

Effect of Different Diets on Human Gut Microbiome Health

Jingjian Lin^{1,2,*}

¹ Department of Forestry, University of British Columbia, Vancouver, Canada

² College of Biological Sciences and Technology, Beijing Forestry University, Beijing, China

* Corresponding Author Email: linjj@student.ubc.ca

Abstract. In the past 20 years, research on the human gut microbiome and human health has exploded. Diet and gut microbiota are considered important parts of human health. Therefore, it is important and urgent to dig deeper into the impacts of different diets on the human gut and human health. This paper mainly compared the impacts of plant-based diets and animal-based high-fat low-fiber western diets on gut health and human diseases. Through introducing vegan, vegetarian, and mediterranean diets and related research, plant-based diets are much healthier than high-fat low-fiber western diets when it comes to fighting cancer and maintaining a healthy weight. The paper also focuses on the components and their effects in plant-based food and animal-based foods such as plant protein, animal protein, prebiotics, probiotics, and dietary iron such as heme as well as mentioning the effect of shifting diets. In the future, research can look for more evidence of people who change diets, such as changing from omnivorous to vegetarian, because nowadays more people change diets based due to recognition of the bad effect of western diets. However, those who switch diets may suffer from eating disorders so future research could look into this effect. Overall, this paper gives basic knowledge about the effect of different diets on human gut health and human health.

Keywords: Microbiome, Diets, Human Health.

1. Introduction

In the human body, gut bacteria outnumber human cells and many ways can impact the gut microbiome including geography, medications such as antibiotics, feeding, illness, stress, lifestyle, and diets. Among them, food or diet can significantly affect the human gut microbiome directly and the human gut microbiota are important for humans in some aspects, such as digesting foods and taking in nutrients, promoting new tissue, and affecting the brain. The human gut microbiome also impacts human brain health in many ways, most notably by affecting the human adaptive immune system and protecting the gut from inflammation and pathogens. Foods can change microbiota diversity and dysbiosis in the gut microbiota may lead to a higher risk of many diseases.

A healthy person is inhabited by trillions of microbes and hundreds of microbial species in the gut but only a small number of gut bacteria is known to be beneficial for human health. In the past 20 years, research and interest in the human gut microbiome have exploded. The gut microbiota is important for the immune system, keeping energy flowing, and digestion. Gut microbiota composition can change in infants and becomes stable until they are older when the gut microbiota composition is similar to an adult. Bacteroidetes- and firmicutes- are two major bacteria types that exist in a human and this situation is stable unless a long-term dietary change occurs. The impact of diet shows on infants because breastfed infants have better health status as well as intestinal microbiota than formula-fed infants. However, microbiome composition varies across individuals and races. Most of those microbial taxa are the same as genetically associated taxa, which means specific microbial taxa exist in specific ethnicity but there are significant differences between individuals.

It's known that the change of gut microbiota composition is associated with many diseases including inflammatory bowel disease. Research has shown that a diet with high saturated fat can cause gut microbiota to change in a bad direction because dietary lipids in foods can have a big impact on lipid digestion and cause more inflammation. Previous research focused on certain bioactive components and their effect on gut health. Bioactive components such as phenolics and antioxidant vitamins can protect the gut cell from being attacked by free radicals, which can attack cell

membranes, cause incomplete intestinal mucosa, and damage membranes. Those bioactive components are rich in vegetables such as broccoli and they can regulate enzymes in the gut and control apoptosis and cell cycle to provide its benefit. However, a plant-based diet can include many bioactive components and it is not appropriate to focus on the effect of one kind of food or one component.

