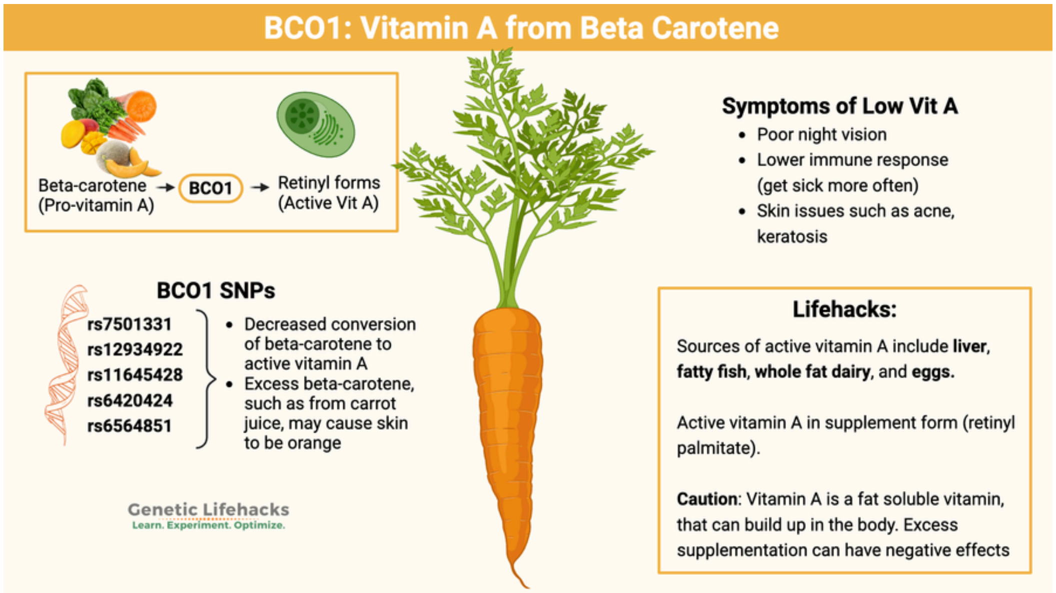
BCO1 Gene: Converting Beta-Carotene to Vitamin A



Key Takeaways:
~Beta-carotene is converted to active vitamin A by the BCO1 gene.
~Variants in the BCO1 gene decrease the conversion of beta-carotene to the active form of vitamin A used by the body. This means that people with BCO1 variants may not be getting as much vitamin A from plant sources.
~Low vitamin A can lead to poor night vision, skin problems, and lower immune response.

Vitamin A and Beta Carotene:

Vitamin A is a general term that covers several different forms of the vitamin.

- Animal food sources mainly provide retinyl palmitate, which breaks down in the intestines into retinol. It is stored, in this form, by the body and then converted to an active form for use.
- Carotenes are the plant forms of a precursor to vitamin A. The most common form, beta-carotene, shows up in abundance in carrots and other orange-colored foods. An enzyme in the intestine breaks down beta-carotene, converting it into retinol.[ref]

Interestingly, most carnivores (entirely meat-eating animals) are poor converters of beta-carotene. For example, cats cannot create any vitamin A from beta-carotene.

How does the body use vitamin A?

About 80-90% of the retinoids in the body are stored in the liver and used to maintain a steady level in the blood.[ref]

The cells in your body use retinoids in a variety of ways.

Retinol is important for:

- Stem cells
- Photoreceptors in the eye
- Epithelial cells
- Embryonic cells
- Various immune cells
- Red blood cells
- Circadian rhythm
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Deficiency: A deficiency in vitamin A can cause poor night vision, worsen infectious diseases, and, when severe, cause blindness. In the immune system, retinol is involved with both innate and adaptive immune responses.[ref]

Skin problems: Low levels of vitamin A may cause skin problems such as some types of acne and keratosis pilaris (bumps on the back of the arms).[ref]

How is beta-carotene absorbed?

Carotenoids, including beta-carotene, are produced by a number of different plants and some microorganisms (bacteria and algae). While over 600 different carotenoids are produced in nature, only about 20 have been identified in humans via their dietary intake. The primary sources of carotenoids in the diet are colorful fruits and vegetables, such as carrots and spinach.[ref]

Beta-carotene (and all the carotenoids) are fat-soluble micronutrients. They are digested in the upper part of the digestive tract and dissolve in any available fat from the meal. It forms a micelle (droplets of fat surrounding a molecule), easily absorbed in the intestines.

Processing – or how the food is prepared – also impacts the absorption of beta-carotene. A study investigating the bioavailability of beta-carotene and other carotenoids found that raw carrots had about a 2% bioavailability for beta-carotene, while carrot juice was much higher at 14%.[ref]

Within the intestines, the beta-carotene has to be taken into the intestinal cells, called enterocytes. Recent research shows that there are a couple of transporters that facilitate this process.[ref]

How is beta-carotene converted to vitamin A?

