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The Gießen Vegan Food Pyramid

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Abstract

The number of vegans has probably increased in the last few years. For a well-balanced vegan diet with an adequate nutrient intake, scientific based dietary recommendations are necessary. With this background in mind, the Giessen Vegan Food Pyramid has been developed. It is based on the calculated nutrient intake of a 14-day vegan meal plan. Particular focus was on meeting the German Dietary Reference Values (DRV) for potential critical nutrients of a vegan diet, e. g. protein, long-chain n-3-fatty acids, vitamin D, vitamin B_2, vitamin B_{12}, calcium, iron, zinc, iodine, and selenium. Based on the calculated mean intake quantities of the meal plans, food groups and the daily intake recommendations were derived. For almost all nutrients, the DRVs were reached or exceeded, except for vitamin B_{12} and vitamin D, as expected. As a next step the Giessen Vegan Food Pyramid should be tested and evaluated in practice.

Keywords: vegan diet, nutrient intake, nutrition counseling, Giessen Vegan Food Pyramid

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Introduction and objectives

With the increasing public interest in plant-based diets, the number of scientific publications studying vegan diets has increased as well (PubMed search, title 'vegan' [title/abstract] up to Dec 2010: 388 results, up to Dec 2015: 501, up to July 2018: 662) [1, 2]. Exact data on the number of vegans in Germany is lacking, but according to estimates, approximately 0.1–1.6% of the population in Germany is living vegan, with a rising tendency [3–7].

The current literature reveals that vegans tend to meet official dietary recommendations more often than the general population, especially regarding the intake of vegetables, fruit and (whole) grain products [8]. On average, vegans are often more closely in accordance with the reference values for energy, protein, fat and carbohydrates intake (percentages of energy [%E] and g/d), compared to omnivores whose intakes of fat and protein exceed the recommendations whereas their intakes of carbohydrates are below the reference values on average. The average intakes of beta-carotene, vitamin C and E, thiamine, folate, biotin, pantothenic acid, potassium, magnesium, dietary fiber, and phytochemicals are mostly higher or at least similar to those of omnivorous control groups [9].

In addition, many observational studies show that vegans (and vegetarians) show a lower risk for obesity, type-2-diabetes, hypertension, metabolic syndrome, ischemic heart disease, and partially cancer, compared to omnivores [10–15]. These effects persist after adjusting for several confounders, e. g. BMI and age, but are slightly attenuated. Furthermore, the overall healthier lifestyle of vegans (less smoking, lower alcohol consumption, more physical activity) contributes to the decreased disease risk [16].

However, there are some nutrients considered as critical in vegan diets. These include protein, vitamin B_{12}, calcium, iron, zinc, vitamin B_2, selenium, the long-chain n-3 fatty acids (eicosapentaenoic acid [EPA], and docosahexaenoic acid [DHA]), as well as iodine and vitamin D, which are generally considered critical nutrients in Germany [17]. Therefore, vegans should ensure a sufficient intake of these critical nutrients.

Considering the benefits of a plant-based diet in addition to the increasing popularity amongst the population, it is necessary to provide scientific-based diet recommendations, which can be implemented by vegans in their daily meal plan and serve as basis for nutrition counseling. Therefore, we aimed to develop a vegan food pyramid, in order to maximize the potential health benefits of a vegan diet and to minimize the potential health risks.

Methods

Based on a broad selection of practical approved vegan recipes, a 14-day meal plan was created. Central was a wholesome nutrition, with realistic food intake quantities and its practicability for daily life. The evaluation of the meal plan was performed with OptiDiet Basic (GOE mbH).
The aim was a total energy intake (TEI) of 2,050 kcal/d (2,300 kcal/d for men; 1,800 kcal/d for women, age 25–50 years; physical activity level [PAL] of 1.4) [18]. Intake goals for macro- and micronutrients also were based on the German DRV for adults aged 25–50 years. If there were different recommendations for men and women, the higher DRV was targeted (e. g. iron DRV for women).
After a first calculation, the meal plans were modified in order to optimize the nutrient intake. For example, the TEI had to be increased to reach 2,050 kcal/d. To enhance the calcium intake, plant-based milk alternatives enriched with calcium and a daily consumption of 1.5 L of calcium-rich mineral water (460 mg Ca/L) were added to the meal plan. The daily intake recommendations of each food group and the consecutive composition of the Vegan Food Pyramid are the results of the mean values ($\bar{x}$) and the variability of the daily consumption of the different food groups. Thus, the recommended intake quantities should not exceed or fall below the maximum and minimum quantities of the food groups and should be as realistic as possible.

