

Tackling the problem of elevated acrylamide levels

By Serena Lim, editor: *Oils & Fats International (OFI)*

New European Union (EU) legislation that came into force on 11 April last year has meant that all businesses that manufacture food, or prepare and serve it to customers, must understand the potential risk of the carcinogen acrylamide, and take steps to reduce it.

Acrylamide is a chemical substance formed when starchy foods with higher levels of the amino acid asparagine are cooked at temperatures above 120°C in processes such as frying, roasting, baking, grilling and toasting. Acrylamide is potentially carcinogenic and is found in a wide range of foods including roast potatoes and root vegetables, chips, crisps, toast, cakes, biscuits, cereals and instant coffee.

Acrylamide develops as a natural by-product in food through the Maillard reaction, in which a chemical reaction occurs between reducing sugars and amino acids to create a food's characteristic flavour, colour and smell.

Temperature is the most important factor in acrylamide formation. Long frying times at low temperatures causes less acrylamide than short frying times at high temperatures. It is not possible to eliminate acrylamide from foods, but action can be taken to reduce its levels.

Legislation and benchmarks

EU legislation sets benchmark levels for acrylamide and describes practical measures to mitigate its formation. Businesses that manufacture food, or prepare and serve it to customers, must be aware of the potential risk of acrylamide and take steps to reduce its formation. They must sample to monitor levels and record mitigation measures according to the AAK Food Service.

Legislation sets benchmark levels for acrylamide in different products. Examples of this are 40 microgrammes

(µg)/kg in baby foods, 350µg/kg in biscuits and cookies, 750µg/kg in potato crisps, 850µg/kg in instant soluble coffee and 300µg/kg in most breakfast cereals, except for maize, oats, spelt, barley and rice-based products, where the benchmark level is 50% lower. The European Commission (EC) will review the levels every three years, gradually setting lower levels.

Cancer risk

The presence of elevated levels of acrylamide in food was first reported in April 2002, when the Swedish National Food Administration announced that acrylamide had been found at higher levels in starch-containing foods, such as potato products and bread, cooked at high temperatures.

The UK Committee on Mutagenicity (CoM) suggested in 2006 that acrylamide could damage DNA, stating: "There is no level of exposure to this genotoxic carcinogen that is without some risk".

In 2013, the EC introduced 'indicative values' as a guide for food groups most associated with acrylamide. In 2014, the European Food Safety Authority (EFSA) supported the CoM's views and EFSA's Scientific Panel on Contaminants in the Food Chain confirmed that acrylamide in food potentially increased the risk of developing cancer, in people of all ages.

As it is not possible to establish a safe level of exposure for acrylamide to quantify the risk, the EFSA has used a 'margin of exposure' approach, indicating the level of health concern posed by a substance's presence in food. Acrylamide has a margin of exposure of 100, compared with a value of 100 000 for aflatoxins and nitrosamines, which are therefore 100 times less dangerous.

Acrylamide in oil

Acrylamide is not found in cooking oil but if starchy food, such as potatoes, is fried

in oil and that oil is re-used, acrylamide levels can build up. According to the AAK Food Service, it is the crumbs and fine particles of food left in the frying oil after cooking that may contain, and continue to create, acrylamide in the hot oil. "If the frying oil is not skimmed or filtered out, the fine particles may stick to the next batch of food, raising acrylamide levels."

According to food chemist Dr Christian Gertz, of Germany's Maxfry GmbH, acrylamide levels are not influenced by the use life of frying oils. "You can produce fried products in fresh oil with a high level of acrylamide and vice versa. The main factor is the applied temperature and frying time," Gertz says.

UK food safety firm, Klipspringer, recommends replacing cooking oil when it reaches a 25% total polar compound (TPC) level. "There is no direct correlation between acrylamide and TPC levels, but it is widely acknowledged that oils with a high TPC level also contain higher levels of acrylamide," says the food safety firm. The 25% TPC level is a rough guide as the limits in Europe are different, according to Gertz.

"The problem is really much more complex," he adds. "TPCs give only limited information on the real status of an oil. In industrial practice, for example, it can be found that production with oils that have less than 25% leads to products of low quality and off-flavours. Levels of 12% to 18% can already be a problem depending on the application and product."

