Slovenian Medical Journal

Alternative nutrition: literature review

Alternativna prehrana: pregled literature

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Abstract

The recent years have seen an increase in alternative nutrition practices in which certain nutrients are excluded from a person's diet; most commonly observed are variations of vegetarianism and veganism which limit to varying extents the inclusion of meat, eggs, and dairy products in the diet. Such diets without the addition of necessary food supplements can lead to growth retardation, developmental delay, and irreversible physical damage; health professionals in Slovenia, therefore, advise against such diets especially in pregnant women, newborns, and infants. Certain published and regularly cited research works, e.g. the statement on vegetarianism by the American Dietetic Association published in 2009, support to a certain extent the use of alternative nutrition practices even in earlier stages of the life cycle and could have contributed to the increase of such practices in Slovenia. This article aims to identify the effects of alternative nutrition practices on health and development in all stages of life cycle and to provide advice for preventing nutrient deficiencies when such practices are used. We included the most cited and clinically relevant articles published on the topic of vegetarianism and veganism and listed the dietary guidelines supported by the Slovenian Paediatric Society and the Slovenian Ministry of Health. Alternative nutrition practices can lead to nutrient deficiencies, especially deficiency of vitamin B_{12}, iron, and calcium. Other nutrients that require medical attention in people following such practices are proteins, ω-3 fatty acids, zinc, and vitamin D. Vegetarian and vegan diets can lead to nutrient deficiencies especially in pregnant and lactating women, newborns, infants, and children. In line with the proven effects of vegetarian and vegan diets on health and development, the Slovenian Paediatric Society advises against the use of such diets in pregnant and lactating women, newborns, infants, children, and adolescents. Alternative nutrition practices in these stages of the life cycle require supervision and monitoring by a clinical dietitian, a paediatrician, or a family physician.

Izvleček

V zadnjih letih narašča prevalenca načinov prehranjevanja, pri katerih oseba iz svoje prehrane izključuje določena hranila; najpogosteje gre za oblike vegetarijanstva in veganstva, ki v različni meri omejujejo uživanje mesa, jajc in mlečnih izdelkov. Izključujoči načini prehranjevanja ob neupoštevanju navodil o potrebnih prehranskih dopolnilih lahko privedejo do zaostajanja v rasti in razvoju in do nepopravljivih telesnih okvar, zato zdravstvena stroka v Sloveniji takšne načine prehranjevanja odsvetuje zlasti pri nosečnicah, novorojenčkih in dojenčkih. Nekatere pogosto citirane raziskave in smernice navajajo,

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Key words: diet; vegetarian; vegan; malnutrition; growth and development

Ključne besede: prehrana; vegetarijanstvo; veganstvo; podhranjenost; rast in razvoj

Received / Prispelo: 8. 10. 2019 | **Accepted / Sprejeto:** 24. 7. 2021

Cite as / Citirajte kot: Šetinc L. Alternative nutrition: literature review. Zdrav Vestn. 2022;91(5–6):242–54. **DOI:** https://doi.org/10.6016/ZdravVestn.2994

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da so alternativni načini prehranjevanja ustrezni v vseh obdobjih življenjskega cikla, kar je verjetno prispevalo k popularizaciji tovrstnih načinov prehranjevanja tudi pri nas. Presečne raziskave pri vegetarijancih ugotavljajo nižjo incidenco ishemične bolezni srca in rakavih bolezni ter ugodnejšo sestavo črevesnega mikrobioma, vendar so našteti učinki lahko posledica zdravega življenjskega sloga in nižje telesne mase pri vegetarijancih in veganih, ne pa neposredno izključevanja mesa iz prehrane. Po drugi strani lahko vsi omejevalni načini prehranjevanja privedejo do pomanjkanja hranil, zlasti vitamina B_{12}, železa, kalcija, pa tudi beljakovin, maščobnih kislin ω-3, cinka in vitamina D. Pomanjkanje makro- in mikrohranil je nevarno predvsem v zgodnjih obdobjih življenjskega cikla, saj lahko povzroči hud zaostanek v rasti in razvoju, v najhujših primerih pa celo smrt. Zdravstveni zapleti pri odraslih vključujejo osteopenijo in osteoporozo, anemijo, kognitivni upad in »paradoksno« povečanje tveganja za srčno-žilne bolezni. Tveganje za neustrezno prehranjenost ob vegetarijanski ali veganski prehrani je večje pri športnikih, starostnikih in kroničnih bolnikih. Pravilno vodena vegetarijanska in veganska prehrana je ob strokovno načtovani in nadzorovani prehranski strategiji lahko ustrezna za zdrave odrasle ljudi. V skladu z znanimi podatki o hranilih, potrebnih za normalno rast in razvoj, in zaradi hudih posledic ob morebitnem pomanjkanju teh hranil slovenska pediatrična stroka odsvetuje izključujoče načine prehranjevanja pri nosečnicah, doječih materah, novorojenčkih, dojenčkih, otrocih in mladostnikih. Ob vegetarijanskem ali veganskem načinu prehranjevanja v teh obdobjih je priporočljivo spremljanje kliničnega dietetika, izbranega pediatra ali osebnega zdravnika.

