B12 and the vegan diet

All you need to know about vitamin B12 in vegan diets

Viva! HEALTH

The association of vitamin B12 with animal products such as meat, fish, eggs and dairy has helped create the myth that these foods are a natural source and that vegans will inevitably miss out. Vitamin B12 is essential, but if you eat meat, you won't automatically get enough and if you're vegan, it doesn't mean you'll end up with a deficiency.

Why do we need vitamin B12?

Vitamin B12 is a complex molecule – its chemical name, cobalamin, reflects the presence of the mineral cobalt in the centre of its structure. In the human body, B12 is essential for 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. In addition, B12 helps to release energy from our food and is vital in amino acid and fatty acid metabolism.

Sources of B12

In nature, a range of bacteria manufacture vitamin B12. These bacteria are present in soil and water and before the advent of modern farming and improved hygiene, people probably consumed enough food contaminated with these bacteria to cover their B12 needs (Zugravu *et al.*, 2021). Plants do not require B12 and therefore have no mechanism to produce, absorb or store it.

People and most animals have B12-producing bacteria living in their intestines. In people, these bacteria are too far down the digestive tract for the B12 they make to be absorbed. Nevertheless, faeces in general tend to be a rich source of B12 – that we certainly do not recommend – but it's a source of B12 for many animals and may explain why in predominantly vegetarian populations in areas lacking sanitation, poor people tend to have a better B12 status than the urban middle class (Sobczyńska-Malefora *et al.*, 2021).

In nature, pigs and chickens would eat a variety of foods that ensure vitamin B12 intake but at farms, where they don't have any access to their natural environment, they must receive B12 supplemented feed. Pork, chicken meat and eggs only contain B12 because these animals are given supplements (and also may eat their own excrements or contaminated feed).

Interestingly, pork-based products have significantly lower vitamin B12 content (and iodine), around one-third less, compared with the early 1990s (Niklewicz *et al.*, 2023). This may be because pigs are no longer fed animal offal which is a rich B12 source.

Ruminants, such as cows and sheep, do have B12-producing bacteria in their stomachs but they need the mineral cobalt to make B12. Therefore, ruminants receive either cobalt-fortified food or mineral licks. This applies to both factory-farmed and grazing animals because pasture soil often doesn't have enough cobalt in it.

In short, most animal products only contain B12 because the animals were given supplements and so are not a more natural source of this vitamin than if you take a supplement yourself.

No plant food is a reliable source of vitamin B12, except for B12-fortified products, such as plant milks, some mock meats, cereals or nutritional yeast but those alone cannot guarantee a sufficient intake (Rizzo *et al.*, 2016). There have been many claims about various plant foods containing vitamin B12 but most of these don't stand up to scientific scrutiny. According to two studies analysing the evidence on B12 in plant-based foods, only the seaweeds hijiki, nori and chlorella, mushrooms, a few non-common plants and a type of fermented soya yoghurt contained some – all due to bacterial activity – but amounts vary with some of the samples containing no B12 (Watanabe and Bito, 2018; Marques de Brito *et al.*, 2023).

All vegans should take a B12 supplement to ensure adequate B12 intake. Vitamin B12 for supplements is made using bacterial cultures and so is always vegan (Fang *et al.*, 2017).

How much vitamin B12 do we need?

The UK Government suggests that adults aged between 19 and 50 years of age need 1.5 micrograms per day (NHS, 2020). The current European Union (EU) recommended daily intake is 1.5 micrograms for infants and children under six, 2.5 micrograms for seven to 10-year-olds, 3.5 micrograms for 11 to 14-year-olds, four micrograms for everyone over 15, increasing to 4.5 micrograms during pregnancy and five micrograms for breastfeeding women (EFSA, 2015).

These figures are based on preventing B12 deficiency and therefore may not represent the optimum intake. It has been suggested that vitamin B12 daily requirement actually ranges between four and 20 micrograms (EFSA, 2015).

Not all B12 that you eat or take in supplements is absorbed and research indicates that to achieve a sufficient daily dose of B12, you should take at least five to 50 micrograms daily or 1,000 to 2,000 micrograms weekly (Del Bo' *et al.*, 2019; Benham *et al.*, 2022). Viva! Health recommends the higher doses – 50 micrograms daily or 2,000 weekly.

The reason we advise 50 micrograms a day or 2,000 a week is because the less frequently you take vitamin B12, even at high doses, the percentage your body absorbs drops. So, a high oral dose of 2,000 micrograms might only deliver 26 micrograms of B12 into the body (Carmel, 2008). However, it's much better to take a daily supplement as you absorb more from it than from one large weekly dose (more on that below) (Zugravu *et al.*, 2021).

