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Review paper

Being a vegetarian: health benefits and hazards

Svetlana Stanisic[1], Vladan Markovic[1], Sarcevic Danijela[2], Milan Z. Baltic[3], Marija Boskovic[3], Milka Popovic[4], Natasa Kilibarda[1]*

A b s t r a c t: Although their anatomical features disclose the herbivorous nature of humans, an omnivorous diet can be considered an evolutionary advantage that has supported human survival. Over recent decades, vegetarianism has significantly increased in developed countries due to the support of scientific research, emerging supermarkets and restaurants, and easy-to-access soy products and healthy foods. According to current knowledge, vegetarian diets are associated with significantly lower prevalence of non-infectious chronic diseases. However, while the overall risk of cancer is slightly lower in vegetarians, the findings regarding the location and type of cancer that can be prevented by vegetarian diets are inconclusive. In addition to this, it remains unclear whether health benefits of vegetarian diets can be attributed to the avoidance of meat, or to the increased intake of dietary fibre, n-6 fatty acids, vitamins C, B9 and E, potassium, magnesium and phyto-chemicals, or to both of these factors. As a vegetarian diet becomes more restrictive, intake of adequate daily energy and of n-3 fatty acids, essential amino acids, vitamin B12, zinc, calcium and iron becomes more difficult to achieve, which is particularly challenging in children who have higher nutrient requirements relative to body weight than adults.

Keywords: vegetarianism, vegan, pescovegetarian, meat-based diet.

Vegetarianism through time and space

The anatomical features that allow predators to effectively stab and kill their prey include a wide mouth opening, blade-shaped molars for flesh ripping, a massive temporalis muscle and a jaw joint located in the same plane as the teeth. According to evolutionary theory, these anatomical features of carnivores are more primitive than herbivore adaptations, which suggest that herbivores are basically carnivores that adopted significant anatomical modifications consistent with a plant-based diet (*Provenza et al*., 2015). These modifications are reflected in a small oral cavity opening, flat and spade-like incisors for peeling and biting, an herbivore-style jaw joint that is more efficient for crushing and grinding plant tissue, and carbohydrate-digesting enzymes in saliva, all of which are features of modern human anatomy (*Mills*, 1996). However, the most striking anatomical differences between carnivores and herbivores are related to the stomach and intestines (*Danowitz and Solounias*, 2016). A single-chambered stomach, lengthening small intestine and a shrinking distensible colon in humans can be considered as appropriately designed for digestion of soft and pulpy plant food (*Armelagos*, 2014).

Although observations of comparative anatomy disclosing the herbivorous nature of humans have often been often cited as core arguments for vegetarian diets, the fact that some herbivores exhibit anatomical features consistent with carnivorous diets and vice versa clearly suggests that the anatomy of the gastrointestinal tract is not the only feature that predicts food-related behaviour of an animal species (*Ramalanjaona et al*., 2016). Another factor that has had a significant bearing on human food selection throughout history was the struggle for survival in new climatic conditions. In this terms, an omnivorous diet was one of the evolutionary advantages (*Spencer*, 1996).

The term 'vegetarianism' refers to a wide spectrum of dietary patterns characterised by an emphasis on plant foods and avoidance of animal foods. Ovovegetarians consume eggs, lactovegetarian's diet consists of legumes, grains, fruits, nuts and vegetables, together with milk and dairy products, while semivegetarians restrict the type of meat to only fish (pescovegetarian), poultry (pollovegetarian), or both fish and poultry (pesco-pollovegetarians).

