairy product that may contain probiotics, is culturally acceptable in a variety of diets, and consumption is associated with less weight gain over time.
A. Kimchi
B. Kombucha
C. Miso
D. Tempeh
E. Yogurt

8. Some research studies have demonstrated that certain prebiotics can reduce:
A. C-reactive protein.
B. LDL cholesterol.
C. Total cholesterol.
D. Postprandial glucose.
E. All of the above.

9. Research studies have demonstrated that certain probiotics have which of the following health benefits?
A. Reducing the incidence and duration of antibiotic-associated diarrhea
B. Improving tolerance of lactose for lactose maldigesters
C. Supporting immune health
D. Reduce incidence of common respiratory tract infections
E. All of the above

10. The most evidence-based recommendation for a woman with slow intestinal transit time would be which probiotic?
A. *Bifidobacterium*
B. *Bifidobacterium lactis*
C. *Bifidobacterium lactis* strain CNCM I-2494
D. *Lactobacillus*