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Absorption of vitamin B12

B12 metabolism is complex and includes many processes. The first stage is consumption of B12-containing food. Vitamin B12 in animal products is always bound to protein. In order to absorb this form of B12, stomach secretions are required to remove the animal protein and release the B12. The B12 used in fortified foods and supplements it is not bound this way and so is easier to absorb.

The next step is for B12 to be bound to other proteins so it can travel further along the digestive system. In the small intestine, enzymes break these bonds to release the B12 molecule which then binds with a special protein called intrinsic factor (IF). B12 can only be absorbed in the presence of IF. The B12-IF complex is absorbed by cells in the final section of the small intestine (the ileum), where IF is cleaved from B12 and subsequently, B12 passes into the blood where transport proteins bind to it and is distributed to cells all around the body (Obeid *et al.*, 2015; Temova Rakuša *et al.*, 2022).

A small amount of the ingested vitamin B12 (one to two per cent) is absorbed by passive diffusion – simply crossing the cell membranes without binding to anything (Temova Rakuša *et al.*, 2022).

When B12 enters the cells, it is converted into active forms necessary for vital reactions in the cells. The liver and kidneys are an exception because they serve as storage facilities for B12. In fact, the liver stores so much B12 that it can take years for a deficiency to develop (EFSA, 2015; Temova Rakuša *et al.*, 2022).

Vitamin B12 absorption depends on stomach secretions and IF – the more of it you produce, the more B12 can be absorbed. Another factor is the amount of receptors that your small intestine cells have for the B12-IF complex which is largely determined by your genes.

Interestingly, while you absorb 40 to 50 per cent of vitamin B12 from foods, including fortified foods, the absorption from supplements depends on the dose (EFSA, 2015; Benham *et al.*, 2022). For example, if you take five micrograms, you absorb around 1.2 micrograms; if you take 25 micrograms, you absorb 1.6 micrograms; and if you take 100 micrograms, you absorb 2.4 micrograms. Remember, these numbers are estimates – your ability to absorb B12 depends on the factors above and also on the bioavailability of the B12 your diet.

There's also the option of B12 injections from which you absorb around 10 per cent of the dose and this doesn't vary as much as with oral B12 intake (Temova Rakuša *et al.*, 2022). Studies show that sublingual (under the tongue) and nasal forms of B12 supplements offer a similar absorption rate as injections (Temova Rakuša *et al.*, 2022).

In older age, vitamin B12 absorption tends to be less efficient due to a range of health issues, including gastritis – stomach lining inflammation and thinning – but also because of decreased production of stomach secretions (EFSA, 2015; Sobczyńska-Malefora *et al.*, 2021). That's why everyone over the age of 50 should take a supplement, regardless of their diet.

If you have more B12 than the body needs and is able to absorb, the excess is excreted in urine (EFSA, 2015; Temova Rakuša *et al.*, 2022).

What hinders B12 absorption?

It's clear that to be able to absorb vitamin B12, you need a healthy digestive system. Stomach issues, such as gastritis, infection with Helicobacter pylori or bariatric surgery (reducing stomach size) can all significantly reduce B12 absorption (Sobczyńska-Malefora *et al.*, 2021). Both Crohn's disease and colitis severely affect gut health and can prevent sufficient B12 absorption (Sobczyńska-Malefora *et al.*, 2021). The same applies to people who had surgery removing a part of or the whole stomach or small intestine.

Some medications also reduce B12 absorption (Sobczyńska-Malefora *et al.*, 2021) – among the main ones are: metformin, proton pump inhibitors (PPIs), such as omeprazole, lansoprazole and esomeprazole, and H2-receptor antagonists, such as ranitidine, cimetidine, famotidine and nizatidine.

Interestingly, oral contraceptives also reduce B12 absorption – according to research, women taking them have as much as 45 per cent lower levels of B12 compared to women not on the pill (Riedel *et al.*, 2005; McArthur *et al.*, 2013).

Nitrous oxide, aka laughing gas, is commonly used for sedation and pain relief, but it is also widely abused for its ability to induce a very brief 'high'. The gas is also a food additive used as a propellant for whipped cream. It disrupts vitamin B12 structure and disables a number of reactions vital in B12 metabolism in the body. If it's used for a medical procedure, it won't cause lasting effects but if it's frequently used recreationally, it can seriously affect B12 levels, cause a deficiency and impair healthy functioning of the body (Campdesuner *et al.*, 2020; Sobczyńska-Malefora *et al.*, 2021).