[1]*Singidunum University, 32 Danijelova St., 11010 Belgrade, Republic of Serbia;*
[2]*Institute of Meat Hygiene and Technology, Kacanskog 13, 11000 Belgrade, Republic of Serbia;*
[3]*University of Belgrade, Faculty of Veterinary Medicine, Bulevar Oslobodjenja 18, 11000 Belgrade, Republic of Serbia.*
[4]*Institute for Public Health of Vojvodina, Futoska 121, 21000 Novi Sad, Republic of Serbia.*

***Corresponding author:** Svetlana Stanisic, *sstanisic@singidunum.ac.rs*

Finally, the strictest form of vegetarianism is veganism, and it involves avoidance of all foods of animal origin, including eggs and milk (*Lanham-New*, 2009). The main goal of this review is to briefly summarise current knowledge on health advantages and disadvantages associated with vegetarian diets in order to provide a better understanding of the effects such a specific food choice exerts on human health.

Throughout history, different people have chosen vegetarian dietary patterns for a variety of reasons, including to demarcate important common cultural grounds. The first philosophical arguments for animal food avoidance dating back to ancient Egypt were related to the belief in transmigration i.e. reincarnation of souls. In the centuries that followed, avoidance of animal foods was adopted among ancient Greeks and Indians, while ethical principles supporting a plant-based diet were instilled in the teaching of Pythagoras and Buddha. Nowadays, among a variety of non-religious motivations for adopting a meat-free diet, the most highly ranked are weight loss, potential health benefits, disgust of meat smell and consistency, and moral imperatives to preserve the environment and avoid sacrificing animals (*Fox and Ward*, 2008b). In modern societies, vegetarianism can also be perceived as a cue to individual identity, with certain psychological factors or life events having been shown to provoke sudden rejection of meat (*Fox and Ward*, 2008a). In contrast to multiple ethical justifications for vegetarianism that have their roots in religion and philosophy of ancient civilisations, the scientific evidence for the health effects of vegetarian diets is relatively recent, emerging in the 19th century. The last but not least reason for adopting a plant-based diet is the environmental impact of food production, which remains a matter of scientific debate. In terms of biological diversity and habitat loss, human consumption of animal-based foods/products is estimated to be among the most negative factors affecting the preservation of terrestrial ecosystems (*Machovina et al*., 2015). Some researchers estimate that switching from an animal-based diet to vegetarianism is a feasible tool for climate change mitigation that would contribute to a three-fold reduction of greenhouse gas emissions (*Marlow et al*., 2009), while more recent research suggests that increased intake of fruits, vegetables, dairy and seafood might pose a higher risk for the environment due to relatively high greenhouse gas emissions per calorie produced (*Tom et al.*, 2015). Probably the most feasible explanation is offered in the recent study of *Rosi et al*. (2017), which showed that some vegan diets had greater negative environmental impacts than non-vegetarian diets. This suggests that the individual variability of dietary habits is more important than the type of diet itself.

Vegetarianism is not the only food phenomenon on the rise over recent decades. Namely, the two-fold increase in global meat consumption over the last 50 years has placed a significant burden on the environment, leading to unbalanced diets, particularly in industrialised areas and emerging countries, mainly Brazil and China (*Baltic et al*., 2010a; *Sans and Combris*, 2015; *Odusanya and Atanda, 2018*). Among developing countries, India is a notable exception because a significant proportion of the population (up to 35–40%) follows a traditional vegetarian diet and has done so for many generations (*Ponzio et al*., 2015). The study of *Vranken et al*. (2014) based on data from 120 countries reported an inverted U-shaped relationship between meat consumption and income level, complemented by the remark that at a turning point between income levels of US$32,000 to US$55,000, average meat consumption will stagnate or even decline. In compliance with this, the number of vegetarians is significantly increasing in some of the most affluent countries, although it still comprises a relatively small proportion of the population. Nowadays, approximately 9% of Germans, 8% of Canadians, and 3% of United States, United Kingdom and Australian citizens declare themselves as vegetarians. Apart from income, culture plays an important role in dietary preferences – in traditional societies, milk and meat are rated as more masculine foods than vegetables, and male meat-eaters are perceived as being more masculine than vegetarians. *Rozin et al*. (2012) analysed 23 world languages that use gendered pronouns, and confirmed that meat was associated with the male gender across most of them.

