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Vegetarianism in India: Health Benefits, Risks, and the Environment's Role in Risk Mitigation

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Abstract

Vegetarian diets lack vitamins and nutrients vital for the human body, which can have severe adverse effects and cause illnesses and pathology. However, vegetarians in India do not seem to suffer from the same pathologies that are expected to be associated with this level of vitamin and nutrient deficiency. This paper explores how vegetarians in India escape immune deficiency and whether this can be attributed to natural immunity that correlates with vegetarianism or even induced by it. The phenomenon of natural immunity in Indian vegetarians is due to a unique combination of genetic diversity, environmental exposure frequency, dietary habits, and sociocultural practices. Genetic factors such as HLA diversity, cytokine gene polymorphisms, and a rich anti-inflammatory, spice-heavy diet contribute to a robust immune system. These environmental lifestyle factors have shaped the immune responses of the Indian population, protecting Indian vegetarians from vegetarianism-related pathology.

Key Words: vegetarianism, compromised immunity, micronutrient deficiencies, gut microbiome, inflammation, traditional diet

I. Introduction

A. Vegetarianism Overview

Vegetarianism is the practice of not eating certain foods derived from animals. This includes but is not limited to, meat, poultry, and seafood. Vegetarians typically follow a diet of plant-based foods such as fruits, vegetables, grains, nuts, seeds, beans, legumes, and soy products.

There are four main reasons people choose a vegetarian diet: (I) physical benefits, including lowering the risk of noncommunicable diseases; (ii) social benefits, such as gaining a sense of belonging; (iii) psychological benefits, including a feel-good sensation due to ethical, moral, and spiritual reasons; (iv) environmental benefits that stem from the environmental cost of consuming meat products (Hargreaves et al., 2021).

The term vegetarian refers to an extensive range of dietary restrictions, some of which are listed in Table 1 (Pilis et al., 2014).

Types of Vegetarianism	Definition
Lacto-ovo-vegetarian	Excludes all types of flesh foodstuffs (meat, poultry, fish), but permits eating all other animal products (e.g. eggs, milk, honey).
Lacto-vegetarian	Excludes flesh foodstuffs and eggs but allows dairy products, honey, etc.
Ovo-vegetarian	Excludes consumption of all animal products with the exception of eggs
Vegan	Excludes all animal products
Vitarian	Permits consumption of organic, raw and fresh foods only. Excludes coffee and tea.
Liquidarian	Consumption of vegetarian food in the form of juices
Fruitarian	Excludes flesh foodstuffs, animal products and vegetables.
Sproutarian	Eating foods in the form of sprouted plant seedlings, such as grains, vegetables, fruits.

FIGURE 1. Types of Vegetarianism

Vegetarianism is prevalent worldwide, with 22% of the world's population being vegetarian (Leahy, 2019). India ranks first by the percentage of vegetarians in its population, with 43%. A far second is Mexico, with 19%, followed by Brazil and Taiwan, with 14% each ("Which Countries Have the Most Vegetarians?" 2019).

A cross-sectional study in India examined the specifics. Of the residents, 43.7% were vegetarians, while 56.3% were nonvegetarians or had a mixed diet. Of the 43.7% who were vegetarians, 40.4% were lacto-vegetarians, 34.6% were ovo-lacto-vegetarians, 15.4% were vegans, and 9.6% were ovo-vegetarians (Turaga, 2023).

The source of vegetarianism's popularity in India is the practice of many religions and belief systems, such as Hinduism, Jainism, and Buddhism, that share a fundamental principle called Ahimsa. Ahimsa is a Sanskrit word for non-violence or non-injury and is aligned with avoiding hurting animals even for the sake of eating.