Pernicious anaemia is an autoimmune disease that causes inadequate production of IF, the protein vital for B12 absorption. It can cause severe deficiency even with an adequate B12 intake. People with pernicious anaemia need large doses of vitamin B12 given at regular intervals, usually as an intramuscular injection (Obeid *et al.*, 2015; Temova Rakuša *et al.*, 2022).

Some people may have poor B12 absorption due to genetics and therefore need an individual B12 intake plan to maintain healthy levels (Temova Rakuša *et al.*, 2022).

And lastly, alcohol abuse may also impair B12 levels and metabolism (Temova Rakuša *et al.*, 2022).

Recommended daily intake of B12, accounting for imperfect absorption (µg)

Six months to three years	5
Four to 10 years	25
From 11 years	50

(Agnoli *et al.*, 2017; Baroni *et al.*, 2018; Del Bo' *et al.*, 2019; Benham *et al.*, 2022)

Different types of B12

Vitamin B12, also called cyanocobalamin, is turned into its active co-enzyme forms – adenosylcobalamin and methylcobalamin – within your cells. A step between cyanocobalamin and the two active forms is hydroxycobalamin.

Cyanocobalamin is a stable and inexpensive form of B12 made by bacteria and commonly used for food fortification and supplements. The other forms – hydroxycobalamin, adenosylcobalamin and methylcobalamin are also available as supplements but they are less stable and more expensive.

When you take a cyanocobalamin supplement, it needs to be converted into methylcobalamin and adenosylcobalamin in order to fulfil its biological function so it's been suggested that taking the active forms directly makes it a superior, more straightforward way of obtaining B12.

However, research shows that all forms of B12 follow the same route of absorption, including being bound to and released from the same transport and other proteins and so researchers believe that supplementing with adenosylcobalamin or methylcobalamin is unlikely to offer an advantage over cyanocobalamin in healthy people (Obeid *et al.*, 2015).

Numerous studies have shown that all four vitamin B12 forms are converted to the same intermediate form in the cells and during this process, ligands of the specific supplemented vitamin B12 form – cyano, hydroxy, adenosyl or methyl – are removed (Obeid *et al.*, 2015; Paul and Brady, 2017; Zugravu *et al.*, 2021; Temova Rakuša *et al.*, 2022). The intermediate form is then converted into methylcobalamin in the cell and into adenosylcobalamin in mitochondria (the powerhouses of our cells).

What's important is that all four vitamin B12 forms are reported as being effective in improving B12 levels in the human body (Paul and Brady, 2017; Temova Rakuša *et al.*, 2022).

In people with a genetic disorder affecting intracellular vitamin B12 metabolism, hydroxycobalamin achieves the best results (Obeid *et al.*, 2015; Paul and Brady, 2017). People with specific digestive disorders or conditions affecting their digestive tract should follow their health professional's guidance and personalised advice.

Whatever form you use, follow the product's storage instructions strictly to ensure that the B12 in it doesn't degrade.

B12 and cooking

When we consider vitamin B12 content in foods, we must take into account the effect of cooking. Studies found that 40 to 59 per cent of B12 in meat, fish and cow's milk is degraded during cooking (Rizzo *et al.*, 2016; Temova Rakuša *et al.*, 2022).

There isn't enough data on B12 fortified foods and cooking but as high temperatures lasting for an extended period of time are needed for B12 to be destroyed, it's unlikely that, for example, heating plant milk for coffee would cause significant losses.

What happens when you have B12 deficiency?

We store vitamin B12 in the liver – some of it is continuously excreted with bile into the small intestine where it's absorbed again. This way it gets largely recycled so even if you don't have any B12 in your diet, it can take years for deficiency to develop (Temova Rakuša *et al.*, 2022).

Vitamin B12 deficiency typically causes a condition called megaloblastic anaemia – making red blood cells too large and reducing their numbers. It's a serious condition because it reduces oxygen transport around the body and the most common causes by far are vitamin B12 and folate deficiency (Hariz and Bhattacharya, 2023). Symptoms of the disease include weakness, tiredness or even exhaustion and dyspnoea – a sensation of running out of the air and of not being able to breathe fast enough or deeply enough.

Another set of B12 deficiency symptoms are neurological, such as irritability, memory problems, depression, visual disturbances, tingling or numbness of hands and feet, pins and needles and eventually, in severe cases, a dementia-like illness, psychosis with hallucinations and paranoia (EFSA, 2015; Temova Rakuša *et al.*, 2022). Long-term deficiency may cause nerve damage and if treatment comes too late, the damage may be irreversible (Rizzo *et al.*, 2016).