Results

The intake quantities (◆ Table 1a–c) were obtained after optimization in accordance with the German DRV. ◆ Figure 1 illustrates the nutrient intakes of the analyzed plans relative to the DRV. Examples for the daily meal plans are shown in ◆ Table 3 (see end of the article).

Nutrients

The target value of the TEI was reached. Carbohydrate intake was slightly lower than recommended (96%). However, the intakes of pro-

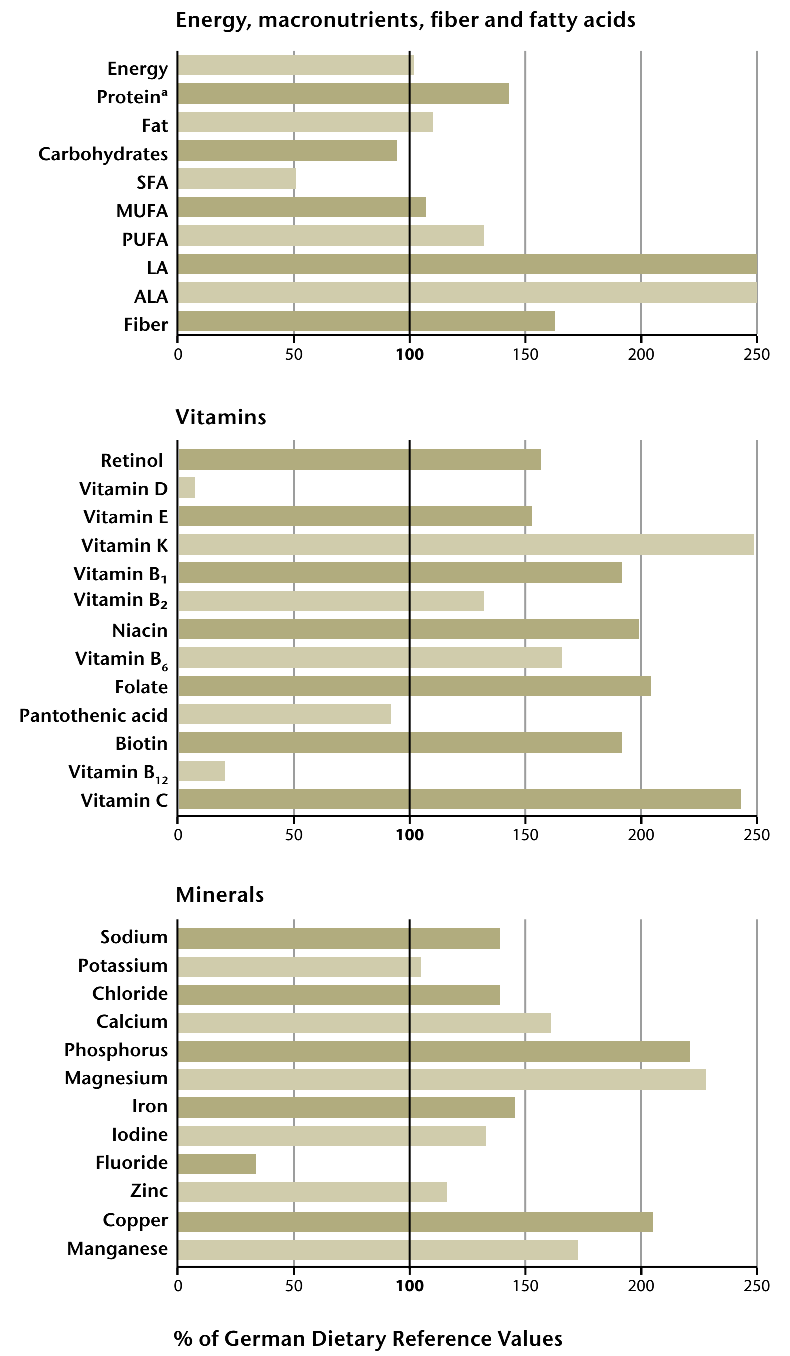

Fig. 1: **Average energy and nutrient intake from 14-day meal plans, expressed as percentage of the German DRV**
[a] based on 48 g of protein intake per day
ALA = α-linolenic acid; LA = linoleic acid; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SFA = saturated fatty acids

tein (118–144%) and fat (111%) exceeded the DRV.

