MICROBIOMIX™ CLINICAL REFERENCE GUIDE

GENOVA DIAGNOSTICS®

	MARKER	CLINICAL RELEVANCE	CONSIDERATIONS
Diversity	Shannon Diversity Index	**Average to high diversity is associated with good health.** The Shannon Diversity index reflects the number and amount of different species within a microbiome.	A varied diet rich in plant-based foods such as fruits, vegetables, whole grains, and nuts can help increase microbiome diversity. Fermented foods, such as kombucha, sauerkraut, or yogurt have been shown to increase microbial diversity.
Digestion Potential	Fiber Digestion Potential	**Average to high fiber digestion potential is ideal.** Fiber is the preferred energy source of gut bacteria, who break it down into beneficial short chain fatty acids.	If there is a low fiber digestion potential, increase the amount and diversity of prebiotic fiber in the diet.
	Mucin Digestion Potential	**An average mucin digestion potential is ideal.** Some bacteria can use the intestinal mucus lining as a fuel source. Mucus turnover is a normal part of gut function. However, an excess of bacteria that consume mucus can result in a thinning of the mucus layer and activation of the immune system.	If there is a low or high mucin digestion potential, increase the amount and diversity of prebiotic fiber in the diet. If mucin digestion potential is high, ensure the diet contains sufficient slowly fermented fibers, such as resistant starch, that will make it to the lower colon. If mucin digestion potential is low, consider polyphenol-rich foods such as pomegranates to support mucin-degrading species such as Akkermansia.[1]
	Protein Digestion Potential	**Low to average protein digestion potential is ideal.** When adequate fiber does not reach the distal colon, species that can break down protein tend to increase in abundance along with the potential to produce pro-inflammatory metabolites. Having a high proportion of these species may reflect an insufficient amount of fiber in the diet or an excessive intake of protein.	A high proportion of protein-degrading bacteria suggests that not enough fiber is reaching the lower colon to feed the bacteria that specialize in eating fiber. Ensure the diet contains sufficient slowly fermented fibers, such as resistant starch, that will make it to the lower colon.

	MARKER	CLINICAL RELEVANCE	CONSIDERATIONS
Health Indicators	Hexa-acylated lipopolysaccharide (Hexa-LPS)	**A low to average potential to produce hexa-LPS is ideal.** Hexa-LPS is a pro-inflammatory compound. In circulation, LPS elevations and metabolic endotoxemia are associated with obesity, Type 2 DM, Alzheimer's disease, and non-alcoholic fatty liver disease.[2-4]	Avoiding excessive intake of saturated fat and maximizing omega-3 fats and fiber can help reduce the ability of hexa-LPS to enter the bloodstream. Common dietary sources of saturated fats include butter, coconut, palm oil, cheese, fatty meats, cakes, chocolate, and ice cream. Ensuring adequate butyrate production is another important strategy for promoting gut barrier function.[5,6]
	Methane	**Low to average potential to produce methane is ideal.** Elevated methane production is associated with prolonged intestinal transit time and constipation.[7,8]	Insoluble fiber can add fecal bulk and reduce intestinal transit time. Consider breath testing in symptomatic patients.
	Trimethylamine (TMA)	**Low to average potential to produce TMA is ideal.** Trimethylamine (TMA) can be oxidized in the liver to become trimethylamine N-oxide (TMAO). TMAO is a risk factor for cardiovascular disease, cancer, and Type 2 DM.[9]	If the potential to produce TMA is high, consider increasing consumption of cruciferous vegetables (e.g., broccoli, cauliflower, cabbage, kale) and limiting red meat intake if appropriate.[10,11] Free choline and carnitine supplements are associated with increased plasma TMAO levels while lipid soluble supplements do not increase TMAO levels.[12,13]
	Ammonia	**Low to average potential to produce ammonia is ideal.** Excess ammonia production has been observed in individuals with impaired gut barrier function and gut inflammation.[14,15]	To prevent excess ammonia production, ensure that protein intake is balanced with sufficient fiber and resistant starch intake.[16]
	Bacteroides fragilis toxin	**Low to average potential to produce this toxin is ideal. (High average levels may require action.)** This toxin can cause intestinal inflammation and diarrhea however, some patients remain asymptomatic.[17,18]	If all other causes of GI symptoms have been ruled out, treatment may be warranted.[19]