1 Introduction

1.1 Types and prevalence of vegetarianism

Vegetarianism refers to diets in which a person excludes foods of animal origin from their diet to varying degrees (1-6). Less restrictive vegetarian diets include pescatarianism, which allows the consumption of milk, dairy products, eggs, fish and seafood (but no red meat or poultry), and lacto-ovo vegetarianism, which allows the consumption of milk, dairy products and eggs (but not meat of any kind) (2). Vegans do not consume any products of animal origin (1-6). According to various data, the estimate of the prevalence of vegetarianism is 1-10%. It has been growing in Europe and the US for the last three decades (1-6). The growing prevalence of vegetarianism is likely to be due to a growing body of research and reports that label vegetarian and vegan diets safe and appropriate, regardless of age (3,4,7-11).

1.2 The impact of vegetarian diet on health

In 2005, Campbell et al. published the now well-known "China Study" in which they concluded that a plant-based diet reduces the incidence of cardiovascular disease, diabetes, and certain cancers (9). Some of the listed effects of plant-based diets were later confirmed in many studies (12-20); however, a similar impact on health can be achieved by increasing the intake of plant foods and by reducing the intake of foods of animal origin, but not necessarily by completely excluding meat and animal products (8,21-23). In addition, vegetarian diets are associated with a healthier lifestyle in general. It is possible that the positive health effects are an indirect result of lower body weight and lower fast food and alcohol intake in vegetarians and vegans, but not a direct consequence of the exclusion of meat and animal products from the diet (7,8,23-25,39). As vegetarians and vegans are at higher risk of nutrient deficiencies and related conditions, the topic remains problematic and will require more prospective research in the future (26,27).

1.2.1 Cardiovascular diseases

People who maintain a vegetarian or vegan diet have significantly lower cardiovascular disease morbidity and mortality (12-14).

A meatless diet helps lower blood pressure (29,30). In a 2014 meta-analysis, Yokoyama et al. found that both systolic and diastolic blood pressure were lower in vegetarians (14). Pettersen et al. report a lower likelihood of developing hypertension in vegans, vegetarians and partial vegetarians, although only part of this effect is attributed to the diet itself; the difference between the calculated odds ratio for the development of hypertension in vegetarians and non-vegetarians decreased significantly when the model was corrected for body mass index (30). The causes of lower blood pressure in vegetarians are not fully understood and are likely to be numerous: they include a higher intake of potassium and plant proteins and a lower intake of saturated fatty acids (14). According to some data in the literature, sodium intake in vegetarians is significantly lower (31,32), while in others it is similar to that of omnivores (33); differences in sodium intake are not a satisfactory explanation for the lower prevalence of arterial hypertension in vegetarians (4,14).

Total cholesterol and low-density lipoprotein (LDL) levels are significantly lower in vegetarians and vegans, contributing to a lower prevalence of ischemic heart disease in these groups (28,34). Reasons for a better lipid profile in vegetarians include increased intake of fibre, plant protein, and antioxidants (34). Non-vegetarians can achieve a similar effect if they limit their meat intake and increase their intake of whole grains, legumes, nuts, fruit and vegetables (8).

