

Evaluating the Health and Environmental Impacts of Vegetarian and Meat-Based Diets

Xingcheng Hou*

College of Art and Science, University of Miami, Coral Gables, FL 33124, United States

*Corresponding author: xxh465@miami.edu

Abstract. With the advancement of nutrition, the health effects of vegetarian diets and meat-based diets have been re-evaluated, giving the nutritional balance of meals a new way of evaluation. This paper assesses the comparative impact of vegetarian and meat diets on human health and environmental sustainability. It synthesizes research from multiple disciplines to assess the impact of these dietary patterns on health, with a focus on their role in the prevalence and management of chronic disease. Environmental assessments highlight the resource inefficiency of meat production and its ecological footprint, and advocate reducing meat consumption. In addition, the emergence of plant-based meat alternatives is discussed, considering their potential to mitigate health and environmental concerns. This paper concludes by promoting flexible eating habits, particularly Mediterranean and flexitarian diets, as a balanced approach to achieving health benefits and environmental sustainability.

Keywords: Vegetarian diet; Meat-based diet; Flexitarian diet; Chronic diseases.

1. Introduction

Historically, meat has played a central role in human diets around the world. From the earliest hunters to modern traditions, meat consumption has been linked not only to survival, but also to social status or cultural identity [1]. For example, in the United States, Turkey is a staple of Thanksgiving celebrations, symbolizing gratitude and family unity, while in China, eating fish during the Spring Festival is a sign of prosperity. Despite these different cultural practices, the global dependence on meat is universal. However, as the people faces unprecedented health and environmental challenges, people are increasingly turning to understanding the impact of meat consumption and exploring sustainable dietary alternatives. In current discussions about diet and health, the contrast between plant-based diets versus meat-heavy diets has been the focus of extensive research. The impact of these dietary choices affects not only individual health, but also broader issues such as environmental sustainability. This paper explores the health effects of inflammatory dietary patterns, contrasts plant-based and meat-based diets, examines healthier diet like flexitarian diets and Mediterranean diets, and introduce the plant-based meat. It also explores the environmental consequences of meat versus vegetarian diets, advocating for a balanced approach to meet nutritional needs and ecological sustainability.

2. Health Impact of Meat-Based Diet

2.1. Potential Challenges in Meat Diet

The increasing consumption of meat poses significant health risks, as highlighted by research from the International Agency for Research on Cancer (IARC), a part of the World Health Organization (WHO). Their 2015 report classified processed meat as "carcinogenic to humans" and red meat as "probably carcinogenic to humans" [1]. Despite these findings, the demand for meat continues to rise, as evidenced by real-time data on platforms like The World Counts website. According to The World Counts, global meat consumption reached a staggering 346.14 million tons in 2018, with projections indicating a further increase to 453 million tons by 2030—a 44 percent rise in just over a decade [2]. This upward trend in meat consumption underscores the urgent need to address the associated health risks.

2.2. Pro-Inflammatory Effects of Meat Consumption

The rise in global meat consumption has caused significant concern in the health and scientific communities. There are growing evidence linking high intakes of red and processed meat directly to a range of adverse health outcomes. Red meat and processed meat are known as inflammatory foods because they contain compounds that can trigger or exacerbate chronic inflammatory responses in the body. Bing Chen's research delves into the diet related to chronic disease, focusing on the harmful role of a pro-inflammatory diet rich in animal products in raising the risk of CVD and pancreatic disease[3]. Normally, the immune system protects the body from infection and injury through an inflammatory response. This is a defense mechanism designed to destroy invading microbes or repair damaged tissue. Nevertheless, when inflammation persists and is no longer a direct response to a specific external threat, it can turn into a chronic disease, such as type 2 diabetes and heart disease. However, a plant-based diet can exert a positive influence on inflammation, including reducing the risk of CVD, which will be discussed in more detail in this article on plant-based diets part.

In addition, inflammatory food is also associated with obesity. Obesity is one of the major risk factors for cardiovascular disease[4]. Research by Eichelmann's team suggests that a plant-based diet can reduce the chronic low-grade inflammation caused by obesity, thereby preventing the risk of chronic diseases[5]. In the meta-analysis of systematic reviews and intervention trials, it included 2,689 patients who were primarily obese and had metabolic abnormalities. The team found that the plant-based diet effectively improved inflammatory profiles of patients. Overall, the plant-based diet had the most significant effects on the biomarkers CRP and IL-6(table 1). These markers are associated with chronic low-grade inflammation and activated innate immunity.