Health Indicators continued

	MARKER	CLINICAL RELEVANCE	CONSIDERATIONS
Health Indicators	Beta-glucuronidase	**Low to average potential to produce beta-glucuronidase is preferred.** Some bacteria use beta-glucuronidase to get energy from compounds the body has deactivated (e.g., drugs and hormones), thus re-activating the compound and possibly increasing sensitivity to specific medicines/hormones.[20,21]	One human study has suggested that consuming glucomannan can reduce fecal beta-glucuronidase activity. Glucomannan is a type of prebiotic fiber found in konjac root.[22]
	Hydrogen sulfide (H2S)	**Low potential to produce H2S is ideal. Average to high potential may require action.** The gas hydrogen sulfide is produced by bacteria when they break down sulfur-containing amino acids found in foods such as eggs, meat, and fish. This gas is responsible for the rotten egg smell of flatulence. At high levels, hydrogen sulfide can inhibit energy production in gut cells and disrupt the gut mucus barrier.[23] Elevated levels of hydrogen sulfide have been associated with inflammatory bowel disease (IBD) and colorectal cancer.[23,24]	Eating foods high in resistant starch (e.g., lentils, peas, beans, rolled oats and cooked and cooled potatoes) or fructooligosaccharides (FOS) (e.g., onions, garlic, leek, banana, peaches, wheat, barley) can reduce the production of hydrogen sulfide by the microbiome.[25]
	Branched chain amino acids	**Low potential to make BCAA is ideal. Average to high potential may require action.** Increased microbial BCAAs is associated with insulin resistance and Type 2 DM since blood levels of BCAAs exceed the capacity of the muscle to utilize them resulting in the accumulation of toxic compounds.[26]	Physical activity can increase the muscle's capacity to utilize BCAAs. Increasing dietary fiber intake can decrease microbial BCAA production and affect amino acid metabolism.[27,28]
	Oxalate	**Average to high potential to consume oxalate is ideal.** Some bacteria can break down oxalates in the colon, thus reducing the risk of forming calcium oxalate kidney stones.[29] People who suffer from repeated unexplained kidney stones are observed to have a low potential for oxalate degradation in their microbiome compared to non-stone formers.[30]	If the microbiome has a low potential to break down oxalate in a patient prone to kidney stones, a low oxalate diet may be considered.

	MARKER	CLINICAL RELEVANCE	CONSIDERATIONS
Neuroendocrine	Gamma-aminobutyric acid (GABA)	**In general, a balance between GABA production and consumption is preferred.** The role of gut bacteria that produce or consume GABA in anxiety and depression is currently not understood.[31]	If there is a mental health concern, it is important to seek professional help.
Neuroendocrine	3-indolepropionic acid (3-IPA)	**Average to high potential to produce IPA is ideal.** 3-indolepropionic acid (IPA) is a strong antioxidant produced by some gut bacteria that can protect the nervous system from damage and may help prevent type 2 diabetes, suppress inflammation, and maintain the gut barrier.[32-35]	Research suggests foods rich in ellagic acid (e.g., chestnuts, and ellagic acid enriched pomegranate juice), as well as wholegrain wheat and rye may help support IPA production.[34-36]
Neuroendocrine	Histamine	**A low potential to produce histamine is ideal.** Histamine plays an important role in immune regulation, gut function, and the nervous system. Gut microbes that can produce histamine have been observed at increased levels in patients with asthma. Additionally, people with food allergies and irritable bowel syndrome may be more sensitive to histamine in the gut.[37-40]	Consider the result in the context of the clinical picture. Strategies to reduce the overall histamine load and effect may be considered. Outcome studies are lacking regarding microbiome modulation to alter systemic histamine levels.[41]
Short Chain Fatty Acids	Butyrate	**Average is a good level, with high potential to produce butyrate being ideal.** Butyrate is the main fuel source for gut cells, helps keep the gut barrier intact, suppresses inflammation, helps control appetite, and promotes the production of serotonin in the gut.[42-45]	Consuming foods high in resistant starch (e.g., lentils, peas, beans, cooked and cooled potatoes, rolled oats) or pectin (e.g., avocado, kiwifruit, berries, citrus fruits, pumpkin, zucchini) have been shown to increase butyrate levels.[46-48]

