Corrected version (Erratum)

Vegan Diet

Position of the German Nutrition Society (DGE)

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Abstract

On the basis of current scientific literature, the German Nutrition Society (DGE) has developed a position on the vegan diet. With a pure plant-based diet, it is difficult or impossible to attain an adequate supply of some nutrients. The most critical nutrient is vitamin B_{12}. Other potentially critical nutrients in a vegan diet include protein resp. indispensable amino acids, long-chain n-3 fatty acids, other vitamins (riboflavin, vitamin D) and minerals (calcium, iron, iodine, zinc and selenium). The DGE does not recommend a vegan diet for pregnant women, lactating women, infants, children or adolescents. Persons who nevertheless wish to follow a vegan diet should permanently take a vitamin B_{12} supplement, pay attention to an adequate intake of nutrients, especially critical nutrients, and possibly use fortified foods or dietary supplements. They should receive advice from a nutrition counsellor and their supply of critical nutrients should be regularly checked by a physician.

Keywords: vegan diet, critical nutrients, vitamin B_{12}

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Introduction

Background

The vegan diet is exclusively restricted to the consumption of plant-based foods. As with other forms of vegetarian diets, it is becoming increasingly popular among the population of the Western world. It is not known precisely how many individuals in Germany adhere to a vegan diet. The data vary between 0.1% and 1% of the population, corresponding to between 81,000 and 810,000 individuals. Excluding animal foods from the diet is usually a conscious and voluntary decision [1, 2]. A vegan diet as part of a "Western" lifestyle differs from a "traditional" plant-based diet, which is mostly practiced in developing countries, where it is often accompanied by restricted food availability and low energy intake, due to low incomes and levels of education [3]. In Western countries, the typical vegetarian is female, young, educated and wealthy, lives in a city and follows a "healthy lifestyle" [1, 2].

Vegetarian diets

Depending on the form of vegetarianism (◆ Table 1), either selected animal foods (e.g. eggs or milk) are consumed, or animal foods and additives are totally avoided, including foods where animal components are added during the production process. A vegan diet is a very strict form of vegetarian diets. Vegans exclusively consume plant-based foods and reject all kinds of animal foods, sometimes including honey, as well as articles of daily use made of animal body parts – such as fur and leather [2]. The principle reasons for a vegetarian diet are ethical (e.g. rejection of intensive livestock farming), as well as ecological aspects, sustainability and health aspects.
According to current knowledge, the risk of nutrition-related diseases is determined by food composition, particularly the balance between animal and plant-based foods, as well as the degree of processing. Epidemiological studies have shown that a high intake of red meat and, particularly, meat products increases the risk of many diseases (e.g. certain cancer sites [5–7]), whereas high levels of dietary fibre-rich cereal products, vegetables and fruit can decrease the risk of many diseases (e.g. cardiovascular diseases [8], and type 2 diabetes mellitus [9]).

[1] Complete information on the authors can be found on p. 99.

Vegetarian diets often have a more favourable composition with respect to these foods than the mixed diet which is conventional in Germany considering the supply of nutrients and other beneficial phytochemicals. A meta-analysis of observational studies found that persons adhering to a vegetarian diet exhibited a lower risk of metabolic and cardiovascular diseases than persons not on a vegetarian diet. The risks of ischaemic heart disease and cancer were also lower [10]. However, within the different studies, it is important to consider which reference groups are used and whether other differences in lifestyle were considered in the statistical analysis. There is evidence that some of the investigated groups had very different lifestyles, so that the lower risk of disease is presumably not only due to nutritional differences [11]. In an analysis of two prospective studies, persons adhering to a vegetarian diet (pesco, ovo-lacto vegetarians and vegans) were compared with persons on a high vegetable mixed diet, containing low levels of meat and meat products. There were no differences between the two groups with respect to mortality [12]. These results indicate that we cannot currently assume a health advantage of vegetarians in comparison with persons consuming a comparable diet with a low level of meat. However, it can be assumed that a plant-based diet (with or without low levels of meat) is associated to a reduced risk of nutrition-related diseases in comparison with the currently conventional German diet.