Prebiotics are also a hot topic related to gut health and there is growing interest in finding the impacts of prebiotics and probiotics because they have been used in the treatment of some diseases. It is worth noting that different individuals have a big difference in reaction to prebiotics. Prebiotics are non-digestible carbohydrates that can be used to produce short-chain oligosaccharides in the human body and they can improve human health and reduce the risk of many diseases [1]. Non-digestible oligosaccharides may function as prebiotics that positively influences intestinal microbiota and they exist in many vegetables, beans, and fruits in the plant-based diet. Prebiotics can benefit human gut health by improving microbiota composition, metabolism, digestion, absorbing some nutrients, and reducing the risk of some diseases [1]. In fact, many foods in a plant-based diet include much dietary fiber which could be fermented in the gut and produce health benefits. Among them, some particular prebiotics such as oligosaccharides and carotenoids which are rich in broccoli, carrots, and many dark-colored vegetables, and fructooligosaccharides which exist in some particular plants such as onion, garlic, and banana, seem particularly beneficial for gut health. These prebiotics impact gut health by increasing beneficial bacteria in the gut, and nutrient absorption, decreasing some harmful bacteria populations, producing some beneficial products, and protecting the gut from being invaded. For example, garlic is a good source of prebiotics. Garlic has a much higher level of allicin diallyl disulfide-s-oxide than other foods. Research with mice shows that allicin-free garlic extract may slow down the aging of the mice gut and balance the gut microbiome by decreasing the overgrowth of bad bacteria caused by a high-fat low-fiber diet. Prebiotics are usually composed of *Lactobacillus* and *Bifidobacterium*. They can help control glycemic and decrease fasting blood glucose and insulin levels.

High-fat western diets are often associated with bad effects on gut health. Research shows that high fat and animal-based diet will increase gut inflammation and alter the gut microbiome by increasing the abundance and activity of *Bilophila* [2]. A high-fat and high-sugar diet may rapidly change the genome and metabolism of the gut, for example, this kind of animal-based high-fat food, such as cheese, meat, and eggs, is related to more abundance of *Lactococcus lactis*, *Pediococcus acidilactici*, *Staphylococcus*-associated bacteria and *Penicillium*-related fungi [2]. The study also found that gut microbiome diversity decreased after consuming lots of highly processed food and this might lead to the imbalance of short-chain fatty acids in the body and organic acids, which come from undigested complex carbohydrates in plant-based foods and are generally beneficial for the human gut, and other probiotics [3].

Therefore, the hypothesis is that too much highly-processed food and saturated fat in a diet are related to imbalance in the human gut microbiota. On the contrary, plant-based and unprocessed diets are more beneficial for human gut health. There is more research and more attention to the gut microbiome in recent years. Many studies have focused on plant-based diets which are rich in dietary fiber, polyphenols, and antioxidant vitamins. The differences between the gut microbiome in people using plant-based diets and the gut microbiome in people using omnivorous diets have been well studied. Plant-based diets are known to be healthier for humans. This research will focus on comparing the effect of high-fiber plant-based diets, such as vegetarian, vegan, and Mediterranean which contain mostly plants, with western diets, which contain more saturated fat and animal-based food.

2. Effect of different diets on human gut microbiome health

2.1. Plant-based diets

The function of the gut microbiome and diets is one of the hottest topics in science in recent years and diets can significantly influence health. Mediterranean diet and intermittent vegan diets are known as healthy diets in the world in recent years. In this context, the topic regarding diets and gut microbiome exploded in recent twenty years. Therefore, the importance of finding more relationships and evidence between diets and the gut microbiome is obvious.

It is acknowledged that diets high in plants, especially whole grains, vegetables, fruits, legumes, and nuts, low in processed meat, salt and sugar are good for human health. Plant-based diets, such as vegetarian, vegan, and Mediterranean, are normally recognized as beneficial diets for human health because they are rich in fiber and vitamins, and low in red meat and saturated fats. Many people of longevity in the world share this kind of plant-based diet. Plant-based diets and low risk of many cancers and cardiovascular diseases are more closely related compared to diets with much meat. Among them, red meat consumption, especially highly-processed meat sausage, bacon, salami, and ham, are increasing rapidly in developing countries and lots of evidence shows that a higher risk of some chronic diseases are often associated with eating a lot of red meat. As shown in Figure 1, the research found that even 50 grams of highly-processed meat per day can cause an increase in most chronic diseases including stroke, breast cancer, colorectal, cardiovascular disease, pancreatic cancer, and prostate cancer [4]. People consuming many vegetables is associated with a more diverse microbiome in the gut and more beneficial bacteria (e.g., Bifidobacteria and Lactobacillus). Plant-based diets are rich in dietary fiber, which will not be digested and will go into the large intestine and produce beneficial things, such as short-chain fatty acids. Dietary fiber in vegetables, which means you consume the fiber from eating plants, is beneficial for human health such as cardiovascular health, weight control and necrotizing enterocolitis.

