German Federal Institute for Risk Assessment

Rare but avoidable: questions and answers about botulism

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Botulism is a serious disease caused by toxins known as “botulinum neurotoxins”. Under certain conditions, these toxins are produced in food or animal feed by bacteria mainly of the species *Clostridium (C.) botulinum* and are then ingested with food or animal feed. In rare cases, the bacterium itself can also cause botulism. The disease usually leads to specific neurological disorders, e.g. vision disorders, dry mouth, speech and swallowing disorders, and can be fatal. Both humans and animals can fall ill, and among the latter cattle and also poultry, such as chickens and turkeys, are primarily affected.

What is botulism?

Botulism is a disease caused by “botulinum neurotoxins”. Botulinum neurotoxins are mainly produced by bacteria of the species *Clostridium* (*C.*) *botulinum* and can cause nausea, diarrhoea and constipation, as well as neurological symptoms such as vision disorders (e.g. double vision) and paralysis including respiratory paralysis. In addition to *C. botulinum*, some C. *butyricum* and *C. baratii* strains are also capable of producing botulinum neurotoxins. The disease can occur in animals as well as humans.

What is the difference between the bacterium *Clostridium botulinum*, *Clostridium botulinum* spores and botulinum neurotoxins?

***Clostridium (C.) botulinum* bacterium**: *C. botulinum* is a rod-shaped bacterium, which is also referred to as “anaerobe” because it only grows in oxygen-free environments. It is widely distributed in the environment and is inactivated when food is heated (at least 70 °C, homogeneously throughout the food). This proliferating bacterium is also “(vegetative) cell” and can form spores and toxins.

***Clostridium botulinum* spores**: These are heat-resistant developmental stages that can be formed by *C. botulinum* and are widely distributed in the environment. In contrast to the cells, they do not multiply, but exist in an inert state. They can only be inactivated at temperatures above 100 °C. That’s why the so-called botulinum cook at 121 °C for 3 minutes was developed for the canning process.

***Clostridium botulinum* neurotoxins**: Also abbreviated as BoNTs, these toxins are formed by *C. botulinum* cells in an oxygen-free environment. They can be inactivated by boiling food at 100 °C, when heated to only 80 °C, it takes several minutes to inactivate the food.

How often does botulism occur in Germany?

Botulism is very rare nowadays. In Germany, fewer than ten cases of botulism are reported every year, most of which are caused by contaminated food.

How is botulism transferred to humans?

Human botulism is predominantly a food-borne disease. It has always been associated with consumption of processed food products, in which bacteria have had the opportunity to multiply and form neurotoxins in the absence of oxygen.

Another form of botulism that is transmitted via food is infant botulism, in which the bacteria colonise the intestine, due to the still lacking intestinal flora, and form their neurotoxins there. The BfR has summarised how the risk of disease can be reduced in its leaflet “Consumer Guidance About Botulism From Food” https://www.bfr.bund.de/cm/350/hinweise_fuer_verbraucher_zum_botulismus_durch_lebensmittel.pdf (only available in German).

In addition, botulism can also be caused by wound infections with *C. botulinum*.

Which food items primarily cause botulism?
C. botulinum is an environmental pathogen and is therefore present everywhere. The bacterium forms heat-resistant spores and can also contaminate food via dust and soil particles. In the absence of oxygen and with sufficient nutrient supply, it is able to form neurotoxins. Therefore, foods stored under low oxygen conditions may primarily contain botulinum neurotoxins. Eating such foods can cause botulism.

A typical example of food that has caused botulism is canned vegetables or meat produced without sufficient heating in private households. Any surviving spores can then germinate in the absence of oxygen into cells capable of multiplying, which then form neurotoxins. In industrial production, on the other hand, the food is sufficiently heated so that the spores are killed.

There is currently no evidence that raw milk and fresh meat pose a risk of botulism in humans.

What other food items can cause botulism?
In the case of vegetables preserved in oil, e.g. peppers, chilli, eggplants, garlic or fresh herbs, there is no guarantee for the prevention of the reproduction of *C. botulinum* and the formation of botulinum neurotoxins in the products in private households. The BfR therefore advises against producing and storing home-made products such as vegetables in oil or so-called herbal oils in private households. They should be kept in the refrigerator and consumed no later than the day after manufacture. This is especially true when the products are not sufficiently heated before consumption or used for cooking and roasting, but are intended for the preparation of salads and other raw foods.

