B12 and the Vegan Diet

All You Need To Know About Vitamin B12 in Vegetarian and Vegan Diets

By Dr Justine Butler

The association of vitamin B12 with animal foods such as fish, meat, poultry, eggs, milk and dairy products has helped create the myth that this vitamin can only be obtained from these foods and that a vegetarian or vegan diet provides a substandard amount. Consequently B12 has become a contentious issue. Concerns that vegetarians, and especially vegans, are at risk of B12 deficiency prevail even though the evidence suggests the meat-eating elderly are by far the group most likely to be deficient in B12. Furthermore, research suggests that the B12 present in meat, poultry and fish is not as easily absorbed as the B12 present in fortified vegetarian foods.

What are the B Complex Vitamins and Why Do We Need Them?

The B complex vitamins are a group of water-soluble compounds that act as 'cofactors' or helpers in different enzyme systems in the body. In other words, they are involved in a wide range of biochemical reactions in the body. Reactions include the synthesis of fatty acids and DNA.

Vitamin B12

Vitamin B12 is a complex molecule; its common name, cobalamin reflects the presence of the mineral cobalt in the centre of its structure. As with the other B vitamins, B12 helps build the material that makes up our genetic blueprint; our DNA. It is also particularly important in the production of red blood cells and in maintaining a healthy nervous system. B12 also helps release energy from our food. A further important role of B12 is to act in conjunction with folic acid (another B vitamin) in the synthesis of the amino acid methionine; this limits the build up of a potentially damaging molecule known as homocysteine (more on this later).

How Much Vitamin B12 Do We Need?

In the UK, the reference nutrient intake value (RNI) is used; this is similar to the Recommended Daily Amount (RDA) used previously. The RNI value for a nutrient is the amount of that nutrient that is sufficient for 97.5 per cent of the people in a given group. The UK government currently suggests that the RNI value for vitamin B12 in adults aged between 19 and 50 years of age is one-and-a-half micrograms per day (1). The current European Union (EU) recommended daily allowance is even lower at only one microgram per day. These figures are based on preventing B12 deficiency and therefore may not represent the optimum intake. It has been suggested that three micrograms per day from fortified foods (or 10.0 micrograms per day from a supplement if you don't eat fortified foods) should ensure an adequate intake of B12 and minimise the build up of homocysteine (2). Currently, there isn't enough evidence to know what the effects of taking high doses of vitamin B12 supplements each day might be.

Food Sources of Vitamin B12

Vitamin B12 is manufactured by microorganisms (bacteria, fungi and algae) - especially bacteria in soil and water, and to some extent bacteria in the gut, although production in the gut occurs in a different area to where absorption takes place. Animals obtain B12 from food and water contaminated with these microorganisms. Plants do not require B12 and therefore have no mechanism to produce, absorb or store it. Therefore humans must obtain B12 in the diet, either from animal sources (red meat, fish, poultry, eggs and dairy products) or from fortified plant-based foods. While plants do not naturally contain B12, they may carry some through microbial contamination. Plant-eating primates such as the gorilla (and our human ancestors and many people in developing countries) obtain a plentiful supply of B12 from their consumption of plants due to the presence of insects and bacterial contamination of their plant foods and water. Some primates eat faeces and soil which may also provide a source of B12. When fed a sanitised diet, in a zoo for example, primates often develop B12 deficiency (2).

In modern society, fruit and vegetable production is far more sanitised in that fruit and vegetables for sale in supermarkets are washed in chlorine. This removes the B12-producing bacteria and so vegetarians and vegans must obtain vitamin B12 from other sources, this means fortified foods. The industrial production of vitamin B12 for the fortification of foods involves fermentation with bacteria. Large-scale production is carried out using a number of bacterial species, including for example *Pseudomonas denitrificans, Propionibacterium freudenreichii* and *Propionibacterium shermanii*. Bacterial cultures are grown in huge vats for the extraction of B12.

B12 can be obtained from many everyday food items that are fortified such as veggie burger and sausage mixes, yeast extracts, vegetables stocks, margarines, breakfast cereals and soya milks. See below for guide to how much B12 is contained in a range of these foods.

So, as the table shows, the EU recommended daily amount of B12 can be obtained for example from one slice of Meridian yeast extract on toast or one glass of B12–fortified soya milk.

