Frequently Asked Questions on nitrate and nitrite in food

FAQ by the BfR of 11 June 2013

Lettuce and vegetables such as rocket, spinach, kohlrabi, beetroot and radish can contain high quantities of nitrate. Nitrite can form from nitrate in the body or even in the foods themselves due to improper storage, incorrect transport or non-observance of the standard rules of hygiene. Together with the amines or amides produced naturally in the body or ingested with food, N-nitroso compounds can then be produced. Most of these compounds have been proven to be carcinogenic in animal tests. In the view of the Federal Institute for Risk Assessment (BfR), the intake of nitrate and nitrite via food should be reduced. This should be achieved primarily through suitable cultivation and harvesting methods, as well as a targeted selection of foods.

The advantages of a vegetable-rich diet outweigh the possible risks caused by slightly increased nitrate and nitrite levels. Consumers should therefore in no way limit their vegetable consumption, but they should ensure plenty of variety in the vegetables they eat.

The BfR has compiled below a list of common questions and answers on nitrate and nitrite in food:

What are nitrates?
Nitrates are nitrogen compounds which occur naturally in soil, but which can also be spread through fertilisation. Plants utilise the nitrogen contained in nitrates for their own metabolism and to produce protein. Nitrate is extracted from the soil by the roots and distributed throughout the plant where it is converted into high-energy protein compounds by means of photosynthesis. Excess quantities of nitrate are stored, with food plants having different nitrate storage capacities. Nitrate from soil can also be washed into groundwater through rainfall, which means that it can ultimately be found in drinking water too. The nitrate levels in ground and drinking water can be considerable, depending on the predominant form of land use.

What are nitrites?
Nitrite is an interim product in the supply of the plant with nitrogen. As plants cover their nitrogen requirements through nitrate, plant-based foods - especially various vegetable varieties - can contain comparatively high quantities of nitrate. In vegetables containing nitrate, microbiological or enzymatic effects can cause conversion of the nitrate into nitrite. This can happen as a result of improper storage, incorrect transport and/or non-observance of the standard rules of hygiene.

Which foods have high nitrate levels?
Because plants cover their nitrogen requirements through nitrate, plant-based foods - especially various vegetable varieties - can contain high nitrate levels. As a basic principle, the nitrate accumulation in the plant depends on the amounts of nitrogen contained in the soil. Storage capacities vary depending on the type and part of the plant.

Vegetables such as rocket and other leaf lettuces, spinach, kohlrabi, beetroot, as well as red and white radish store a lot of nitrate. As nitrate accumulates particulary in the segments of the plant that conduct water, it is to be found in higher concentrations in the stem, leaf veins and outer green leaves.

Which factors influence the nitrate content in foods?
In addition to the nitrate content of the soil, genetic, geographic and climatic factors also have an influence on the nitrate concentration in the plant: high temperatures result in lower and sustained drought in higher nitrate accumulation. As a rule, higher levels are also to be found in products from northern latitudes of Europe than in those from southern regions. Irrespective of this, levels in greenhouse vegetables normally exceed those of free-range plants. Since climatic conditions and horticultural methods have a major influence on nitrate in certain vegetables, different maximum levels are fixed depending on the season (harvest in winter/summer) and type of cultivation (grown in the open air or grown under cover).

Which foods have high nitrite content?
Although endogenous nitrite levels in plant-based foods are low, via the conversion of nitrate into nitrite considerable quantities of nitrite can occur in food containing high primary quantities of nitrate which are stored/ transported incorrectly or with which standard hygiene rules are not observed. Nitrite can also be ingested via pickled meat products as it is a component of pickling salts.

How can poor food hygiene influence the nitrite content?
Bacteria which are in or on plant-based foods can convert nitrate into nitrite. For this reason, spinach which has been cooked once should not be re-heated because the microorganisms in this nitrate-rich vegetable contribute towards the increased production of nitrite.

Why is pickling salt with nitrite used in foods?
Pickling salt with nitrite is an authorised food additive for certain meat products. It was previously added mainly to inhibit the growth of the bacterium *Clostridium botulinum*. The main reason today is that it gives the product a red colour and a particular aroma (“pickling aroma”).

Is there a health risk through nitrate and nitrite in foods?
Nitrates by themselves are relatively safe. However, they can convert themselves into nitrite, a substance which can actually cause health problems. This can happen already in the foods or during the digestion process through the influence of bacteria. .A distinction should be made here between the acute and the chronic effects. An acute health risk is conceivable in the case of a high nitrate and/or nitrite intake by infants during the first few months of their lives. The ingested nitrite disrupts the transport of oxygen by the red blood corpuscles. The red blood colorant haemoglobin is converted into methaemoglobin and is no longer capable of reversible oxygen bonding which can then lead to an oxygen shortage in the tissues or even internal suffocation. This leads to a so-called methaemoglobinemia (“blue baby syndrome” = cyanosis). With bacterial infections of the gastro-intestinal tract, there is also the risk that more nitrate is converted into nitrite in the gut after the intake of high-nitrate foods. For this reason, the European Food Safety Authority (EFSA) recommends that children suffering from a bacterial gastro-intestinal infection should not be given spinach because this increases the risk of methaemoglobinemia.

