Vitamin B12 in Vegetarian Diets

What about Vitamin B12?

Vitamin B12, originally discovered as an anti-pernicious factor, has been named cobalamin because it contains the rare element cobalt in its chemical structure. Methylcobalamin and adenosylcobalamin are two biologically active forms of B12. Other forms, such as hydroxycobalamin (or aquacobalamin) and cyanocobalamin, must be metabolized to either of the two active forms in order to be utilized in human cells.

Function

Functions driven by Vitamin B12 include the activation of folate, which is essential in DNA synthesis and thus in synthesis of all new cells in the body. B12 plays a critical role in erythropoiesis. Since methionine is needed for the synthesis of myelin, a coating of the nerve pathways, B12 deficiency may result in inadequate myelin synthesis, maintenance and repair and may impair nerve transmission.

Digestion and Absorption

The process of digestion and absorption of B12 takes place in a few stages and requires adequate synthesis of hydrochloric acid, proteases and an intrinsic factor (IF). B12 is released from dietary proteins by pepsin, an enzyme secreted in the stomach, and activated by hydrochloric acid. Once released, B12 binds with R-proteins secreted in the saliva. In the small intestine, pancreatic proteases digest the R-proteins, making it possible for the IF to bind to the newly freed B12, forming an IF-B12 (or IF-Cbl) complex. B12 can be absorbed into the bloodstream either via receptor-mediated endocytosis in the distal ileum or, in the absence of IF, by passive diffusion.

Recommendation

The RDA for B12 for an adult, as issued by the Institute of Medicine, is 2.4μg/day. The daily amount that is actually needed to maintain an adequate serum level that promotes erythropoiesis and other hematological functions is considerably smaller, but this recommendation assumes a 50% absorption rate of B12 from the amount ingested with foods. The RDA issued by the Institute of Medicine is consistent with recommendations of other organizations including the World Health Organization (1.9μg/day).

Deficiency

Although B12 deficiency was once believed to be rare and unlikely to develop, except in strict vegetarians, studies conducted in the last few decades have shown that this view has been based on the incorrect assumption that it takes many years for the deficiency to develop. Although B12 deficiency was once believed to be rare and unlikely to develop, except in strict vegetarians, studies conducted in the last few decades have shown that B12 deficiencies “are common in wealthier countries, particularly among the elderly, and are most prevalent in poorer populations around the world.” It is now believed that megaloblastic anemia, a common symptom of B12 deficiency, is common among people of European and African descents, as well as those living on the Indian subcontinent, and populations of Central and South
America. In Asia, B12 deficiency is less prevalent except in vegetarians.⁶,⁷

B12 deficiency may develop as a result of malabsorption (due to gastrointestinal condition), inadequate intake, lack of synthesis of holotranscobalamin II (TCII), genetic defect of methylmalonyl co-enzyme A mutase and nitrous oxide poisoning.³,⁴,⁸ Malabsorption, the main cause of deficiency, may have two primary causes: inadequate or complete inability of IF synthesis and/or inadequate synthesis of, or synthesis of weak, hydrochloric acid, which is essential in activating pepsinogen to pepsin in order to digest dietary proteins.³,⁴,⁹ Although malabsorption due to the above listed conditions is most prevalent among the elderly, it may also occur at any age among people who have undergone gastrectomy, such as in cases of ulcer disease and gastric bypass for obesity.¹⁰,¹¹ Deficiency due to inadequate intake has been reported in strict vegetarians, lacto-ovo vegetarians, people following macrobiotic diets and alcoholics.³,⁴

