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Gut Bacteria May Transform Spinach, Beets, and Plant Iron Into Protective Compounds

Analysis by Dr. Joseph Mercola | November 21, 2026

STORY AT-A-GLANCE

- Certain gut bacteria transform nitrate and non-heme iron from plant foods into DNICs — compounds that, in animal and laboratory studies, traveled beyond the digestive tract and influenced functions throughout the body
- In mice, higher DNIC levels improved blood pressure, blood vessel function, blood sugar control, insulin levels and body composition, promising results that haven't yet been confirmed in people
- DNICs substantially reduced liver fat in mice and experimental human liver tissue, partly by turning down cellular signals that promote fat production and storage
- Nitrate and iron worked together to support DNIC production, highlighting how your gut microbiome changes nutrients from foods such as leafy greens and beets into biologically active compounds
- Supporting your gut and mitochondrial health with appropriate carbohydrates, low linoleic acid intake, whole-food nutrient sources and regular movement helps create a healthier metabolic environment

You're likely familiar with how gut bacteria break down fiber into short-chain fatty acids. The compounds described in this article are something else entirely — a class of gut-derived molecules I haven't written about before, and ones that may reshape how we think about the metabolic benefits of eating vegetables.

Research published in Cell found that gut microbes combined two common plant nutrients — inorganic nitrate and non-heme iron — into dinitrosyl iron complexes, or DNICs. Rather than staying in the intestine, these mobile compounds traveled to distant tissues and influenced blood vessel function, nutrient sensing and liver fat metabolism.

Foods provide the raw materials for this process. Inorganic nitrate is abundant in leafy vegetables and beets, while non-heme iron is the form of iron found in plants. Unlike heme iron — the form your body absorbs from red meat and organ meats — non-heme iron is less readily absorbed on its own but appears to be the form gut bacteria use to build DNICs.

Foods such as spinach contain both inorganic nitrate and non-heme iron. Rather than viewing these nutrients in isolation, consider what happens after they reach your gut. Your microbiome acts like a chemical processing system that transforms dietary compounds into entirely different substances with biological effects.

Gut Bacteria Turned Plant Nutrients Into Protective Compounds

A study published in Cell found that certain **gut bacteria** transform nitrate and non-heme iron from food into compounds called dinitrosyl iron complexes (DNICs), molecular complexes built from iron atoms bonded to nitric oxide.[1] Researchers at Karolinska Institutet studied this process using mice, bacteria, cells and human samples.[2]

Their experiments showed that DNICs didn't simply remain in the digestive tract. Once formed, they traveled to other parts of the body, with especially high levels reaching the liver and kidneys.

- **Gut bacteria were necessary to make DNICs —** Researchers found DNICs in mice with normal gut bacteria but couldn't detect them in germ-free mice, which are raised without gut microbes. This provided a major clue that bacteria were responsible for making these compounds.

Researchers then looked more closely at how bacteria accomplish this. Certain gut bacteria have an enzyme that allows them to process nitrate. Normal E. coli produced DNICs when nitrate was available, but E. coli altered to remove this ability didn't. Adding iron increased DNIC production even further.

- **Nitrate and iron worked together —** The researchers found that nitrate alone wasn't enough to produce the same metabolic effects when little iron was available. In a separate 14-week experiment, mice received a Western diet containing almost no iron. Nitrate alone didn't improve their metabolic health.

  When researchers provided nitrate together with iron, however, DNIC levels rose markedly and metabolic function improved. This helps explain why the combination matters: Gut bacteria need nitrate and iron as raw materials to produce these compounds.

- **Higher DNIC levels improved several markers of metabolic health —** Researchers tested the compounds in mice with experimentally induced cardiovascular and metabolic problems. These mice developed high blood pressure, poor blood sugar control, higher insulin levels, more body fat and less lean mass. They also accumulated large amounts of fat in their livers.

  Raising DNIC levels produced broad improvements. Blood pressure and blood vessel function improved, while blood sugar control, insulin levels and body composition moved toward healthier levels. Nitrate plus iron also significantly lowered cholesterol. These results were observed in mice, so they don't prove that the same treatment produces these benefits in people.

- **DNICs reduced liver fat buildup in experimental models —** The liver findings were especially notable. Mice with poor metabolic health developed severe fatty liver, while nitrate plus iron or laboratory-made DNICs substantially reduced this fat buildup.