Nutrient intake in vegan nutrition

The mixed diet recommended by the DGE contains low levels of meat and meat products, as well as fish. The animal-based foods in this diet contribute to the supply of the nutrients protein resp. essential amino acids, as well as long chain n-3 fatty acids (eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]), vitamin D, riboflavin, vitamin B_{12} (cobalamin), calcium, iron, iodine, zinc and selenium. As vegetarian diets (◆ Table 1) avoid several or even all of these foods, an adequate supply of these nutrients may be difficult. Adequate supply of these nutrients must be ensured by a well-directed selection of plant-based foods. Alternative sources of nutrients for vegans are summarised in ◆ Table 2.

Only a few studies have investigated the nutritional physiological quality of restrictive diets such as the vegan diet and compared these with other diets [13–15]. Vegetable-rich diets such as vegetarian diets (◆ Table 1) are associated with good supplies of some vitamins (vitamin C, vitamin E, thiamine and folate [14, 16–23]), minerals (magnesium and potassium [14, 17–19]), dietary fibre and phytochemicals [24, 25]. In comparison to a mixed diet, all vegetarian diets contain, for example, lower levels of saturated fatty acids and cholesterol [14, 24, 25].

The risk of an inadequate supply of nutrients or of nutritional deficiency progressively increases as the selection of foods becomes more restrictive and the diet becomes less varied. This applies in principle to all forms of nutrition. Adequate nutrition can be achieved for vegetarians who eat no meat or meat products, but consume other animal foods, e.g. milk, dairy products and eggs. In a vegan diet, the most critical nutrient is vitamin B_{12}. Potentially critical nutrients in a vegan diet moreover include protein resp. indispensable amino acids, as well as long-chain n-3 fatty acids (EPA and DHA), other vitamins (riboflavin, vitamin D[2]) and minerals (calcium, iron, iodine, zinc and selenium)[3] [14, 25, 29].

An overview of the functions and signs of deficiencies for the potentially critical nutrients can be found in the reference values for nutrient intake [30].

	Foods that are eaten	Foods that are avoided
Pesco vegetarians	plant-based foods, fish, eggs, milk and dairy products	Meat and all products derived thereof
Ovo-lacto vegetarians	plant-based foods, eggs, milk and dairy products	meat, fish (including other aquatic animals) and all products derived thereof
Lacto vegetarians	plant-based foods, milk and dairy products	meat, fish (including other aquatic animals), eggs and all products derived thereof
Ovo vegetarians	plant-based foods, eggs	meat, fish (including other aquatic animals), milk and dairy products and all products derived thereof
Vegans	plant-based foods	all animal foods, also honey

Tab. 1: **Forms of vegetarianism resp. vegetarian oriented diets** (mod. from: [4])