In the past, spurious claims have been made that certain fermented soya foods such as miso, tamari and tempeh are rich in vitamin B12; the B12 content of these foods may vary widely and cannot be depended on as a reliable source. Furthermore there have been claims that the algae spirulina and the seaweed nori contain

Product (and serving size)	B12 (micrograms)
Sosmix and Sosmix Country herb (175g sachet- around six sausages)	0.26
Marmite (typical 4g serving- enough for one slice of toast)	0.6
Meridian Yeast Extract (typical 4g serving- enough for one slice of toast)	2.0
Vecon vegetable stock (5g serving- one small teaspoonful)	0.65
Pure Soya and Pure Sunflower spread (typical 10g serving- enough for two pieces of toast)	0.5
Alpro soya milk with B12 (200ml glass)	1.0

Note that some of the organic versions of these products are not fortified with B12.

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significant amounts of B12. However, the current consensus now is that they contain compounds structurally similar to B12, known as B12 analogues, which may disrupt normal B12 metabolism by competing with B12 for absorption. It is wise to assume that no plant foods can be relied on as an adequate source of vitamin B12. While vegetarians may obtain some of their B12 from free-range eggs and dairy products, vegans must obtain their B12 from fortified foods. To ensure that you get enough vitamin B12 become a label reader! If the food is fortified then B12 will be listed in the list of ingredients (how much is present will be given in the nutritional information). Check the nutritional information on the label of fortified foods to ensure that you are getting sufficient B12; it is quite easy to attain the target of three micrograms of B12 per day using fortified foods. Frequent use of fortified foods will ensure an adequate intake for most healthy people.

Vitamin B12 Absorption

B12 metabolism is complex and requires many processes. The first stage is consumption of B12-containing food. B12 from meat is bound to animal protein. In order to absorb this form of B12 gastric secretions are required to remove the animal protein and release the B12. B12 produced by bacteria (used in fortified foods) is not bound in this way and so is easier to absorb. Once the animal protein is removed (or if it was never present as in fortified foods supplemented with B12 produced by bacteria), the free B12 binds to other proteins to form complexes that travel further along the digestive system. Enzymes break up these complexes to release the B12 molecule which then binds with an important molecule called intrinsic factor. B12 can only be absorbed in the small intestine in the presence of intrinsic factor. The B12-intrinsic factor complex attaches to cells in the final section of the small intestine (the ileum) where transport proteins bind to it and distribute it into cells all around the body (the liver is the predominant storage site). B12 enters the cells where it is broken down and converted into biologically useful molecules.

The ability to absorb B12 is important but it is not the only factor that determines B12 status. The bioavailability of the B12 in the diet is just as important as including B12 in the diet; it is pointless consuming lots of B12-rich food if it occurs in a form that the body cannot absorb. The bioavailability of B12 from different food sources has been shown to differ. It has been shown that B12 in fortified foods (such as breakfast cereals) is easier to absorb than the B12 in meat, poultry and fish sources; this seems to apply particularly to the elderly. Indeed, the National Academy of Sciences in the US advise that adults aged 50 and over obtain most of their B12 from supplements or fortified foods, this raises the question that maybe younger adults should consider using these sources as well (7).

Vitamin B12 Deficiency

B12 deficiency can be divided into four stages. First of all, levels of B12 in the blood drop, then levels of B12 in the cells fall, then a biochemical deficiency occurs whereby levels of B12-related compounds are disrupted and finally clinical deficiency (or megaloblastic anaemia) occurs (3). This condition is characterised by abnormally enlarged immature red blood cells that are unable to divide properly. The abnormal cells are unable to transport oxygen efficiently thus chronic vitamin B12 deficiency can lead to a range of problems from fatigue, tingling and numbness of the limbs (4) to damage to nerve cells (3), the spinal chord (5) and the brain (6). In extreme cases paralysis or death may result from vitamin B12 deficiency.

What Causes B12 Deficiency?

B12 deficiency is rare; the most common cause is malabsorption which results from some condition of the stomach or of the small intestine. This type of deficiency usually requires treatment with B12 injections. This type of deficiency has nothing to do with the amount of B12 present in the diet - it arises from inadequate absorption due to a wide range of physiological or medical conditions. Furthermore, B12 absorption tends to decrease with age (7). For example, in the elderly a decline in the production of acid in the stomach may reduce B12 absorption, although this mainly affects B12 absorption from meat. The most common cause of B12 deficiency in the UK is the loss of intrinsic factor; this may result from a genetic predisposition and tends to be age-related (3).