Salted, dried fish, e.g. roach, can also cause botulism if these products are consumed without sufficient heating. The health risk is increased if the fish have not been carefully gutted and their innards are not removed completely. These fish should be carefully and completely gutted as soon as they are caught and then thoroughly washed inside and out. In addition, they should be stored at a maximum of 3 °C until salting, additionally cooled during any salting process that lasts more than one day and adequately salted before drying above 8 °C. The BfR advises consumers to only consume salted and dried roach if it has been heated for at least ten minutes at a core temperature of 85 °C or more.

Honey is a well-known source of so-called infant botulism. Therefore, honey should not be fed to infants under one year of age. Other foods that may cause infant botulism are yet unknown.

How can we reduce the risk of botulism from home-made preserved food that has been heated insufficiently?
Only a few methods for preserving food prevent *C. botulinum* from multiplying and therefore the formation of neurotoxins. This includes sterilisation, in which food is heated to above 100°C under overpressure. This procedure (so-called botulinum cook, 121 °C for 3 minutes, homogeneously throughout the food) is used in commercial canned food production.

Most food items do not indicate whether they contain cells, spores or neurotoxins of *C. botulinum*. However, so-called “swelling” can give an indication of this. Swelling is caused by gas-forming clostridia, which have survived the canned food production process. As a precaution, such “swollen” food cans should not be opened, but rather destroyed. Most of the reported

botulism cases in humans are due to home-made canned foods. The reason for this is that, in private households, it is physically impossible to exceed a maximum of 100 °C (boiling water) during conventional “preserving”. This also applies to canning in water baths and ovens, as well as to so-called “Kesselkonserven” produced at home slaughtering, since also in this case, a temperature of 100 °C cannot be exceeded in the preserves.

Anyone who preserves food items that contain little acid, e.g. meat or vegetables (especially beans), should heat these under pressure to 121 °C if possible, so that the spores of *C. botulinum* are inactivated. If this is not possible, the food should be heated twice to 100°C at intervals of one to two days. This reduces the risk of *C. botulinum* spores surviving. The best way to store the preserves between the two rounds of heating is at room temperature. During the initial heating, the bacteria capable of multiplying are killed but the spores can germinate and develop into multiplying and neurotoxin-forming bacteria . These can then be killed during the second heating. If botulinum neurotoxins have formed during storage despite all precautions, they can be inactivated by boiling the preserves at 100 °C directly before consumption, as the neurotoxins are heat-sensitive in contrast to the spores. Heating at only 80 °C requires several minutes to ensure inactivation.

For which foods are *C. botulinum* spores a problem?

Spores of *C. botulinum* can be found on many foods. They are formed by the bacterium *C. botulinum* and are very heat-resistant. They can only be inactivated at temperatures above 100 °C. Cells of *C. botulinum*, however, can only grow under airtight conditions. Therefore, spores are not a problem for fresh food. Foods that are packed airtight (e.g. home-made canned foods, vacuum-packed foods or food packaged in a protective atmosphere) may allow *C. botulinum* to grow when stored unrefrigerated. Therefore, the storage temperatures specified by the manufacturer should always be observed.

Spores of *C. botulinum* are also common in honey. Although they do not become neurotoxin-producing cells, they pose a risk of infant botulism for infants under one year of age. Therefore, honey should not be fed to children under one year of age.

What should be considered when preserving food items that contain little acid?

C. botulinum can only multiply poorly in acidic environments. Accordingly, it can be assumed that acidic foods present a low risk of botulism. The BfR itself did not collect any data on the pH value (a measure of the degree of acidity or basicity of an aqueous solution) of various foods. General information can be found e.g. in the lists of Clemson University (references: https://hgic.clemson.edu/factsheet/canning-foods-the-ph-factor/ and https://www.clemson.edu/extension/food/food2market/documents/ph). According to these lists, most fruits and berries have a pH value below 4.6 (acidic). Exceptions are mainly melons and ripe mangoes, but also pears, in some cases. Meat, poultry, fish, milk and vegetables (with the exception of most tomato varieties) usually have a pH value above 4.6. However, these data provide no certainty, as the pH values may vary strongly in general, e.g. depending on the variety, ripeness and water content.