For this reason, choosing the right anti-inflammatory foods, especially plant-based diet, may help reduce the risk of several chronic disease. The Mediterranean diet can be a proper dietary pattern example for anti-inflammatory foods, which include plenty of fruits, vegetables, nuts, whole grains, fish and healthy oils[6]. More details about the Mediterranean diet will be provided later in this article.

Table 1. Summary of pooled estimates for mean differences in biomarker concentrations after plant-based dietary intervention[5]

| Biomarker | Number of studies | Pooled observations | Mean difference [95% CI] | I ² [95%CI] |
|--------------------|-------------------|---------------------|--------------------------|------------------------|
| CPR [mg/l] | 24 | 2008 | -0.55[-0.78;-0.32] | 94.4% [92.8;95.7] |
| IL-6 [ng/l] | 8 | 975 | -0.25[-0.56;0.06] | 74% [47.2;87.2] |
| TNF-a [ng/l] | 5 | 368 | 0.02[-0.17;0.21] | 0% [0.0;74.1] |
| sICAM [ng/l] | 5 | 534 | -25.07[-52.32;2.17] | 93.2% [87.1;96.4] |
| Resistin [ng/l] | 3 | 275 | 0.00[-0.14;0.14] | 0% [0.0;83.7] |
| Leptin [ng/l] | 4 | 488 | -0.24[-0.68;0.21] | 0% [0.0;0.0] |
| Adiponectin [mg/l] | 7 | 911 | 0.62[-0.55;1.78] | 95.5% [92.8;97.2] |

2.3. Unfriendly to Environment

In agricultural products, ecological footprint determines how much resources(land, water, nutrients, energy, fuel, electricity, and carbon) are used in the production of each product[7]. Meat's ecological footprint is indeed substantial, and the production process is notably energy-intensive when compared to plant-based alternatives. In Europe, producing food for cattle and other livestock requires seven times more vegetation than in the European Union. Also, it takes 75 times more energy to produce meat than it does to produce corn[2]. Researchers at LEAD (Livestock, Environment and Development) found that the global livestock industry has consumed dwindling freshwater supplies, destroyed forests and grasslands. There are also concerns about the rise of antibiotic resistance, as livestock account for 50 percent of global antibiotic use[8]. Every year, 33,000 people die as a direct consequence of infections caused by antibiotic-resistant bacteria, a number comparable to the passengers of more than 100 medium-sized aircraft[9].

In contrast, plant-based diets offer a more sustainable and eco-friendlier alternative. The production of plant foods generally requires less water, energy, and land. Plants have a lower ecological footprint because they are often grown directly for human consumption, bypassing the energy-intensive animal feed production process. In addition, plant agriculture tends to emit fewer greenhouse gases and rely less on antibiotics, which is consistent with the goal of reducing antibiotic resistance and protecting ecosystems.

3. Health Effects of Diet Based on Plant

3.1. Toward to Plant Diet

Awareness of the harmful health and environmental effects of a meat-based diet has been increasing. Consequently, the alternative adoption of a plant-based diet has been increased. These individuals are often referred to as vegetarians or vegans. Usually, vegetarians avoid eating meat, while vegans extend this exclusion to all animal products. In addition to concerns about their own health and the environment, these vegetarians or vegans may be motivated based on other factors such as socioeconomic status, religious beliefs, and ethical issues related to the use of animal products. For example, Gallup research shows that politically liberal and lower-income adults are more likely to be vegetarians[10]. As this shift toward plant-based diets continues, it is becoming increasingly important to fully understand the nutritional outcomes, health consequences, and potential obstacles of these diets.

3.2. Nutritional Adequacy in Protein

People usually assumed that a vegetarian diet relies on plant-based foods may result in a deficiency of protein and essential amino acids due to the relatively low calories and limited nutrition they provide. However, research by Mariotti and Gardner critically examined the protein intake of vegetarians and found that plant-based foods such as legumes, nuts and seeds adequately meet the protein needs of adults[11]. These foods are not only rich in high-quality protein, but also provide other important nutrients such as fiber, unsaturated fatty acids, vitamins, and minerals.