B. Benefits of a Vegetarian Diet

Compared to meat eaters, vegetarians have lower saturated and monosaturated fat, cholesterol, and urea blood levels, which are biomarkers of an inferior health state (Narasaki et al., 2024). On the contrary, vegetarians present higher levels of health-associated blood components, including albumin, fiber, ascorbic acid, copper, and manganese. They also have lower blood levels of leukocytes and platelets related to inflammatory status. Vegetarian diets also provide the body with multiple antioxidants such as the vitamins α-tocopherol and ascorbic acid, flavonoids, and carotenoids like lycopene, lutein, β-carotene, cryptoxanthin, and zeaxanthin. Vegetarians have higher antioxidant levels than those who eat meat (Pilis et al., 2014; Boada et al., 2016). However, some parameters do not favor vegetarians, and the numbers point to lower protein concentration in vegetarians than meat eaters. Furthermore, vegetarians have been shown to have iron, calcium, zinc, vitamin D, vitamin B12, and amino acid deficiencies.

Being vegetarian can result in other health benefits, such as reducing the risk of heart disease. Heart disease is a leading cause of death in the United States, where it claimed 690,882 deaths last year, a 9% increase from just five years prior and a 4.83% increase from the year prior. This trend is worrying and is the opposite of that of cancer, the second leading cause of death in the US - with 598,932 deaths a year, which only had a 0.5% increase from 5 years ago and decreased by 0.11% from the year prior. Therefore, not only is heart disease the leading cause of death in the US, but it is also increasing at a faster rate compared to other lethal health conditions (Ahmad, 2021). Of note, the risk of hospitalization or death from ischemic heart disease was reported to be 32% lower in vegetarians than in nonvegetarians (Crowe et al., 2013). This is suggested due to the high sodium levels in processed meat, which can raise blood pressure.

Furthermore, processed red meat has high levels of saturated fat, which can increase levels of harmful low-density lipoprotein (LDL) cholesterol, a contributing risk factor for heart disease. A 50g/day higher intake of processed meat such as bacon, ham, or sausages can increase the risk of coronary heart disease by 18%. Similarly, a 50g/day higher intake

of unprocessed red meat such as beef, lamb, or pork can increase the risk of coronary heart disease by 9% (Papier, 2023).

Vegetarian diets can also reduce the risk of cancer. Cancer is still the second leading cause of death in the United States (Ahmad, 2021). Processed meat intake can increase the risk of lung, colorectal, prostate, and other cancers (Boada et al., 2016; Wu et al., 2022). Specifically, the risk of colon cancer is 88% greater in nonvegetarians compared to vegetarians. Both red and white meat consumption increases the risk of colon cancer. The risk of prostate cancer is 54% greater in nonvegetarians compared to vegetarians. The cause for the decreased cancer risk in vegetarians is suggested to be higher consumption of dried fruits and tomatoes and lower consumption of fish compared to nonvegetarians (Fraser, 1999), or the consumption of the carcinogenic compounds polycyclic aromatic compounds and heterocyclic amines that are the result of heating or cooking of meats, especially if burning (Jägerstad, 1999; International Agency for Research on Cancer, 1983). Vegetarian diets are protective from overall cancer incidence in both genders combined and for female-specific cancers, and lacto-ovo-vegetarians have a decreased incidence of gastrointestinal-related cancers (Tantamango-Bartley, 2013).

A vegetarian diet can also reduce the risk of type 2 diabetes. This is because vegetarian diets generally have low-glycemic foods such as whole grains, legumes, and nuts that steady blood sugar levels. Specifically, nonvegetarians who converted to vegetarians experienced a 53% lower hazard risk for diabetes, and consistent vegetarians experienced a 35% lower hazard risk for diabetes (Chiu, 2018).

C. Immune Deficiencies

Immune malfunction refers to conditions in which the immune system is malfunctioning. These can include autoimmune diseases, immunodeficiency disorders, allergies/hypersensitivities, inflammation, cancer, or transplant rejection. There are two kinds of immunodeficiencies: primary, also known as congenital, and secondary, also known as acquired.

Primary (conditional) immunodeficiencies are genetic disorders that individuals are born with. These immunodeficiencies are often inherited and can significantly impact components of an individual's immune system, such as antibodies, T cells, B cells, or other immune components.

Secondary (acquired) immunodeficiencies are not present at birth but develop later in life due to other factors such as malnutrition, infections, or certain medications.

II. Micronutrient deficiencies

A. Indian Micronutrient Profiles

Nutrient limitations refer to deficiencies or inadequacies in essential nutrients that can negatively impact health.