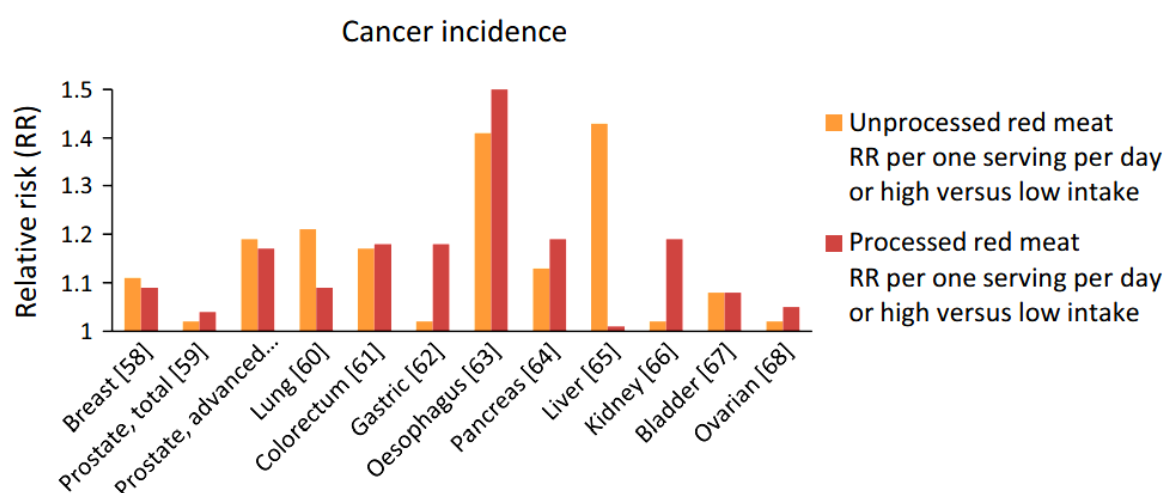


Figure 1. Analysis of the relationship between the consumption of unprocessed red meat and processed meat and the incidence of cancer [4]

Plant-based vegan diets have a close relationship with lower body weight and less inflammatory levels in the body. People using a vegan diet, which is based on all plants, usually have a slimmer body than those who followed a vegetarian and omnivorous diet. Plant-based diets, especially low-fat and high-fiber diets, can reduce inflammation and reduce the risk of some diseases, such as ulcerative colitis. In 2015, the researchers studied 17 patients with ulcerative colitis by giving them low-fat diets or high-fat western diets for 4 weeks and found that a low-fat diet is healthier than the high-fat western diet by reducing inflammation and intestinal dysbiosis in fecal [5]. It is also worth mentioning that adding vegetables and fruits to a standard American diet (SAD) can make the diet less inflammatory and increase the health of the gut.

The Mediterranean diet is well known as the healthiest diet in the genre of plant-based diets and has the benefit of curing some diseases. People who use the Mediterranean diet consistently can protect themselves from diseases, for example, diabetes and cancers such as breast cancer. Mediterranean diet is also beneficial for gut health by increasing the beneficial bacterium and reducing those pathogenic and harmful bacteria. A recent study found that less *Escherichia coli*, higher levels of *Candida albicans*, and higher levels of acetate in the people who stick more to the Mediterranean diet [6]. A review studied the relationship between fiber intake and the rate of inflammatory disease and found that a plant-based diet can reduce chronic diseases and reduce the pathogenic bacteria in patients.