Nitrite can react with amines in the body to produce N-nitroso compounds (e.g. nitrosamines), most of which have proven to be carcinogenic in animal tests. Whether or not this also applies to humans has not yet been clarified. The question regarding the extent to which the intake of nitrite and/or nitrate from food leads to the endogenous formation of carcinogenic N-nitroso compounds, and the relation in which this stands to the contamination with compounds of this kind which already exists has still not been sufficiently clarified. Accordingly, the BfR regards the long-term intake of larger quantities of nitrate and/or nitrite as problematic. Consequently, nitrate/nitrite in humans should be reduced to the maximum possible

extent through such means as appropriate harvesting and cultivation measures for vegetables containing particularly high levels of nitrate.

What quantities of nitrate can be ingested without any health considerations?
The WHO has derived an acceptable daily intake (ADI) for nitrate of 3.7 mg/kg body weight, but this does not apply to infants aged less than 3 months. This value equates to a nitrate quantity of 222 mg/day for an adult weighing 60 kg. A maximum intake of 93 mg/day (25 kg body weight) applies for children aged 3 years and over.

The ADI value indicates the quantity of a substance which a person can ingest per kg of body weight for his or her entire life without having to expect any health risks. If the ADI is exceeded for short periods, no health risk is to be expected. Nitrate intake is regarded as safe for human health until the ADI is reached, and it is not regarded as health-relevant if it is exceeded occasionally. However, regional and individual peculiarities must be taken into consideration. This means that, depending on their consumption habits and the nitrate content of the drinking water in any given region, consumers can ingest relatively high quantities of increased nitrate levels.

Are there any legally prescribed maximum levels of nitrate in plant-based foods?
In the regulations (EC) No. 1881/2006 and (EU) No. 1258/2011 setting maximum levels for certain contaminants in foods, maximum levels were established for nitrates in certain leafy vegetables. When determining maximum levels for nitrate in plant-based foods, the influence of climatic factors (harvest in winter/summer) and horticultural factors (cultivation under cover or in the open air) are taken into account.

Leafy Vegetables	Time Period	Max. Nitrate Level
Fresh spinach	All year round	3500 mg / kg
Preserved, deep-frozen or frozen spinach	All year round	2000 mg/ kg
Fresh lettuce grown under cover	Harvested from 01 Oct. to 31 Mar. (winter season)	5000 mg / kg
Fresh lettuce grown in the open air	Harvested from 01 Oct. to 31 Mar. (winter season)	4000 mg / kg
Fresh lettuce grown under cover	Harvested from 01 Apr. to 30 Sep.	4000 mg / kg
Fresh lettuce grown in the open air	Harvested from 01 Apr. to 30 Sep.	3000 mg / kg
Rocket	Harvested from 01 Oct. to 31 Mar. (winter season)	7000 mg / kg
Rocket	Harvested from 01 Apr. to 30 Sep.	6000 mg / kg

Which measures lead to a reduction of the nitrate and nitrite content in foods?
The following measures are conceivable to keep the nitrate levels in vegetables and lettuce as low as possible:

- Minimisation of the nitrate content in the soil (by a reduced use of fertilisers) so that less nitrate is absorbed by plants and groundwater.
- Free-range cultivation of vegetables because higher light exposure and fresh air supply reduce the nitrate level in the plants.

- Adjustment of harvest times: nitrate levels are lower if the vegetables are harvested in the evening because exposure to light during the day reduces the nitrate level.
- Specific preparation and processing methods, e.g. removal of stalks, stems, leaf ribs and outer husks.
- Reduction in the use of additives such as potassium nitrate and sodium nitrate which are permitted for use as pickling salts and preservatives.

A reduction of the nitrite level in foods and overall nitrite intake can be achieved through:

- Minimisation of nitrate levels (see above)
- Proper storage and transport
- Good hygiene practices

Consumers can influence their nitrate and nitrite intake by specifically selecting their foods (choosing low-nitrate vegetable varieties, such as tomatoes, cucumbers, carrots etc and reducing the proportion of pickled meat products) and only eating vegetable varieties with a naturally high nitrate content, such as rocket and leaf lettuce, when they are in season.

