

A Comprehensive Examination of the Nutritional Sufficiency of Vegan Recipes Widely Available in the Market

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Abstract:

The popularity of plant-based and vegan diets has experienced significant growth in recent years. While adhering to a vegan diet has been linked to various health benefits, it is important to note that certain essential vitamins and minerals, such as vitamins B12 and D, calcium, and iron, may be insufficient in an exclusively plant-based diet. Prolonged inadequate intake of these nutrients can lead to nutritional deficiencies and potentially increase the risk of adverse health outcomes. To further investigate this matter, we conducted a study in which we analyzed a one-week meal plan consisting of vegan recipes from Forks Over Knives (FOK), an organization that advocates for a low-fat, whole-food, vegan diet as a means to prevent or reverse chronic diseases. Through a detailed examination of the meal plan. Based on the evidence derived from this analysis, it is imperative for vegans and their healthcare providers to be cognizant of the potential nutrient deficiencies and associated health consequences that may arise from following this type of diet.

Key words: vegan; plant based diets; nutrition

1. Introduction

Plant-based diets have experienced a surge in popularity in recent years due to various factors such as concerns for the environment, ethics, and health. The adoption of exclusively plant-based or vegan diets, which exclude all animal-derived foods, is gradually becoming more mainstream. The sales of plant-based dairy and meat alternatives saw a significant increase of 27% from 2019 to 2020, contributing to a total estimated market value of \$7 billion for plant-based products [1]. Furthermore, the global market for dairy alternatives is projected to reach \$25 billion by 2026 [2]. A survey conducted between 2004 and 2019 revealed a remarkable 300% rise in the number of individuals identifying as vegans, accounting for approximately 3% of the total population or nearly 10 million people [3]. According to the Vegetarian Resource Group's 2020 Harris Poll, 3% of adults in the United States follow a vegan diet, while 6% adhere to a vegetarian diet (including vegans) [4]. The potential health benefits associated with plant-based diets have been extensively documented. These diets typically consist of higher quantities of fruits, vegetables, whole grains, nuts, soy products, and phytochemicals. Moreover, plant-based diets generally contain lower levels of saturated fat and cholesterol, while being richer in dietary fiber [5]. Research has shown that individuals following plant-based diets have a reduced risk of mortality from ischemic heart disease, lower levels of low-density lipoprotein (LDL) cholesterol and blood pressure, and lower rates of hypertension and type 2 diabetes compared to those following

nonvegetarian diets [5]. Additionally, vegans and vegetarians tend to have a lower body mass index and a lower overall cancer rate compared to omnivores [5]. Furthermore, randomized controlled trials investigating vegan and vegetarian interventions have demonstrated improvements in body weight and cardiometabolic risk factors [6].

Despite the numerous health advantages associated with plant-based diets, studies indicate that vegan diets may be deficient in certain nutrients, potentially leading to nutrient deficiencies and related negative health consequences over time. These consequences may include an increased risk of bone fractures, vitamin B12 deficiency and peripheral neuropathy, as well as hemorrhagic stroke [6-8].

A comprehensive analysis discovered that vegan diets are deficient in various essential nutrients such as vitamin B2, niacin (B3), vitamin B12, vitamin D, iodine, zinc, calcium, potassium, and selenium [9]. Another systematic review, which examined 141 studies, revealed that vegans and vegetarians had lower intakes of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) compared to individuals who consume meat. This review also found that plant-based diets resulted in lower intakes and levels of vitamin B12, vitamin D, iron, zinc, iodine, and calcium. Among those following vegan diets, the lowest intakes of vitamin B12, calcium, and iodine were observed, along with lower bone mineral density (BMD) [10].

For individuals seeking vegan recipes, there is a plethora of resources available, including websites, YouTube videos, books, magazines, and more. One notable resource is Forks Over Knives (FOK), an organization renowned for its 2011 documentary promoting a low-fat, whole-food, vegan diet as a means to prevent or reverse various chronic diseases. The FOK diet emphasizes the avoidance of highly refined and processed foods, such as refined sugars, bleached flours, and oils, and instead encourages the consumption of predominantly whole grains, legumes, tubers, vegetables, and fruits. Since 2011, FOK has expanded its offerings to include several books, a mobile recipe app, a magazine, a line of food products, and a website that provides research, recipes, and tools to assist individuals in planning their plant-based meals [11].

