German Federal Institute for Risk Assessment

FAQ

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Gilding instead of charring: questions and answers about acrylamide in food

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When food is heated, its chemical composition often changes. Under certain conditions, the heating of food can also be accompanied by the formation of undesirable substances that are potentially hazardous to health. These are generally referred to as “heat-induced contaminants”. Burnt food often has particularly high concentrations of such substances due to the previous exposure to high heat. One substance belonging to this group is acrylamide, for which the German Federal Institute for Risk Assessment (BfR) has compiled selected questions and answers.

What is acrylamide?

Acrylamide is an organic (carbon-containing) compound that is highly soluble in water. In food, acrylamide forms as a byproduct of what is known as the Maillard reaction, which is responsible for food becoming brown during baking, roasting, grilling, deep-frying and frying. When carbohydrate-rich foods which also have a high concentration of the amino acid asparagine and a low water content are heated to high temperatures, large amounts of acrylamide are formed. This effect is already seen at temperatures of approx. 120 °C and increases sharply from 170-180 °C.

However, acrylamide is not only formed during the Maillard reaction in food. The substance is also used as a chemical in the production of plastics and dyes. However, the industrial use of acrylamide is not directly related to the occurrence of acrylamide in food.

Which foods contain a lot of acrylamide?

Products or dishes made from potatoes such as crisps, potato pancakes, chips, and fried potatoes often contain particularly high concentrations of acrylamide. Grain products such as crispbread, crackers, biscuits, and breakfast cereals can also contain relevant amounts of acrylamide.

As acrylamide is formed during roasting, it is also found in coffee. Recent investigations as part of the BfR MEAL study also indicate that vegetable crisps can contain very high concentrations of acrylamide.

In contrast, only very small amounts of acrylamide are absorbed through drinking water.

How much acrylamide do consumers ingest?

Dietary intake is the primary source of acrylamide for consumers. According to calculations by the European Food Safety Authority (EFSA) from 2015, the daily intake via this route is between 0.4 and 1.9 micrograms per kilogram of bodyweight (µg/kg bw).

Smokers are additionally exposed by inhaling tobacco smoke, which also contains acrylamide. It is estimated that they ingest 0.5 to 2 µg of acrylamide per kg of bodyweight per day. (Schettgen et al., 2004a; Vesper et al., 2008; von Stedingk et al., 2011; Phillips and Venitt, 2012).

How high is human exposure to acrylamide from sources other than food and smoking?

Currently available data suggests that other sources of exposure are negligible. For acrylamide in cosmetics, regulations have been adopted at the European level that significantly limit the residual acrylamide content. Thus, consumer exposure to acrylamide from cosmetic products is now not considered significant.

What are the harmful effects of acrylamide?

Acrylamide ingested through food is absorbed from the gastrointestinal tract and distributed to all organs. Most of the ingested substance is metabolised. Both acrylamide and the metabolites of acrylamide formed in the human body can cross the placenta and also pass into breast milk.

In 2015, the European Food Safety Authority (EFSA) published a comprehensive opinion on possible health risks associated with the intake of acrylamide from food. Taking into account all available data, but based predominantly on animal studies, the opinion identified mutagenic and carcinogenic effects as well as effects on the nervous system, male fertility, and embryonic development.

What role do mutagenic and carcinogenic effects play in humans?

When assessing the health risks posed by acrylamide, the mutagenic and carcinogenic effects of the substance play an important role. In animal studies, acrylamide was almost completely absorbed in the gastrointestinal tract after dietary intake and subsequently metabolised, primarily in the liver. One of the metabolites formed is glycidamide, which has an increased reactivity compared to acrylamide and binds very quickly to cellular components such as proteins and DNA.

The carcinogenic effect of acrylamide, which has been shown in animal experiments on various organs, is mainly attributed to glycidamide. Glycidamide binds to the DNA and can thus trigger changes to the DNA sequence (mutations). The formation of reactive oxygen species (ROS) and non-mutagenic (epigenetic) effects on the control of the cell cycle are also potential mechanisms of action. This conclusion on the mutagenic effect of acrylamide was confirmed by EFSA in another opinion from 2022 in which more recent data was considered.

With regard to mutagenic and carcinogenic effects, it is currently not possible to determine with sufficient certainty a daily intake level for acrylamide at which adverse effects on human health are not to be expected.

What is the probability of non-neoplastic effects occurring in humans? "Non-neoplastic effects" are effects that are not associated with the development of cancer, but which can still cause health impairments. In the case of acrylamide, these include effects on the nervous system, on male fertility, and on embryonic development. They occurred in animal studies at doses of more than 430 µg/kg bodyweight per day.

As a rule, humans do not ingest such high amounts through food. Average dietary intake in humans is between 0.4 and 1.9 µg/kg bodyweight (bw) per day (EFSA, 2015). Therefore, such non-neoplastic effects are not expected to occur in humans.

Does intake of acrylamide pose a health risk to consumers?