However, despite these effects, a vegetarian diet can in some cases even increase the risk of ischemic heart disease and stroke: lower body stores of vitamin B_{12} can lead to decreased levels of high-density serum lipoproteins (HDL) and elevated homocysteine levels, leading to thrombosis (34-36). The risk of developing cardiovascular disease in vegetarians may also increase with insufficient intake of ω-3 fatty acids (37).

To prevent cardiovascular disease, a balanced diet with less meat and more fruit and vegetables is recommended (8,21).

1.2.2 Body mass index and obesity

Body mass index is lower in vegetarians than in omnivores and lowest in vegans (38-41). Vegetarian diets are usually lower in energy and contain more fibre and less animal fat, so the prevalence of obesity in vegetarians and vegans is lower (38,40,41). Several studies have shown that a plant-based diet is effective in both preventing and treating obesity (19,38,40). Nevertheless, it should be noted that the body mass index of vegetarians and vegans may be lower also due to lower muscle mass as a result of lower total protein intake and lower intake of individual amino acids (39).

1.2.3 Diabetes

Vegetarians and vegans have a lower risk of developing type 2 diabetes than omnivores (15-18). This is due to a higher intake of fibre, fruit and vegetables and a lower intake of saturated fatty acids, and indirectly to a lower energy content in the diet (15). In omnivores, the consumption of red meat is an independent risk factor for the development of type 2 diabetes (16) and the incidence is also increased by the intake of other types of products, especially meat products (25,42).

Vegetarian diet is also beneficial in already developed diabetes, as it can help reduce insulin resistance and oxidative stress and provide better glycaemic control, as well as reduce the likelihood of cardiovascular and neurological complications of diabetes (15-18).

1.2.4 Cancer

Some research has shown that a vegetarian diet reduces the risk of developing cancer (43,44), but other authors report a comparable incidence of malignancies in vegetarians and omnivores (12). Some studies describe a lower incidence of prostate, breast, stomach, bladder, ovarian and bone marrow cancers in vegetarians (43,45,46), but the results are unreliable due to limited research and conflicting data (44). Nevertheless, it is likely that a vegetarian diet reduces the risk of cancer, as such a diet avoids the intake of red meat and meat products, which in large quantities have been shown to increase cancer mortality (47), and increases the intake of fibre, antioxidants, isoflavones and other chemicals of plant origin that act protectively against the development of malignant diseases (48,49).

1.2.5 Osteoporosis

Vegetarian diet can affect bone mineral density, as, on the one hand, it contains less calcium, vitamin D, vitamin B_{12}, ω-3 fatty acids and proteins that are important for maintaining bone health, and, on the other hand, more magnesium, potassium and antioxidants, which have a protective effect on bone (50). Research shows that bone mineral density in vegetarians, especially vegans, is reduced (50-52). Bone fracture risk reports in vegetarians and vegans are inconsistent; research reports both unchanged and higher risk of breakage compared to omnivores (50-54).

1.2.6 Dementia

The pathogenesis of dementia is influenced by several factors, so the type of diet is only one of the possible causes for its development (55). Antioxidants, ω-3 fatty acids and B vitamins are mentioned in the literature as neuroprotective nutrients that inhibit the development of dementia (55-57). According to the data so far, the type of diet that has the most beneficial effect on brain function is the Mediterranean diet which is rich in fruit, vegetables, whole grains, legumes, and nuts, and a low to moderate intake of dairy products, fish, and poultry (55). Research has reported various effects of a vegetarian diet on the development of dementia, focusing in particular on Alzheimer's disease and vascular dementia (55-59). Some authors report a lower risk of developing dementia in vegetarians (58,59), but according to other data the risk does not change (56) and a higher risk is reported in vegetarians who have elevated serum homocysteine

levels as a result of a vitamin B_{12} deficiency (60).

1.2.7 Gut microbiome

Increasingly, research is linking changes in the commensal bacteria of the gut flora with the development of cardiovascular, autoimmune and neurological diseases (61,62). A diet with a higher intake of fibre and a lower intake of fat increases the number of beneficial commensals in the gut and the synthesis of protective short-chain fatty acids, which has a beneficial effect on glycaemic control and regulates the immune response (61-68); according to some data, it could also prevent the development of some psychiatric illnesses, especially chronic depression (69-71). These findings are based on studies of the effects of a predominantly plant-based diet, where the diet is not necessarily meatless (61,64).