As regards personal characteristics, a typical vegetarian is described as a female of higher social status and academic or vocational qualifications, although these attainments need not be reflected in income. Interestingly, *Gale et al*. (2007) showed that higher IQ at a young age remains a statistically significant predictor of vegetarianism, even after accounting for social class, sex and academic or professional qualifications. On the other hand, although vegetarianism is supported by scientific research, emerging supermarkets and trendy restaurants that offer access to soy products and healthy foods, consumers of restrictive plant-based diets are often confronted with various challenges and social alienation because of their choices and beliefs. As noted by *Menzies and Sheeshka* (2012), five central food values, *i.e.* taste, health, time, cost, and social

relationships, have the potential to significantly undermine people's commitment to a vegetarian diet chosen largely for health or moral reasons.

Health benefits of vegetarianism

Vegetarian diets contain high amounts of dietary fibre, n-6 fatty acids, vitamins C, B9 and E, magnesium, potassium, carotenoids, plant sterols and many other phyto-chemicals, which are commonly associated with numerous health benefits. The wide range of antioxidants in a plant-based diet prevents oxidative stress that plays an important role in carcinogenesis and development of endothelial dysfunction, and in the initial steps of pathogenesis in atherosclerosis (*Chauveau et al*., 2013). Unlike other types of vegetarianism, a vegan diet implies lower intake of saturated fatty acids, cholesterol, calcium, vitamin B12 and D, as well as a higher intake of dietary fibre (*Fields et al*., 2016).

To date, a large body of evidence has shown that a vegetarian diet is associated with significantly lower prevalence of overweight and obesity, as well as with a lower risk of cardiovascular hospital admission and 32% less mortality. As concluded by *Crowe et al*. (2013), even after accounting for body mass index, vegetarians remain 28% less likely to develop ischemic heart disease. A recent meta-analysis (*Yokoyama et al*., 2014) examining the relationship between vegetarian diet and blood pressure has shown that a diet excluding meat, but involving regular consumption of dairy products, eggs and fish was associated with 4.8–6.9 mm Hg lower systolic blood pressure, compared to an omnivorous diet. The estimated reduction in blood pressure was associated with 9% decreased risk of death from coronary heart disease and can be equated to the health benefits of a 5 kg weight reduction or a low-sodium diet.

In addition to this, the vast number of studies that have explored the link between plant-based diets and malignant diseases reported the overall risk of cancer is somewhat lower in vegetarians compared to omnivores. However, when it comes to the location and type of cancer that can be prevented by plant-based diets, findings are rather scarce and inconclusive (*Key*, 2017). The prospective cohort study of *Bradbury et al*. (2014) aimed at exploring the associations between fruit, vegetable and/or fibre intake and cancer risk and included more than 500,000 participants from 10 European countries. According to the results, the risk of gastrointestinal tract cancer and liver cancer was inversely associated with excessive consumption of plant-based foods, while for lymphoma, as well as for stomach, cervix, biliary tract, pancreas, prostate, kidney, endometrium and bladder cancer, no significant association was reported between incidence and total intake of fruit, vegetables or fibre. Similarly, *Gilsing et al*. (2016) reported that after accounting for confounding factors, vegetarians, pescovegetarians and 1 day-per-week meat-eaters did not have a reduced risk of postmenopausal breast, lung or prostate cancer compared to those consuming meat on a daily basis.

The largest body of epidemiological data relates to the risk of colorectal cancer and excessive consumption of red and processed meat (*Chauveau et al*., 2013), but the results also turned out to be divergent (*Boskovic and Baltic*, 2016). A recent study (*Michelle et al*., 2015) with 77,659 participants showed that vegetarians have a 22% lower risk of developing all colorectal cancers compared to non-vegetarians with a similar background. Furthermore, the authors emphasised that eating a pescovegetarian diet was associated with the lowest risk of colorectal cancer (a 43% risk reduction compared with omnivores), while the risk of colorectal cancer in semivegetarians (risk reduction of 8%) was closest to the risk that meat consumers face (*Michelle et al*., 2015). A similar conclusion was reported in a meta-analysis and systematic review of prospective cohort studies by *Godos et al*. (2017). According to their findings, the risk of colorectal cancer was lower in the population that consumed a semivegetarian diet (relative risk 0.86) and pescovegetarian diet (relative risk 0.67) when compared to non-vegetarians (*Godos et al*., 2017). However, in contrast to this, *Koushik et al*. (2007) followed 756,217 men and women for 6 to 20 years and showed that excessive intake of fruit and vegetables was not strongly associated with colon cancer risk reduction.