Potentially critical nutrient[a]	Vegetable nutrient source	Comments on the vegan diet[b]
Protein	legumes, nuts, cereals (whole-grain), oil seeds, potatoes specifically combined and consumed over the day (e.g. cereals + legumes, soya products and/or oil seeds).	• If a variety of vegetable protein sources, such as cereals, legumes and potatoes, are distributed over the day [83] along with adequate energy intake [84], protein requirements can be covered [85, 86]. It is unclear whether this is also possible for toddlers. According to YOUNG and PELLETT, normal growth is indeed possible in children if they receive an exclusively plant-based diet and if different protein sources are combined [83]. On the other hand, KRAJCOVICOVA-KUDLACKOVA et al. considered that the requirements for indispensable amino acids cannot be exclusively covered by plant protein in phases of high requirements, such as growth, as the protein quality of plant protein is lower than that of animal protein [87]. • By well-directed combining different sources of plant protein, the protein quality of daily protein intake can be increased, as can the intake of all indispensable amino acids [88, 89]. • Infants and children require relatively more indispensable amino acids in protein than adults do [90]. During growth, it is therefore essential to ensure that intake of protein and of indispensable amino acids as well as energy intake are adequate.
Long-chain n-3 fatty acids	food fortified with oil from microalgae	• With a strict vegan diet, there is hardly any intake of eicosapentaenoic acid (EPA) or docosahexaenoic acid (DHA). Moreover, conversion of the n-3 fatty acid α-linolenic acid (ALA; e.g. from flaxseed, walnuts, rape or their oils) to EPA and DHA is limited [91]. • Oils from microalgae contain DHA [92–94]. Microalgal oils from the microalgae Ulkenia and Schizochytrium have been approved as Novel Foods [95, 96].
Vitamin D	Some mushrooms (e.g. common mushrooms, chanterelles), foods fortified with vitamin D	A unique characteristic of vitamin D is that it cannot only be obtained from food, but can also be synthesised by the human body itself if the skin is exposed to sunlight (UVB) [30].
Riboflavin	Oil seeds, nuts, legumes, various types of vegetable (e.g. broccoli, kale) and whole-grain cereals	
Vitamin B_{12}	Foods fortified with vitamin B_{12}	• If fortified foods are strictly excluded in a vegan diet, hardly any vitamin B_{12} is consumed. • As a result of bacterial fermentation, plant-based foods, such as sauerkraut, may contain traces of vitamin B_{12}. However, it is unclear whether this form of vitamin B_{12} can be utilised in the human body. Moreover, the levels are so low that adequate intake is not possible [2]. • Shiitake mushrooms contain vitamin B_{12}, although the quantities may vary greatly [97]. Sea algae such as nori may also contain vitamin B_{12}. Attention must then be paid to the declared moderate content of iodine. However, these foods are unsuited to be the sole source of vitamin B_{12}, as the bioavailability is unclear resp. the vitamin B_{12} is in an inactive form [97–102]. • Spirulina and other products with cyanobacteria marketed as natural sources of vitamin B_{12} for persons adhering to a vegan diet contain no cobalamin in a form that is active in the human body and are therefore unsuited for fulfilling requirements [102]. • Vegans cannot ensure their supply of vitamin B_{12} with conventional foods, including fermented foods. An adequate supply of vitamin B_{12} can only be ensured by taking a vitamin B_{12} supplement [32, 33].
Calcium	Vegetables (e.g. broccoli, kale, rocket), nuts (e.g. hazelnuts and Brazil nuts), legumes, soya meat replacement products ("textured soya protein"), tofu, mineral water (calcium-rich, > 150 mg/L), foods fortified with calcium	
Iron	legumes, oil seeds, nuts, whole-grain cereals and various types of vegetable (e.g. spinach, black salsify)	• Simultaneous consumption of foods rich in vitamin C or other organic acids improves iron bioavailability [2]. • Substances such as phytates and polyphenols (e.g. in tea and coffee) may reduce iron absorption [2, 103]. Black tea and coffee should not be drunk directly before, during or after meals of high iron content. • As generally recommended, it is particularly important that pregnant women and lactating women should take an iron supplement if they are known to suffer from iron deficiency.
Iodine	• Iodinated and fluoridated table salt as well as foods prepared thereof (as generally recommended) • Sea salt fortified with sea algae and of defined iodine content, or occasional consumption of sea algae of moderate iodine content, e.g. nori	• The Federal Institute for Risk Assessment considers that dried algal products of iodine content > 20 mg/kg are harmful to health and advises against their consumption [104]. • Goitrogenic substances in plant-based foods, such as cabbage plants, soya beans and sweet potatoes, may decrease the bioavailability of iodine, which may be important if iodine intake is very low [2]. • As generally recommended, it is particularly important that pregnant women and lactating women should take iodine supplements, after consulting a physician and considering their individual iodine intake.
Zinc	Whole-grain, legumes, oil seeds, nuts	Preparation procedures such as sour dough fermentation and germination improve bioavailability [2].
Selenium	Cabbage (e.g. broccoli, white cabbage), bulb vegetables (e.g. garlic, onions), mushrooms, asparagus and legumes, Brazil nuts	The content in plant-based foods is highly dependent on the area of culture, as it depends on the selenium content in the soil [2].

Tab. 2: **Potential critical nutrients in a vegan diet and vegetable nutrient sources**

[a] For reference values for the intake of these nutrients, see [30] and URL: www.dge.de/wissenschaft/referenzwerte/

[b] Aside from the comments here on taking dietary supplements, vegans, like the general population, should comply with the recommendations on vitamin K administration to neonates (oral administration of 3 x 2 mg vitamin K) and on vitamin D administration to infants (daily 10 µg vitamin D) and for the intake of folic acid supplements by women intending to get pregnant (daily 400 µg synthetic folic acid); folic acid intake should start not later than 4 weeks before the start of the pregnancy and continue until the end of the first trimester of pregnancy [30].

