Technical Brief

Acrylamide in Food

Spurr, M. (2024)

What is acrylamide?

A chemical compound (C3H5NO) used in industrial applications such as manufacturing polymers and cements. Also formed in some foods as a normal product of cooking or heating. Common foods containing acrylamide include:

• Potato products - French fries, potato chips, other fried or baked potato-based snacks

• Cereal products - bread, toast, cookies, biscuits, crackers, breakfast cereals, especially those browned or toasted

• Coffee - roasting coffee leads to the formation of acrylamide and is affected by other factors, such as bean varieties.

Mechanism of formation

Primarily occurs through the Maillard reaction, responsible for the browning and flavour development in cooked foods. This complex mechanism involves the amino acid asparagine and reducing sugars, such as glucose or fructose. Various factors influence its formation, in food, and the precise mechanism is difficult to predict:

• Temperature - higher temperatures significantly increase formation, such as frying, roasting and baking at temperatures above 120°C

• Time - prolonged cooking times, at high temperatures, lead to higher levels

• Composition - foods rich in asparagine and reducing sugars are more likely to form acrylamide e.g. potatoes and cereal grains

• Moisture content - lower water activities can enhance formation since dry heat facilitates the Maillard reaction

• pH - can affect the Maillard reaction and slightly acidic to neutral pH conditions are more favorable for its formation

• Others - salt, metal ions and complexing compounds.

Analysis in food

Through comprehensive analytical techniques, scientists and food safety authorities can monitor and manage acrylamide levels in the food supply chain, ensuring consumer safety and informed dietary choices. Analysis involves sample preparation, extraction, purification and quantification, using sophisticated techniques. Acrylamide formation is not homogenous in a food, so sampling is important, for example most acrylamide in a loaf of bread will be in the crust [1]. Preparation can involve grinding or blending to create a consistent mixture. Extraction can be carried out with solvents (e.g. water, methanol, acetonitrile) or by Solid-Phase Extraction (SPE).

Analysis requires high-specification and specialist laboratory testing, usually Liquid Chromatography-Mass Spectrometry (LC-MSMS) and, less commonly, Gas Chromatography-Mass Spectrometry (GC-MS) after derivatisation[2]. Once typical acrylamide levels are modelled for a particular production process, and product design, then indirect indicators can be used for in-process specification control e.g. monitoring of raw materials for formation precursors, such as asparagine.

What are the health risks?

The European Food Standards Agency (EFSA) concluded that acrylamide is a genotoxic carcinogen, but also that the current levels of dietary exposure are not of concern with respect to neurotoxicity (damage to nerves outside the brain and spinal cord) or reproductive and developmental effects[3]. Various health organisations, and regulatory agencies, have conducted risk assessments and developed guidelines to limit acrylamide exposure in the population, in the form of:

• dietary recommendations, so boiling or steaming instead of frying or roasting

• advisory limits indicative for acrylamide levels in certain foods, e.g. UK/EC law sets benchmark levels for acrylamide in different food categories

• regulatory limits - proposals are under discussion in the EC though none proposed in UK.

UK's National Health Service (NHS) and Cancer Research UK have conflicting views on the relevancy of acrylamide for cancer in humans.

What regulations and recommendations are in place?

• UK's Food Standards Agency (FSA) has guidelines and recommendations aimed at reducing acrylamide in foods, including: guidance for food businesses to follow best practices; consumer information on how to reduce intake at home; monitoring and reporting to ensure public awareness and safety

• EFSA has concluded that the current levels of exposure are of concern. Regulation (EU) 2017/2158 sets out practical measures and benchmarks to reduce acrylamide, such as: raw material selection, product formulation and processing techniques, requiring businesses to implement monitoring and mitigation measures to keep levels as low as reasonably achievable (ALARA principle).