B12 deficiency can arise if any of the stages of metabolism are not completed. For example B12 malabsorption may occur if surgery has been performed on the digestive system (such as a gastrectomy or ileal resection) or in the case of gastrointestinal disorders such as Crohn's disease (8). In autoimmune diseases the body's normal responses to molecules perceived as foreign invaders (such as bacteria and viruses) go wrong and the body attacks itself. A condition called pernicious anaemia may result from an autoimmune disease that targets the cells that produce intrinsic factor, this condition is characterised by large immature red blood cells. Pernicious anaemia is most common in older people. It affects about 1 in 8,000 people over the age of 60. It is more common in women than in men and in people with fairer colouring. Symptoms of anaemia include tiredness, shortness of breath and palpitations. In some more serious cases symptoms may include soreness of the tongue, weight loss, paling skin colour, diarrhoea and poor resistance to infections. In extreme cases there may be a tingling sensation in the fingers and toes, muscle weakness and confusion.

Additional causes include stomach infections with the bacterium *Helicobacter pylori* (3), the single-celled parasite *Giardia lamblia* (9) or the parasitic worm *Enterobius vermicularis* (10). These parasites can interfere with normal B12 absorption by competing with the host organism (that could be you!) for the B12 present in the diet.

The total number of people estimated to have B12 deficiency varies widely; this is largely due to how B12 deficiency is defined. The discrepancy in the figures reflects how B12 deficiency may go undiagnosed as symptoms are subtle and may not be noticed. A recent review reported that B12 deficiency is estimated to occur in anything between five and 60 per cent of the general population of industrialised countries (11). This suggests B12 deficiency is a problem for meat, poultry and fish eaters as much as anyone else. Indeed it may be worse for them as they do not actively seek out fortified foods and the B12 they consume is bound to animal protein. However, in 2004 a UK government survey suggested that only two per cent of men and four per cent of women had a serum vitamin B12 concentration below the limit of the normal range (1). Vitamin B12 deficiency does however occur frequently in the elderly (12), indeed it has been estimated that up to 40 per cent of elderly people suffer B12 malabsorption due to atrophic gastritis; inflammation of the stomach leading to a reduction in acid production (7).

More rarely, B12 deficiency may occur among people whose diets lack any B12. This type of deficiency is very rare but the consequences can be extremely serious, especially for infants. Furthermore, when vitamin B12 is absent from the diet, deficiency may take some time to occur as stores in the liver are used up. The authors of a recent review of studies on B12 deficiency agree that nutritional deficiency of B12 is rare among healthy adults in industrialised countries and estimate that deficiency caused by lack of B12 in the diet only accounts for five per cent of all cases seen (13).

Homocysteine

Since the early 1990s the amino acid homocysteine has become the subject of much interest among the scientific community. Evidence suggests that homocysteine damages the lining of blood vessels and enhances blood clotting. Elevated

concentrations of homocysteine in the blood have been linked to an increased risk for heart disease and stroke. Some studies suggest it may have an even more important role in determining the health of individuals than cholesterol (2). Homocysteine is converted into the amino acid methionine in the presence of B12. In the same reaction, methyltetrahydrofolate is converted to folate which is used in the synthesis of DNA. This entire reaction relies on sufficient supplies of B12, B6 and folate. In B12 deficiency, the amount of homocysteine in the body can escalate to potentially dangerous levels and has been linked to a range of disorders including depression, dementia, damage to the inner lining of the artery walls and may be a trigger for heart disease. While increased homocysteine levels have been observed in vegetarians and vegans they do not occur in those ensuring an adequate B12 intake of three micrograms per day. Whereas elevated homocysteine levels are not uncommon among meat-eaters due to a low folate intake (2), and tend to increase in the elderly for reasons discussed above. Interestingly a recent study showed how a daily serving of breakfast cereal fortified with folic acid, B6 and B12 not only contributed to the plasma status of these vitamins but significantly reduced homocysteine concentrations in a randomly selected group of relatively healthy 50-85 year olds (14), these were not vegetarians or vegans!