The controversial findings in the current literature are driven by the fact that studies exploring the relationships between diet and health face two main challenges. First, it is difficult to discriminate the specific effects of vegetarian diets from those lifestyle factors that are often associated with vegetarianism, such as lighter body mass index, higher levels of physical activity, and lower prevalences of smoking and alcohol consumption. In addition to this, it remains unclear whether the established health benefits of vegetarian diets can be attributed to the avoidance of red meat, avoidance of processed meat, limited intake of saturated fatty acids and cholesterol, increased intake of fruit, legumes, vegetables, grains nuts, and soya protein-foods, or to all or combinations of these.

Although nutritionally dense, red meat with high fat content and processed meat are often mentioned as risk factors for cancer development. According to the results of a study including 450,000 participants, the overall risk of cardiovascular and malignant mortality increases by 18% for every 50 grams of processed meat per day, due to the presence of carcinogenic nitrosamines, as well as the high content of cholesterol and saturated fats (*Rohrmann et al*., 2013). The core results of the study remained the same after taking into account the level of physical activity, smoking, alcohol consumption and other factors that can confound the relationship between nutrition and morbidity (*Rohrmann et al*., 2013). Furthermore, a positive association between excessive red meat consumption and colorectal cancer was found in a large number of cohort studies (*Bouvard et al.*, 2015). In addition to this, high intake of red meat was associated with pancreatic and prostate cancers, while consumption of processed meat was strongly related to stomach cancer (*Bouvard et al*., 2015). In a review of meta-analyses, *Yip et al*. (2018) concluded that 21 morbidity burdens were significantly associated with meat intake, with the highest dose-response for a 50 g increase in processed meat daily intake for oesophageal, stomach and colon cancer, as well as for coronary heart disease and cardiovascular mortality. Furthermore, the highest dose-response for each 65 g increase in red meat daily intake was detected for endometrial, oesophageal and lung cancer.

The abundance of fruits and vegetables in vegetarian diets overlaps with conventionally recommended healthy dietary patterns, which leads us to the conclusion that a significant share of health benefits associated with vegetarianism comes from increased intake of plant-based foods, even though these benefits seem to remain rather restricted to cardiovascular health. The study of *Aune et al*. (2017) showed increasing fruit and vegetable daily intake by 200 g decreased the relative risk of stroke to 0.84, of coronary heart disease to 0.92 and of cancer morbidity to only 0.97. Furthermore, by reviewing the epidemiological evidence on diet and cancer, *Key et al*. (2004) concluded that consumption of fruits and vegetables probably reduces the risk of gastrointestinal cancers located in the oral cavity, oesophagus, stomach and colorectum.

Apart from cancer, high fruit and vegetable intake as well as vegetarian diets have been associated with lower risk of diabetes type II (*Cooper et al*., 2015; *Appleby and Key*, 2016). Furthermore, some authors mention auxiliary impacts of restrictive vegetarian diet on gut health. Namely, *Bauer and Yeh* (2014) showed that vegans displayed a gut microbiota that was most distinct from that of omnivores, but was not always significantly different from that of vegetarians, with a reduced concentration of pathological species and abundance of protective species. The unique gut microbial profile might be a key feature linking veganism with protective health effects.