On the other hand, the quality of protein in plant diet is a general concern, particularly about the spectrum of essential amino acids provided. Animal proteins are often considered "complete" because they contain all nine essential amino acids needed for human health, which human bodies cannot synthesize independently. In contrast, plant proteins are often described as "incomplete" due to lack one or more of these essential ingredients in plant sources. However, the strategy of protein complementation-combining different plant diet-effectively addresses the problem. For instance, pairing legumes that are rich in lysine but lacking in methionine with whole grains that are high in methionine but low in lysine allows for a balanced intake of amino acids, similar to intake animal protein[12]. This combination ensures that the body obtain complete essential amino acids, which are essential for functions such as muscle repair and enzyme activity.

3.3. Cardiovascular Disease Prevention

Cardiovascular disease (CVD) continues to be the leading cause of death worldwide, causing widespread public health concern. Among many preventive measures, the improvement of nutrition and dietary habits is one of the most effective solutions. As research continues, there is growing evidence that plant-based dietary patterns have important value in preventing and managing cardiovascular disease. Given the significant correlation between inflammatory diet and cardiovascular health, this section delves into the CVD prevention potential of a plant-based diet. Research by Gardner provided early insights into the role of plant-based diets in cardiovascular health, highlighting the multiple benefits of plant-based diets including whole grains, legumes, nuts, seeds, fruits, and vegetables. These foods are not only rich in fiber, vitamins, minerals, and other essential nutrients, but they also contain large amounts of phytochemicals, such as antioxidants and polyphenols, which have been shown to have a protective effect on heart health[13]. Specifically,

phytochemicals work together to reduce the risk of cardiovascular disease by reducing inflammation, improving blood vessel function, lowering blood pressure, and reducing oxidative stress. Fortunately, the cardiovascular protective effect of plant dietary pattern can be attributed the maintenance of a healthy weight and reduce the risk obesity. Because plant-based diets are generally lower in saturated fat and cholesterol than animal-based diets, they also can maintain healthy cholesterol levels and blood pressure, further reducing the risk of heart disease and stroke[5].

3.4. Long-Term Health Outcomes

With an increasing number of individuals adopt plant-based diets, the long-term health outcomes of this diet have become a hot topic. The comprehensive research by Appleby and Key provides insight into this topic by summarizing large-scale cross-sectional and prospective cohort studies. They found that vegetarians generally have a healthier body mass index, as well as a lower risk of ischemic heart disease (IHD), compared to non-vegetarians of similar backgrounds[14]. These studies also indicate that vegetarians have a slightly reduced risk of certain cancers compared to non-vegetarians, particularly those types of cancer that are closely related to dietary habits. In addition, vegetarians have fewer disease such as diabetes, diverticular disease, and cataracts, underscoring the potential of plant-based diets in maintaining long-term health. However, Appleby's study also concern that some specific nutrients are lacking in plant-based diets, such as vitamin B12, vitamin D, calcium, and n-3 fatty acids. To avoid these deficiencies, vegetarians are often advised to seek fortified foods to maintain a balanced intake of nutrients for long-term health. Paired with the plant-based food complementary strategy, it ensures that the transition to a plant-based diet is both nutritionally adequate and conducive to a long-term healthy lifestyle. Unfortunately, currently data and research about long-term health outcome of plant-based diet obtained are insufficient, so it is hard strongly conclude the long-term plant-based diet have no adverse effects at all.

3.5. Plant-Based Meats

Due to rapid economic development and increasing global population, the global meat demand has increased by 58% over the past two decades, with a significantly rising number of scientific publications related to "meat alternative"(Fig. 1). With the development of food technology, nowadays, even vegetarians can taste "meat" that is not made of animals, which is plant-based meat[15]. Growing interest in plant-based meat alternatives is driven by factors of environmental sustainability, ethical treatment of animals and health motivations. As these products continue to develop, it will be critical to evaluate their nutritional content and the role they may play in diets.

From a technical perspective, Sha and Xiong discuss the complex process of creating plant protein fibers that mimic the texture and taste of animal meat, a key consumer demand[16]. They point out that thermoextrusion is found to be the principal reconstructing technique for meat-like fiber synthesis from plant proteins. The main use of thermoextrusion is to restructure plant proteins into fiber, using ingredients such as soy and pea proteins. Furthermore, Wen et al. highlighted innovative applications of 3D printing in the development of plant-based meat analogues[17]. They show that the technology can improve all aspects of meat, including customized shapes, colors, tastes, textures, and nutritional value. Therefore, 3D printing technology gives plant-based meat greater potential in the future.