The FAO/WHO Codex Alimentarius developed a Code of Practice for the 'Reduction of Acrylamide in Foods' which provides national and local authorities, manufacturers and other relevant bodies, with guidance to prevent and reduce formation of acrylamide in potato and cereal products

• The trade body Food Drink Europe (FDE) publish acrylamide toolboxes[4], since 2005, setting out core tools and strategies for acrylamide mitigation in a variety of foods

• In the USA, Food and Drug Administration (FDA) provides guidance on acrylamide reduction strategies such as eating a balanced diet and avoiding overcooking

• Globally, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) has evaluated the risks associated with acrylamide. In 2009, FAO/WHO Codex Alimentarius developed a Code of Practice for the Reduction of Acrylamide in Foods (CAC/RCP 67-2009) which intends to provide national and local authorities, manufacturers and other relevant bodies with guidance to prevent and reduce formation of acrylamide in potato products and cereal products[5]

• Health Canada has published guidelines which emphasise choosing cooking methods and times that reduce formation

• Japan's Food Safety Commission has assessed the risks and issued advisories on controlling processing conditions

• Food Standards Australia New Zealand (FSANZ) provides information to the food industry and consumers

• The People's Republic of China (PRC) has recently consulted as they notified World Trade Organization (WTO) of a new National Food Safety Standard Code of Practice for Principle for the control of acrylamide contamination in food.

What can the food sector to do reduce acrylamide?

By implementing strategies, acrylamide levels can be significantly reduced enhancing food safety and consumer confidence.

Strategies are highly specific to the product type, and detailed guidance has been published for some product types. Common themes include:

1. Raw material selection and preparation:

• use raw materials with naturally low levels of asparagine and reducing sugars (precursors to acrylamide formation)

• implement agricultural practices that lower the concentration of asparagine and sugars in crops, such as optimising fertilisation and harvest timings

• substitute high-asparagine ingredients e.g. partial replacement of wheat flour with rice flour.

2. Formulation adjustments:

• incorporate additives that inhibit formation e.g. citric acid/or calcium salts which lower pH[6]

3. Processing modifications:

• lower cooking temperatures and reduce cooking times, especially for frying, baking and roasting of most foods, aiming for golden yellow rather than dark brown

• maintain higher moisture levels during cooking, as acrylamide forms more readily in dry conditions

• where possible use pre-cooking techniques, such as blanching potatoes before frying to leach asparagine and sugars.

4. Product design: consider alternative cooking technologies that minimise formation, such as vacuum frying which involves lower temperatures than traditional frying.

5. Packaging: to protect the products, cooked at home, from moisture loss during storage.

6. Raw material storage: for example, potatoes and grains are kept in controlled storage conditions, ideally dark, cool, low humidity, with controlled normalisation cycles before entering supply chains.

7. Consumer education: provide clear on-pack cooking instructions (temperature and time), validated that they do not lead to excessive acrylamide, beyond what is reasonable for product quality.

8. Research and development: invest in ongoing research to better understand acrylamide formation mechanisms and develop new mitigation techniques; regularly monitor levels and adjust production processes; characterise levels and develop strategic approaches to minimise formation of acrylamide.

9. Industry collaboration: work with industry peers to share knowledge and best practices.

10. Legislation: stay up-to-date with regulatory guidelines and ensure compliance with relevant standards.

References

1. IFST Information Statement Sampling for Food Analysis - key considerations | Institute of Food Science and Technology (ifst.org)
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4. Toolbox Acrylamide Toolbox - FoodDrinkEurope : FoodDrinkEurope
5. CODEX Alimentarius International Food Standards article Understanding acrylamide | CODEXALIMENTARIUS
6. Research article Calcium Salts Reduce Acrylamide Formation and Improve Qualities of Cookies (sciepub.com)

Further Reading

• IFST Information Statement Acrylamide in foods | Institute of Food Science and Technology (ifst.org)

• IFST Fact Sheet IFST Fact Sheet Safe Heating of Food.pdf

• Food safety advice Acrylamide | Food Standards Agency