All foods that are low in acidity, i.e. have a pH value above 4.6, should be boiled under pressure at 121 °C. If this is not feasible, these foods can also be acidified (addition of e.g. vinegar or lemon juice) in advance such that the measured pH is below 4.6. Additional risk mitigation measures are provided in the answer to the question: How can we reduce the risk of botulism from home-made preserved food that has been heated insufficiently?

Can consumers also preserve food in a steam cooker or pressure cooker?

In principle, canned foods are considered safe if they have been heated to 121°C for at least 3 minutes. This is only possible in pressurised production. For safe production, the internal pressure must be precisely determined and readable from the outside. Pressure cookers also work with pressure to reduce the cooking time. However, temperatures are usually not high enough to produce safe canned foods.

How can consumers identify that what they have preserved has gone off?
One indication of this may be the formation of gas by the metabolism of microorganisms. For tin cans or jars with a screwed metal lid, this can be recognised by the bulged container or lid. These swollen cans should be disposed of unopened, as opening them may cause the contents including the neurotoxins to escape explosively. In the case of typical mason jars with rubber sealing ring, if bacteria grow during storage, the vacuum in the jar may be degraded, thus loosening the lid, and the typical hissing during opening may be missing. The contents of these preserves should no longer be consumed.

However, there are certain *C. botulinum* strains that can form neurotoxins without producing gas. With these strains, the formation of neurotoxins is not indicated either by appearance, smell or taste. To be on the safe side, you should therefore heat preserves (especially meat, fish and vegetables), as a matter of principle, thoroughly to 100 °C immediately before consumption. The botulinum neurotoxins that may have been formed are inactivated by this heating.

If no vacuum has formed after the preserving process when using a classic mason jar with rubber sealing ring, and the lid can be lifted off, the preserving process can be repeated immediately after replacing the defective lid or rubber seal. Otherwise, the contents should be consumed at the latest within the following day after thorough heating to 100 °C. The same applies to twist-off glasses, where the lid can still be pressed in flexibly shortly after heating.

What are the most important measures to protect against human botulism?

- Wash food thoroughly before preserving
- Kill existing spores of *C. botulinum* by safely heating
- Create conditions that prevent the growth of *C. botulinum*
- Dispose of swollen cans without opening
- No consumption of food from unsealed mason jars
- If required, additionally heat the preserves thoroughly to 100 °C immediately before consumption
- Store home-made herbal oils or vegetables in oil in the refrigerator and consume them no later than the day after production
- Heat salted, dried fish sufficiently immediately before consumption
- Do not give honey to children under one year of age

How widespread is botulism in livestock?
Botulism in livestock is currently not subject to notification or reporting requirements in Germany. Therefore, there is currently no scientifically collected data on the number of infected animals or affected herds.

Can sick animals be slaughtered and processed into food?
In principle, only healthy animals may be slaughtered and processed into food. If animals do not show symptoms of disease but originate from a farm with infected animals, the farmer must inform the slaughterhouse. In such cases, the competent veterinarian must first check whether the animal is actually healthy prior to slaughter. Stringent hygiene requirements during slaughter also provide additional precautionary measures to ensure that pathogenic microorganisms are not transferred to meat.

What is "visceral" or "chronic" botulism?
Since roughly the late 1990s, scientific publications have reported a disease of unexplained cause in cattle, which is known as "visceral" or "chronic" botulism. The disease is characterised by a wide range of clinical symptoms ranging from difficulty swallowing to udder inflammation to abomasal displacement.

However, it is not yet clear what causes the disease. On behalf of the Federal Ministry of Food and Agriculture, the University of Veterinary Medicine Hannover conducted a study on this topic. The study concludes that a direct and clear correlation between the occurrence of *C. botulinum* and a chronic disease process on dairy farms cannot be confirmed with the statistical methods used. Details of this study and the final report are available at the following link:
https://www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Tiergesundheit/Tierseuchen/Botulismus-Abschlussbericht-Hannover.pdf?__blob=publicationFile&v=2

Further information on the subject of botulism from the BfR website

https://www.bfr.bund.de/en/a-z_index/botulism-129779.html#fragment-2

https://www.bfr.bund.de/cm/350/hinweise_fuer_verbraucher_zum_botulismus_durch_lebensmittel.pdf (only available in German)

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