However, Research by Crimarco et al. highlights the technical challenges associated with plant-based meat[18]. The SWAP-MEAT study, which scrutinized the effects of plant-based meat on inflammation through the lens of inflammatory biomarkers, reveals a nuanced picture. Contrary to previous assumptions, the findings do not consistently show that switching to plant-based meat alternatives improves inflammatory conditions. It suggests that plant-based meats, despite their popularity, may have different health effects and require further research.

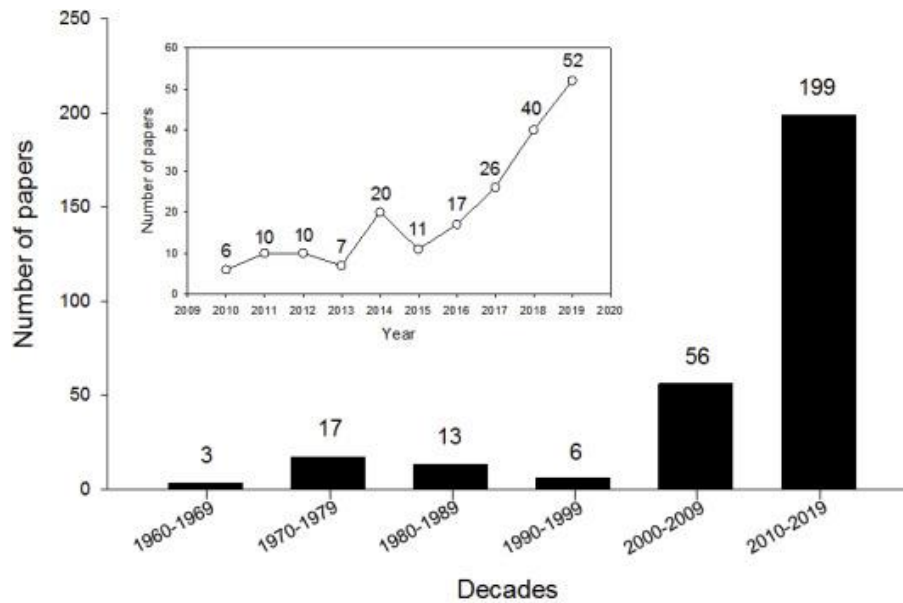


Fig. 1 Number of scientific publications on "meat alternatives" or "meat analogues" by Scopus (1960-2019)[16]

4. Planning and Promotion of Healthy Eating Patterns

4.1. The Mediterranean Diet

The Mediterranean diet (MD) is inspired by the traditional dietary patterns of countries bordering the Mediterranean Sea, such as Italy, Greece, and Spain. It emphasizes high consumption of fruits, vegetables and nuts, using olive oil as the primary source of fat, low consumption of red meat, and moderate intake of fish and poultry[19]. This diet has been linked to numerous health benefits, particularly in preventing cardiovascular diseases and managing weight.

Ramon’s study involving 7,447 participants aged between 55 and 80 years—of which 57% were women—provide strong evidence supporting the effectiveness of the Mediterranean diet in promoting health and preventing disease. This research particularly examined the diet's impact on major health events when supplemented with extra-virgin olive oil (EVOO) or nuts. Participants in both Mediterranean diet groups demonstrated good adherence to the dietary interventions, validated through self-reported dietary intake and biomarker analysis. The outcomes of this study are compelling. Fig. 2 shows that group consuming a Mediterranean diet with EVOO or nuts experienced a significantly reduced risk of major health events compared to the control group[20]. These results underscore the protective benefits of the Mediterranean diet against serious health outcomes.

In addition, no diet-related adverse reactions were reported, affirming the safety and suitability of the Mediterranean diet for widespread adoption. This makes the Mediterranean diet not only a culturally rich and delicious choice, but also a scientifically proven way to enhance health and prevent disease. Hence, this diet represents a practical and enjoyable approach to sustainable healthy eating that appeals to those who wish to improve their eating habits without giving up on the pleasures of food.