2. Methods

A comprehensive examination was conducted on a meal plan derived from a week's worth of FOK vegan meal and snack recipes, totaling 35 recipes. The analysis was performed using Nutritionist Pro version 8.1.0 software. The selection of FOK recipes for this study was based on their widespread availability to consumers through various platforms such as the FOK website, mobile app, and print magazine sold in grocery stores. These plant-based recipes were thoughtfully curated and likely to cater to a diverse range of consumers. The recipes included in the analysis were randomly chosen from the FOK magazine's 100 Best Plant-Based Recipes of 2021 issue. Each day's meal plan consisted of breakfast, lunch, snacks, dinner, and dessert, with serving sizes carefully determined to achieve an average daily calorie intake of 2,000, aligning with the percent Daily Value (DV) based on a 2,000-calorie diet.

The Nutritionist Pro analysis encompassed various nutritional aspects, including calories, protein and amino acids, carbohydrates, fat and fatty acids, vitamins, and minerals. The objective of this analysis was to evaluate which micronutrients met 90% of the Daily Value (DV) for adults and children over the age of four.

3. Results

The meal plan successfully fulfilled the recommended daily values (DV) for macronutrients. It provided 100% of the DV for calories, 140% of the DV for protein, 127% of the DV for carbohydrates, 237% of the DV for dietary fiber, 54% of the DV for total fat, and 29% of the DV for saturated fat. These results can be observed in Figure 1, which displays the nutrient analysis findings for macronutrients. However, the meal plan exhibited deficiencies in various micronutrients. It failed to meet at least 90% of the DV for several vitamins, including biotin (56% DV), choline (30% DV), niacin (75% DV), vitamin B12 (82% DV), vitamin D (5% DV), and vitamin E (7% DV) [11]. The nutrient analysis results for vitamins can be found in Figure 1. Similarly, the meal plan did not meet at least 90% of the DV for certain minerals, such as calcium (58% DV), iodine (1% DV), selenium (68% DV), and zinc (64% DV) [11]. These findings are presented in Figure 1, which showcases the nutrient analysis results for minerals. Although the meal plan fulfilled the DV for iron, it did not meet the adjusted Recommended Dietary Allowance (RDA) for iron specifically designed for vegetarian and vegan adults [12]. Lastly, Figure 1 displays the nutrient analysis results for omega-3 and omega-6 fatty acids, revealing that the meal plan lacked long-chain omega-3 fatty acids.

4. Discussion

In summary, while the meal plan adequately provided macronutrients, it fell short in meeting the recommended DV for various micronutrients, as well as the adjusted RDA for iron in vegetarian and vegan adults. The absence of long-chain omega-3 fatty acids was also noted in the analysis.

4.1 Biotin

The recommended daily value (DV) for biotin is 30 mcg [12]. The FOK recipes provided 56% of the DV, equivalent to 16.762 mcg. Biotin is a water-soluble vitamin that acts as a cofactor for enzymes involved in intermediary metabolism and plays a role in regulating gene expression. It is also crucial for fetal development. Although biotin deficiency is uncommon, its symptoms may include hair loss, a scaly red rash on the face and genital area, and neurological issues [13]. Animal-derived foods like egg yolk and liver are rich sources of biotin. Nutritional yeast is the most abundant vegan source of biotin. Peanuts, soybeans, sunflower seeds, mushrooms, sweet potatoes, and some other vegetables and fruits also contain smaller amounts of biotin. Including nutritional yeast and other biotin sources in the diet or taking biotin supplements can help vegans meet their daily requirements.