2 Macro- and micronutrients in vegetarians and vegans

In all types of vegetarian diets, especially vegan diets, there can be a significant deficiency of macro- and micronutrients: iron, zinc, calcium, vitamins B_{12}, B_2, A and D, ω-3 fatty acids and protein (1-8,26,73). The risk of malnutrition is higher in more exclusive diets and in younger children. As a result of prolonged nutrient deficiencies, growth and developmental disorders may develop and immune resistance may be impaired (1,2,26). Exclusive diets are problematic, especially in the case of inadequate implementation and non-compliance with the recommendations on the addition of dietary supplements (75,76).

Table 1 shows possible nutrient deficiencies in vegetarian and vegan diets.

2.1 Protein

Protein intake in vegetarians may be insufficient for three reasons: (a) there is less protein in plant foods, (b) plant proteins are less digestible than animal proteins, and (c) in plant proteins, one or more essential amino acids may be present in smaller amounts (e.g. lysine in maize, rye and wheat and methionine and cysteine in legumes) (77-79). Lack of protein can lead to loss of muscle mass, decreased immunity, weakening of the heart and respiratory system, as well as stunted growth in children, protein malnutrition despite sufficient calorie intake and, in extreme cases, even death (26,27).

The recommended daily protein intake in an adult omnivore is 0.8 g/kg of body weight (79). In several clinical trials, the average protein intake was highest in omnivores, slightly lower in pescatarians, even lower in lacto-ovo vegetarians, and lowest in vegans. However, in all groups it was above the recommended daily intake (79,80). In all groups studied, there were several people who did not achieve the recommended protein intake: 1–3% of them were omnivores, 6–10% were vegetarians and 8–16.5% were vegans (79,80). Research finds the lowest protein intake in vegan women (79-81).

Protein deficiency in vegetarians and vegans is also possible with a seemingly sufficient intake, as the absorption of protein from plant-based foods is less efficient (8,79). While protein intake in lacto-ovo vegetarians

Table 1: Possible nutrient deficiencies in vegetarian and vegan diets. Taken from Fewtrell M. et al., 2017 (73).

	Type of diet			
Type of nutrient	**lacto-ovo-vegetarian**	**lacto-vegetarian**	**ovo-vegetarian**	**vegan**
Iron	X	X	X	X
Zinc	X	X	X	X
Calcium			X	X
Vitamin B_{12}			X	X
Vitamin B_2				X
Vitamin D	X	X	X	X
Vitamin A				X
ω-3 fatty acids (DHA)	X	X	X	X
Protein	X	X	X	X

may be sufficient at all life stages (22,82), vegan pregnant women, breastfeeding mothers and toddlers are recommended to consume protein-rich foods or dietary supplements (73). The European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) warns of possible protein deficiencies in children with all forms of vegetarian diet (73).

Adult vegetarians and vegans are recommended to have up to 1.3 times higher protein intake than omnivores; a sufficient protein intake can be achieved by eating a veried diet of plant origin and no other measures are needed (8). Amino acid digestibility values can be helpful to vegetarians and vegans when choosing quality protein-rich foods (8).

2.2 Fats and fatty acids

Vegetarian diets are typically rich in ω-6 fatty acids (linoleic and α-linolenic acids) and less ω-3 fatty acids (eicosapentaenoic, docosapentaenoic and docosahexaenoic acids); the latter are especially lacking in people who do not include fish and eggs in their diet (78). Ω-3 fatty acids are important for the health of the cardiovascular system, and in children also for normal psychomotor development and vision development (4).

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) levels are significantly lower in vegetarian and especially vegan diets (83). Vegetable oils contain α-linolenic acid (ALA), which is converted to EPA and DHA, but only in a small proportion (4). Dietary intake of ALA as a precursor to DHA is much less effective in accumulating DHA in the brain than consuming DHA (4). An additional source of DHA in vegetarians may be microalgae and DHA-enriched soy milk or bars (3).

