ACRYLAMIDE

What is acrylamide?

Acrylamide (CH$_2$=CH—CONH$_2$) is a synthetic vinyl compound produced by the chemical industry mainly as a building block for polymers, particularly polyacrylamide. Polyacrylamide is widely used in industrial applications, such as in the treatment of wastewater, in textile and paper processing and in mining and mineral production. Acrylamide is also present in cigarette smoke.

The wide use of polyacrylamide in industry means that human exposure to acrylamide is likely and a number of toxicological studies have been carried out. The results of these studies suggest that acrylamide may have adverse effects on human health under some circumstances. In 2002 it was discovered that acrylamide could be generated in some food products during processing and should therefore be investigated as a potential food safety hazard.

What foods can be contaminated?

The possibility of acrylamide contamination of foods did not become widely known until April 2002, when a report from the Swedish National Food Administration was published. This report revealed that acrylamide could be produced in significant concentrations in certain carbohydrate-rich foods processed at relatively high temperatures, such as fried potato and baked cereal products. The work on which this report was based was done after an earlier toxicological study discovered unexplained exposure to acrylamide in a control group, leading to the idea that food could be a source of the chemical.

Since 2002 a very wide range of foods around the world have been surveyed for the presence of acrylamide and the contaminant has been found to occur widely in many different food categories. Fried
potato products, notably French fries and crisps, and baked cereal products, such as biscuits, bread, toasted breakfast cereals and pastries are the main foods affected, but roasted and ground coffee has also been found to be an important source. Animal-based foods and plant foods that are eaten raw, or cooked at lower temperatures, tend not to contain significant levels of acrylamide.

Acrylamide is not confined to commercially processed foods. It can also be found in home-baked or fried foods at relatively high levels. It seems certain that acrylamide has been present, but gone undetected, in cooked foods for centuries. It has been found in such diverse products as olives, prune juice and chocolate confectionery and many countries have published survey data covering a wide range of foods.

The amount of acrylamide found in foods varies widely, both with the food category and with the process applied. Some approximate examples of recorded levels in different food groups are given below.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Acrylamide (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast cereals</td>
<td>20 – 250</td>
</tr>
<tr>
<td>Bread</td>
<td>10 – 130</td>
</tr>
<tr>
<td>Roast and ground coffee</td>
<td>100 – 400</td>
</tr>
<tr>
<td>Crackers</td>
<td>50 – 600</td>
</tr>
<tr>
<td>Potato crisps and snacks</td>
<td>100 – 2500</td>
</tr>
<tr>
<td>Chocolate products</td>
<td>10 – 100</td>
</tr>
</tbody>
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* Source: FAO/WHO Acrylamide Infonet Analytical Database
Acrylamide levels in a number of food groups have been monitored in the EU since 2003. The most recent data, covering the period from 2007-2009, indicates that levels have fallen in some foods, but remained static, or even increased, in others. The reasons for this are unclear and further monitoring may be needed before clear trends emerge. Nevertheless overall exposure to acrylamide in the diets of European consumers is reported to have fallen by approximately 30% since 2003.

How does it affect human health?

Acrylamide is a neurotoxin at high levels of exposure and may cause a range of symptoms such as numbness in the hands and feet. It has also been shown to be genotoxic in animal studies. However, it is considered unlikely that the levels found in foods could result in sufficient exposure to cause neurological damage or reproductive toxicity.

Of more concern to the food industry is the finding that acrylamide is also carcinogenic in animal studies. The International Agency on Research on Cancer (IARC) classifies it as “probably carcinogenic to humans (IARC Group 2A).” Results of epidemiological studies searching for evidence of a link between acrylamide in the diet and the development of certain common cancers in humans have so far been inconclusive. A number of long term carcinogenicity and toxicological studies are currently in progress and these should help to reduce the level of uncertainty.

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) reviewed all the available toxicity and likely intake data for acrylamide in 2005 and carried out a risk assessment for the effect on human health. They found that the average person ingests enough acrylamide in the diet each day to equate to 1/300th of the dose required to cause a 10% increase in the risk of breast cancer in rats, with high consumers ingesting as much as 1/75th of that dose. The Committee considered this to be a low safety margin in comparison
with other carcinogens in the diet. They concluded that, although there was considerable uncertainty in estimating the risk to human health, exposure to acrylamide in the diet might indeed be a concern.