Sometimes, B12 deficiency triggers gastrointestinal symptoms, such as appetite loss, sore tongue and mouth, stomach discomfort, heartburn, nausea and even vomiting (Sobczyńska-Malefora *et al.*, 2021). Some people may also experience loss of taste and smell.

There's yet another serious issue that B12 deficiency causes and that's accumulation of homocysteine and methylmalonic acid in the blood but it doesn't produce any specific symptoms – a blood test would be able to reveal these issues (EFSA, 2015; Temova Rakuša *et al.*, 2022). However, this situation is very dangerous in the long term – see more below.

In infants, vitamin B12 deficiency results in a number of serious symptoms and may be linked to cerebral atrophy – loss of brain cells (EFSA, 2015). B12 deficiency in pregnancy may negatively impact the baby's development and lead to failure to thrive and other complications (Rizzo *et al.*, 2016). It is vital that pregnant and breastfeeding women have adequate B12 intake and vegan children must receive a B12 supplement from the age of six months (Agnoli *et al.*, 2017; Baroni *et al.*, 2018).

Each case of B12 deficiency may have a different combination of symptoms, probably depending on the person's folate levels (Sobczyńska-Malefora *et al.*, 2021). It would be extremely rare for a person to experience all of them at once.

Homocysteine

Vitamin B12 deficiency leads to the accumulation of the amino acid homocysteine in the blood. Elevated homocysteine levels have been linked to the increased risk of cardiovascular disease, stroke, osteoporosis, Alzheimer's disease, Parkinson's disease, dementia, diabetes and more (Rizzo *et al.*, 2016; Kumar *et al.*, 2017).

Under normal circumstances, homocysteine is an in-between step in amino acid metabolism. It's formed from the amino acid methionine (and can also revert back to become methionine again) and is then converted into another amino acid – cysteine. This only happens in the presence of B12 and when there's deficiency, homocysteine levels build up. Vitamins B6 and folate are also needed for the process.

Interestingly, meat and dairy consumption increase homocysteine levels as well and a diet high in meat can achieve dangerously high levels (Grant, 2016; Kumar *et al.*, 2017).

The reason why homocysteine is dangerous is because it damages cells and tissues of the arteries, triggers inflammatory reactions and enables cholesterol oxidation, which contributes to the build-up of atherosclerotic plaques – the main culprits in cardiovascular disease (Kumar *et al.*, 2017). Research also suggests that high homocysteine levels may affect the blood-brain barrier, contribute to the build-ups of amyloid plaques (in Alzheimer's disease), reduce bone density, impair correct functioning of insulin and even promote cancer cell division (Kumar *et al.*, 2017). In infants, high homocysteine levels can cause serious developmental problems.

Who needs a B12 supplement?

Vitamin B12 supplements are recommended to population groups at higher risk for developing vitamin B12 deficiency: everyone (no matter what their diet) over 50 years old, people with diseases of the gastrointestinal system such as Chrohn's and IBS, women on oral contraceptives and people who regularly use nitrous oxide or are alcoholics.

Also vegans, vegetarians, the elderly, pregnant and lactating women – even when B12 fortified foods are consumed (Temova Rakuša *et al.*, 2022).

There's no bargaining – research clearly shows that consuming fortified foods alone may be insufficient to cover your B12 needs and, as described above, when symptoms of B12 deficiency develop, it may be too late to repair the damage.

How much is too much?

According to The European Food Safety Authority (EFSA, 2015), no adverse effects have been associated with excess B12 intake from food or supplements in healthy individuals. Even long-term daily doses between one and five milligrams (1,000 to 5,000 micrograms) given to patients with compromised B12 absorption did not reveal side effects. However, the UK Government says to avoid taking too much, as it could be harmful. They say taking two milligrams (2,000 micrograms) or less a day of vitamin B12 in supplements is unlikely to cause any harm.

Beware of B12 analogues

Some foods contain so-called B12 analogues – molecules that are almost the same as B12 but not quite. The analogues are dangerous because they can block your B12 receptors and prevent the real B12 from being absorbed. Some algae that are advertised as a source of B12, such as spirulina, in fact, contain these analogues (Rizzo *et al.*, 2016).

Is taking a B12 supplement necessary for vegans?

Yes, it is. Studies show that vegans and vegetarians who don't take any B12 supplements have markedly lower B12 status and may be at risk of deficiency or already deficient (Gallego-Narbón *et al.*, 2019; Selinger *et al.*, 2019; Storz *et al.* 2023). Because B12 deficiency takes years to develop, your B12 status depends on how long you've been vegan or vegetarian and if you eat any B12 fortified foods. However, experts agree that it is necessary for vegans to take a B12 supplement to ensure that enough of it is absorbed.

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