Once beta-carotene has been digested, mixed with fats, and absorbed, it has to be converted into retinol. This conversion uses the enzyme β-carotene 15,15′-monooxygenase (BCO1 gene), which converts beta-carotene into retinal. The retinal converts into retinol.[ref] BCO1 is also known as BCMO1.

Genetic variants in the BCO1 gene cause varying amounts of the enzyme to be produced and cause a large difference in the amount of vitamin A produced from dietary beta-carotene.

There is also a feedback loop in the body where higher levels of retinoic acid will decrease the production of the BCO1 enzyme, thus decreasing the amount of beta-carotene converted to retinal.[ref]

The BCO1 enzyme is active in the intestines, liver, and mucosal epithelium (e.g., lining of the lungs). As a result, the conversion of beta-carotene to vitamin A occurs in all of those locations.[ref]

Are you turning orange from carrot juice?

Interestingly, up to 40% of carotenoids are not metabolized and used by the body.[ref] This can have consequences when you consume a lot of foods high in beta-carotene.

For example, excessive consumption of carrot juice causes your skin to take on an orange-ish hue called carotenemia.[ref] A carotenoid reflection spectroscopy device (called the Veggie Meter :-) tests the changes in skin hue from carotenoid consumption.[ref]

The orangish coloration in some salmon species is another example of beta-carotene not being converted. Salmon do not convert carotenoids into vitamin A very well and thus accumulate these colorful nutrients in their flesh, depending on the carotenoid content of their diet.[ref]

Is consuming large amounts of beta-carotene healthy?

Some people consider turning orange from too much beta-carotene benign, but studies indicate excess beta-carotene may not be a good thing.

First, let me caution that the research is not definitive on this topic. Therefore, I will simply present the research and let you draw your conclusions.Overall mortality rates are lower in people with higher levels of beta-carotene. It indicates links between higher fruit and vegetable consumption and lower all-cause mortality.[ref]

Increased Cancer Mortality: On the other hand, some large studies using beta-carotene supplementation to prevent cancer showed increased deaths linked to beta-carotene supplementation for a couple of specific types of cancer.

One large study (18,000+ people) included smokers, former smokers, and people exposed to asbestos. Half of the study participants received a combo of beta-carotene and vitamin A, and the other half received a placebo. The results showed a 46% increase in the relative risk of lung cancer in the group receiving the beta-carotene and vitamin A supplement. Researchers ended the trial early to prevent more deaths.[ref][ref]

Another large study examined the effects of supplementing with beta-carotene, vitamin E, a combo of both, or a placebo. Again, an association exists between beta-carotene supplementation and an increased risk of lung cancer, especially in smokers.[ref]

Several smaller studies back up the large studies with the same results:

- Beta-carotene (20 – 30 mg/day) increases the risk of lung cancer in smokers.[ref]
- Beta-carotene supplementation also increases the risk of bladder cancer a little bit.[ref]

Why would high doses of beta-carotene cause an increase in cancer risk?

Research shows that carotenoids can act as pro-oxidants at higher levels. The breakdown products from beta-carotene include aldehydes and epoxides, which impair mitochondrial function.[ref] Similarly, animal studies show that low-dose beta-carotene supplementation is health-promoting after a heart attack but that higher doses are not beneficial and possibly deleterious.[ref]

Animal studies also show that high doses of beta-carotene also cause lung cancer in animals exposed to cigarette smoke. The high beta-carotene actually caused an increase in enzymes that destroyed retinoic acid (the active form of vitamin A).[ref] Paradoxically, high levels of beta-carotene act as a pro-oxidant and also decrease retinoic acid.

Increased Cardiovascular Disease Risk tied to Beta-Carotene Supplementation:

Similar to the cancer studies, large studies of supplemental beta-carotene for reducing cardiovascular disease also show that it is associated with a slight increase in cardiovascular disease mortality and stroke.[ref][ref]

An analysis of cardiovascular mortality risk based on serum β-carotene concentrations also found that people in the top quartile of levels were at more than double the risk of cardiovascular mortality.[ref]

Keep in mind with these types of epidemiological studies that causation isn't completely proven. The theory is that β-carotene may show pro-oxidant effects under certain conditions, but it could also be that people who know that they have heart disease are more likely to start taking multi-vitamins with beta-carotene (or perhaps guzzling gallons of carrot juice).

What else does BCO1 (BCMO1) do?

While this article has focused on beta-carotene, the BCMO1 enzyme converts other carotenoids, such as lycopene. Lycopene is a bright red carotenoid found in tomatoes, watermelon, and papayas.[ref]

Genotype Report (Members)

In the Genotype Report section, Genetic Lifehacks members see their genotype data directly in the articles.

There are two well-studied genetic variants in the BCMO1 gene that help determine a person's ability to convert beta-carotene into useful retinol for the body.