4.2 Calcium

The DV for calcium is 1,300 mg per day [12]. The FOK recipes provided 58% of the DV, equivalent to 756.227 mg. In the United States, approximately 72% of calcium intake comes from dairy products or foods with added dairy ingredients [14]. Research indicates that vegans generally have lower calcium intake compared to vegetarians or omnivores [15]. Furthermore, studies suggest that individuals following a vegan diet may have lower bone mineral density (BMD) and a higher risk of fractures [16]. A recent meta-analysis found a correlation between plant-based diets and lower BMD, particularly among females compared to omnivores [17]. Adequate calcium is essential for proper nerve and muscle function, maintaining bone density, regulating blood vessel contraction and dilation, blood clotting, and hormone secretion. Calcium deficiency can lead to conditions such as osteoporosis, osteomalacia, or rickets [18].

Consuming plant-based sources of calcium, such as soy-based foods (tofu, tempeh), legumes, almonds, seaweed, dark leafy greens (spinach, bok choy, mustard, collard, turnip), blackstrap molasses, and fortified plant-based foods and beverages (plant milks, orange juice), can assist individuals following a vegan diet in meeting their daily calcium requirements. However, vegans who do not carefully monitor their calcium intake from food and fail to consume sufficient amounts may need to consider calcium supplementation to fulfill their needs.

4.3 Choline

The recommended daily value (DV) for choline is 550 mg per day [12]. The recipes provided in the FOK (Forks Over Knives) met 30% of the DV, equivalent to 162.820 mg. Choline is an essential nutrient that plays a crucial role in liver, muscle, and brain function, as well as lipid metabolism and cellular membrane composition and repair. Choline and its metabolites are involved in cell signaling, nerve transmission, and methyl donation. Although the liver synthesizes a small amount of choline, adequate intake from dietary sources is necessary to prevent deficiency [19]. Insufficient choline intake can lead to fatty liver, liver damage, and muscle damage [20].

While choline is essential throughout all stages of life, it holds particular importance during pregnancy and lactation for the development of the fetus and infant. Consequently, the American Medical Association recommends that all prenatal vitamin supplements contain choline [21].

Animal-derived foods generally contain higher amounts of choline compared to plant-based foods. Naturally rich animal sources include beef, chicken, egg yolks, fish, and pork. Plant-based sources of choline

include soy-based foods (tofu, soynuts, soymilk), cruciferous vegetables, cooked dried beans, peanuts, or peanut butter [20].

Although specific studies have not been conducted to determine the choline intake and status of vegans and vegetarians, a recent study discovered that vegan and dairy-free vegetarian menus, based on the Dietary Guidelines for Americans, did not provide sufficient amounts of choline [22].

Legumes and cruciferous vegetables are beneficial for individuals who adhere to a vegan diet as they can help meet the recommended daily value (DV) for choline. Vegetarians, on the other hand, can also fulfill their choline needs by consuming eggs and dairy products. However, depending on their specific dietary intake, some vegans may require a choline supplement to ensure adequate levels.

4.4 Iodine

Iodine, an essential trace mineral, plays a crucial role in the production of thyroid hormones T3 and T4, which are involved in metabolism and protein synthesis. It is also vital for fetal neurodevelopment. The recommended DV for iodine is 150 mcg. Unfortunately, recipes from the Forks Over Knives (FOK) program, which exclusively advocate the use of sea salt, only provide 1% of the DV, equivalent to 1.4 mcg. This falls significantly short of the required amount.

Dairy products and iodized salt are the primary dietary sources of iodine, although seafood is also rich in this mineral. Seaweed is the only plant-based source of naturally occurring iodine. It is important to note that Himalayan salt, sea salt, and kosher salt do not contain iodine. Substituting iodized table salt with these specialty salts can potentially increase the risk of iodine deficiency.

Research indicates that vegans face a higher risk of low iodine status, deficiency, and inadequate intake compared to omnivores and even vegetarians. To address this, individuals following a vegan diet can increase their iodine intake by incorporating iodized salt into their meals or by taking a daily multivitamin and mineral supplement that includes iodine. These measures can help ensure sufficient iodine levels and mitigate the potential consequences of iodine deficiency, such as goiter, hypothyroidism, cretinism, and impaired cognitive development.