In an Indian cross-sectional study, 78.7% of vegetarians faced nutritional deficiencies and required dietary supplements, but only 33.5% consumed them (Turaga, 2023).

When the vegetarian population was analyzed for the least present nutrient in their bodies, 53.7% had minerals such as iron, B12, and calcium as the least abundant nutrient in their blood, and 27.3% had fat as the most minor nutrient. The difference between vegetarians with minerals as the most minor nutrient in their diet and nonvegetarians was statistically significant. Vegetarian diets that avoid entirely animal products (eggs, dairy, etc.) are at higher risk of nutritional deficiencies (Turaga, 2023).

In addition, since non-vegetarians, or those who eat meat, consume most of their fat from meat, a study revealed what high-fat foods vegetarians consume to replace meat. 34% of the population ate potatoes and other carbohydrate-filled vegetables to replace meat, 17% ate ice cream, 16% ate chocolate, 8% ate brownies, and 25% did not eat any high-fat foods to replace meat (Turaga, 2023).

B. Sources of Vitamins and Minerals in Non-Vegetarian Food

Non-vegetarian foods often contain vitamins and minerals that vegetarians lack in their diet. A deficiency of critical micronutrients can have severe adverse effects, therefore impacting the length and quality of life of those who are deficient.

Animal liver is a storage organ of vitamin A and, therefore, a rich source of vitamin A (Chapman, 2012). Some examples of rich liver sources include beef liver, lamb liver, liver sausage, and cod liver oil. A 3-ounce pan-fried beef contains 6582 micrograms of vitamin A, 731% of the daily value (DV). One tablespoon of cod liver oil provides 4080 micrograms of vitamin A. Liver meat also contains other nutrients such as copper, vitamin B2, vitamin B12, iron, folate, and choline. Cod liver oil and other fish oils can reduce inflammation and are a rich source of omega-3 fatty acids. They were also shown to alleviate or prevent depression (Blaner et al., 2016). One tablespoon of cod liver oil also contains 107% of the DV of vitamin D, boosting immunity and bone health (Bhat, 2015). Vitamin A is essential for humans, and absence or deficiency in vitamin A can lead to

compromised vision. Specifically, bilateral liquefactive corneal necrosis, a severe form of xerophthalmia, can lead to corneal ulceration and keratomalacia, the melting away of the cornea, destroying the cornea in just a few days (Laird et al., 2010). Furthermore, vitamin A deficiency is the single greatest cause of childhood blindness and severe visual impairment in India (Lata et al., 2021). Vitamin A has also been associated with increased susceptibility to infections, skin issues such as keratinization, and stunted growth in children (Chapman, 2012).

Vitamin B12 is another essential vitamin lacking in vegetarian diets. Vitamin B12 is mainly found in meat and other animal products such as eggs, fish, and shellfish; none of these is vegetarian-friendly hemoglobin and contains heme-bound iron and four globulin protein chains. Vitamin B12 is essential for proper hemoglobin synthesis, enabling the production of healthy red blood cells that effectively transport oxygen and support robust immune responses. This molecule carries oxygen from the lungs to the tissues through the blood and returns carbon dioxide to the lungs (Geissler, 2011). However, plant foods mainly contain non-heme-bound iron. The body absorbs heme-bound iron more readily than non-heme-bound iron (Carpenter & Mahoney, 1992; Lombardi‐Boccia et al., 2002). Iron deficiency is often the cause of anemia, specifically iron deficiency anemia, which can lead to a diminished ability to work or exercise, difficulties with thermoregulation, reduced immune function, GI disturbances, and neurocognitive impairment. Iron deficiency also causes impaired cognitive function and cold hands and feet (Lynch, 1989). Zinc deficiency can cause increased susceptibility to a variety of infections, hair loss, skin issues, loss of appetite, growth retardation, and cognitive impairment, especially as it relates to Alzheimer's (Prasad, 2000).

Vitamin B2 (riboflavin) deficiency can lead to ariboflavinosis, which is characterized by sore throat, redness, and swelling of the lining of the mouth and throat. This can also lead to cracks or sores on the outside of the lips (cheilosis) and at the corners of the mouth (angular stomatitis). Like other vitamin deficiencies, vitamin B2 can also cause skin disorders, anemia, eye problems, and growth retardation (Geissler, 2011).