Intakes of the essential fatty acids alpha-linolenic acid (4.3%E) and linoleic acid (8.9%E) were quite high. The average supply of folate, vitamin C, vitamin K, phosphorus, magnesium, copper, and manganese exceeded the DRV more than 2-fold. Furthermore, the intakes of vitamin A (retinol-eq), vitamin E, vitamin B_1, niacin, biotin, vitamin B_6, calcium, and fiber exceeded the recommendations clearly (> 150%). However, none of the calculated nutrient intakes exceeded the Tolerable Upper Intake Level (UL) of the European Agency for Food Safety (EFSA) [20].

Sodium intake (2.1 g/d) was lower than the recommended maximum daily intake of sodium for adults by the American Institute of Medicine (2.3 g/d) [21]. All critical nutrients of vegan diets (except vitamin B_{12} and Vitamin D) met the DRV sufficiently.

Food quantities

From the optimized daily meal plans, recommendations for food intake quantities were derived. Due to the similarities regarding food groups and intake recommendations, the existing Giessen Vegetarian Food Pyramid by Leitzmann and Keller (2013) served as a basis [8].

In variation from that, the category milk and dairy products was replaced by plant-based milk and dairy alternatives and the category vegetables was expanded by algae. The derived intake recommendations (◆ Table 2) include specific information regarding serving size and consumption frequency as well as supplementation. These indications were phrased rather unspecific to facilitate the implementation. However, in some cases it was necessary to give more specific recommendations if supplementation is essential to meet the DRV of some nutrients.

In particular, the use of iodized salt has to be emphasized, as well as the regular consumption of the algae Nori *(Ulva species)* with a moderate iodine content. Used in form of algae flakes, Nori can easily be implemented in everyday meal plans. Additionally, the pyramid points out the use of DHA-enriched linseed oil, calcium-rich mineral water (≥ 400 mg Ca/L) as well as calcium-enriched plant-based milk alternatives. Each recommendation is reflected in the pyramid's food groups ('top' or 'basis', ◆ Figure 2). The Giessen Vegan Food Pyramid visualizes the

Energy/Nutrient		Target value [18]	Calculated intake ($\bar{x}$ ± SD)	DRV compliance	% of DRV[a]	UL adults/day [19, 20]
Energy, macronutrients, fiber, fatty acids						
Energy	kcal	2,050	2,083 ± 151	slightly exceeded	102	–
Protein	g	~ 48–57[b]	66.2 ± 7.8	exceeded	118–144	–
Carbohydrates	%E	> 50 En%	48.1 ± 3.0	slightly below	96	–
Fiber	g	≥ 30	49.2 ± 8.1	substantially exceeded	164	–
Fat	%E	30	33.3 ± 2.9	exceeded	111	–
SFA	%E	≤ 10	5.2 ± 0.8	fulfilled	52	–
MUFA	%E	total fat intake – (PUFA + SFA) (approx. 10–13)	14.0 ± 2.9	exceeded	108 (at 13%E)	–
PUFA	%E	7(–10[c])	13.4 ± 1.8	substantially exceeded	190 (133)	–
LA (n-6)	%E	2,5	8.9 ± 1.6	substantially exceeded	357	–
ALA (n-3)	%E	0,5	4.3 ± 0.5	substantially exceeded	865	–
LA:ALA ratio		≤ 5:1	2.1:1	fulfilled	41	–
EPA (n-3)	mg	–[d]	67.0 ± 3.3	–[d]	–[d]	–
DHA (n-3)	mg	–[d]	147.5 ± 12.8	–[d]	–[d]	–

Tab. 1a: **Comparison of targeted and calculated average daily energy and nutrient intake (arithmetic means of 14-day meal plans)**