Researchers then tested DNICs directly on liver cells exposed to high levels of fatty acids. DNIC treatment reduced the amount of fat that accumulated inside the cells. The researchers saw similar results in three-dimensional liver tissue models made from human cells from three different donors.

Notably, DNICs reduced fat buildup even when treatment began after accumulation was already underway, suggesting the effect isn't limited to prevention — DNICs appeared to reduce fat that had already accumulated in these models.

- **DNICs acted as biological messengers throughout the body —** Researchers once thought these compounds worked mainly by breaking apart and releasing nitric oxide, a substance known for helping blood vessels relax. Instead, the study showed that DNICs stayed remarkably stable in blood and released almost no free nitric oxide.

  This matters because the DNIC itself appears to carry the message. In experiments with mouse arteries, DNICs activated a natural signaling system that tells the muscles surrounding blood vessels to relax. This distinction matters beyond the lab.

  If DNICs simply released nitric oxide, their effects would be brief and local, limited to wherever the molecule happened to break apart. This suggests that, unlike free nitric oxide, DNICs may be able to deliver more coordinated signals to multiple organs. The research suggests gut bacteria may produce not just a raw material, but a more stable, targeted messenger.

- **DNICs also reduced signals that encourage liver fat production —** Inside cells, researchers found that DNICs affected a nutrient-sensing system called mTORC1. Think of this system as a thermostat for fat production. It's supposed to ramp up when nutrients come in and dial back when they're not needed. In metabolic dysfunction, it gets stuck on high, continuously signaling your liver to make and store fat even when it shouldn't.

DNICs helped reset it toward normal in the experimental models. DNICs also reduced the amount of leucine, an amino acid that activates this metabolic switch, entering laboratory cells. Together, these findings provide a straightforward explanation for the liver results: DNICs turned down cellular signals that encourage fat production and storage.

The bigger takeaway is that digestion may not be the end of the story when you eat vegetables. Research suggests gut bacteria can transform nutrients from food into entirely new compounds that travel beyond the intestines and may communicate with other parts of the body — though this pathway hasn't yet been confirmed in humans.

The researchers now want to determine how much DNIC people produce, how diet and differences in gut bacteria affect those levels, and whether this pathway helps explain the long-term health benefits associated with vegetable-rich diets.

Support the Gut Environment That Produces Beneficial Compounds

Your gut bacteria sit at the center of the pathway described in the Cell study, so addressing the terrain those microbes live in comes first. From there, you can supply the whole-food nutrients involved in the pathway while protecting the mitochondrial function that supports healthy glucose and fat metabolism.

1. **Build your gut health before pushing fiber higher —** If your gut is healthy and you tolerate plant foods well, whole fruits and vegetables provide carbohydrates and other nutrients that support your intestinal environment. If you have significant bloating, gas or digestive discomfort, however, don't suddenly load your diet with high-fiber foods. An unhealthy microbiome can turn excessive fiber into a source of endotoxin, a bacterial toxin that disrupts cellular energy production.

Give your gut time to recover before increasing fiber. If your digestive health is severely compromised, start with easy-to-digest carbohydrates, like fruit and white rice, which place the least strain on your gut, then gradually expand your choices as your symptoms improve. This helps create a healthier environment for beneficial gut bacteria instead of feeding an intestinal ecosystem that's already out of balance.

2. **Eat enough carbohydrates to fuel your mitochondria —** Your mitochondria are the tiny energy-producing structures inside your cells, and adequate glucose helps them produce the energy your body needs to function properly. Most adults need roughly 250 grams of healthy carbohydrates per day, with more if you're highly active.

   Avoid treating carbohydrate restriction as the answer to poor metabolic health. Supplying enough carbohydrate helps support cellular energy production, which affects how your body handles glucose, fat and other nutrients. Your individual needs vary with your activity level, body size and metabolic demands, but the goal is straightforward: Give your cells enough carbohydrate fuel to produce energy efficiently.

3. **Get nitrate and non-heme iron from whole foods —** Your gut bacteria need the right raw materials to make DNICs. The Cell study found that nitrate alone didn't provide the same metabolic benefits when dietary iron was nearly absent; nitrate plus iron markedly increased DNIC levels and improved metabolic measures in mice.[3] Leafy vegetables provide nitrate along with plant-based non-heme iron, making foods such as spinach a practical choice. Beets are another useful nitrate-rich whole food.