Short Chain Fatty Acids continued

	MARKER	CLINICAL RELEVANCE	CONSIDERATIONS
Short Chain Fatty Acids	Lactate	**Average to high potential to produce lactate is preferred.** Lactate/lactic acid can reduce inflammation, help maintain the gut barrier, and reduce colonization by pathogens by lowering the pH in the gut. Lactate can also be converted by some bacterial species to other short chain fatty acids.[49,50]	Lactate or lactic acid-producing bacteria have a long tradition of being used to produce fermented foods such as yogurt, kefir, sauerkraut, and kimchi.[49]
	Propionate	**Average to high potential to produce propionate is preferred.** Propionate helps maintain blood glucose levels, can reduce inflammation, helps control appetite and promotes the production of serotonin from the gut.[51,52]	The prebiotic fiber beta-glucan, found in oats and barley, has been shown to increase propionate production[53,54]
	Acetate	**Average to high potential to produce acetate is preferred.** Acetate is the most abundant short chain fatty acid produced in the gut. It plays an important role in fat and glucose metabolism and the immune system.[55]	The consumption of whole grains, fruits, vegetables, legumes, nuts, and seeds are associated with increased short chain fatty acids, including acetate.[56]
Essential Vitamins	Vitamin B12 (Cobalamin)	**Average to high potential to produce B12 is ideal.** Although the gut bacteria are unlikely to provide useable vitamin B12, an average to high potential to produce B12 means your bacteria will not compete with you for available vitamin B12.[57,58] Vitamin B12 is important for ensuring normal functioning of the nervous system and in the development of red blood cells.	Reduced vitamin B12 production is often seen in the gut microbiome of people as they age and a study in elderly individuals observed that a multi-strain probiotic increased plasma B12 levels.[59] The most important dietary sources of vitamin B12 are meat, milk, and dairy products.
	Vitamin B9 (Folate)	**Average to high potential to produce folate is ideal.** Folate cannot be produced by human cells and must be obtained through diet or from the microbiome.[58,60,61] Folate plays an important role in cell replication and repair. Low folate levels can result in anemia and have been linked to an increased risk of heart disease and stroke.	If the gut microbiome is not contributing folate to the body, ensure adequate folate is obtained from the diet. Dietary sources include dark green leafy vegetables, fruit, legumes, and nuts.

Essential Vitamins continued

	MARKER	CLINICAL RELEVANCE	CONSIDERATIONS
Essential Vitamins	Vitamin B7 (Biotin)	**Average to high potential to produce biotin is ideal.** Biotin cannot be produced by human cells and must be obtained through diet or the microbiome. Biotin plays a critical role in metabolism and in the regulation of the immune system.[62]	The large intestine has the ability to absorb biotin but it is estimated that the gut microbiome can only provide up to 4.5% of the human daily biotin requirement.[58] Dietary sources of biotin include liver, meat, fish, eggs, and nuts.
	Vitamin B2 (Riboflavin)	**Average to high potential to produce B2 is ideal.** Riboflavin cannot be produced by human cells and must be obtained through diet or the microbiome. Riboflavin plays a crucial role in fat, vitamin B6, folate, tryptophan and homocysteine metabolism.[62]	The large intestine has the ability to absorb riboflavin but it is estimated that the gut microbiome can only provide up to 2.8% of the human daily riboflavin requirement.[58] Dietary sources of riboflavin include milk and milk products, eggs, green vegetables, mushrooms, and fortified breads and cereals.
	Vitamin K	**Average to high potential to produce vitamin K is ideal.** K vitamins are a family of fat-soluble vitamins which play an important role in blood clotting. Vitamin K cannot be produced by human cells and must be obtained through diet or the microbiome.[63]	Vitamin K1 (phylloquinone) is found in plants such as dark green leafy vegetables and canola oil and is the principal form of dietary vitamin K used by the body. Bacterially derived vitamin K (menaquinones) are produced by our gut bacteria and are found in fermented foods, dairy products, and meat. The amount of bacterially derived vitamin K (menaquinones) that can be absorbed by the large intestine is still unknown.[64]