– = no data or not sufficient evidence for an UL value; ALA = α-linolenic acid; DHA = docosahexaenoic acid; DRV = Dietary Reference Values; EPA = eicosapentaenoic acid; LA = linoleic acid; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SD = standard deviation; SFA = saturated fatty acids, UL = Tolerable Upper Intake Level; $\bar{x}$ = arithmetic mean

[a] rounded

[b] values are based on respective reference bodyweight

[c] if SFA intake exceeds 10% of TEI

[d] for the primary prevention of coronary heart disease a daily intake of 250 mg EPA and DHA is recommended [18, chapter fats, p. 4]

Energy/Nutrient		Target value [18]	Calculated intake ($\bar{x}$ ± SD)	DRV compliance	% of DRV[a]	UL adults/day [19, 20]
Vitamins						
Retinol (retinol eq)	mg	1.0	1.6 ± 0.6	substantially exceeded	157	3 mg
Vitamin D	µg	20.0[e]	1.6 ± 1.2	below	7	100 µg
Vitamin E (tocopherol eq)	mg	14.0	21.5 ± 3.7	substantially exceeded	154	300 mg
Vitamin K	µg	70	443.6 ± 315.2	substantially exceeded	634	–
Vitamin B_1	mg	1.2	2.3 ± 0.7	substantially exceeded	193	–
Vitamin B_2	mg	1.4	1.9 ± 0.3	exceeded	133	–
Niacin eq	mg	15.0	30 ± 3.6	exceeded	200	nicotinamide 900 mg nicotinic acid 10 mg
Vitamin B_6	mg	1.5	2.5 ± 0.3	substantially exceeded	167	25 mg
Folate eq	µg	300	616.8 ± 142.2	exceeded	206	1,000 µg
Pantothenic acid	mg	6.0	5.7 ± 0.9	slightly below	94	–
Biotin	µg	30–60	58.2 ± 11.5	fulfilled	97–194	–
Vitamin B_{12}	µg	3.0	0.6 ± 0.3	below	21	–
Vitamin C	mg	110	270 ± 91.7	substantially exceeded	245	–

Tab. 1b: **Comparison of targeted and calculated average daily vitamin intake (arithmetic means of 14-day meal plans)**
– = no data or not sufficient evidence for an UL value; DRV = Dietary Reference Values; eq = equivalent; SD = standard deviation; UL = Tolerable Upper Intake Level; $\bar{x}$ = arithmetic mean
[a] rounded
[e] when endogenous synthesis is lacking

Energy/Nutrient		Target value [18]	Calculated intake ($\bar{x}$ ± SD)	DRV compliance	% of DRV[a]	UL adults/day [19, 20]
Minerals						
Sodium	mg	1,500	2,112 ± 0.7	exceeded	141	–
Potassium	mg	4,000	4,242 ± 0.5	exceeded	106	–
Chloride	mg	2,300	3,232 ± 1.1	exceeded	141	–
Calcium	mg	1,000	1,625 ± 0.1	substantially exceeded	163	2,500 mg
Phosphorus	mg	700	1,561 ± 0.2	substantially exceeded	223	–
Magnesium	mg	350	805 ± 83.4	substantially exceeded	230	250 mg[f]
Iron	mg	15.0	22.2 ± 3.8	exceeded	148	–
Iodine	µg	200	269 ± 116.7	exceeded	135	600 µg
Fluoride	mg	3.8	1.3 ± 0.1	below	34	7 mg
Zinc	mg	10.0	11.7 ± 1.9	exceeded	117	25 mg
Selenium	µg	70	–	–	–	300 µg
Copper	mg	1.0–1.5	3.1 ± 0.4	substantially exceeded	207–310	–
Manganese	mg	2.0–5.0	8.7 ± 1.5	substantially exceeded	174–435	–
Chromium	µg	30–100	–	–	–	–
Molybdenum	µg	50–100	–	–	–	0.6 mg

Tab. 1c: **Comparison of targeted and calculated average daily mineral intake (arithmetic means of 14-day meal plans)**
– = no data or not sufficient evidence for an UL value; DRV = dietary reference values; SD = standard deviation; UL = Tolerable Upper Intake Level; $\bar{x}$ = arithmetic means
[a] rounded
[f] in form of supplements, water or fortified foods (not included Mg which occurs naturally in food)

recommendations in order to make them comprehensible and feasible. Apart from that, the recommendations given in ◆ Table 2 are integral parts of the pyramid.