Do nitrate and its metabolic products (nitrite and reactive nitrogen compounds such as nitrogen monoxide etc) also have positive effects on human health?
New scientific findings have been made in recent years regarding the physiological role of nitrate and its metabolic nitrite products and reactive nitrogen compounds, such as nitrogen monoxide (NO). It has been established, for instance, that nitrogen monoxide (NO), which is produced spontaneously from nitrite in an acidic milieu, has a vasodilatating and therefore anti-hypertensive effect. NO plays an important role in the healing of wounds by limiting the adhesion and aggregation of platelets. It also plays a role in the central and peripheral nervous system in the conducting of stimuli. The antibacterial effect of NO was proven several years ago: pathogenic germs ingested with food, such as *Salmonella* or *E. Coli,* can be rendered harmless through the interactions of NO and acidic gastric acid. Furthermore, it has been shown that NO stimulates the circulation of blood in the stomach lining and has positive effects on the thickness of the mucous layer on the stomach wall, which has a protective effect on the stomach.

Several authors even raise nitrate to the status of a nutrient. They attribute the positive effects associated with the consumption of fruit and vegetables, such as the reduction of the risk of cardiovascular disease, to the nitrate which can be contained in these foods in comparatively large quantities. The BfR is of the opinion, however, that this hypothesis has not been substantiated as to date it has not been clarified which of the ingredients present in vegetables are responsible for the positive effects described, since nitrate occurs in vegetables in combination with a large number of phytonutrients.

Just like the EFSA, the BfR sees no genuine health benefit of nitrate by itself for the sole purpose of maintaining human physiology. The further clarification in recent years of the physiological role of nitrate must not be allowed to have the result that it is now indiscriminately alleged to have health benefits. In several instances, the alimentary intake of nitrate within the limits of the ADI can prove to be beneficial for replenishing the endogenous nitrate pool. However, the contribution the exogenous intake of nitrate makes to the physiology of healthy humans has yet to be established. Therefore, the BfR currently sees no reason to amend its previous risk assessments in any way.

The BfR would also like to point out that some population groups can react more sensitively than others to nitrate exposure. Additional nitrate intake could result in a greater health risk

for persons with increased endogenous production of N-nitroso compounds. Chronic exposure to nitrogen monoxide is seen by several authors as a critical factor in the connection between inflammation and cancer. NO and NO synthase are also associated with increasing oxidative stress and DNA damage.

How does the BfR view the raising of the maximum nitrate levels for lettuce (winter and grown under cover) by the European Commission from 4500 to 5000 mg/kg and the newly established maximum nitrate level of 6000 mg/kg (summer) and 7000 mg/kg (winter) for rocket?

The maximum levels established for nitrate in various leafy vegetable varieties and in lettuce are not toxicological limit values. They are based on the principle of good agricultural practice. As lettuce and leafy vegetables are cultivated under different climatic and horticultural conditions in the member states of the European Union, the European Commission had to take these factors into account for the entire EU when determining the maximum levels. It has proven impossible in several regions of the EU to consistently achieve nitrate levels in lettuce and fresh spinach which lie below the maximum levels stipulated in Regulation (EU) No. 1881/2006 (Contaminants Regulation), even under strict application of the rules of good agricultural practice. For this reason the maximum levels had to be raised slightly. Maximum levels for rocket were established for the first time in Regulation (EU) No. 1258/2011 which amends the Contaminants Regulation. The maximum levels for rocket which now apply should be checked regularly with a view towards lowering them. From a toxicological point of view, the maximum nitrate levels which currently apply can be regarded as safe in the opinion of the BfR. At the same time, however, efforts should be made to further minimise nitrate levels by taking suitable measures.

What recommendations does the BfR give to consumers regarding nitrate levels in foods?

The benefits of a high proportion of vegetables in our diet outweigh by a very large margin the possible risks posed by nitrate and nitrite levels. Consumers should therefore not limit their consumption of vegetables, but they should ensure that there is plenty of variety in the vegetable types they eat. Seasonal vegetables also contain less nitrate.

Do nitrate and nitrite pose any special risks for babies and infants?

In 2010 the European Food Safety Authority (EFSA) assessed the possible health risk for children through nitrate in leafy vegetables. According to this, the nitrate levels in the vegetable varieties mentioned do not pose a health risk to most children. Babies and infants aged 1 to 3 years who eat a lot of spinach with a high nitrate content in the course of one day can sometimes reach an intake level at which an increased risk of methaemoglobinemia (“blue disease” = cyanosis) cannot be excluded.

Babies in particular show a sensitive reaction to nitrite during the first months of their lives because it alters the red blood cells (haemoglobin). Because of this change, they cannot absorb any oxygen which disrupts the transport of oxygen and can lead to an oxygen shortage (methaemoglobinemia). Consequently, a health risk through an increased nitrite intake brought about by the consumption of foods containing nitrate and nitrite is conceivable for babies during the first months of their lives. In practice, however, they hardly consume any food contaminated with nitrite or nitrate during this period.

According to the EFSA report, children suffering from bacterial gastro-intestinal infections should not be given spinach because this can result in a higher conversion rate of nitrate into nitrite, thus increasing the risk of methaemoglobinemia.