Vitamin B_{12}

Vitamin B_{12} is solely produced by microorganisms. The form that is available to the human body occurs almost exclusively in animal foods (◆ Table 2) [2]. Thus a vegan diet increases the risk of vitamin B_{12} deficiency (unless a vitamin B_{12} supplement is used) [31]. Several studies on vegans who took no vitamin B_{12} supplements have found that the prevalence of low vitamin B_{12} supply resp. vitamin B_{12} deficiency was up to 86%, depending on the parameters examined [32, 33].

Vitamin B_{12} participates in the regulation of homocysteine concentrations and methionine metabolism, as well as haematopoiesis and the metabolism of fatty acids and amino acids. Low serum concentrations of vitamin B_{12} are associated with high plasma concentrations of homocysteine. High plasma homocysteine concentrations have been considered to be a risk factor for cardiovascular diseases [34–36]. Protracted low vitamin B_{12} intake can also impair cell function and DNA synthesis and may lead to megaloblastic anaemia or neurological disorders [37].

As the liver store of vitamin B_{12} is relatively large and the reutilisation rate through enterohepatic circulation is high, clinical symptoms of deficiency only become evident after some years of vitamin B_{12}-free nutrition. Thus, vegans should regularly have their vitamin B_{12} supply checked. Neonates depend on the mother receiving adequate vitamin B_{12} intake during pregnancy and lactation. There is preliminary evidence that vitamin B_{12} deficiency before conception is an independent risk factor for complications during pregnancy (miscarriage, pre-eclampsia) and for negative effects on the neonate (low birth weight, neural tube defect) [38–41]. If the mother is on a strict vegan diet without dietary supplements and the neonate is exclusively breastfed, vitamin B_{12} deficiency and its consequences (neurological disorders, megaloblastic anaemia) could already be observed in the first months of life [42–54].

Vitamin B_{12} supply can be assessed with several biomarkers. These include blood concentrations of vitamin B_{12}, holotranscobalamin (HTC), serum methylmalonic acid (MMA) and plasma homocysteine. None of these biomarkers is suitable as the sole parameter to evaluate vitamin B_{12} supply [55].

Population groups with special requirements for nutrient supply

In persons on a vegan diet, there are difficulties with the supply of some nutrients (◆ Table 2), and this may have unfavourable consequences for health, particularly for people in sensitive phases of life (e.g. growth). Therefore special attention is required for pregnant and lactating women on a vegan diet, as well as children from infants through the growth phase up to adolescence who adhere to or who are given a vegan diet. These special population groups are at greater risk of nutritional deficiencies [30].There are currently no conclusive studies with persons on a vegan diet that might allow a comprehensive evaluation of the supply situation for these groups at risk. Case reports show that the supply of vitamin B_{12} and iodine of infants whose mothers were on a vegan diet was not adequately guaranteed and that they developed neurological disorders and megaloblastic anaemia or goitre [46, 47, 52, 56].

Nutrient supply in a vegan diet in pregnancy was investigated in a systematic review. The studies were heterogenous, with respect to both their methodology and their results. Some of the studies were rated as being of poor quality. Bearing in mind these limitations, the authors concluded that a freely chosen vegetarian or vegan diet without financial restrictions is safe during pregnancy, if nutrient supply is observed and nutrient deficits are compensated for [3].

For population groups with special requirements for nutrient supply, a well-directed selection of foods and modes of preparation is necessary, i.e. high quality, nutrient dense foods, preparation and administration appropriate to age. Particularly in phases of growth or of increased requirements for nutrients, the intake and supply of nutrients should be regularly checked by a nutrition counsellor or physician. If intake is inadequate, this can be optimised by

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[2] Aside from vitamin D intake in food, vitamin D can also be produced in the human body by UVB light exposure (sunlight). The synthesis of vitamin D in skin depends on various factors, e.g. the dose and wavelength of UVB exposure and the area of the exposed skin, the skin type and the age [26, 27].

[3] Among these vitamins and minerals, vitamin D and iodine should be regarded as critical nutrients in the general population, iron and calcium only in specific population groups [28].

increasing the intake of individual nutrients by means of the – precisely calculated – consumption of fortified foods or by taking dietary supplements [2, 3]. According to the current state of knowledge, it is not possible to ensure an adequate vitamin B_{12} supply with a vegan diet without taking dietary supplements.