4.5 Iron

The FOK recipes provided an iron content of 21.67 mg, surpassing the recommended daily value (DV) of 18 mg. However, a recent review discovered that vegetarians have a higher prevalence of depleted iron stores based on ferritin levels, and they also face a greater risk of developing low iron stores, iron depletion, and iron deficiency anemia compared to non-vegetarians. This discrepancy is likely due to the lower bioavailability of non-heme iron found in plant-based foods compared to the heme iron present in animal-based foods. To address this, it has been suggested that vegetarians and vegans require 1.8 times more iron than individuals who consume meat. If the DV for adult vegans and vegetarians were recalculated to meet these increased needs, the FOK recipes would only fulfill 67% of the "adjusted" DV.

For those following a vegan diet, their iron requirements can be met by consuming plant-based sources of iron such as leafy greens, legumes, nuts, and seeds. Additionally, pairing these iron-rich foods with vitamin C-rich foods can enhance the absorption of nonheme iron. Iron supplementation may also be beneficial for vegans and vegetarians to meet their daily iron needs.

4.6 Niacin

The DV for niacin is 16 mg. The FOK recipes provided 75% of the DV, equivalent to 14.947 mg. Niacin, also known as vitamin B3, is a water-soluble vitamin that undergoes conversion into its main metabolically active form, the coenzyme nicotinamide adenine dinucleotide (NAD), within the body. NAD is essential for hundreds of enzymes to catalyze reactions in the body. Furthermore, NAD is further converted into another active form called nicotinamide adenine dinucleotide phosphate (NADP). Both NAD and NADP play crucial roles in numerous metabolic processes within cells.

Animal-based foods such as poultry, beef, and fish contain approximately 5-10 mg of niacin per serving, primarily in the highly bioavailable forms of NAD and NADP. On the other hand, plant-based foods like nuts, legumes, and grains contain around 2-5 mg of niacin per serving, mainly in the form of nicotinic acid.

The conversion of the amino acid tryptophan to NAD can occur when there is an excess amount of tryptophan beyond what is needed for protein synthesis. While tryptophan is commonly found in animal foods like poultry, beef, pork, milk, and eggs, it can also be found in plant-based foods such as soybeans (tofu and edamame), pumpkin seeds, and oatmeal [26].

Although niacin deficiency is not common in the United States, some individuals may have a slightly low niacin status. Those who do not consume enough niacin from their diet and do not obtain sufficient amounts of other nutrients required for the conversion of tryptophan to niacin (riboflavin, pyridoxine, or iron) may be at a higher risk of inadequacy [26]. Including niacin-rich plant foods in the diet can help individuals following a vegan diet meet their daily niacin needs.

4.7 Selenium

Selenium is an essential trace mineral that plays a crucial role in reproduction, thyroid hormone metabolism, DNA synthesis, and protection against oxidative damage and infection. The recommended daily value (DV) for selenium is 55 mcg [12]. The recipes provided by FOK contribute to 68% of the DV, which is equivalent to 37.492 mcg. Brazil nuts, seafood, and organ meat are the richest sources of selenium, although breads, grains, meat, poultry, fish, and eggs are the main dietary sources of selenium in the United States. The selenium content in plant-based foods varies depending on factors such as soil pH, organic matter in the soil, and selenium levels in the soil. Consequently, the amount of selenium in plant-based foods can vary significantly based on geographic location [27]. Research suggests that vegan diets tend to be low in selenium [28]. However, consuming a few Brazil nuts each week, along with other plant sources of selenium, can help individuals following a vegan diet meet their daily selenium requirements.

4.8 Vitamin B12

The recommended daily value (DV) for vitamin B12 is 2.4 mcg [12]. The recipes provided by FOK contribute to 82% of the DV, which is equivalent to 1.959 mcg. Vitamin B12 is an essential water-soluble vitamin that plays a crucial role in the functioning of the central nervous system, the formation of red blood cells, and DNA synthesis [29]. It is naturally found in animal-based foods such as meat, fish, poultry, eggs, and dairy products. However, plant-based foods do not naturally contain vitamin B12. Nevertheless, some fortified plant-based products like breakfast cereals, nutritional yeast, almond milk, and soymilk are enriched with vitamin B12. Many of the FOK recipes include these fortified plant-based beverages to ensure an adequate intake of vitamin B12. Research studies have consistently shown that vegan diets tend to be

deficient in vitamin B12 [9]. Individuals who follow a plant-based diet generally have lower vitamin B12 levels compared to those who consume meat [10]. Insufficient intake of vitamin B12 over a prolonged period can lead to vitamin B12 deficiency, which can have various adverse effects on the body. These effects include megaloblastic anemia, low levels of white and red blood cells and platelets, fatigue, heart palpitations, and neurological changes [29]. To maintain sufficient vitamin B12 levels, it is crucial for vegans and vegetarians to consume fortified foods or dietary supplements that provide an adequate amount of vitamin B12.