Discussion

The nutrient analysis showed that after optimizing the daily meal plans, most of the critical nutrients of vegan diets could be sufficiently provided (at least in theory). Vitamin B_{12} and vitamin D were excluded during optimization because adequate intakes are impossible if only plant foods are consumed. The intakes of some other nutrients could not be calculated with the software (e. g. selenium, molybdenum) since the underlying German food database is incomplete.

The German DRV are derived from an omnivorous diet. For some nutrients, the bioavailability in a plant-based diet is lower than in an omnivorous diet [22]. Therefore, there should be special recommendations for vegetarians and vegans. Dietary Reference Intakes in Australia/New Zealand as well as in the US recommend a 1.5-fold higher intake zinc and a 1.8-fold higher intake for iron in a vegetarian or vegan diet [23, 24]. However, there is a dispute over these increased intake recommendations, e. g. because of the adaption ability of the human body due to a lower zinc intake [25, 26].

Using the Giessen Vegan Food Pyramid, nutrition counselors should emphasize on appropriate processing techniques to enhance the bioavailability of certain nutrients, e. g. by soaking and germination of grains (activation of phytase), the reuse of cooking water and the combination of foods (e. g. iron-rich foods with vitamin C).

Food (group)	Recommended intake quantity
Beverages	daily • approx. 1.5 L/d • water and other non-alcoholic, low-energy beverages (recommended: calcium-rich mineral water [≥ 400 mg Ca/L])
Vegetables	at least 3 servings per day • at least 400 g/d
Seaweed (Nori) (alternative: iodine supplementation)	daily • approx. 1–3 g (dry) equal to a heaped teaspoon of Nori flakes or 1.5 Nori leafs[a]
Fruit	at least 2 servings per day • at least 250 g/d
Whole grains and potatoes	3 servings per day per serving: • grain and rice: 60–75 g (raw) or approx. 250–300 g (cooked) • whole meal bread: 2–3 slices (1 slice = 50 g) • whole meal pasta: 125–150 g (raw) • potatoes: 2–3 (approx. 200–350 g)
Pulses and other protein sources	approx. 1 serving per day per serving: • pulses: 40–50 g (raw) or approx. 150–220 g (cooked) • tofu, tempeh, seitan and lupine products: 50–100 g
Milk alternatives	1–3 servings per day, preferably unsweetened products per serving: 100–200 g of soy milk[b], grain milk[b], nut milk[b], soy yogurt alternative[b]
Nuts and seeds (including nut butter)	1–2 servings per day • per serving: approx. 30 g
Vegetable oils and fats	2 servings per day • 2–3 table spoons per day (including 1 tablespoon [12 g] DHA-enriched linseed oil[c])
Additional recommendations	daily • Vitamin B_{12} supplementation • iodized salt or sea salt enriched with iodine containing algae (max. 1.5 g/d) • outdoor activity for vitamin D synthesis (vitamin D supplementation between October and March)
If desired, in moderation: snacks, sweets and alcohol	

Tab. 2: **Recommended intake quantities for each food group**
[a] calculations are based on Nori algae with an iodine content of 5 or 15 mg/100g (Nori leaves or Nori flakes)
[b] preferably enriched with calcium
[c] DHA content 1,000 mg/100 mL; EPA content 500 mg/100 mL