III. Gut microbiome and vegetarian diets

Vegetarian diets profoundly impact the gut microbiome, primarily through increased fiber and polyphenols, lower saturated fat and animal protein levels, and other factors.

Compared to non-vegetarian diets, vegetarian diets are higher in dietary fibers from fruits, vegetables, legumes, and whole grains since they proportionately eat more of these foods. Higher fiber intake directly corresponds to the growth of beneficial gut bacteria such as Bifidobacterial and Lactobacilli (Slavin, 2013). These bacteria produce short-chain fatty acids (SCFAs) such as butyrate, acetate, and propionate. Furthermore, SCFAs help regulate immune responses, reduce inflammation in the gut and other body parts, strengthen the gut lining to protect against harmful bacteria infiltrating the bloodstream, and improve immune cell function to protect against infections.

Vegetarian diets are rich in polyphenols, bioactive compounds in various plant foods, such as fruits and vegetables, and drinks, such as tea, coffee, and red wine (Wachtel-Galor, 2014). Polyphenols enhance beneficial bacteria in the gut while inhibiting pathogenic bacteria and reducing oxidative stress and inflammation. This, in turn, creates a stronger, more balanced immune system. Prebiotic intake is often high in vegetarians, who consume more prebiotic-rich food such as garlic, onions, bananas, and whole grains.

Prebiotics are non-digestible food ingredients that stimulate the growth and metabolism of beneficial intestinal bacteria. Of the prebiotics found in vegetarian diets, the most common are inulin, fructooligosaccharides, and resistant starches (Sharma, 2011). By feeding beneficial bacteria, these prebiotics enhance the production of SCFAs and other metabolites that support gut and immune health. Furthermore, prebiotics bolster immune cells and antimicrobial compounds, improving immune function.

Overall, vegetarian diets can enhance immune function by creating a healthy gut microbiome that can outcompete harmful bacteria, reduce infection, lower chronic inflammation due to a higher fiber and polyphenol intake, and regulate immune response due to metabolites produced by beneficial bacteria.

IV. Immune Response Studies

A. Gut and Immune Benefits of an Indian Vegetarian Diet

Indian vegetarians' diets are rich in plant-based foods, emphasizing lentils, legumes, whole grains, vegetables, fruits, and various spices. These foods provide vegetarians with various nutrients, fibers, and bioactive compounds that can profoundly impact the gut microbiome.

First, Indian vegetarians incorporate many different types of lentils, legumes, and whole grains in their diet. These are rich sources of dietary fiber and promote beneficial gut bacteria such as Bifidobacteria and Lactobacilli. These bacteria produce SCFAs like butyrate, acetate, and propionate, which are immensely crucial in modulating immune responses, reducing inflammation, and maintaining gut barrier integrity.

Moreover, Indian vegetarian cuisine is rich in fermented foods such as yogurt (dahi), buttermilk (chaas), and pickles (achar). Often consumed daily, these fermented foods strengthen the gut microbiome by enhancing microbial diversity and introducing beneficial probiotics into the gut (Jain et al., 2016). This, in turn, also promotes a healthy immune system among Indian vegetarians.

Indian cuisine is known for its rich and diverse set of spices, which range from Kashmiri red chili powder to cumin powder. Furthermore, many other natural herbs, such as turmeric, ginger, garlic, cumin, and coriander, are constantly used in dishes. These spices have anti-inflammatory, antioxidant, and antimicrobial properties, which support gut health and boost immune function.

When comparing the gut microbiome of Indian vegetarians to non-vegetarians, vegetarians typically show a higher abundance of beneficial bacteria (Tomova et al., 2019). This translates to a better-functioning immune system because of immune modulation due to the enhanced production of SCFAs, increased resilience and stability due to the increased microbial diversity, and anti-inflammatory effects due to the consumption of anti-inflammatory foods, resulting in bacteria that drive the inflammatory effect.