2.3 Iron

Iron is found in plant foods in non-haem iron form, which has a lower bioavailability (approx. 10%) compared to iron in haem-iron form (approx. 18%) (77). Sources of iron of plant origin are whole grains, legumes, leafy green vegetables, nuts, dried fruits and fortified cereals (4). Absorption of iron in non-haem iron form is more susceptible to the effects of inhibitors and absorption enhancers than iron in haem-iron form (4); absorption is impaired by phytates, calcium, polyphenols in tea and coffee, and fibre, and improved by vitamin C and other organic acids in fruit and vegetables (3,78). Taking vitamin C together with a source of iron may reduce the inhibitory effects of phytates (4). Iron absorption can also be improved by soaking or sprouting beans, cereals, and seeds, as this leads to the hydrolysis of phytates (4). The body can adapt to a longer period of reduced iron intake with improved absorption and reduced loss of iron (84,85).

Due to the poorer bioavailability of iron in foods of plant origin, 1.8 times higher iron intake is recommended for vegetarians than for people who eat a mixed diet (4,78). However, too much iron in food, especially in the form of dietary supplements, is harmful because it hinders the absorption of other minerals and increases cellular oxidative stress (86).

Iron deficiency can be present in all vegetarian diets, especially vegan diets (4). Children with long-term iron deficiency experience impaired growth and development; the consequences can be permanent and include low growth and reduced motor and cognitive skills (1). Iron deficiency is otherwise first and foremost manifested by microcytic hypochromic anaemia (77,78). Some research has shown that the prevalence of hypochromic anaemia in vegetarians and vegans is similar to that of omnivores (32,87,88), but in the most recent meta-analysis of this issue from 2018 R. Pawlak et al. note that the incidence of iron deficiency anaemia in vegetarians is significantly higher (89).

2.4 Zinc

Sources of zinc in the diet are beef, pork, poultry, eggs, milk and cheese, and plant foods include soy, legumes, cereals and nuts (3). The bioavailability of zinc in vegetarian diets is lower mainly due to the higher content of phytates, calcium and fibre in the diet, but it can be increased by soaking seeds and cereals and by increasing the intake of certain organic acids (e.g. citrates) (3,78). Zinc is not stored in large quantities in the body, so its constant intake is required (1). According to some studies, zinc intake in vegetarians is sufficient (80,92), but other studies report it is too low (93,94).

2.5 Calcium

The source of calcium in the vegan diet is green vegetables with low oxalate content, e.g. broccoli, kale, cabbage and certain types of cauliflower (4). Possible additional sources include mineral waters, juices, and calcium-fortified foods. The bioavailability of calcium from these sources is lower (4). Calcium from nuts, dried legumes and vegetables high in oxalates (e.g. spinach) has low bioavailability (1). Calcium absorption improves with adequate intake of vitamin D and protein (4).

According to the American Dietetic Association,

calcium intake of lacto-ovo vegetarians is on average higher than calcium intake in people with mixed diets, while calcium intake in vegans is lower than in the other two groups, so it may be too low according to recommendations (4). Decreased plasma calcium concentrations lead to increased calcium resorption from bone, which manifests as decreased bone mineralization and osteopenia or rickets in children (1).

2.6 Vitamin B_{12}

The only reliable source of vitamin B_{12} or cobalamin is food of animal origin; plant foods do not contain significant amounts of vitamin B_{12} (1). Vitamin B_{12} deficiency is possible in all people who eat meat or fish less than once a week (8). Lacto-ovo vegetarians can achieve a sufficient intake of vitamin B_{12} by regular consumption of milk and eggs, and vegans need to replace vitamin B_{12} with dietary supplements and foods enriched with vitamin B_{12} (3). Dairy products contain less vitamin B_{12} than eggs, meat and fish (8), but the bioavailability of vitamin B_{12} from milk is higher than from eggs or meat (97,98). The bioavailability of vitamin B_{12} from dietary supplements is significantly lower than from foods of animal origin (1).