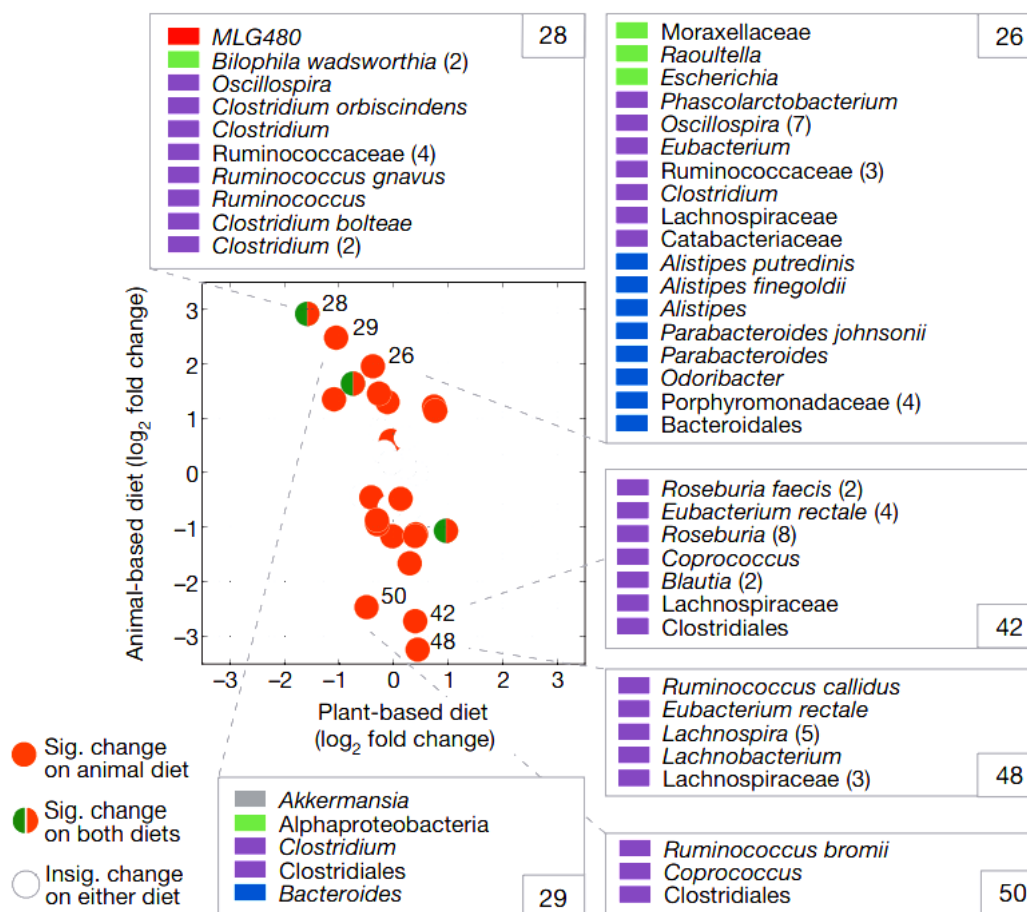


Figure 2. Analysis of bacterial response to diet [7]

Diet is related to chronic diseases. For example, diets have close relationship with obesity, osteoporosis, diabetes, cardiovascular disease, and cancer. Microbiomes can adjust inflammatory responses and more diversity of bacteria in the gut is related to better health. Some bacteria genera, such as *Eubacterium*, *Bifidobacterium*, and *Lactobacillus*, are usually related to health because they can reduce inflammation. *Lactobacillus gasseri* species, which is normally a beneficial species in the gut, disappeared in mice using an animal-based western diet [7], as shown in Figure 2. Besides, animal-based diets in mice are associated with higher bile level, rapidly showing higher inflammation levels in gut, and decreased plant polysaccharides, which are normally beneficial for the mice gut. Thus, the Mediterranean diet has obvious advantages over animal-based diets for human health.

Plant-based protein in whole foods is generally beneficial for humans but isolated plant protein is risky for health. For example, soy foods have been consumed for centuries in many countries and soy foods, especially soybeans, are beneficial for heart health and cardiovascular disease. However, academia has controversy about soy protein without isoflavones. In 2018, the research found that in 5509 Korean adults whose ages are greater than 40, long-term consumption of soy protein and isoflavones are beneficial for human, especially for metabolic health [8]. Though soy protein has been

applied to formula and in some developed countries, about 20-25% of formula-fed infants are using soy-based formulas because of many reasons such as milk allergies and using soy-based formula to reduce the time of diarrhea in infants [9]. However, isolated soy protein-based formula is not beneficial as a supplement for breastfed infants. Overall, as shown in Figure 3, eating soybeans can benefit cardiovascular health and it can reduce cholesterol level if some of the animal-based protein is replaced by soybean because soybeans contain not only soy protein, but also isoflavones, lecithins and other beneficial components such as fiber but it is risky to consume isolated soy protein.