B. The "Natural Immunity" Phenomenon

"Natural immunity" refers to individuals' inherent immune response against infections (Tauber, 2017). The so-called natural immunity of people in the Indian subcontinent is due to genetic, environmental, dietary, and sociocultural factors.

The Indian population is genetically diverse due to its history of admixture among various ethnic groups. The diversity of the HLA system, which are genes that encode surface proteins and are essential to immune function, can lead to varied immune responses to pathogens among the Indian population.

Indians are more frequently exposed to a wide range of pathogens than Western populations. This can promote the development of a more robust immune system that is exposed and trained to fight a wide range of

bacteria, viruses, and parasites, as well as environmental antigens, such as unfiltered water and soil. This intense immune system stimulation can lead to better immunity against future infections.

Moreover, as outlined before, the dietary habits of vegetarian Indians, such as the rich spices and high fiber intake, enhance immune function and bolster immune regulation.

C. Genes and Cytokines Involved

The HLA (human leukocyte antigen) class I (A, B, C) and class II (DP, DQ, DR) genes play an essential role in pathogenic recognition in the immune systems. The diversity of HLA alleles and these highly polymorphic genes in Indian vegetarians can influence susceptibility and resistance to various harmful diseases.

There are also many different cytokines involved. The Interleukin-6 (IL-6) cytokine plays a crucial role in the immune response to infections as it is a pro-inflammatory cytokine. Therefore, the less IL-6 in the body, the less inflammation one experiences. The Indian vegetarian diet contains many anti-inflammatory foods, such as turmeric, ginger, and garlic, which have been shown to downregulate pro-inflammatory cytokines like IL-6 (Ansar et al., 2016). Tumor necrosis factor-alpha (TNF-α) is a pro-inflammatory cytokine-like IL-6, which means, just like IL-6, the absence of TNF-α decreases inflammation. Antioxidant-rich foods, like fruits, vegetables, and spices, and healthy fats, like nuts, seeds, and oils, can help reduce TNF-α levels or inhibit them, limiting the pro-inflammatory cytokine. Lower TNF-α levels also reduce the risk of rheumatoid arthritis, cardiovascular diseases, and inflammatory bowel disease (Ansar et al., 2016).

Conversely, the Interleukin-10 (IL-10) cytokine is anti-inflammatory, meaning the more IL-10 in the body, the less inflammation one experiences. Foods rich in polyphenols, such as fruits, vegetables, tea, and spices—all highly abundant in the Indian diet—can enhance the production of IL-10, therefore acting as an anti-inflammatory agent. The high fiber consumption from legumes, whole grains, and vegetables promotes the production of SCFAs, which have been shown to increase IL-10 production (Q. Ali et al., 2022).

The information included here about IL-6, IL-10, and TNF-α and the anti-inflammatory benefits of vegetarian diets in the context of their regulation only provides an example of molecular components that are subject to change due to dietary habits. Other cytokines and

immune-related genes are also involved with the anti-inflammatory benefits of a vegetarian diet and are not addressed in this paper.

V. Discussion

This paper was written to filter a large amount of misinformation in the realm of diets and healthcare and distill relevant and accurate data to address a specific biological question: what is the health toll and benefit of vegetarianism, and is it different in India compared to the US? The paper summarizes the health benefits of vegetarianism but also flags one serious risk: a compromised immune system due to nutritional deprivation of some micronutrients. Yet, this risk is diminished in Indian vegetarians due to natural immunity. However, this paper assumes a vegetarian diet with sufficient macronutrients such as protein. This assumption might not reflect the state of many vegetarians who suffer from various insufficiencies, including macronutrients. One specific macronutrient that is often discussed as deficient among Indian vegetarians is protein. The Indian vegetarian protein profile is diverse, typically consisting of legumes, lentils, and dairy. On the other hand, the US and Western protein diet consists more of processed plant proteins and soy derivatives. This difference in continental vegetarian diets can translate to different amino acid compositions and bioavailability. Furthermore, traditional Indian cooking techniques like fermentation, sprouting, and specific spice combinations enhance nutrient bioavailability. These methods may mitigate potential nutritional deficiencies inherent in plant-based diets and can be a new avenue for research. The warrant behind this is that specific cooking methods like pressure cooking, tempering, and traditional fermentation have higher rates of nutrient absorption in plant-based diets (A. Ali et al., 2022). These techniques, in their primitive forms, have been employed in the Indian subcontinent for thousands of years, well before the modern vegetarianism revolution present in Western society.