Food selection in a vegan diet

The foods consumed in a vegan diet are not necessarily nutritionally favourable or health-promoting. The foods consumed may include vegetables, legumes, fruit, nuts, seeds, valuable plant oils or whole-grain products, all of which have been shown to have favourable effects [8, 9, 57]. If however high levels of sugar, fat or table salt are added to vegan dishes, then they are nutritionally unfavourable [9, 57, 58]. Food selection may depend on the individual motive for a vegan diet (e.g. animal welfare or health reasons) [15, 59].

Due to many changes and an enlargement in the available (processed) foods and possible food supplies for vegans in the recent years, the supply situation for persons on a vegan diet has probably improved. About 90% of the 852 vegans surveyed in an online survey (July/August 2013) reported that it had become much simpler in recent years to follow a vegan diet [1]. Due to the increased demand, an abundant range of vegan convenience and replacement products are now available, even including imitates of meat products and cheese. These are intended to respond to the customers' wish for a wide range of choices and accustomed dishes. The manufacturing conditions have long achieved the level for conventional foods [60]. Some of these are highly processed products containing many additives, and their nutritional value has sometimes been criticised [61–63]. However, these foods can support nutrient supply to vegans, in so far as they are fortified with nutrients.

◆ Table 2 shows the options for vegan nutrition that ensure the intake of potentially critical nutrients. The sources for potentially critical nutrients are natural foods rich in these nutrients, fortified foods and dietary supplements. Vegans should specifically incorporate these in their menus. In this way and with specific food selection and good planning, it is possible to create a vegan diet in which no nutrient deficiency develops.

One sensitive population group are infants who are not – or only partially – breastfed. With industrially produced infant formulas based on cows' milk, healthy non-breastfed infants after a mature birth are provided with adequate nutrients in the first months, independently of the mother's diet. Apart from infant formulas based on cows' milk, there are also infant formulas based on soya. A current review [64] concludes that modern infant formulas based on soya are safe and that their effects on growth, bone health, and on reproductive, endocrine and neurological function and the immune system do not differ from those of other infant formulas or of breast milk. On the other hand, the Federal Institute for Risk Assessment (BfR) [65], the Young Family Network [66] and the Nutrition Committee of the German Paediatric [67, 68] consider that infant formulas based on soya cannot replace products based on cows' milk and are not intended for the nutrition of healthy infants. Because of their content of phyto-oestrogens and the higher level of aluminium in comparison to infant formulas based on cows' milk, infants who have not been breastfed (or only partially) should only be given soya products regularly in exceptional and justified cases (e.g. galactosaemia) and on medical recommendation [65–68].

Food-related nutrition recommendations

Food-related nutrition recommendations for vegan nutrition have been published by various scientific societies and experts. The Giessen vegetarian food pyramid contains all food groups for ovo-lacto vegetarians and also for vegans, with the comment that vegans should use fortified foods or dietary supplements to cover their requirements [2]. In order to support the planning of a vegetarian diet, the Dietary Guidelines for Australia contain specific notes for ovo-lacto vegetarians and vegans on individual food groups [69]. As part of the 2015 Dietary Guidelines for Americans, the United States Department of Agriculture (USDA) developed nutrition recommendations for a Healthy Vegetarian Pattern [70] and provides suggestions for consumers who wish to adhere to a vegetarian diet [71].

In the Giessen vegetarian food pyramid, it is recommended that vegetarians and vegans should replace meat, fish, milk and eggs with legumes, such as peas, beans, chickpeas and lentils, or with soya products and other protein sources. A comparison between a wholesome diet in accordance with the recommendations of the DGE and the recommendations for a vegan diet in the Giessen vegetarian food pyramid shows that both have the same basis and the corresponding food-related recommendations are very similar (◆ Table 3). However, the following specific points must be considered for vegan nutrition:

Vegetables, including legumes and fruit provide the basis for health-promoting nutrition, because of their high nutrient density, their high content of dietary fibre and phytochemicals and their potential to prevent various nutrition-related diseases. "5 a day", i.e. 5 portions of vegetables and fruit a day, are recommended. For vegetarian (including vegan) nutrition, the Giessen vegeta-