Several studies have shown reduced levels of vitamin B_{12} in children on a strict vegan diet (10,77,78,99,100) and in infants breastfed by vegan mothers, even in cases where the mother's vitamin B_{12} stores were sufficient (8,100). Vitamin B_{12} deficiency in infants can cause slower growth and slower cognitive development, hypotension, microcephaly, and megaloblastic anaemia (100). Prolonged neurological damage due to vitamin B_{12} deficiency cannot be completely rerversed even with proper treatment (77). In adults, symptoms of vitamin B_{12} deficiency may be absent for a long time, as the vegetarian diet contains large amounts of folic acid, which obscures the haematologic symptoms of vitamin B_{12} deficiency (101,102).

2.7 Vitamin B_2

Sources of vitamin B_2 or riboflavin include milk and dairy products, meat, fish and eggs, and in plant-based foods the sources include beans, broccoli, asparagus, kale, lentils, bananas, figs, sweet potatoes and tofu. Vitamin B_2 deficiency is rare in vegetarians and vegans (4,78). Deficiency can occur with a strict vegan diet, especially if plasma homocysteine levels are elevated (1). Consequences of riboflavin deficiency include dermatitis, inflammation of the oral mucosa and tongue, ulcers of the corners of the mouth and, in severe cases, normocytic anaemia, as well as growth disorders in children (1).

2.8 Vitamin A

Vitamin A is crucial for the growth and proper functioning of the immune system, and vitamin A aldehyde is important for vision (1). The only source of vitamin A is food of animal origin. Dark green and yellow-orange vegetables and fruit contain a precursor of vitamin A (β-carotene) (4). The process of absorption of β-carotene from food of plant origin is relatively inefficient, so the intake may be too low for both vegetarians and vegans (105,106). For adequate intake of vitamin A in vegetarians, it is recommended to eat leafy green and yellow-orange vegetables and fruit three times a day (78). The absorption of β-carotene is improved by cooking with the addition of small amounts of fat (107,108), and possibly also by chopping and grinding (108,109).

Vitamin A deficiency in vegetarians and vegans is rare in developed countries (4); it is most common in children fed a strictly vegan diet (110). Additional vitamin A in the form of dietary supplements is not recommended to vegetarians and vegans due to its lipid solubility and possible hypervitaminosis (4).

2.9 Vitamin D

Vitamin D is synthesized during exposure to sunlight. Dietary sources of vitamin D are meat, sea fish, fish oil, egg yolk, and to a lesser extent milk and plant-based beverages (3,78). Vitamin D deficiency can occur in all forms of vegetarian diets (3). Deficiency is more likely to be greater in infants, children, and the elderly, as their vitamin D synthesis is less efficient (111,112). In infants and children, deficiency manifests itself with the onset of rickets, decreased muscle strength, and increased susceptibility to infections (1). In adults, severe vitamin D deficiency causes osteomalacia (3).

All forms of vegetarian diets require the addition of vitamin D in forms of vitamin D-fortified beverages or dietary supplements (78). Vitamin D-3 is of animal origin, so vegans only take vitamin D-2. According to some studies, vitamin D-2 is less effective than vitamin D-3 in maintaining sufficient serum concentrations of 25-hydroxy vitamin D (113), but other studies have shown comparable efficacy (114).

3 Implementation of alternative diets in life stages

3.1 Pregnant and breastfeeding mothers

Several studies have found lower protein intake, higher carbohydrate intake, and lower intake of vitamin B_{12}, vitamin C, calcium, and zinc in pregnant and breastfeeding vegetarian mothers (73). In some cases, the intake of vitamin B_{12}, iron and zinc was too low according to recommendations (115). Adequate intake of vitamin B_{12}, vitamin D, iron, and folate is particularly important during pregnancy, while vitamin B_{12}, vitamin D, calcium and zinc are important in breastfeeding mothers (73). Serum DHA levels are significantly lower in newborns and infants of vegetarian mothers (3). According to some studies, newborns of vegetarian mothers are more likely to have low birth weight, although other studies contradict this finding (115,116).

Regardless of the diet, all pregnant women are recommended to consume 400 µg of folate per day (4). It is recommended that pregnant women and breastfeeding mothers on a vegetarian diet receive at least 200 mg of DHA per day as a dietary supplement (78,117). Consumption of trans-fatty acids, which inhibit the formation of DHA, is not recommend (78).