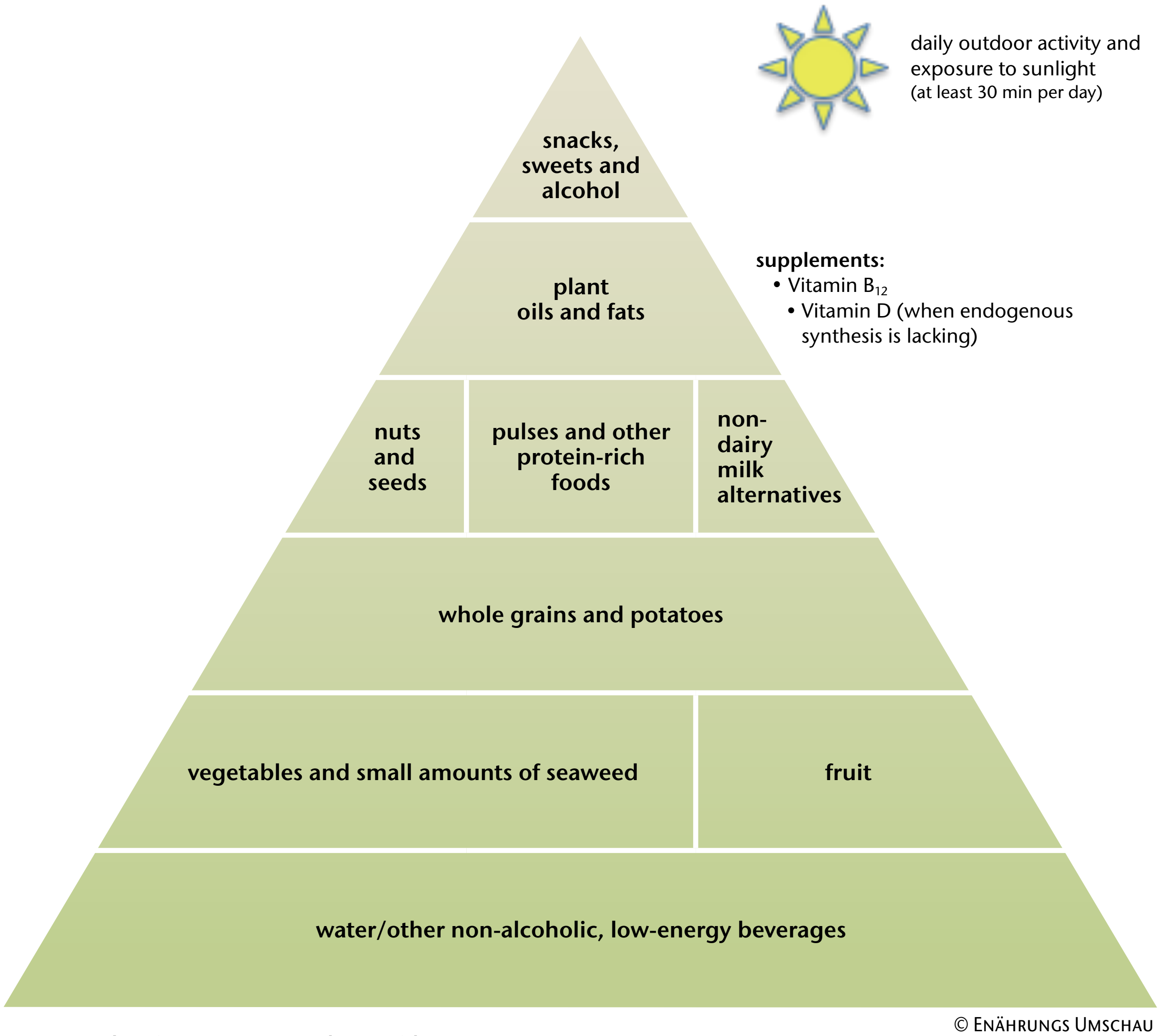

Fig. 2: **The Giessen Vegan Food Pyramid**

Macronutrients, essential fatty acids and fiber

The analysis of the daily meal plans showed a higher protein and fat level at the expense of a lower carbohydrate level. This concurs with the German Nutrition Society's position paper "Guidelines for energy intake from carbohydrates and fats" [27].

The ratio of linoleic acid (LA) (n-6) to alpha-linolenic acid (ALA) (n-3) was about 1:2.1, which means that the preferable proportions (%E) were substantially exceeded (LA: 8.9 vs. 2.5%E; ALA: 4.3 vs. 0.5%E). The high proportion of the essential fatty acids LA and ALA of the total fatty acids resulted from the low proportion of saturated fatty acids (SFA; 5.2%E). The latter is consistent with the German DRV (SFA ≤ 10%E) and therefore can be considered as favorable [13].

It should be verified if the much higher intake level of LA and ALA and their ratio of approximately 1:2.1 has negative health effects in the long-term. A higher hemorrhagic tendency has not been confirmed in the literature and is only described at very high intake levels of n-3 fatty acids (> 20 g/d) (here: 9.3 g/d) [28]. Considering the high intake of vitamin E (~ 21.5 mg/d) in the meal plans, negative effects of fatty acid oxidation can be ruled out, at least theoretically (~ 16.0 mg tocopherol-eq are required; 0.06 mg tocopherol-eq for monounsaturated fatty acids; 0.4 mg tocopherol-eq for di-unsaturated fatty acids; 0.2 mg tocopherol-eq each additional double bond) [15].