Klipspringer outlines some advice for any food business that cooks with oil, or cooks food containing acrylamide:

- Abide by the new standards.
- Cook food at lower temperatures for less time and fry at a maximum temperature of 175°C.
- Cook food to a maximum light golden brown colour.
- Check the levels of TPC in oil and discard at 25%.



Formation in frying

The most important condition affecting acrylamide formation during frying is temperature. "In chemistry, a rule of thumb is that the speed of a reaction doubles in steps of 10°C. A critical temperature for deep frying is 175°C. From that point on, the formation of acrylamide increases exponentially," says Gertz.

According to Gertz, S Klostermann and Parkash Kochar in their study, *Deep frying – the role of water from food being fried and acrylamide formation*, frying is basically a dehydration process. After food is immersed in oil, a sharp superficial crust region is immediately formed. The thickness of the crust increases with the frying time from about 0,3mm to 2mm.

Heat is transferred from the frying oil to the core centre of the food via the crust. Water evaporates at the moving boundary. After the boundary zone is dehydrated, water migrates from the food outwards to the walls to replace what is lost during heating. Behind this front, the temperature within the food is about 100°C to 104°C, representing the temperature change from water to steam. The temperature in the crust remains at the boiling point of water.

When frying potato crisps, the crust region enlarges quickly and the core zone disappears. The lack of water to be evaporated causes pressure to drop, and heat transfer rapidly raises the temperature of the material to above 100°C. When no more water can escape through the crust, the temperature increases to above 120°C, when acrylamide starts to form.

Comparing different oils and fats

Different oils and fats have different abilities to transfer heat to food as they contain different quantities of substances such as mono- and diglycerides, or short- or middle-chain fatty acids.

In Gertz's 2014 paper *Fundamentals of the frying process*, palm olein and beef tallow were found to contain more polar components than oils such as rapeseed oil, sunflower oil or groundnut oil. It is possible that more polar compounds reduce the surface tension between the oil and food surface.

The surfactant theory of frying suggests that as oil degrades, more surfactant materials are formed, causing increased contact between oil and food. These materials lead to better heat transfer, the water in the food evaporates faster and the time the temperature takes to exceed 100°C to 104°C is shorter. This suggests that frying with palm olein and tallow can cause higher acrylamide levels in comparison to vegetable oils such as sunflower or rapeseed, if no attention is paid to the frying time.

Mechanism of formation

According to Gertz, a number of theories have been proposed to account for the mechanism by which acrylamide is formed in fried food. "In experiments with asparagine, it has been confirmed that asparagine is the nitrogen source for acrylamide."

Asparagine is found abundantly in wheat, corn, potatoes, green beans and peanuts. Heating of asparagine alone does

not efficiently produce acrylamide but, combined with reducing sugars and some fat degradation (oxidation) products, the formation of acrylamide is accelerated. Other factors which may influence the reaction include the potato variety, the temperature, product moisture and acidity.

Gertz says in discussions about possible pathways to the formation of acrylamide in deep-fried products, it has been assumed that acrylamide is formed via glycerol by oxidation of acrolein to acrylic acid, which reacts with ammonium from amino acids.

Another possible mechanism describes acrylic acid arising directly from the decomposition of two common amino acids, alanin and aspartic acid. Acrolein is also formed in various concentrations in the oxidation of linolenic acid (not via glycerol), depending on the kind of cooking oil heated and the temperature applied to the oil.

The role of silicone additives

Silicone is legally permitted in Europe as additive E900 and is often used as an anti-foaming agent in frying oils and fats. According to Gertz, the role of silicone in acrylamide formation is not clear. "It is evident that heat stabilising agents (not simple antioxidants) added to vegetable oils rich in linolenic or linoleic acid – such as rapeseed, sunflower and soya bean – help reduce the formation of oxidised reaction products, which can act as a partner in the Maillard reaction.

"Unfortunately, the standard antioxidants butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) do not have this effect."

Conclusions

Acrylamide formation during frying depends on many conditions, the most important being temperature and frying time. The formation of acrylamide in fried food can be decreased by lowering frying temperatures to below 175°C. However, this does not necessarily reduce acrylamide concentration in fried products unless all process parameters are taken into account. 🍌

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