The JECFA review acknowledged that acrylamide is an inadvertent contaminant introduced during cooking and unlikely ever to be eliminated from foods. Nevertheless, the Committee recommended that the food industry should work towards lowering acrylamide levels in critical food groups, such as potato crisps and chips, coffee, bakery products and biscuits and that guidance should be developed to help consumers reduce the levels produced in home cooked foods.

JECFA carried out a re-evaluation of acrylamide in 2010 using new exposure and toxicity data. They noted that, despite attempts to reduce levels of acrylamide in some foods, overall dietary exposure for most people had remained the same. The committee concluded that the additional data confirmed that acrylamide in the diet is a “human health concern.”

Where does it come from?

The original Swedish report into acrylamide in food in 2002 indicated that the contaminant is produced as a result of heating certain foods, especially those containing high levels of carbohydrate, at temperatures above 120°C. It is therefore a contaminant generated during processing. Since then considerable research has been carried out into the mechanism by which acrylamide is generated during frying, baking or roasting.

The major mechanism for the formation of acrylamide during cooking is now acknowledged to be the reaction of the free amino acid asparagine with reducing sugars, such as glucose or fructose, during the Maillard browning reactions that occur during cooking at high temperatures. Other mechanisms have since been suggested, but most attention has been focused on Maillard browning as the main source of acrylamide. The key factors that affect the quantity of
acrylamide produced appear to be the amount of free asparagine and sugars present in the food and the cooking time and temperature.

**Is it stable in food?**

The large amount of data collected from food surveys suggests that acrylamide is relatively stable in food, but this has not been widely studied to date. Nevertheless, acrylamide levels have been found not to decrease significantly in crisps or baked cereal products during shelf life, while levels in roast and ground coffee are reported to decrease significantly.

**How can it be controlled?**

A considerable amount of research has been initiated since 2002 to investigate possible strategies for minimising the formation of acrylamide during the cooking of food products. Much of this work has been published and many of the most useful and practical techniques have been brought together by FoodDrinkEurope (formerly the Confederation of the Food and Drink Industries of the EU, or CIAA) in an ‘Acrylamide Toolbox’ available on-line (link provided below). The Codex Alimentarius Commission has published a ‘Code of Practice for the Reduction of Acrylamide in Foods’ and this too is available on-line.

*For food processors*

One obvious strategy for the control of acrylamide formation is to minimise the amount of free asparagine and reducing sugars in food prior to cooking. The development of low-asparagine varieties of potato is one approach that is receiving attention.

The modification of product recipes also shows some promise. For example, replacing ammonium bicarbonate with other raising agents in baked products can reduce acrylamide formation significantly, as can a reduction in pH. However, care must be taken to ensure that
unacceptable textural and flavour changes do not result from such modifications.

The main factors that can be modified to minimise acrylamide formation are cooking time and temperature. The ‘thermal input’ to a cooking process has been shown to be directly linked to the amount of acrylamide produced. As a general rule, higher thermal input results in higher levels, with the exception of coffee production, where acrylamide levels decrease with longer roasting times and ‘darker’ roasts.

Frying, baking and roasting at lower temperatures and for shorter times reduce the amount of browning of the product and also reduce the amount of acrylamide produced. For example, caterers have been advised to cook French fries only until golden, rather than brown, and some crisp manufacturers have altered frying times and temperatures to reduce acrylamide production. While this may be successful, it must be recognised that the browning of baked and fried foods is an essential component in their sensory acceptability. Also, frying at lower temperatures may allow foods to take up higher levels of fat, which may be undesirable from a nutritional point of view. Reducing acrylamide by changing processing times and temperatures results in a compromise between product quality and safety. Even with improved control strategies it has been estimated that a 40% overall reduction of acrylamide in food may be the best achievable.

For consumers

Consumers have also been advised to reduce cooking times and temperatures, especially for fried foods. For example, French fries should be cooked until golden, rather than brown.
Are there rules and regulations?

Acrylamide is not yet covered specifically by legislation in Europe or North America and no permitted limits have been set. At present, national and international food safety and public health authorities request that the food industry continue to work to minimise the levels of acrylamide in critical food groups.

In the EU, member states have been requested to extend monitoring of acrylamide levels in food until 2012, when the European Commission will assess the situation.

Where can I learn more?

JECFA monograph on acrylamide (2006)

FoodDrinkEurope ‘Acrylamide Toolbox’ 2011

Codex Alimentarius COP for the Reduction of Acrylamide in Foods

European Commission acrylamide pages

US Food and Drug Administration acrylamide pages