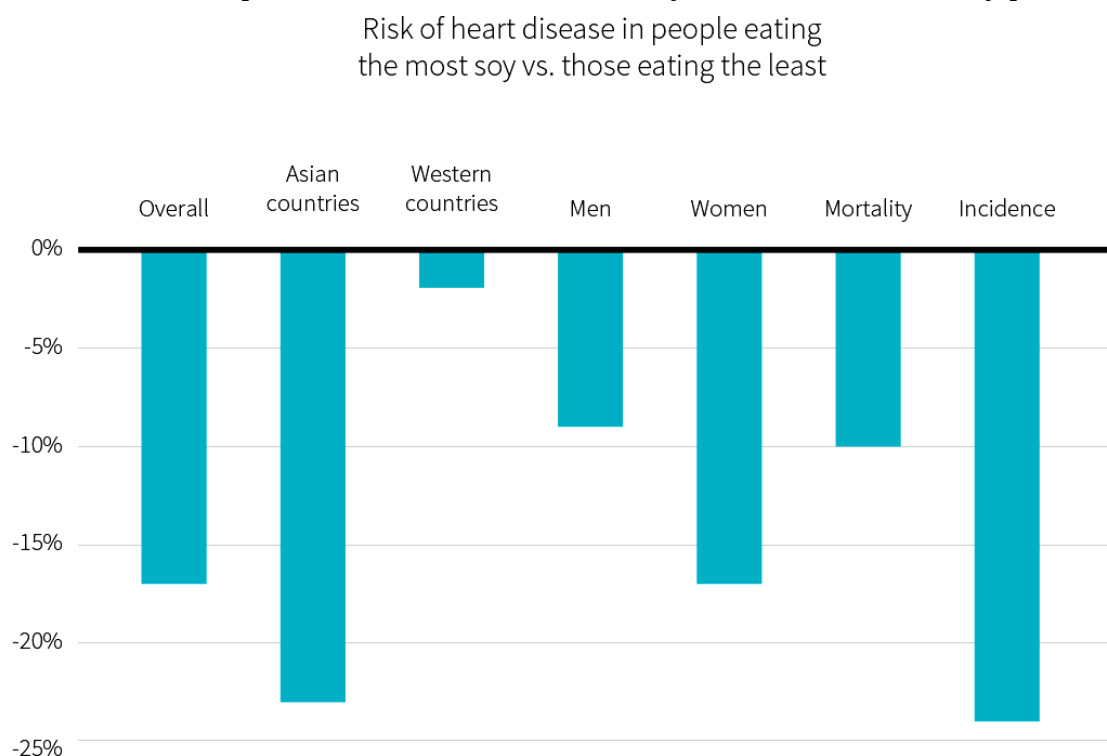


Figure 3. Risk of heart disease in people eating most soy vs. those eating least [10]

Overall, most plant-based diets contain many beneficial things such as enough fiber, vitamin A, vitamin C and vitamin E, plant-based protein, but infants and the elderly, who are over 65 years old, may need some specific supplements or nutrition to meet their specific need [8].

2.2. High-fat low-fiber western diet

There is much research exploring the effect of a typical western diet, such as the American standard diet and it is well known that this kind of diet is bad for human health and many diseases.

High-fat low-fiber western diets, which are composed of a large amount of meat, milk, eggs, cheeses, and small amounts of whole grains, vegetables, and plant-based protein, especially the standard American diet, are high in red meat, saturated animal fat, and low in fiber. 60% of calories could come from highly processed foods in a typical western diet. High-fat or high-sugar “western” diets are widely known as bad diets for health and they are concerned to change human gene composition and gut environment. The rapid change from healthy diets to “western” diets can cause an unbalance in the gut and increase the risk of many chronic diseases. Besides, a low-fiber western diet usually contains more calories than a plant-based diet. In recent years, the obesity rate increases rapidly in developing countries and remains a big problem in developed countries such as the United States. In this context, the high calories in a high-fat low-fiber diet are increasing the risk of obesity along with diabetes and other chronic diseases.