References on following page

REFERENCES

1. Rodríguez-Daza MC, Pulido-Mateos EC, Lupien-Meilleur J, Guyonnet D, Desjardins Y, Roy D. Polyphenol-Mediated Gut Microbiota Modulation: Toward Prebiotics and Further. Front Nutr. 2021;8:689456.
2. Maldonado RF, Sá-Correia I, Valvano MA. Lipopolysaccharide modification in Gram-negative bacteria during chronic infection. FEMS Microbiol Rev. 2016;40(4):480-493.
3. Moreira AP, Texeira TF, Ferreira AB, Peluzio Mdo C, Alfenas Rde C. Influence of a high-fat diet on gut microbiota, intestinal permeability and metabolic endotoxaemia. Br J Nutr. 2012;108(5):801-809.
4. Cani PD, Amar J, Iglesias MA, et al. Metabolic endotoxemia initiates obesity and insulin resistance. Diabetes. 2007;56(7):1761-1772.
5. Moreira APB, Texeira TFS, Ferreira AB, do Carmo Gouveia Peluzio M, de Cássia Gonçalves Alfenas R. Influence of a high-fat diet on gut microbiota, intestinal permeability and metabolic endotoxaemia. Br J Nutr. 2012;108(5):801-809.
6. Lyte JM, Gabler NK, Hollis JH. Postprandial serum endotoxin in healthy humans is modulated by dietary fat in a randomized, controlled, cross-over study. Lipids Health Dis. 2016;15(1):186.
7. Kunkel D, Basseri RJ, Makhani MD, Chong K, Chang C, Pimentel M. Methane on breath testing is associated with constipation: a systematic review and meta-analysis. Dig Dis Sci. 2011;56(6):1612-1618.
8. Friedrich MW. Methyl-coenzyme M reductase genes: unique functional markers for methanogenic and anaerobic methane-oxidizing Archaea. Methods Enzymol. 2005;397:428-442.
9. Cho CE, Caudill MA. Trimethylamine-N-Oxide: Friend, Foe, or Simply Caught in the Cross-Fire? Trends Endocrinol Metab. 2017;28(2):121-130.
10. Xu R, Wang Q, Li L. A genome-wide systems analysis reveals strong link between colorectal cancer and trimethylamine N-oxide (TMAO), a gut microbial metabolite of dietary meat and fat. BMC Genomics. 2015;16(7):S4.
11. Tang WHW, Li DY, Hazen SL. Dietary metabolism, the gut microbiome, and heart failure. Nat Rev Cardiol. 2019;16(3):137-154.
12. Mödinger Y, Schön C, Wilhelm M, Hals PA. Plasma Kinetics of Choline and Choline Metabolites After A Single Dose of SuperbaBoost(TM) Krill Oil or Choline Bitartrate in Healthy Volunteers. Nutrients. 2019;11(10).
13. Wilcox J, Skye SM, Graham B, et al. Dietary Choline Supplements, but Not Eggs, Raise Fasting TMAO Levels in Participants with Normal Renal Function: A Randomized Clinical Trial. Am J Med. 2021;134(9):1160-1169.e1163.
14. Vaziri ND, Yuan J, Norris K. Role of urea in intestinal barrier dysfunction and disruption of epithelial tight junction in chronic kidney disease. Am J Nephrol. 2013;37(1):1-6.
15. Ni J, Shen TD, Chen EZ, et al. A role for bacterial urease in gut dysbiosis and Crohn's disease. Sci Transl Med. 2017;9(416).
16. Birkett A, Muir J, Phillips J, Jones G, O'Dea K. Resistant starch lowers fecal concentrations of ammonia and phenols in humans. Am J Clin Nutr. 1996;63(5):766-772.
17. Sassone-Corsi M, Raffatellu M. Close encounters of the type-six kind: injected bacterial toxins modulate gut microbial composition. EMBO Rep. 2016;17(9):1242-1244.
18. Sears CL, Geis AL, Housseau F. Bacteroides fragilis subverts mucosal biology: from symbiont to colon carcinogenesis. J Clin Investig. 2014;124(10):4166-4172.
19. Hecht DW. Bacteroides Species. In: antimicrobe. http://www.antimicrobe.org/b85.asp#top.
20. Pellock SJ, Redinbo MR. Glucuronides in the gut: Sugar-driven symbioses between microbe and host. J Biol Chem. 2017;292(21):8569-8576.
21. Pollet RM, D'Agostino EH, Walton WG, et al. An Atlas of β-Glucuronidases in the Human Intestinal Microbiome. Structure. 2017;25(7):967-977.e965.
22. Wu WT, Cheng HC, Chen HL. Ameliorative effects of konjac glucomannan on human faecal β-glucuronidase activity, secondary bile acid levels and faecal water toxicity towards Caco-2 cells. Br J Nutr. 2011;105(4):593-600.