Check your genetic data for rs7501331 (23andMe v4 and v5, AncestryDNA):

- C/C: typical
- C/T: decreased beta-carotene conversion
- T/T: decreased beta-carotene conversion[ref]; lower lutein (another carotenoid) levels[ref]; may affect lycopene also[ref]

Members: Your genotype for rs7501331 is --.

Check your genetic data for rs12934922 (23andMe v4 and v5):

- A/A: typical
- A/T: decreased beta-carotene conversion; increased risk of atherosclerosis with poor diet
- T/T: decreased beta-carotene conversion[ref]; increased risk of atherosclerosis with poor diet[ref]; may affect lycopene also[ref]

Members: Your genotype for rs12934922 is --.

Combination of the above: People with a T allele on both rs12934922 and rs7501331 have a 69% decreased conversion of beta-carotene to retinol. For people with only a single T in the rs7501331 SNP, the conversion is decreased by 32%.[ref]

Genotype Report (Continued)

Check your genetic data for rs11645428 (23andMe v4, v5, AncestryDNA):

- G/G: lower beta-carotene conversion
- A/G: slightly higher beta-carotene conversion
- A/A: higher beta-carotene conversion[ref]

Members: Your genotype for rs11645428 is --.

Check your genetic data for rs6420424 (23andMe v4, v5, AncestryDNA):

- A/A: lower beta-carotene conversion[ref]
- A/G: slightly lower beta-carotene conversion
- G/G: normal beta-carotene conversion

Members: Your genotype for rs6420424 is --.

Check your genetic data for rs6564851 (23andMe v4, v5, AncestryDNA):

- G/G: lower beta-carotene conversion (thus higher circulating beta-carotene)[ref]
- G/T: somewhat lower beta-carotene conversion
- T/T: typical conversion

Members: Your genotype for rs6564851 is --.

Lifehacks for Poor Beta-Carotene Conversion

If you have genetic variants that decrease the BCO1 enzyme production, you may wonder if it is worthwhile to eat vegetables.

The answer seems to be **yes**. A study examining the effects of the BCO1 genetic variants on lung cancer risk and fruit and vegetable consumption found that, regardless of enzyme function, higher fruit and vegetable consumption reduced the risk of lung cancer considerably.[ref]

Even with reduced enzyme function, you still get some vitamin A from fruits and vegetables - along with all of the other nutritional benefits.

Test your vitamin A levels:
If you have symptoms of vitamin A deficiency (poor night vision, lowered immunity, skin problems, keratosis pilaris, etc.), check your vitamin A levels with a blood test. You could get this through your doctor or order it online.

Foods rich in the active form of vitamin A:
If you are looking for ideas and recipes for retinol-rich foods, check out this article: Foods rich in retinol and recipe ideas

Vegan and Vegetarian Diets:
If you eat a vegan or vegetarian diet, your body's sole source of vitamin A is from converting beta-carotene. Suppose you don't process beta-carotene into retinol very well, and you don't eat large amounts of beta-carotene. In that case, you may want to increase your vegetables that are high in beta-carotene.

- Increasing beta-carotene consumption may help your vitamin A status - up to a point. Research shows that "in humans, beta-carotene conversion to vitamin A decreases as the dietary dose increases."[ref]
- Another option is to consider supplementing with a retinol form of Vitamin A. Some supplement forms of retinyl palmitate are derived from soy oil and are considered vegan.[ref]

How much beta-carotene is in carrot juice?

According to the Nutridesk website, one cup of carrot juice contains 22mg of beta-carotene. The site also claims that for an average person, the conversion of only 1/12th of that beta-carotene into retinol gives 1.8 mg of retinol per cup of carrot juice. If you are a poor converter of beta-carotene, you will get less than 1.8 mg/ cup of pure carrot juice.

Caution with high-dose vitamin A:

Vitamin A is a fat-soluble vitamin that can build up in the body, so you don't want to go overboard with it. (Get a blood test to determine your level.) The upper daily recommended limit for vitamin A in the retinol form is 10,000 IU per day. [ref] Talk to your doctor if you have questions about whether a specific supplement or dose is right for you.
Pregnancy warning: High doses of vitamin A can cause birth defects. If you plan to get pregnant, talk with your doctor before taking vitamin A supplements.

Supplement stack:

☑️ Include vitamin D with vitamin A:
Studies show that too much vitamin A without enough vitamin D can be a risk factor for osteoporosis.[ref]. If you aren't supplementing with vitamin D, make sun exposure each day a priority. Also, if you check your vitamin A levels, make sure you test your vitamin D levels at the same time.
☑️ Include fat with beta-carotene for absorption: Beta-carotene is hydrophobic and needs fat to be absorbed in the intestines. Adding a little fat to your beta-carotene-rich food should help a little with absorption.[ref]
Ideas for better beta-carotene absorption:

- include butter or coconut oil with your vegetables
- add an avocado to your carrot-rich smoothie

☑️ Retinyl palmitate supplements are available online and in health stores. Vitamin A needs to be absorbed with fat, so look for one that includes fat with it. Be sure to check the ingredients label, though, and look for high-quality fat.