The animal protein in the western diet is a reason why this kind of diet is unhealthy for humans. Animal protein is not safe because it is often suspected of causing diseases such as inflammatory bowel disease. Compared to animal protein, plant-based proteins such as soy protein and pea protein can cause a decrease in cholesterol levels, which is beneficial. Scholars have different opinions about

the effect of animal protein. Protein is an important nutrient for human health and protein consumption is related to microbial diversity. Generally, animal protein is higher in quality because it is more efficient to digest than plant protein and animal protein contains better amino acid patterns for humans. However, a plant-based diet can also contain all the amino acid that human needs and provides enough protein, especially from beans. As shown in Figure 4, high animal protein in a western diet is associated with diabetes and other unhealthy factors such as a higher risk for noncommunicable diseases [11]. Low protein intake and medium protein intake, which means approximately lower than 20% of energy is from protein, have not yet found an impact on cardiovascular disease but it points out that the limitation of the study is that food is not accurate. A high intake of animal food is generally unhealthy and is associated with many cancers and diseases but plant-based protein is protective and associated with lower mortality. Research showed that when people use a low-carbohydrate diet, such as a ketogenic diet, animal protein, and animal fat are obviously harmful because they are related to a higher risk of mortality and some diseases [10].

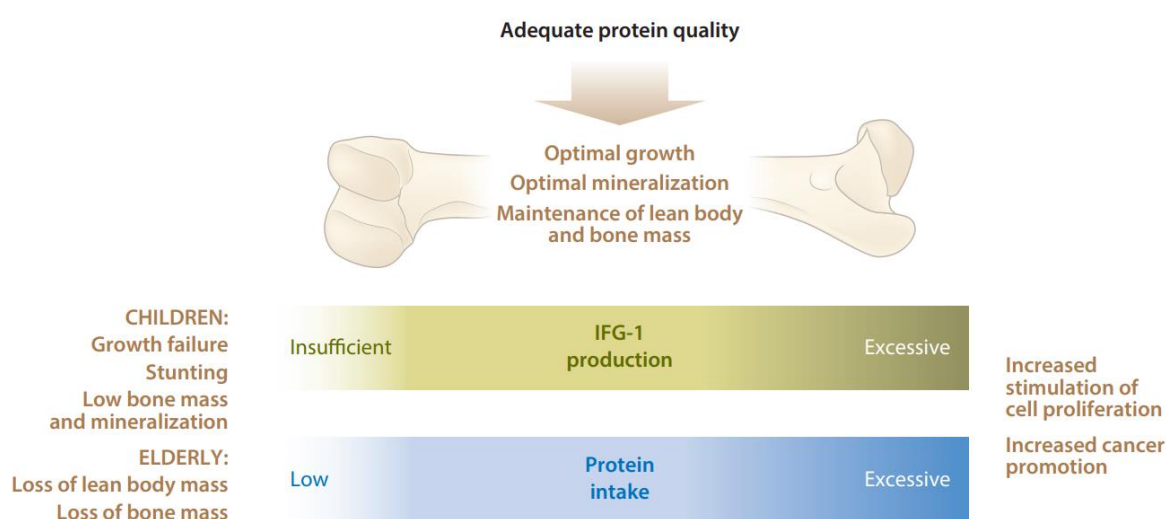


Figure 4. Effects of protein intake on IFG-1 and human health [11]

Other nutrients in animal food can be harmful to health such as dietary iron. Dietary iron, which mostly comes from red meat and cereals, could be harmful by increasing pathogenic bacteria in the gut. The research found that only heme iron, which exists in meat, has strong relationship with the risk of a kind of cancer and more iron intake can lead to the emergence of some bacterial pathogens, such as Salmonella [12].

Another research found that ultra-processed foods, such as pizza in a typical western diet, in the high-fat western diet can reduce gut microbiome diversity and composition in a bad way, especially by reducing the anti-inflammatory bacteria. The research used rRNA sequencing and found that increase in some pathogenic bacteria and a decrease in Melainabacter and Lachnospira [3]. Bifidobacterium and significant bad effects on the body (e.g., depression, anxiety, and inflammation) are related to a relatively large amount of pizza intake in women human. Bifidobacterium can degrade polysaccharides, oligosaccharides, and sugars, which are rich in plants, vegetables, and fungus so when Bifidobacterium decreased, the ability to digest those beneficial compounds decreased as well. The abundance of Bacteroidetes in the children who usually consume a western diet was much less than in those who consume a plant-based diet.