Health hazards associated with plant-based diets

While higher intake of plant foods and moderate amounts of saturated fatty acids, cholesterol and processed meat can be considered beneficial for health, the existing evidence from cohort studies suggests that the complete elimination of animal foods might not be associated with additional benefits for human health (*Godos et al*., 2017). Meat is a source of biologically valuable proteins, long chain n-3 fatty acids, essential trace elements (iron, copper, manganese, iodine, zinc, selenium), vitamin D and several B vitamins (*Baltic et al*., 2010; *Ivanovic et al*., 2016; *De Smet and Vossen*, 2016). Therefore, the potential drawbacks of vegetarian diets mostly refer to the reduced supply of essential amino acids, n-3 fatty acids, vitamin B12, zinc, iron and calcium (*Petti et al*., 2017).

Vegetarian diets are abundant in n-6 fatty acids (linoleic acid), while lower serum levels of n-3 fatty acids, i.e. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are thought to be important for immune, cognitive and cardiac functions, have been reported in vegans (*Pavlicevic et al*., 2014). Plant-derived linolenic acid can be converted to EPA and DHA *in vivo*, but the conversion rate is rather slow and vegan sources of n-3 fatty acids are limited to canola oil, flaxseed and flaxseed oil, and olive oil (*McEvoy et al*., 2012).

Iron deficiency is a cause of anaemia in approximately 30% of the population in wealthy countries, particularly in urban residents and young females. The vegan population exhibits an even higher tendency for anaemia, not because their iron intake is below recommended levels, but because non-haeme iron from plants is less bioavailable and because plant-abundant diets contain substances such as phytic acid and polyphenols/tannin, which can impair mineral absorption.

A vast number of studies aimed at exploring vegan health with respect to vitamin B12 deficiency, since B12 requirements cannot be met without animal-based food intake or supplementation, and in affected people, B12 deficiency and the accompanying haematological symptoms can be mimicked

by folic acid intake, which is high in vegan diets (*Baltic et al*., 2010; *McEvoy et al*., 2012). Although plasma levels of vitamin B12 are lower in the entire vegetarian population than in meat-eaters, cases of pronounced vitamin B12 deficiency with subsequent haematological and neurological damage, such as central nervous system demyelination, have been reported only in vegans (*Kapoor et al.*, 2017). This is because followers of less strict vegetarian diets, such as ovolactovegetarians, lactovegetarians and semivegetarians, obtain B12 through consumption of cheese, eggs, milk, and artificially fortified products. Apart from haematological and neurological effects, vitamin B12 deficiency is shown to be associated with atherosclerosis. As reported by *Woo et al*. (2014), low intake of meat, egg or dairy products in poor residents of northern Chinese rural communities and consequent vitamin B12 deficiency have been associated with impaired arterial endothelial function and increased thickness of carotid intima-media.

In addition to vitamin B12 deficiency, plant-eaters who avoid animal-based protein might be lacking several key nutrients, including sulphur amino acids, iron, zinc and omega-3 fatty acids, which can be associated with the elevated blood levels of homocysteine and decreased high-density lipoprotein levels often reported in vegans (*Ingenbleek and McCully*, 2012). In order to meet the daily requirements and decrease vulnerability to atherosclerosis, vegans should be encouraged to take vitamin B12 supplements and consume walnuts as a source of n-3 fatty acids (*Li*, 2011).

The relationship between vegetarian diets and skeletal integrity was a matter of scientific debate due to the fact that it is challenging to distinguish between the effects of diet and certain lifestyle factors (e.g. physical activity, smoking and caffeine intake) on bone health. The EPIC-Oxford study (European Prospective Investigation into Cancer and Nutrition – University in Oxford) performed between 1993 and 1999 showed veganism poses a risk of calcium and vitamin D deficiency, particularly for people living in northern latitudes with low sunlight exposure (*Crowe et al*., 2011). Nevertheless, more recent findings have shown the daily average vitamin D intake of vegans has increased noticeably by almost 12-fold in the last 20 years due to newer dairy replacement products that are typically fortified (*Dagbasi et al*., 2015). Moreover, the lower bone density in people consuming plant-based diets was confirmed, but it cannot be considered as clinically relevant as no significant differences in osteoporotic fracture rates between vegetarians and non-vegetarians were registered (*Chauveau et al*., 2013).