4.9 Vitamin D

The recommended daily value (DV) for vitamin D is 20 mcg [12]. However, the recipes provided by FOK only contribute 5% of the DV, equivalent to 1.006 mcg. Vitamin D plays a crucial role in the absorption of calcium and maintaining bone health. Additionally, research suggests that vitamin D is involved in regulating the immune system and may reduce the risk of various health conditions. Deficiency in vitamin D has been associated with different types of cancers (such as breast and colorectal), heart disease, cardiovascular disease mortality, macular degeneration, falls in the elderly, depression, impaired immune function, type 2 diabetes, and other chronic diseases [30]. Furthermore, low levels of 25(OH)D have been linked to lower pregnancy rates in women trying to conceive and an increased risk of pregnancy complications like gestational diabetes [31, 32]. Supplementation of vitamin D during pregnancy has been shown to decrease the likelihood of complications such as preeclampsia, low birthweight, and preterm birth [33, 34]. Naturally, vitamin D is found in only a few foods, mostly derived from animals. Good sources include fatty fish, cod liver oil, and egg yolks. Some beverages, like dairy milk, are fortified with vitamin D. Mushrooms can produce vitamin D2 when exposed to sunlight or UV lamps, but the more bioavailable form, vitamin D3 [35], is synthesized in the skin through sunlight exposure. However, various factors influence the production of vitamin D, including environmental conditions, skin pigmentation, clothing, sunscreen use, geographic location, and body weight [36]. Despite the DV for vitamin D being 20 mcg (800 IU), many experts in the field recommend higher doses to maintain optimal levels of 25(OH)D, especially for individuals at risk of vitamin D deficiency [37]. Since plant-based sources of vitamin D3 are limited, individuals following a vegan diet may need to supplement with vitamin D3 to meet their daily requirements.

4.10 Vitamin E

The recommended daily value (DV) for vitamin E is 15 mg [12]. However, the recipes provided by FOK only contribute 7% of the DV, equivalent to 1.317 mg. Vitamin E is a type of fat-soluble vitamin that naturally occurs in various foods in eight different chemical forms, each with varying levels of biological activity. This vitamin serves as an antioxidant and plays a role in immune function, cell signaling, gene expression regulation, and other metabolic processes [38].

To obtain an adequate amount of vitamin E, it is advisable to consume rich sources such as nuts, seeds, and vegetable oils. Green leafy vegetables and fortified cereals also provide a significant amount of this vitamin. In the United States, the majority of dietary vitamin E comes from gamma-tocopherol found in soybean, canola, corn, and other vegetable oils [38]. Vitamin E deficiency is uncommon, as it is naturally present in foods rich in fat. However, due to its requirement for fat absorption, a low-fat vegan diet, like the one recommended by FOK, may be lacking in vitamin E. To address this, individuals following a vegan

diet can incorporate more nuts, seeds, and oils into their daily meals to meet their vitamin E needs.

4.11 Zinc

Moving on to zinc, the DV for this essential mineral is 11 mg [12]. The FOK recipes, on the other hand, provide 64% of the DV, which amounts to 7.064 mg. Zinc plays a crucial role in various bodily functions, including enzyme activity, protein and DNA synthesis, cell division, immune function, wound healing, sense of taste and smell, as well as growth and development. Symptoms of zinc deficiency include stunted growth, impaired immune function, hair loss, diarrhea, delayed wound healing, and loss of appetite [39]. A systematic review and meta-analysis of 26 studies revealed that vegetarians tend to have lower zinc intakes and serum zinc concentrations compared to non-vegetarians. This effect is more pronounced among females and vegans, indicating a greater impact on zinc intake and status [40]. The lower bioavailability of zinc in plant-based foods, such as legumes, whole grains, nuts, and seeds, may contribute to this disparity. These foods contain phytates, which can reduce the absorption of zinc [41]. Hence, individuals following a vegan or vegetarian diet may require an increased amount of zinc compared to nonvegetarians, potentially up to 50% more [21]. To meet their zinc needs, vegans and vegetarians may need to consider taking zinc supplements.