23. Wallace JL, Motta JP, Buret AG. Hydrogen sulfide: an agent of stability at the microbiome-mucosa interface. Am J Physiol Gastrointest Liver Physiol. 2018;314(2):G143-g149.
24. Guo FF, Yu TC, Hong J, Fang JY. Emerging Roles of Hydrogen Sulfide in Inflammatory and Neoplastic Colonic Diseases. Front Physiol. 2016;7:156.
25. Yao CK, Rotbart A, Ou JZ, Kalantar-Zadeh K, Muir JG, Gibson PR. Modulation of colonic hydrogen sulfide production by diet and mesalazine utilizing a novel gas-profiling technology. Gut Microbes. 2018;9(6):510-522.
26. Pedersen HK, Gudmundsdottir V, Nielsen HB, et al. Human gut microbes impact host serum metabolome and insulin sensitivity. Nature. 2016;535(7612):376-381.
27. Utzschneider KM, Kratz M, Damman CJ, Hullarg M. Mechanisms Linking the Gut Microbiome and Glucose Metabolism. The Journal of Clin Endocrinol Metab. 2016;101(4):1445-1454.
28. Wang F, Wan Y, Yin K, et al. Lower Circulating Branched- Chain Amino Acid Concentrations Among Vegetarians are Associated with Changes in Gut Microbial Composition and Function. Mol Nutr Food Res. 2019;63(24):1900612.
29. Hatch M. Gut microbiota and oxalate homeostasis. Ann Transl Med. 2017;5(2):36.
30. Ticinesi A, Milani C, Guerra A, et al. Understanding the gut-kidney axis in nephrolithiasis: an analysis of the gut microbiota composition and functionality of stone formers. Gut. 2018;67(12):2097-2106.
31. Quillin SJ, Tran P, Prindle A. Potential Roles for Gamma-Aminobutyric Acid Signaling in Bacterial Communities. Bioelectricity. 2021;3(2):120-125.
32. Jennis M, Cavanaugh CR, Leo GC, Mabus JR, Lenhard J, Hornby PJ. Microbiota-derived tryptophan indoles increase after gastric bypass surgery and reduce intestinal permeability in vitro and in vivo. Neurogastroenterol Motil. 2018;30(2).
33. Venkatesh M, Mukherjee S, Wang H, et al. Symbiotic bacterial metabolites regulate gastrointestinal barrier function via the xenobiotic sensor PXR and Toll-like receptor 4. Immunity. 2014;41(2):296-310.
34. Tuomainen M, Lindström J, Lehtonen M, et al. Associations of serum indolepropionic acid, a gut microbiota metabolite, with type 2 diabetes and low-grade inflammation in high-risk individuals. Nutr Diab. 2018;8(1):35.
35. de Mello VD, Paananen J, Lindström J, et al. Indolepropionic acid and novel lipid metabolites are associated with a lower risk of type 2 diabetes in the Finnish Diabetes Prevention Study. Sci Rep. 2017;7:46337.
36. Yang J, Guo Y, Lee R, et al. Pomegranate Metabolites Impact Tryptophan Metabolism in Humans and Mice. Curr Dev Nutr. 2020;4(11):nzaa165.
37. Barcik W, Wawrzyniak M, Akdis CA, O'Mahony L. Immune regulation by histamine and histamine-secreting bacteria. Curr Opin Immunol. 2017;48:108-113.
38. Barcik W, Pugin B, Westermann P, et al. Histamine-secreting microbes are increased in the gut of adult asthma patients. J Allergy Clin immunology. 2016;138(5):1491-1494.e1497.
39. Sander LE, Lorentz A, Sellge G, et al. Selective expression of histamine receptors H1R, H2R, and H4R, but not H3R, in the human intestinal tract. Gut. 2006;55(4):498-504.
40. Krell T, Gavira JA, Velando F, et al. Histamine: A Bacterial Signal Molecule. Int J Mol Sci. 2021;22(12).
41. Smolinska S, Jutel M, Crameri R, O'Mahony L. Histamine and gut mucosal immune regulation. Allergy. 2014;69(3):273-281.
42. Bourassa MW, Alim I, Bultman SJ, Ratan RR. Butyrate, neuroepigenetics and the gut microbiome: Can a high fiber diet improve brain health? Neurosci Lett. 2016;625:56-63.
43. Cushing K, Alvarado DM, Ciorba MA. Butyrate and Mucosal Inflammation: New Scientific Evidence Supports Clinical Observation. Clin Transl Gastroenterol. 2015;6(8):e108.