To ensure the supply of the long-chain n-3-fatty acid DHA, a DHA-enriched linseed oil was used. This DHA originates from micro algae (*Schizochytrium* sp.) [29]. For EPA and DHA, there exist no intake recommendations for the general population in the German speaking countries, but there is a reference that "for the primary prevention of coronary heart disease [...] the literature estimates that an intake of 250 mg long-chain n-3 fatty acids per day is appropriate" [18]. Many international and national organizations propose previously defined clear intake recommendations for the general population (e. g. FAO [30], EFSA [31]: 250 mg EPA+DHA/d; AND [32], AHA [33]: 500 mg EPA+DHA/d). In the Giessen Vegan Food Pyramid, the intake quantity of 214.5 mg/d of EPA and DHA combined is slightly lower than the EFSA recommendation. Nevertheless, it could be increased by a higher intake of EPA/DHA-enriched linseed oil. Studies show that

vegans have often (but not always) much lower tissue and blood levels of DHA (and EPA) than omnivorous control groups, especially those with a high fish consumption [34–39]. Whether these lower body contents have health consequences, like an elevated risk for inflammatory and/or neurological diseases, is unclear and requires further research.
This research should also address the possible adequacy of the DHA auto-synthesis, when there is an adequate ALA intake with a plant-based diet. Additionally, it is important to clarify the DHA (and EPA) intake recommendations for the general population by national nutrition associations or authorities. Thereby it has to be considered that some studies show a higher conversion rate of ALA to EPA and DHA when the EPA and DHA intake is low [18]. Another way to improve the conversion rate is to reduce the LA intake while increasing the ALA intake [40].

Vitamins and minerals

Most of the micronutrients could be supplied sufficiently with a wholesome and varied composition of the daily meal plans. This included critical nutrients like vitamin B_2, iron and zinc. However, taking the Australian/New Zealand and US recommendations for higher intake quantities for iron (+ 80%) and zinc (+ 50%) in a vegetarian or vegan diet as a reference, the supply values in the Giessen Vegan Pyramid are below those recommendations.
After a first evaluation, the calcium supply was modified with enriched plant-based milk alternatives and calcium-rich mineral water (460 mg Ca/L). Although the DRV for calcium was fulfilled even without those adjustments (102%), a further increase of calcium intake was considered as reasonable, because of the variable bioavailability of this mineral in plant-based foods. The use of calcium-rich mineral water might be an easy way to implement another calcium source in the diet. After adjustment the calculated calcium intake was about 160% of the DRV.
For iodine the use of iodized salt as well as the consumption of algae was essential to meet the DRV. The calculation was based on Nori flakes from an organic manufacturer with an iodine level of 15 mg/100 g (= 150 mg/kg). An excessive supply of iodine can yield negative health outcomes (e. g. iodine induced hyperthyroidism), according to the German National Institute for Risk Evaluation (BfR). In a position paper, the BfR advised against the consumption of dried algae products with an iodine level ≥ 20 mg/kg [41]. This statement was, however, based on a consumption quantity of 10 g algae per day. In the calculated meal plans the consumption quantity of algae was ~ 1 g/d. Therefore, consumers should check the manufacturer's information on iodine levels and the corresponding recommendations on the maximum daily dose on the packaging of algae products. Possible residues of heavy metals in sea algae must be valued as critical [42]. According to the manufacturer of the Nori flakes used for this calculation, the products are regularly monitored for heavy metals [43]. Consumers should also check with the manufacturers concerning the contents of heavy metals in algae products. Alternative to the consumption of algae, a supplementation with iodine (e. g. as pills) is possible but should be clarified with the general practitioner.
When special products were necessary to meet the DRV for some nutrients, references were included in the recommendations. Because of low or unreliable levels of vitamin B_{12} and vitamin D in plant foods, it was anticipated that the pyramid would not reach the DRV for these two nutrients. Therefore, a proper recommendation for supplementation was necessary.