4.12 Omega 3

According to the FOK recipe analysis, it was found that the essential omega-3 fatty acid alpha-linolenic acid (ALA) was provided in a quantity of 1.383 g. Although there is no established Daily Value (DV) for ALA, the Food and Nutrition Board of the National Academy of Medicine has set an adequate intake (AI) range for adults, with 1.1 g for females and 1.6 g for males [42]. The FOK recipes exceeded the AI for women, but only provided 86% of the AI for men.

ALA is classified as an essential omega-3 fatty acid, meaning it must be obtained through daily dietary intake as the body cannot produce it. Vegan diets can be a good source of ALA, as it can be found in foods like flaxseeds, walnuts, chia seeds, and plant oils. However, it is important to note that low-fat diets, such as those recommended by FOK, may limit the consumption of nuts and seeds, resulting in a lower intake of ALA.

Omega-3 fatty acids play a crucial role as structural components of cell membranes in the body. They also serve as precursors involved in various cellular functions, including signaling, regulation, and providing a source of energy. Additionally, there are two other significant omega-3 fats known as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

The conversion of ALA to EPA and DHA is minimal, even under optimal conditions. Research indicates that only about 5%-8% of ALA is converted to EPA and DHA. Furthermore, excessive intake of linoleic omega-6 fatty acids hinders this conversion by competing for the necessary enzymes [43]. Consequently, studies have shown that vegans and vegetarians, who do not consume fish, have lower plasma concentrations of EPA and DHA compared to omnivores [44].

A recent review conducted in 2022 examined the bioavailability of plant-based omega-3 oils, focusing on the conversion of ALA to EPA and DHA. The study revealed that high-dose supplements of flaxseed or echium seed oil, both rich in ALA, either had no effect or led to a decrease in the omega-3 index. On the other hand, supplementation with algal oil, which contains EPA and DHA, increased omega-3 index levels in all studies [45].

EPA and DHA offer various health benefits, such as promoting vision and brain development, reducing inflammatory markers, aiding in athletic recovery, and lowering triglyceride levels [42,46,47]. Vegans and vegetarians may consider incorporating algae-based long-chain omega-3 supplements into their diet to enhance their intake and blood levels of EPA and DHA. The potential negative effects of marginal deficiency are summarized in Figure 1. A one-week 2,000-calorie vegan meal plan consisting of randomly selected FOK recipes was subjected to a nutrient analysis. The findings revealed that despite being well-planned and comprised of whole foods, this vegan diet may lack several essential micronutrients. Furthermore, certain nutrients derived from plant-based sources may not be as easily absorbed by the body compared to those obtained from animal-based sources. Therefore, it is advisable to consider adjusting the recommended intake of specific nutrients such as iron, zinc, and omega-3 fatty acids for vegetarian and vegan adults in order to meet their individual nutritional requirements.

5. Summary Box

It is important to acknowledge the limitations of this study. Firstly, the recipes used in the analysis were sourced solely from FOK, which may not represent the entirety of vegan recipes available. Different sources of vegan recipes could yield varying nutrient analyses. Additionally, the analysis was based on a 2,000-calorie intake, and individuals consuming more or fewer calories on a daily basis may experience different nutrient intakes compared to the results obtained in this study. In conclusion, while a vegan diet can offer numerous health benefits, it is crucial to recognize that even with careful meal planning, it may still be deficient in multiple essential nutrients. To address this, individuals following this vegan meal plan can incorporate fortified foods such as plant-based beverages, increase their consumption of nuts and seeds, and substitute sea salt with iodized salt. Furthermore, nutritional supplementation with specific nutrients can help vegans meet their daily nutrient requirements and potentially prevent nutrient deficiencies and associated health complications.

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