Food	Wohlesome diet (mixed diet) in accordance with the DGE (reference values for adults) [80, 81]	Vegan nutrition in accordance with the Giessen vegetarian food pyramid [2]
Group 1: Cereals, cereal products, potatoes	daily ▪ 4–6 slices (200–300 g) of bread **or** 3–5 slices (150–250 g) of bread and 50–60 g cereal flakes and ▪ 1 portion (200–250 g) potatoes (cooked) **or** 1 portion (200–250 g) noodles (cooked) **or** 1 portion (150–180 g) rice (cooked) Preferably whole-grain products	About 2–3 meals a day, e.g. whole-grain bread, potatoes, rice
Group 2: Vegetables (including legumes) and salad	daily ▪ at least 3 portions (400 g) of vegetables: 300 g cooked vegetables and 100 g raw fruit and vegetables/salad **or** 200 g cooked vegetables and 200 g raw fruit and vegetables/salad	At least 400 g or 3 portions of vegetables (for calcium supply, select dark green vegetables frequently)
Group 3: Fruit (including nuts)	daily ▪ At least 2 portions (250 g) fruit	At least 300 g or 2 portions fruit daily, supplement fresh fruit with maximally 50 g dry fruit and fruit juices; Nuts and seeds: 30–60 g daily (in particular, almonds and sesame supply high levels of calcium)
Group 4: Milk and dairy products	daily ▪ 200–250 g low fat milk and dairy products ▪ 2 slices (50–60 g) low fat cheese	not applicable; instead: legumes such as peas, beans, chickpeas and lentils: 1–2 meals per week and soya products (soya milk, soya joghurt, tofu, tempeh, etc. ...) and other protein sources (e.g. seitan): 50–150 g/day
Group 5: Meat, meat products, fish and eggs	weekly ▪ 300–600 g lean meat (prepared) and lean meat products ▪ 1 portion (80–150 g) low fat saltwater fish (prepared) and ▪ 1 portion (70 g) fatty saltwater fish (prepared) and ▪ up to 3 eggs (including processed eggs)	
Group 6: Oils and fats	daily ▪ 10–15 g oil (e.g. rape, walnut or soya oil) and ▪ 15–30 g margarine or butter	unprocessed vegetable oils and fats: 2–4 tablespoons per day – best sources of n-3 fatty acids are rape, flaxseed and walnut oil
Group 7: Drinks	daily ▪ about 1.5 L, preferably low energy or energy free drinks	calcium-rich water and other alcohol free, low calorie drinks: daily 1–2 L
Additional comments	▪ Iodinated and fluoridated table salt is to be used sparely. ▪ A unique characteristic of vitamin D is that it is not only obtained from food, but that the human body can also produce vitamin D itself if the skin is exposed to sunlight (UVB).	▪ Sunlight (at least 15 min./day) for vitamin D ▪ In a vegan diet, the reliable supply of vitamin B_{12} and D should be ensured by appropriate dietary supplements.

Tab. 3: **Food groups in the wholesome nutrition (mixed diet) and in the vegan nutrition**

rian food pyramid emphasises dark green leafy vegetables and dried fruits. In addition, **cereals** in the form of whole-grain products and **potatoes** provide an additional basis and should be a component of meals.

The recommendations for **oils**, **fats** and **drinks** are almost identical (butter and spreadable fat containing butter are excluded from a vegan diet). Although the food groups milk and dairy products and meat and meat products, as well as fish and eggs, are omitted from a vegan diet, the food-related recommendations for a vegan diet in the Giessen vegetarian food pyramid lay more emphasis on **legumes**, **nuts and oil seeds**, as sources of protein, B vitamins, zinc and iron, as well as the use of fortified foods (e.g. soya milk with calcium). If fortified foods are not consumed or are unavailable, intake of various dietary supplements is recommended (vitamin B_{12}, vitamin D, calcium).

Measures to improve nutrient content (e.g. germination of cereals) and the bioavailability of nutrients from plant-based foods are additional strategies that should be recommended to improve nutrient supply in vegan nutrition.

In international publications, it is often stated that **fortified foods** may supply critical nutrients in vegan nutrition. This statement is essentially based on North America, where more fortified foods are on the market than are in Germany. A current survey on fortified foods available in different branches of food retailers in Germany (Bonn) permits the conclusion that in Germany fortified foods may make a noteworthy contribution to nutrient intake too; e.g. the reference value for riboflavin intake can be reached with 200 mL of a multivitamin juice. On the other hand, the added form and the bioavailability of the nutrients from these foods are

often unclear and the added quantities may be very variable within a single product group [72].