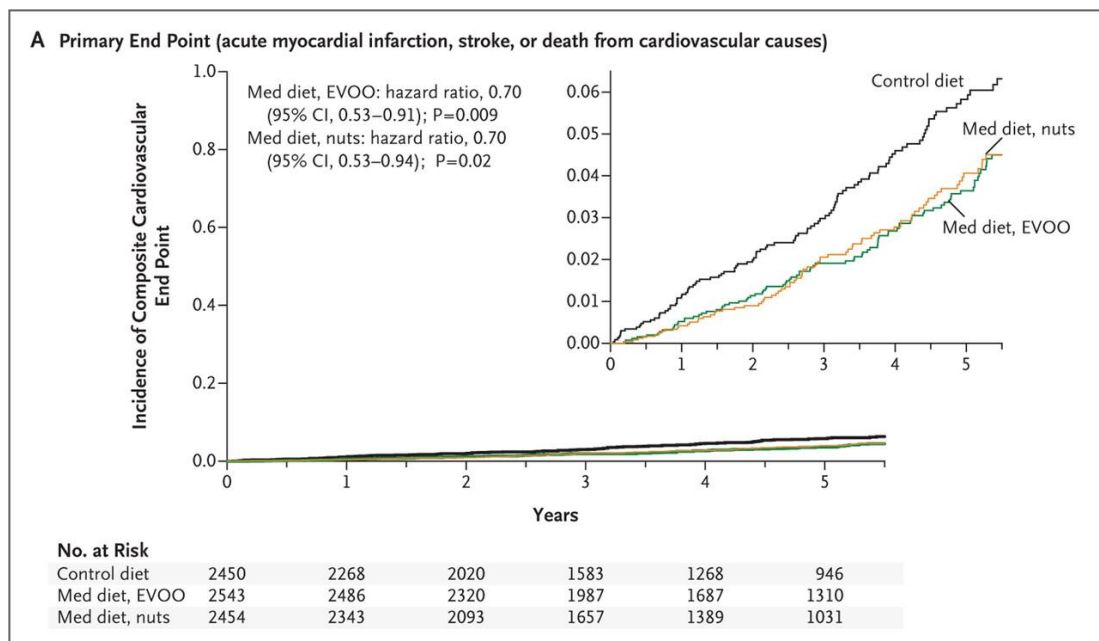


Fig. 2 Kaplan-Meier Curves for Primary Outcome Incidence in the Study Cohort: acute myocardial infarction, stroke, cardiovascular death[20]

4.2. Flexitarian Diet

The flexitarian diet, a concept introduced by Dawn Jackson Blatner, represents a contemporary approach to eating that combines the health advantages of a vegetarian diet with the flexibility to include meat occasionally[21]. Blatner characterizes flexitarians as individuals who are "pro-plant, not anti-meat," emphasizing a dietary lifestyle that prioritizes plant-based foods while still allowing for occasional consumption of meat. This approach enables people to reap the benefits of plant-based eating without completely eliminating meat from their diets, making it a more accessible option for those who may find strict vegetarian or vegan diets challenging to maintain.

The flexitarian diet promotes the incorporation of more vegetarian foods into daily meals while retaining the option to consume meat on occasion, such as during social gatherings or dining out. This balanced approach to meal planning is both realistic and sustainable in the long term, appealing to individuals who desire a healthier diet without completely giving up meat. By advocating for a less restrictive dietary pattern that embraces a variety of food types, Blatner's flexitarian approach encourages a gradual transition toward increased plant consumption.

Emphasizing a balance between plant-based foods and occasional meat consumption not only supports individual health and well-being but also addresses broader environmental concerns associated with high meat intake. The flexitarian diet reflects a growing awareness of the link between diet and health, signaling a shift toward more sustainable eating practices. By offering flexibility and inclusivity without requiring complete dietary exclusivity, the flexitarian approach promotes a balanced and holistic approach to nutrition that can benefit both individuals and the planet., allowing for a balanced inclusion of both plant-based and meat products.

5. Conclusion

This article explores the health effects of different compositions of meat and plant intake, namely meat-based diets and vegetarian diets.

Widespread consumption of meat-based diets is associated with various health risks and serious environmental degradation. High meat intake in the diet can trigger inflammation, which increases the risk of diabetes and obesity, and may even lead to CVD problems. Instead, vegetarian diets offer a sustainable option that can alleviate these concerns by reducing the incidence of chronic diseases and reducing the environmental impacts associated with traditional meat production. The protein

deficiencies and some vitamin deficiencies that plant-based diets may face can be solved by reasonably adjusting the proportions of different amino acids in the diet and taking additional vitamin tablets. The development of plant-based meat technologies further supports this shift by providing meat-like alternatives with potentially lower health risks and a reduced ecological footprint. The adoption of the Mediterranean diet and flexitarian diets, which allow flexibility to combine plant-based and limited meat consumption. Ultimately, acceptance of these dietary patterns can lead to a more balanced, healthier, and sustainable future that meets both nutritional needs and ecological responsibilities.

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