44. Canfora EE, Jocken JW, Blaak EE. Short-chain fatty acids in control of body weight and insulin sensitivity. Nat Rev Endocrinol. 2015;11(10):577-591.
45. Laserna-Mendieta EJ, Clooney AG, Carretero-Gomez JF, et al. Determinants of Reduced Genetic Capacity for Butyrate Synthesis by the Gut Microbiome in Crohn's Disease and Ulcerative Colitis. J Crohns Colitis. 2018;12(2):204-216.
46. Brouns F, Kettlitz B, Arrigoni E. Resistant starch and "the butyrate revolution". Trends Food Sci Technol. 2002;13(8):251-261.
47. McOrist AL, Miller RB, Bird AR, et al. Fecal butyrate levels vary widely among individuals but are usually increased by a diet high in resistant starch. J Nutr. 2011;141(5):883-889.
48. Bang SJ, Kim G, Lim MY, et al. The influence of in vitro pectin fermentation on the human fecal microbiome. AMB Express. 2018;8(1):98.
49. Garrote GL, Abraham AG, Rumbo M. Is lactate an undervalued functional component of fermented food products? Front Microbiol. 2015;6:629.
50. Morrison DJ, Preston T. Formation of short chain fatty acids by the gut microbiota and their impact on human metabolism. Gut Microbes. 2016;7(3):189-200.
51. Hosseini E, Grootaert C, Verstraete W, Van de Wiele T. Propionate as a health-promoting microbial metabolite in the human gut. Nutr Rev. 2011;69(5):245-258.
52. Koh A, De Vadder F, Kovatcheva-Datchary P, Bäckhed F. From Dietary Fiber to Host Physiology: Short-Chain Fatty Acids as Key Bacterial Metabolites. Cell. 2016;165(6):1332-1345.
53. Velikonja A, Lipoglavšek L, Zorec M, Orel R, Avguštin G. Alterations in gut microbiota composition and metabolic parameters after dietary intervention with barley beta glucans in patients with high risk for metabolic syndrome development. Anaerobe. 2019;55:67-77.
54. Carlson JL, Erickson JM, Hess JM, Gould TJ, Slavin JL. Prebiotic Dietary Fiber and Gut Health: Comparing the in Vitro Fermentations of Beta-Glucan, Inulin and Xylooligosaccharide. Nutrients. 2017;9(12).
55. Ríos-Covián D, Ruas-Madiedo P, Margolles A, Gueimonde M, de Los Reyes-Gavilán CG, Salazar N. Intestinal Short Chain Fatty Acids and their Link with Diet and Human Health. Front Microbiol. 2016;7:185.
56. De Filippis F, Pellegrini N, Vannini L, et al. High-level adherence to a Mediterranean diet beneficially impacts the gut microbiota and associated metabolome. Gut. 2016;65(11):1812-1821.
57. Degnan PH, Taga ME, Goodman AL. Vitamin B12 as a modulator of gut microbial ecology. Cell Metab. 2014;20(5):769-778.
58. Magnúsdóttir S, Ravcheev D, de Crécy-Lagard V, Thiele I. Systematic genome assessment of B-vitamin biosynthesis suggests co-operation among gut microbes. Front Genet. 2015;6:148.
59. Valentini L, Pinto A, Bourdel-Marchasson I, et al. Impact of personalized diet and probiotic supplementation on inflammation, nutritional parameters and intestinal microbiota - The "RISTOMED project": Randomized controlled trial in healthy older people. Clin Nutr. 2015;34(4):593-602.
60. Said HM, Mohammed ZM. Intestinal absorption of water-soluble vitamins: an update. Curr Op Gastroenterol. 2006;22(2):140-146.
61. Rossi M, Amaretti A, Raimondi S. Folate production by probiotic bacteria. Nutrients. 2011;3(1):118-134.
62. Said HM. Recent advances in transport of water-soluble vitamins in organs of the digestive system: a focus on the colon and the pancreas. Am J Physiol Gastrointest Liver Physiol. 2013;305(9):G601-610.
63. Ravcheev DA, Thiele I. Genomic Analysis of the Human Gut Microbiome Suggests Novel Enzymes Involved in Quinone Biosynthesis. Front Microbiol. 2016;7:128.
64. Karl JP, Meydani M, Barnett JB, et al. Fecal concentrations of bacterially derived vitamin K forms are associated with gut microbiota composition but not plasma or fecal cytokine concentrations in healthy adults. Am J Clin Nutr. 2017;106(4):1052-1061.