As acrylamide has mutagenic and carcinogenic properties, it is currently not possible to specify a daily intake level with sufficient certainty at which adverse effects on human health are not to be expected. It is therefore not possible to determine a *health-based guidance value* for acrylamide as a basis for risk assessment.

As is common in the European Union (EU) in such cases, the European Food Safety Authority (EFSA) instead applied the *Margin of Exposure* (MOE) concept in its 2015 opinion (more information on the EFSA website: https://www.efsa.europa.eu/de/topics/topic/margin-exposure). The MOE is the quotient of a suitable toxicological reference point and the human exposure to the substance. In the opinion, a reference point of 0.17 mg/kg bodyweight per day was identified on the basis of carcinogenic effects in animal models (mice). Based on this reference point and the assumption of an average acrylamide intake, EFSA calculated MOE values of 89 to 425. MOE values of between 50 and 283 are given for consumers who ingest particularly high levels of acrylamide due to their specific eating habits.

In the case of mutagenic and carcinogenic substances such as acrylamide, an MOE of 10,000 or greater is generally considered to be of low concern – but not harmless – from a public health perspective. In the case of acrylamide, however, all MOE values are well below 10,000. The results of the study have prompted EFSA to consider the total amount of acrylamide ingested through food as a cause for concern.

However, the epidemiological data currently available on acrylamide from observational studies in humans do not provide a clear picture with regard to a statistical correlation between the dietary intake of acrylamide and the incidence of cancer in the population.

Are children particularly at risk from acrylamide in food?

Children eat more in relation to their bodyweight than adults. Acrylamide exposure can therefore be significantly higher than in adults, but also in children, it depends heavily on individual eating habits.

An exposure assessment published by the European Food Safety Authority (EFSA) in 2015 found that infants, toddlers, and children have a higher average acrylamide intake than adolescents, adults, and senior citizens.

Since average exposure to acrylamide is higher and children are generally a particularly vulnerable population group, there is reason to assume that children are at greater health risk than adults.

What is known about the harmful effects of acrylamide during pregnancy?

According to scientific assessment, the amounts of acrylamide ingested by humans through food do not impair embryonic and infant development, nor do they increase the risk of miscarriages. However, acrylamide does have mutagenic and carcinogenic properties. In addition, both acrylamide and its metabolites formed in the human body can cross the placenta and pass into breast milk. In order to minimise the burden on themselves and their child, pregnant women and breastfeeding mothers should ensure that their nutrition is low in acrylamide.

Is there a "tolerable threshold value" for the intake of acrylamide?

In the case of mutagenic and carcinogenic substances such as acrylamide, even low intake levels, especially if consumed regularly, can be associated with an increase in health risks. Therefore, according to the current state of knowledge, it is not possible to derive a tolerable daily intake (TDI) or another health-based guidance value for acrylamide.

Instead, the minimisation requirement generally applicable in the EU provides the frame of reference, the aim being to minimise exposure to mutagenic and carcinogenic substances as far as reasonably achievable (ALARA principle: *As Low As Reasonably Achievable*).

In line with the ALARA principle, EU-wide regulations have been established to reduce acrylamide in food. However, the guideline values set are not maximum levels, but serve as performance indicators to monitor the efficacy of the minimisation measures. They correspond to the concentrations of acrylamide that can reasonably be achieved by applying all relevant minimisation measures. As these guideline values are based solely on technical feasibility and not on health risks, falling below the guideline value does not mean that the food in question is completely harmless to human health.

What can consumers do to reduce their dietary intake of acrylamide?

The levels of acrylamide in prepared food is closely linked to the degree of heat-induced browning: the more browned the food is, the more acrylamide it contains. Consumers should therefore pay attention to gentle cooking methods when processing carbohydrate-rich foods. "Gilding not charring" is the rule of thumb. In other words, the food should not be heated above 180 °C or for longer than necessary.

In principle, it can be assumed that the intake of acrylamide can be reduced by removing an excessively browned layer. However, even moderately browned foods can already contain high levels of acrylamide. It is therefore always better to ensure gentle preparation in advance so that acrylamide is not formed in the first place.

The following also applies: the more water the food contains, the less acrylamide is formed. This is the case, for example, with pre-cooked fried potatoes, which usually contain less acrylamide than fried potatoes made from raw potato slices.

The preparation recommendations on the packaging should be observed. The potential risk for consumers can be reduced if they take into account the general recommendation for variety and diversity when selecting foods. This helps to avoid unbalanced exposure to the

various potentially hazardous substances that can be expected to occur sporadically at low levels in food.

Does the human body produce acrylamide itself?

A research team from the German Federal Institute for Risk Assessment (BfR) confirmed an interesting discovery in a study: there is clear evidence that acrylamide is also formed in the body itself – and to a greater extent than previously assumed. We have issued a separate communication with detailed information on this.

About the BfR

The German Federal Institute for Risk Assessment (BfR) is a scientifically independent institution within the portfolio of the Federal Ministry of Food and Agriculture (BMEL) in Germany. The BfR advises the Federal Government and the States ('Laender') on questions of food, chemicals and product safety. The BfR conducts independent research on topics that are closely linked to its assessment tasks.

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