During pregnancy, zinc is recommended for vegetarians and vegans in the form of dietary supplements (1). During breastfeeding, vegetarians can achieve adequate zinc and calcium intake through proper diet or nutritional supplements (3). A vegan mother's milk does not contain enough zinc for a baby after 7 months of age, so zinc should be added to the baby's diet (78).

It is also recommended to add vitamin B_{12} and vitamin D in the form of dietary supplements (78). Iron supplements are necessary in the event of sideropenic anaemia (3).

A vegetarian diet during pregnancy with the recommended nutritional supplements can provide all the necessary nutrients for the baby (4). However, there is not enough research in this area to be able to determine with certainty the impact of a pregnant woman's vegetarian diet on the health of the newborn or the baby in later life (115,116). A mixed diet is recommended for pregnant and breastfeeding mothers, while choosing one of the vegetarian diets requires taking care of the appropriate level of critical nutrients obtained from a varied diet and nutritional supplements, and regular monitoring of the course of pregnancy (1,8).

3.2 Babies

A vegetarian diet is not recommended for infants, although it can provide adequate growth and development with appropriate food supplements (8,10,24,73). A vegan diet with proper implementation and medical monitoring can provide all the important nutrients for a baby, but the consequences of inadequate or incomplete feeding can be extremely severe and include irreversible neurological damage due to vitamin B_{12} deficiency and even death (8,26,27,73). Special attention is required regarding the content of vitamin B_{12}, vitamin D, iron, zinc, folate, ω-3 fatty acids (especially DHA), calcium, and protein in infants, and it is necessary to ensure adequate energy intake (26,73).

Infants that are not breastfed should be formula-fed for the first 6 months (73). The introduction of a mixed diet is recommended between 17 and 26 weeks of age (applies to all infants) (1). From the age of 6 months, the baby can enjoy tofu, soy products or legumes enriched with iron and vitamin B_{12} (73). Sufficient energy intake can be ensured by adding vegetable oils (1).

The European Society of Paediatric Gastroenterology, Hepatology and Nutrition (ESPHGAN) advises against feeding infants a vegetarian diet, especially a vegan diet, due to the risk of nutrient deficiencies (73). A similar position is shared by the German Nutrition Association (DGE) (26), the French-speaking Paediatric Hepatology, Gastroenterology and Nutrition Group (GFHGNP) (27) and the Slovenian Paediatric Society (1). However, some guidelines advocate the appropriateness of a vegetarian and vegan diet during infancy (4,10,11).

3.3 Children and adolescents

The growth of lacto-ovo-vegetarian children is comparable to the growth of their peers (120-122). The growth of children with markedly restrictive diets is slowed (123); due to the inadequacy of such diets in children, data on this are based on individual reports (3,120). In vegetarians, the age of girls at the onset of their first menstrual period is similar to that of omnivores (121). Vegetarian adolescents consume more fibre, iron, folate, vitamin A, and vitamin C, and less fast food and salty snacks (122,124). According to some data, vegetarian children have a lower body mass index than their peers, and the difference increases during adolescence (24,125). Several authors report an increased prevalence of eating disorders in adolescents who eat a vegetarian or vegan diet (126-129).

Adequate intake of vitamin B_{12}, vitamin D, iron, calcium, zinc, ω-3 fatty acids, and protein should be ensured in children and adolescents who eat a vegetarian and especially a vegan diet (122). The risk of iron deficiency is reduced by an iron-fortified diet (122). In children and adolescents who do not consume milk, the addition of calcium in the form of calcium-fortified plant drinks is necessary, and in vegans also the addition of vitamin B_{12} in the form of dietary supplements or consumption of Chlorella algae (10,122).

The growth and development of children who eat exclusive diets must be monitored, paying attention to signs of possible nutrient deficiencies (8).