A limitation of the paper is that the generalizations made here must capture the diversity of dietary habits and metabolic needs of individuals within different geographical areas and cultures.

In summary, various diets can benefit health and mental state. Still, these vary and are influenced by external factors such as cuisine, genetic background, environmental exposures and risks, and lifestyle.

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References

Ahmad, F. B., & Anderson, R. N. (2021). The leading causes of death in the US for 2020. *Jama*, 325(18), 1829-1830.

Ali, A., Devarajan, S., Manickavasagan, A., & Ata, A. (2022). Antinutritional factors and biological constraints in the utilization of plant protein foods. In *Plant protein foods* (pp. 407–438). Cham: Springer International Publishing.

Ali, Q., Ma, S., La, S., Guo, Z., Liu, B., Gao, Z., ... & Shi, Y. (2022). Microbial short-chain fatty acids: a bridge between dietary fibers and poultry gut health—a review. *Animal bioscience*, 35(10), 1461.

Ansar, W., Ghosh, S., Ansar, W., & Ghosh, S. (2016). Inflammation and inflammatory diseases, markers, and mediators: Role of CRP in some inflammatory diseases. *Biology of C reactive protein in health and disease*, 67–107.

Bhat, S. A., & Ara, A. (2015). Omega-3 fatty acids and the treatment of depression: a review of scientific evidence. *Integrative medicine research*, 4(3), 132-141.

Blaner, W. S., Li, Y., Brun, P. J., Yuen, J. J., Lee, S. A., & Clugston, R. D. (2016). Vitamin A absorption, storage, and mobilization. *The Biochemistry of Retinoid Signaling II: The Physiology of Vitamin A-Uptake, Transport, Metabolism and Signaling*, 95–125.

Boada, L. D., Henríquez-Hernández, L. A., & Luzardo, O. P. (2016). The impact of red and processed meat consumption on cancer and other health outcomes: Epidemiological evidences. *Food and Chemical Toxicology*, 92, 236-244.

Carpenter, C. E., & Mahoney, A. W. (1992). Contributions of heme and nonheme iron to human nutrition. *Critical Reviews in Food Science & Nutrition*, 31(4), 333–367.

Chapman, M. S. (2012). Vitamin A: history, current uses, and controversies. In *Seminars in cutaneous medicine and surgery* (Vol. 31, No. 1, pp. 11–16). WB Saunders.

Chiu, T. H., Pan, W. H., Lin, M. N., & Lin, C. L. (2018). Vegetarian diet, change in dietary patterns, and diabetes risk: a prospective study. *Nutrition & diabetes*, 8(1), 12.

Crowe, F. L., Appleby, P. N., Travis, R. C., & Key, T. J. (2013). Risk of hospitalization or death from ischemic heart disease among British vegetarians and nonvegetarians: results from the EPIC-Oxford cohort study. *The American journal of clinical nutrition*, 97(3), 597–603.

Fraser, G. E. (1999). Associations between diet and cancer, ischemic heart

disease, and all-cause mortality in non-Hispanic white California Seventh-day Adventists. *The American journal of clinical nutrition*, 70(3), 532S-538S.

Geissler, C., & Singh, M. (2011). Iron, meat, and health. *Nutrients*, 3(3), 283-316.

Hargreaves, S. M., Raposo, A., Saraiva, A., & Zandonadi, R. P. (2021). Vegetarian diet: an overview through the perspective of quality of life domains. *International journal of environmental research and public* health, 18(8), 4067.

International Agency for Research on Cancer. (1983). Polynuclear aromatic compounds, part 1. Chemical, environmental and experimental data. *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans*, 32, 419-430.

Jägerstad, M., Skog, K., Grivas, S., & Olsson, K. (1991). Formation of heterocyclic amines using model systems. *Mutation Research/Genetic Toxicology*, 259(3-4), 219-233.