B12 deficiency symptoms can be grouped into several categories including hematological, neurological and psychiatric. Specific symptoms of B12 deficiency in each of the above categories are listed in Table 1. Deficiency of B12 is very often misdiagnosed. This is because symptoms can mimic those of other health conditions such as Alzheimer’s disease, spinal cord compression, amyotrophic lateral sclerosis, diabetic peripheral neuropathy, alcoholic peripheral neuropathy or congestive heart failure. The classic B12 deficiency symptoms include the synthesis of large, immature, oblong-shaped erythrocytes (megaloblasts) and myelin deterioration in both central and peripheral nervous systems. Erythrocytes may appear normal in case of either high intake of folate or iron deficiency anemia. Megaloblastic anemia leads to symptoms such as weakness, fatigue, lightheadedness, tachycardia, angina and pale skin. The deterioration of myelin may progress to axonal degeneration and even axonal death, which leads to neuropathy.³,⁴,¹⁰,¹¹

**Food Sources and Bioavailability of B12**

B12 is only synthesized by microorganisms.³ It is not found in foods of plant origin. It is, however, found in meats and foods of animal origin including dairy products and eggs. Some foods believed to be made exclusively from plant foods (e.g. cereal, breads, pies and even cookies) do contain very small amounts of B12 due to either contamination during processing, the addition of small amounts of animal-derived ingredients such as milk solids, or fortification.¹² However, the amount of B12 found in these foods (see Table 2), except for foods that have been fortified, is negligible.

Milk contains between 0.3–0.4 μg/100g of B12. Boiling milk can destroy 30–50% of B12 depending on the duration of cooking. Pasteurization destroys 5–10% of B12. B12 content of dairy products, such as cheese or cottage cheese, falls between 20–60% that of milk. The B12 content of whole egg is between 0.9–1.4 μg/100g, mostly found in the yolk. Bioavailability of B12 from various preparations of eggs (e.g., scrambled, boiled) ranges from less than 4% to just over 9%.¹³

Fermented soy products, such as tempeh and other plant foods, do not contain biologically active forms of B12.³

**Supplements and fortified foods**

B12 is widely available in supplement form, mostly as cyanocobalamin, in pharmacies and health food stores throughout the United States. Other forms of this vitamin, such as methylcobalamin and hydroxycobalamin, can also be found. “Living” vitamin supplements, made from plants, do not contain biologically active B12. Using probiotics is not a reliable way to prevent B12 deficiency.¹⁴ In the U.S., many foods are fortified with B12. These foods include breakfast cereals, soymeat analogues, and soymilk. These foods contain from less than the adult RDA to more than 200% of the adult RDA for B12. Additionally, some brands of nutritional yeast are fortified with vitamin B12. It is important to read labels as not all cereals, meat analogues, soymilks, and nutritional yeast are fortified with B12, and the amount of fortification can change.¹²

**Bacteria-synthesized B12 in the small intestine**

Although some bacteria in the small intestine produce B12, this amount does not appear to be substantial enough to maintain adequate B12 status in humans.³,¹⁵

**Algae as a source of B12**

It was previously thought that algae, such as spirulina, nori and kombu, were believed to contain B12. However, studies not only showed that they almost exclusively contain inactive analogues of B12, but that they may
interfere with absorption and metabolism of the active B12 forms and thus may contribute to the development of B12 deficiency.3, 14

B12 Status of Vegetarians

The estimation of the prevalence of B12 deficiency among vegetarians varies widely from 12% to as much as 94%, depending upon several factors including deficiency definition, assessment method of B12 status and type of vegetarian diet.3, 4, 16, 17, 18, 19 Although it is theoretically possible to consume adequate B12 regardless of the type of vegetarian diet (either by consuming enough dairy and/or eggs or fortified foods), vegetarians are frequently diagnosed with a deficiency regardless of the type of diet to which they adhere. As a result, all vegetarians should be screened for deficiency.3, 4

Assessment of B12 Status

There are several B12 assessment techniques, such as serum or plasma B12, MCV, tHcy, TCII and serum or urinary methylmalonic acid (MMA). Of these tests, TCII and MMA are the most accurate, while serum B12 and MCV are believed to be unreliable.3, 4

Recommendations for Vegetarians

In order to prevent deficiency, vegetarians should include a reliable B12 source such as fortified foods or supplements. Because food fortification levels and practices change and the vitamin b12 content of eggs and dairy products is variable, the most reliable way for vegetarians to meet recommendations for B12 is to use a vitamin B12 supplement.