How is B12 Deficiency Diagnosed and Treated?

Vitamin B12 deficiency may be diagnosed by measuring the levels of serum B12 or by measuring the levels of homocysteine which can accumulate to high levels in the absence of B12. However, high homocysteine levels can also be caused by folate or vitamin B6 deficiencies. Conventionally vitamin B12 deficiency is treated with a course of intramuscular injections. A B12-like compound called hydroxocobalamin is injected into the muscle every two to four days. Around six injections are given to build up stores of vitamin B12 in the liver. Blood tests are given periodically to monitor the success of the treatment (15).

Vegetarians, Vegans and Vitamin B12 Deficiency

Several reports single out vegetarians, and particularly vegans, as a high risk group for vitamin B12 deficiency (16, 17, 18). One extensive UK study described the nutrient intakes of over 65,000 people including 33,883 meat-eaters, 10,110 fish-eaters, 18,840 lacto-ovo vegetarians and 2,596 vegans (19). This EPIC-Oxford cohort currently includes the largest number of vegetarians than any comparable study in the world. The study concluded that vegans had the highest intakes of fibre, vitamin B1, folate, vitamin C, vitamin E, magnesium and iron, and the lowest intakes of retinol, vitamin B12, vitamin D, calcium and zinc. But this does not necessarily mean they were deficient in any of these nutrients. Furthermore, the study acknowledged that the actual intakes of B12 and calcium might now be higher because the number of foods fortified with B12 has increased in recent years. It may be that vegetarians and vegans have gained an advantage in that they are used to routinely consuming B12-fortified foods and are therefore less likely to experience B12 deficiencies associated with age-related gastrointestinal conditions.

Numerous studies now demonstrate that any actual deficiencies of B12 in a vegetarian or vegan diet are usually due to poor meal planning (20). While vitamin B12 may be the nutrient most likely to be missing from a vegetarian or vegan diet, meat remains an optional rather than essential constituent of the diet as a well-

balanced vegetarian or vegan diet can support normal growth and development (21). Indeed it has been demonstrated that vitamin B12 from fortified foods is better absorbed than B12 from meat, poultry and fish. In the US, the Institute of Medicine of the National Academy of Sciences recommends that adults over 50 years obtain B12 from vitamin supplements or fortified foods because of the high incidence of impaired absorption of B12 from animal foods in this age group (22).

Summary

- B12 helps make fatty acids, DNA, red blood cells and helps the nervous system work.
- The UK government suggests an RNI of one-and-a-half micrograms of B12 per day.
- B12 is made by microorganisms in the soil and water. It is consumed in the diet and taken to every cell in the body, plants do not contain B12.
- Plant-eating primates such as the gorilla (and our human ancestors and many people in developing countries) obtain a plentiful supply of B12 from their consumption of plants due to the presence of insects and bacterial contamination of their plant foods and water.
- B12 is in red meat, fish, poultry, eggs and dairy products; and in fortified foods: veggie burger mixes, yeast extracts, margarines, breakfast cereals and soya milks; or supplements.
- Fermented soya foods and seaweeds do not provide a reliable source of B12.
- B12 from meat is bound to animal protein and so is more difficult to absorb than in its natural unbound form produced by bacteria.
- B12 deficiency can lead to serious health problems especially in the very young.
- B12 deficiency tends to increase with age; up to 40 per cent of the UK's meat-eating elderly population suffers from low B12 due to a reduction in their ability to absorb this vitamin.
- Nutritional deficiency of B12 is rare among healthy adults in industrialised countries.
- A lack of B12, B6 and/or folate can lead to raised homocysteine levels which have been linked to heart disease and stroke; this can affect meat-eaters, vegetarians and vegans.
- B12 deficiency may be treated by a course of injections.
- B12 intakes among vegans are thought to be increasing, reflecting the increase in the number of B12-fortified products available (and a raised awareness). This will undoubtedly confer an advantage on vegans in later life who are used to ensuring B12 is present in their diet.
- You can obtain three micrograms of B12 per day by consuming a wide range of fortified foods.
- A well-planned and varied vegetarian or vegan diet including B12-fortified plant-based foods not only meets our requirements but provides a healthier and safer source of vitamin B12.

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