Jain, A., Li, X. H., & Chen, W. N. (2018). Similarities and differences in gut microbiome composition correlate with dietary patterns of Indian and Chinese adults. *Amb Express*, 8, 1-12.

Laird, E., Ward, M., McSorley, E., Strain, J. J., & Wallace, J. (2010). Vitamin D and bone health; Potential mechanisms. *Nutrients*, 2(7), 693–724.

Lata, S., Bafna, R. K., Asif, M. I., & Sachan, A. (2021). Bilateral liquefactive corneal necrosis: a rare and devastating complication of vitamin A deficiency in the adult. *BMJ Case Reports CP,* 14(2), e237343.

Leahy, E., Lyons, S., & Tol, R. S. (2010). *An estimate of the number of vegetarians in the world* (No. 340). ESRI working paper.

Lombardi‐Boccia, G., Martinez‐Dominguez, B., & Aguzzi, A. (2002). Total heme and non‐heme iron in raw and cooked meats. *Journal of Food Science*, 67(5), 1738-1741.

Lynch, S. R., Hurrell, R. F., Dassenko, S. A., & Cook, J. D. (1989). The effect of dietary proteins on iron bioavailability in man. *Mineral absorption in the monogastric GI tract*, 117-132.

Narasaki, Y., Kalantar-Zadeh, K., Rhee, C. M., Brunori, G., & Zarantonello, D. (2024). Vegetarian Nutrition in Chronic Kidney Disease. *Nutrients*, 16(1), 66.

Papier, K., Knuppel, A., Syam, N., Jebb, S. A., & Key, T. J. (2023). Meat consumption and risk of ischemic heart disease: a systematic review and meta-analysis. *Critical Reviews in Food Science and Nutrition*, 63(3), 426-437.

Pilis, W., Stec, K., Zych, M., & Pilis, A. (2014). Health benefits and risk associated with adopting a vegetarian diet. *Roczniki Państwowego Zakładu Higieny*, 65(1), 9-14.

Prasad, A. S. (2000). Effects of zinc deficiency on immune functions. *The Journal of Trace Elements in Experimental Medicine: The Official*

Publication of the International Society for Trace Element Research in Humans, 13(1), 1–20.

Sharma, A. K., Agarwal, V., Kumar, R., Chaurasia, H., Chaurasia, D., & Bhardwaj, P. (2011). Prebiotics: A review of therapeutic potential. *International Journal of Pharmaceutical Innovations*, 1(3), 28–40.

Slavin, J. (2013). Fiber and prebiotics: mechanisms and health benefits. *Nutrients*, 5(4), 1417–1435.

Tantamango-Bartley, Y., Jaceldo-Siegl, K., Fan, J., & Fraser, G. (2013). Vegetarian diets and the incidence of cancer in a low-risk population. *Cancer epidemiology, biomarkers & prevention*, 22(2), 286-294.

Tauber, A. I. (2017). *Immunity: the evolution of an idea*. Oxford University Press.

Tomova, A., Bukovsky, I., Rembert, E., Yonas, W., Alwarith, J., Barnard, N. D., & Kahleova, H. (2019). The effects of vegetarian and vegan diets on gut microbiota. *Frontiers in nutrition*, 6, 447652.

Turaga, A. H. (2023). Vegetarianism and Its Implications for Body Mass Index, Health, and Dietary Awareness in a Metropolitan City in India: A Cross-Sectional Study. *Cureus*, 15(7).

Wachtel-Galor, S., Siu, P. M., & Benzie, I. F. F. (2014). Antioxidants, vegetarian diets and aging. In *Aging* (pp. 81-91). Academic Press.

Which countries have the most vegetarians? (2019, January 21). *RadioFreeEurope/RadioLiberty*. https://www.rferl.org/a/which-countries-have-the-most-vegetarians/29722181.html

Wu, K., Liu, L., Shu, T., Li, A., Xia, D., & Sun, X. (2022). The relationship between processed meat, red meat, and risk of types of cancer: A Mendelian randomization study. *Frontiers in Nutrition*, 9, 942155.