Properly planned vegetarian and vegan diets in children and adolescents can provide all the necessary nutrients (4,8,122). Some professional associations believe that a lacto-ovo-vegetarian diet in childhood and adolescence may still be appropriate, but advise against a vegan diet, because, despite the possibility of providing missing nutrients with supplements, the risk of nutrient deficiencies is too great, and the consequences of possible deficiency are too severe (21-27,73,122). In Slovenia, members of the Slovenian Professional Board of Paediatrics recommend a balanced diet that includes foods from all groups during childhood and adolescence (21,22).

3.4 Adults

In adulthood, a vegetarian or vegan diet is safe and appropriate if implemented properly; this means consuming a variety of plant-based nutrients and responding to possible signs of critical macro- and micronutrient deficiencies (3-8). Consumption of nutritional supplements in adults with a quality lacto-ovo-vegetarian diet is not necessary; the exceptions are pregnant women, breastfeeding mothers, athletes and the elderly (26,27). Adult vegans should add vitamin B_{12} to their diet and, if necessary, iron, zinc, vitamin D, calcium and ω-3 fatty acids (4,8). A diet based on plant-based foods can contribute to lower cardiovascular morbidity, obesity and diabetes (12-20,38-41).

Vegetarian and vegan diets can also meet the nutritional needs of athletes, but greater caution is needed in these cases (131-137). The diet should contain nutrients rich in vitamin B_{12}, iron, zinc, vitamin D, calcium and vitamin B_2; if necessary, the listed nutrients can be added in the form of food supplements (133,138). Some authors also recommend the addition of protein in the form of dietary supplements to vegan athletes (133). In athletes, higher amounts of fibre should be excluded from the diet, as they cause early satiety and reduce energy intake and absorption of carbohydrates (133). Complications of low nutrient intake in athletes include lower bone mass, bone fractures, weakened immune system, endothelial dysfunction, mood disorders, and menstrual disorders in women (138-141). The performance of vegetarian and omnivorous athletes is comparable (136).

A vegetarian diet in old age can increase the risk of nutrient deficiencies (145,146). Adequate protein intake is especially important for vegetarian elderly people, as it is, in any case, often too low in old age to meet their needs (146). 6–15% of older adults are deficient in vitamin B_{12} (149), and the prevalence of deficiency may be even higher in vegetarians; Vitamin B_{12} supplementation is recommended for all elderly people who eat a vegetarian diet (146). Regular addition of vitamin D is also important, as ultraviolet light-stimulated vitamin D production in the skin decreases with age (4). Calcium and zinc supplementation are also required in some elderly people (145,146).

4 Conclusion

A professionally guided and supervised vegetarian or vegan diet can adequately support an individual's metabolic needs and thus contribute to the prevention of obesity and the development of chronic diseases such as cardiovascular disease, diabetes, and cancer (12-18,44,49). Negative consequences are manifested in particular in the lack of critical nutrients: protein, ω-3 fatty acids, iron, zinc, calcium, vitamin B_{12}, vitamin B_2, vitamin D, and vitamin A (4,8). Deficiency health complications include osteopenia and osteoporosis, anaemia (megaloblastic or microcytic hypochromic), cognitive decline, and, paradoxically, increased risk of cardiovascular disease (50–52,59,78). The consequences are more severe with more restrictive diets; during pregnancy and when a child is still a baby or an infant, nutrient deficiencies can lead to serious growth and developmental delays and, in the worst cases, even death (1,8,26-28).

Vegetarian diets, when properly implemented and controlled, can ensure adequate intake of macro- and micronutrients and do not have harmful effects on health; nutrition education is crucial (4,8,35,78). Due to severe and often irreversible health consequences of nutrient deficiencies, several professional associations advise against vegetarian and vegan diets in pregnant women, breastfeeding mothers, new-borns, infants, children and adolescents (1,26,27,73), while a number of studies, review articles and guidelines support vegetarian and vegan diets at all stages of life (4,8,9-11). When deciding

on a vegetarian or vegan diet, it is important to create a diet plan in accordance with the recommendations, and for children and pregnant women, to be monitored by a paediatrician or clinical dietitian (1,8,73).

Due to the growing importance of the issue of vegetarianism and veganism, further research in this field, training of experts, and the development of the most uniform possible guidelines for the proper implementation of alternative diets are needed (4,61,73).

Conflict of interest

None declared.

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