Vegetarianism and vulnerable population categories

One of the conclusions of the EPIC-Oxford study, that recruited more than 65,000 subjects of which approximately 50% were meat-eaters, was that mean energy intake was 14% lower in vegans than in non-vegetarians (*Davey et al*., 2003). While the mean fat intake was similar, the contribution of saturated fats to total energy intake was significantly lower in vegetarians. Moreover, vegetarianism has been shown to precede different eating disorders associated with low energy consumption and increase the risk of developing anorexia nervosa (*Aloufy and Latzer*, 2016).

Despite the aforementioned assumptions and facts, it has been convincingly highlighted that a vegetarian diet can be nutritionally adequate for all stages of the life cycle from infancy to old age (*Chauveau et al*., 2013). While experts claim that vegetarian diets can be adequate and while the majority of vegetarians interpret their nutrition as a transition to a new and healthier nutrition, some studies have shown that some vegetarians attribute their perceived decline in health or well-being to meat avoidance (*Menzies and Sheeshka*, 2012). A healthy diet is designed to provide the body with all essential nutrients and sufficient energy, but as a vegetarian diet becomes more restrictive, adequate daily energy intake becomes more difficult to achieve. Unlike proteins in animal foods, those in plant-based foods are less digestible and are often deficient in one or more essential amino acids, and thus, human requirements for a well-balanced intake of amino acids in vegetarians can be met only if a variety of plant foods is consumed. Furthermore, monotonous vegetarian diets are nutritionally inadequate and without the appropriate monitoring and supplementation can result in severe nutrient deficiencies with detrimental health effects. The study of *Satija et al*. (2017) based on a sample of 166,030 women and 43,259 men found an unhealthful plant-based diet which emphasised consumption of refined grains was linked to an equal risk of coronary heart disease as that of regular animal-based food intake.

As regards infants, study showed that the majority of vegan children grew and developed normally, although they tended to be smaller in stature and lighter in weight than the general population of their age, and their intake of energy, calcium, vitamin D, B2 and B12 were usually below the recommendations (*Di Genova and Guyda*, 2007; *Rogne et al.,* 2017). Ten years ago, an Internet search of the terms ‘vegan’ and ‘children’ produced 1,380,000 hits (*Di Genova and Guyda*, 2007),

suggesting numerous parents were considering limiting their child/children to the most restrictive type of plant-based diet.

Healthy eating habits in childhood are of vital importance for prevention of under nutrition, growth retardation, and a number of other nutrition-related issues (*Djordjevic et al*., 2016). Due to higher nutrient requirements relative to body weight, vegan children are more likely than adult vegans to face nutritional deficiencies that adversely affect their bone mineral content, growth, as well as their motor and cognitive development. Bulky plant food with a high content of dietary fibre can restrict energy intake in children and lead to lower mean weight (*Katz and Meller*, 2014). Furthermore, vitamin B12 deficiency in toddlers results in severe, long-term megaloblastic anaemia and neurological disorders, including impaired cognitive performance and intelligence, as well as poor spatial ability and short-term memory (*Rogne et al*., 2017).

Conclusions

The current evidence from long-term studies based on large population samples and using methodology that precludes bias and confounding factors is too scarce to resolve the issue of a single best diet, but the weight of evidence strongly supports healthy dietary patterns while allowing for variations in food choice. While the positive effects of a less restrictive vegetarian diet on cardiovascular health are beyond doubt, the data show relatively small differences in overall cancer risk between vegetarians and non-vegetarians. In the absence of direct evidence, claims for the superiority of vegetarianism, and particularly its restrictive forms, are probably exaggerated. However, every diet that contains limited amounts of processed foods, moderate amounts of animal foods, and an abundance of fruit, vegetables and whole cereals will likely be nutritionally adequate, consistent with the current nutritional recommendations, and associated with health promotion and disease prevention.

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