The following supplementation levels are suggested:

- All vegetarians, regardless of type, should periodically be screened for B12 deficiency, using either MMA or TCII assessment.
- All women considering pregnancy, and those already pregnant, should take 250 μg/d* of a B12 supplement.3
- All vegans should take 250 μg/d* of a B12 supplement.3
- All lacto-ovo vegetarians should consider taking 250 μg/d* of B12 supplement a few times per week.

*This amount is about 100 times higher than the RDA due to the fact that only about 1% of ingested B12 from supplements is absorbed.

References


Table 1. Clinical Manifestations of B12 Deficiency

<table>
<thead>
<tr>
<th>Types</th>
<th>Clinical manifestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematological</td>
<td>Megaloblastic anemia4 (large, immature RBC), Leukopenia20 (lower than the normal amount of white blood cells), Thrombocytopenia20 (abnormally low number of platelets in the bloodstream)</td>
</tr>
<tr>
<td>Neurological</td>
<td>Demyelination21,23 and Neuropathy21 (tingling and numbness in legs, paralysis), Dementia22 (memory loss, brain atrophy, white matter damage, cognitive deficits)</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>Psychosis,23 Irritability, Personality changes,24 Mild memory impairment,24 Hallucinations,24 Depression25</td>
</tr>
<tr>
<td>Other</td>
<td>Fatigue,24 Bone loss,26,27 Failure to thrive28,29 (developmental regression), Diabetic retinopathy22 (microvascular damage), Cardiovascular disease25 (vascular damage), Birth defects30</td>
</tr>
</tbody>
</table>
**Table 2. Content of B12 in selected plant products**

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight (g)</th>
<th>Common measure</th>
<th>B12 content (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snacks, granola bars, soft, uncoated, raisin</td>
<td>28.35</td>
<td>1 bar</td>
<td>0.05</td>
</tr>
<tr>
<td>Cereals ready-to-eat, Low Fat 100% Natural Granola with Raisins</td>
<td>50</td>
<td>1/2 cup</td>
<td>0.05</td>
</tr>
<tr>
<td>Mushrooms, white, raw</td>
<td>70</td>
<td>1 cup</td>
<td>0.03</td>
</tr>
<tr>
<td>Bread, mixed-grain, toasted (includes whole-grain, 7-grain)</td>
<td>24</td>
<td>1 slice</td>
<td>0.02</td>
</tr>
<tr>
<td>Rolls, dinner, plain, commercially prepared</td>
<td>28</td>
<td>1 roll</td>
<td>0.02</td>
</tr>
<tr>
<td>Cookies, fig bars</td>
<td>16</td>
<td>1 cookie</td>
<td>0.01</td>
</tr>
<tr>
<td>Margarine, regular, unspecified oils, with salt added</td>
<td>14.1</td>
<td>1 Tbsp</td>
<td>0.01</td>
</tr>
<tr>
<td>Pie, apple, commercially prepared, enriched flour</td>
<td>117</td>
<td>1 piece</td>
<td>0.01</td>
</tr>
<tr>
<td>Bread, cracked-wheat</td>
<td>25</td>
<td>1 slice</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Plant Products Fortified with B12**

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight (g)</th>
<th>Common measure</th>
<th>B12 content (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal (ready-to-eat)</td>
<td>1 cup</td>
<td></td>
<td>&lt; 1.0 to 6.2</td>
</tr>
<tr>
<td>Meat analogues</td>
<td>1 serving according to pkg</td>
<td>1.2 – 4.2</td>
<td></td>
</tr>
<tr>
<td>B12 fortified nutritional yeast</td>
<td>1 Tbsp</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Soymilk</td>
<td>8 fl oz</td>
<td></td>
<td>&lt; 1.0 to 3.0</td>
</tr>
<tr>
<td>Rice drink</td>
<td>8 fl oz</td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Source: https://www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/SR24/nutrlist/sr24w418.pdf


More references for this resource are available at http://vndpg.org/resources/B12