International and national statements and recommendations

The Academy of Nutrition and Dietetics[4] [24][5] takes the position that an appropriately planned vegan diet that includes dietary supplements and fortified foods is nutritionally adequate and is appropriate for individuals during all stages of the lifecycle, including pregnant and lactating women. This position is supported by scientific societies in other countries, including the National Health and Medical Research Council in the nutrition recommendations for Australia [69], the Portuguese National Programme for the Promotion of a Healthy Diet [74] and – for adults – the British Nutrition Foundation [25].

The Canadian Paediatric Society [75] also states that a well-planned vegan diet, including dietary supplements, can cover the nutrient requirements in children and adolescents, if adequate energy intake is ensured. In the opinion of the British Nutrition Foundation [25] a well-planned, balanced vegetarian or vegan diet can be nutritionally adequate. More extreme diets, such as strict macrobiotic and raw food diets, are often low in energy and a range of micronutrients, making them wholly inadequate and inappropriate for children. Moreover, the Portuguese National Programme for the Promotion of a Healthy Diet [74] recommends that breastfeeding for infants on a vegan diet should be extended beyond the recommended period of six months until 2 years of age during the food diversification process. In this way, it could be ensured that infants and toddlers received adequate supplies of high quality milk protein.

The network „Healthy Start – Young Family Network" states that a vegan diet is unsuitable for infants and toddlers, as it does not ensure their nutrient supplies. The network emphasises the risks for the child's development, as well as the necessity of medical advice and taking dietary supplements [76–79]. Moreover, the recommendations of the Nutrition Committee of the German Society of Paediatrics and Adolescent Medicine rejects a vegan diet for healthy infants, unless dietary supplements are taken [68].

[4] until 2012 known as the American Dietetic Association (ADA) [24]

[5] The 2015 Position of the Academy of Nutrition and Dietetics: Vegetarian Diets [73] was withdrawn for revision during the preparation of this position paper. We therefore considered the 2009 Position [24].

Conclusion: The DGE's position

An adequate intake of nutrients (see reference values for nutrient intake [30]) can be assured by a varied and diverse selection of foods. Any diet that does not lead to the intake of adequate levels of essential nutrients and energy is unfavourable.

The DGE recommends a diet that includes all groups of foods in the nutrition circle – including animal products. In other words, the DGE recommends a wholesome diet in the form of a mixed diet that largely consists of plant-based foods and, to a lesser extent, of animal foods, including fish, meat and meat products [80, 81].

The DGE also considers that pesco and ovo-lacto vegetarian diets are suitable for healthy persons in the long term, if appropriate alternatives are considered to optimize the nutrient intake. Special care is needed for groups with special requirements for nutrient supply, e.g. pregnant women, lactating women, infants and toddlers.

On a vegan diet, it is difficult or impossible to ensure adequate supply of some nutrients. The most critical nutrient is vitamin B_{12}. Other potentially critical nutrients on a vegan diet include protein resp. indispensable amino acids and long-chain n-3 fatty acids (EPA and DHA), other vitamins (riboflavin, vitamin D) and minerals (calcium, iron, iodine, zinc and selenium). A vegan diet is only able to fulfil requirements if the following points are considered. Persons on a vegan diet should

- take a vitamin B_{12} supplement in the long term and have their supplies of vitamin B_{12} regularly checked by a physician;
- select very specifically nutrient dense foods and fortified foods, in order to ensure supply of nutrients, particularly critical nutrients (◆ Table 2);
- possibly have the supplies of other critical nutrients regularly checked by a physician; if there is a definite or possible nutritional deficiency, the nutrition should be adjusted and the critical nutrients should be added – either in dietary supplements or fortified foods, until the nutrient deficiency has been corrected;
- consult a qualified nutrition counsellor [82] for receiving advice.

The risk of nutrient undersupply or a nutritional deficiency is greater in persons in sensitive phases of life, such as pregnancy, lactation and in infants, children and adolescents taking or being given a vegan diet, than in healthy adults on a vegan diet. With some nutrients, a vegan diet without fortified foods or dietary supplements leads to inadequate intake, which may have considerable unfavourable consequences for health. Since rejecting any animal foods increases the risk of nutrient deficiencies and thus of health disorders, a vegan diet is not recommended by the DGE during pregnancy or lactation, or for children or adolescents of any age. It is essential that persons who nevertheless decide to adhere to a vegan diet should note the above points.

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Conflict of Interest
The authors declare no conflict of interest.

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