   A practical starting point: include at least one nitrate-rich food daily. A cup of spinach or half a cup of cooked beets each supply meaningful amounts of nitrate. For non-heme iron, beans, lentils and dark leafy greens are reliable sources. Pairing these foods with something containing vitamin C — citrus, bell peppers or tomatoes — improves non-heme iron absorption.

Keep in mind that high iron is an under-recognized health threat, and there's a general lack of awareness about the health risks associated with excess iron. Before significantly increasing iron-rich foods, I recommend checking your ferritin level to measure stored iron — the ideal range is between 60 and 75 ng/mL — and your gamma-glutamyl transpeptidase (GGT), a marker of oxidative stress.

If ferritin is elevated, donating blood two to four times each year gradually lowers excess iron. If blood donation isn't appropriate for you, therapeutic phlebotomy prescribed by your doctor achieves the same result.

Meanwhile, if your iron status is low, eating nitrate-rich vegetables alone may not be enough to support DNIC production. Readers who suspect low iron, particularly women of reproductive age, frequent blood donors or those on plant-heavy diets, may also benefit from having their ferritin levels checked. Talk to your healthcare provider about whether this testing is appropriate for you.

4. **Keep linoleic acid (LA) intake below 5 grams per day —** The metabolic improvements linked to DNICs in this study — better blood sugar control, reduced liver fat, healthier body composition — all depend on mitochondria that can produce energy efficiently. **Excess LA** undermines that foundation, so reducing your intake removes an obstacle that could blunt the benefits of the pathway described above.

   Ideally, keep your intake below 5 grams — or better yet 2 grams — per day. The biggest sources include seed oils like soybean, corn, sunflower, safflower, cottonseed and canola oils, and the processed foods that contain them. Avoid nuts and seeds as well.

   LA becomes incorporated into mitochondrial membranes, where it readily oxidizes into damaging compounds that interfere with energy production. Choose fats such as grass fed butter, ghee or tallow instead. Lowering your LA intake gives your mitochondria a better environment for producing the cellular energy that healthy metabolic function depends on.

5. **Use movement to reinforce healthy metabolic signaling —** Your muscles are powerful metabolic organs, and regular movement gives you another way to improve how your body handles glucose and energy. The study found that DNIC levels improved blood sugar control and insulin sensitivity in mice, two markers that regular movement also targets through independent mechanisms. Supporting both pathways gives your metabolism more than one route toward healthier function.

   Work toward walking for up to 60 minutes each day, add strength training twice a week and break up prolonged sitting with brief periods of movement. If you're currently sedentary, start with an amount you can repeat every day and build from there. You don't need an exhausting routine to begin improving your metabolic environment. Consistency matters more than making your first workout difficult.

FAQs About Gut Bacteria and Protective Compounds

Q: What are DNICs, and why are they important?

A: DNICs are compounds that certain gut bacteria produce when nitrate and non-heme iron are available. In animal and laboratory research, DNICs traveled to other tissues, including the liver and kidneys, where they were found to influence blood vessel function and metabolic processes.

Q: Which foods provide the nutrients gut bacteria use to make DNICs?

A: Nitrate occurs naturally in vegetables such as beets and leafy greens, while non-heme iron is the form of iron found in plant foods such as beans and green vegetables. Spinach supplies both nutrients, making it one example of a whole food that provides the raw materials involved in DNIC production.

Q: What health improvements were linked to higher DNIC levels?

A: In mice with experimentally induced cardiovascular and metabolic problems, higher DNIC levels were associated with lower blood pressure, better blood vessel function and improvements in blood sugar control, insulin levels and body composition. DNICs also substantially reduced liver fat buildup. These findings haven't yet established the same benefits in people.

Q: How do DNICs affect blood vessels and liver fat?

A: DNICs acted as biological messengers that activated a natural pathway that tells muscles around blood vessels to relax. They also turned down excessive cellular signals associated with making and storing fat, helping explain why researchers observed less fat accumulation in experimental liver models.

Q: How can you support the gut and metabolic health discussed in this research?

A: Focus first on maintaining a healthy gut environment, then provide your body with adequate healthy carbohydrates and whole-food sources of nitrate and non-heme iron. Limiting LA from seed oils and processed foods and staying physically active also support mitochondrial and metabolic health.

This article is for informational purposes only and does not constitute medical advice. Consult a qualified healthcare provider before making changes to your health regimen.

Take today's quiz to see how much you've learned from **yesterday's Mercola.com article**.

Sources and References

- [1, 3] Cell August 19, 2026
- [2] Karolinska Institutet August 19, 2026