2.3. Shifting diets and supplements

Diet is a controllable factor in lifestyle which could affect the health and microbiome composition. A healthy individual's gut microbiome is resilient to inflammatory food but changing diet may damage this kind of balance. In the history of human evolution, there are many dietary shifts during human history. From eating plant-based diet to eating larger amount of animal, humans have some

ability to adapt to shifting diets. Plant-based diets have many benefits for humans and those who shift from an unhealthy diet to a plant-based diet can also benefit from the diet.

In the history of human evolution, there are many dietary shifts during hominin evolution from eating plant as a major diet to eating a relatively large amount of animal-based food after animal domestication. Humans have some ability to adapt to the shifting diets. However, we may not be able to adapt to this quick change since animal domestication occurred only in recent centuries.

3. Conclusions

Plant-based diets have many beneficial components, such as plant-based protein, fiber, some vitamins, anti-inflammatory antioxidants, effects on gut health and human health while a high-fat low-fiber western diet has a bad effect on gut health by decreasing beneficial bacteria in the gut and making the gut microbiome imbalanced. Those who shift from unhealthy diets to plant-based diets such as the Mediterranean diet can also get benefits in the long term. Probiotics in fermented plant-based food such as Miso, sauerkraut, Pickle, or Natto are good for gut health as long as you are not eating too many fermented foods at one time. On the other hand, the animal-based western diet could rapidly change the microbiome and metabolism of our resident microbiome by causing the imbalance of some bacteria in the gut. Future studies can keep on looking for the bad effect of plant-based diets and some essential parts of animal-based western diet because there is not enough research about this part.

References

- [1] Pal Kaur, A., Bhardwaj, S., Singh Dhanjal, D., et al. (2021). Plant Prebiotics and Their Role in the Amelioration of Diseases [J]. *Biomolecules*, 11(3), 440.
- [2] David, L. A., Maurice, C. F., Carmody, R. N., et al. (2014). Diet rapidly and reproducibly alters the human gut microbiome. *Nature*, 505(7484), 559–563.
- [3] Cuevas-Sierra, A., Milagro, F. I., Aranaz, P., et al. (2021). Gut Microbiota Differences According to Ultra-Processed Food Consumption in a Spanish Population. *Nutrients*, 13(8), 2710.
- [4] Wolk A. (2017). Potential health hazards of eating red meat. *Journal of internal medicine*, 281(2), 106–122.
- [5] Rivière, P., Vermeire, S., Irlès-Depe, M., et al. (2021). Rates of Postoperative Recurrence of Crohn's Disease and Effects of Immunosuppressive and Biologic Therapies. *Clinical Gastroenterology and Hepatology*, 19(4), 713-720.e1.
- [6] Mitsou, E. K., Kakali, A., Antonopoulou, S., et al. (2017). Adherence to the Mediterranean diet is associated with the gut microbiota pattern and gastrointestinal characteristics in an adult population. *British Journal of Nutrition*, 117(12), 1645–1655.
- [7] David, L. A., Maurice, C. F., Carmody, R. N., et al. (2014). Diet rapidly and reproducibly alters the human gut microbiome. *Nature*, 505(7484), 559–563.
- [8] Woo, H. W., Kim, M. K., Lee, Y. H., Shin, D. H., Shin, M. H., & Choi, B. Y. (2019). Habitual consumption of soy protein and isoflavones and risk of metabolic syndrome in adults ≥ 40 years old: a prospective analysis of the Korean Multi-Rural Communities Cohort Study (MRCohort). *European Journal of Nutrition*, 58(7), 2835–2850.
- [9] Vandenplas, Y., De Greef, E., Devreker, T., & Hauser, B. (2011). Soy infant formula: is it that bad?. *Acta Paediatrica*, 100(2), 162-166.
- [10] <https://a99d9b858c7df59c454c96c6baa7fa2a34c80f17051de799bc8e.ssl.cf1.rackcdn.com/images/blog-soy4.png>
- [11] Elmadfa, I., & Meyer, A. L. (2017). Animal Proteins as Important Contributors to a Healthy Human Diet. *Annual Review of Animal Biosciences*, 5, 111–131.
- [12] Kato, I., Boleij, A., Kortman, G. A. M., et al. (2013). Partial associations of dietary iron, smoking and intestinal bacteria with colorectal cancer risk. *Nutrition and Cancer*, 65(2), 169–177.