Nutrients not considered

Due to the lack of data, a calculation for the selenium intake was not possible. However, since this nutrient is regarded as critical in a vegan diet [17], future studies should take this in consideration separately. Therefore, an additional food recommendation is prudent, e. g. the consumption of Brazil nuts (selenium contents: 1.25–512 μg/g, mean level 36 ± 50 μg/g) [44]. The intake quantities for molybdenum were also impossible to calculate because of missing data. Since molybdenum occurs ubiquitously and nutritional deficiencies are rarely reported, a sufficient supply also in a vegan diet is most likely [45].

Conclusion

The Giessen Vegan Food Pyramid provides the possibility to benefit from the health potential of a plant-based diet and to minimize the risk of possible nutrient deficiencies. Furthermore, it can be used as an advisory tool for nutrition counseling. The application of the Giessen Vegan Food Pyramid should be assessed and evaluated in practice to consider further optimization.

Limitations

The recommendations of the Giessen Vegan Food Pyramid apply to healthy adults. For groups with altered nutritional needs, such as pregnant and breastfeeding women, children and adolescents, a separate assessment and adaptation of the recommendations is required.

Day 1	Day 2
Breakfast Green smoothie	**Breakfast** Amaranth oat cereal
Lunch Whole-grain pasta with kale and dried tomatoes	**Lunch** Potato bean salad
Dinner Radicchio salad with avocado bread	**Dinner** Radicchio salad with avocado bread
In between meal Whole-grain bread with sesame date butter Coffee with soy milk, banana	**In between meal** Soy yogurt with fresh fruits and cereal mix
Day 3	**Day 4**
Breakfast Roasted spelt muesli with fruit	**Breakfast** Scrambled tofu with whole-grain bread
Lunch Whole-grain pasta with leaf spinach	**Lunch** Vegetable millet pan
Dinner Red lentil soup	**Dinner** Whole-grain bread with hummus and raw foods
In between meal Apple slices with almond butter	**In between meal** Semolina pudding with apple
Day 5	**Day 6**
Breakfast Millet oatmeal with fruit	**Breakfast** Whole-grain bread with hummus and raw foods
Lunch Green pelt patty with creamed vegetables	**Lunch** Ratatouille with brown rice
Dinner Miso soup, turnip cabbage raw food with spiced chickpeas	**Dinner** Avocado bean salad
In between meal Crisp bread with avocado and tomatoes Dried figs	**In between meal** Banana shake
Day 7	**Day 8**
Breakfast Porridge with blueberries	**Breakfast** Pancakes with raspberry ice cream
Lunch Vegetable curry with brown rice	**Lunch** Whole-grain pasta with chickpeas arrabiata
Dinner Minestrone with whole-grain bread	**Dinner** Potato asparagus salad
In between meal Soy yogurt with fresh fruit	**In between meal** Whole-grain bread with tahini and jam, Coffee
Day 9	**Day 10**
Breakfast Oatmeal with fruit	**Breakfast** Cereal mix with fresh fruit
Lunch Polenta with mushrooms	**Lunch** Potato sauerkraut gratin with lettuce
Dinner Waldorf salad with whole-grain bread	**Dinner** Bean kale stew
In between meal Hummus with raw food	**In between meal** Whole-grain bread with almond butter and banana Coffee

In addition (daily)
1.5 L mineral water, calcium-rich (calcium content: 460 mg/L)
1 g Nori flakes (iodine content: 15 mg/100 g); alternative: iodine supplementation (after medical consultation)
1.5 g iodized salt (iodine content: 2.5 mg/100 g)
1 tbsp. linseed oil enriched with DHA (DHA content: 1,000 mg/100 mL; EPA content 500 mg/100 mL)
Vitamin B_{12} supplementation

Tab. 3: **10 days of the 14-day vegan meal plan, after optimization**
DHA = docosahexaenoic acid, EPA = eicosapentaenoic acid

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Conflict of Interest

Prof. Keller received fees from Alpro for reviewing and lecturing activities. He is unsalaried member of the Scientific Advisory Board of ProVeg Germany and *Albert Schweitzer Stiftung für unsere Mitwelt*. Also, he authored expert reports for Greenpeace Germany.
The other authors declare no conflict of interest.

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