

# Tackling acrylamide

New EU legislation that came into force in April last year sets benchmark levels of the carcinogen, acrylamide, in various foods such as chips and crisps. What can food businesses do to lower acrylamide levels and what is the role of frying in its formation?

*Serena Lim*



New European Union legislation that came into force on 11 April 2018 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 high temperatures above 120°C in processes such as frying, roasting, baking, grilling and toasting.

The substance has the potential to cause cancer and is found in a wide range of foods including roasted 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, a form of non-enzymatic browning where a chemical reaction occurs between reducing sugars (aldoses such as glucose but not fructose/ketoses) 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 but a low temperature cause less acrylamide than a high temperature and short frying time. It is not possible to eliminate acrylamide from foods but actions can be taken to reduce levels.

The new EU legislation passed in 2017 sets 'benchmark' levels for acrylamide in various products and describes practical measures to mitigate its formation.

Businesses that manufacture food or

prepare and serve it to customers in a retail or food service setting must be aware of the potential risk of acrylamide; take steps to reduce its formation and build these into their food safety management procedures; take samples to monitor levels where appropriate; and keep records of mitigation measures, says AAK Food Service.

The legislation sets out benchmark levels for acrylamide in different products such as 40 microgrammes( $\mu\text{g}$ )/kg in baby foods, 350 $\mu\text{g}$ /kg for biscuits and cookies, 750 $\mu\text{g}$ /kg for potato crisps, 850 $\mu\text{g}$ /kg for instant soluble coffee and 300 $\mu\text{g}$ /kg for most breakfast cereals, except for maize, oat, spelt, barley and rice-based products, for which the benchmark level is 50% lower. The aim is for food businesses to achieve acrylamide levels as low as reasonably achievable below these benchmark levels. The European Commission (EC) will review the levels every three years, with the aim to gradually set lower levels.

## Cancer risk

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

Following the announcement, the World Health Organization said it would organise an expert consultation to determine the

full extent of the public health risk from acrylamide in food.

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' for food groups most associated with acrylamide. These were a guide rather than regulatory limits.

In 2014, the European Food Safety Authority (EFSA) supported the CoM's views and, in an opinion adopted in 2015, the EFSA's Scientific Panel on Contaminants in the Food Chain confirmed that acrylamide in food potentially increased the risk of developing cancer for 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, which provides an indication of 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 both aflatoxins and nitrosamines, which are therefore 100 times less dangerous.

## Acrylamide in oil

Acrylamide is not found in cooking oil but if starchy food like potatoes are fried in oil and that oil is reused, then acrylamide levels can build up.

According to AAK Food Service, it is the crumbs and fine particles of food that are

► 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 crumbs and fine particles of food 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 a fresh oil with a high level of acrylamide and vice versa. The main factor is the applied temperature and frying time."

UK food safety firm Klipspringer recommends that cooking oil should be replaced when it reaches a 25% total polar compound (TPC) level.

"There isn't a direct correlation between acrylamide and TPC levels but it's widely acknowledged that oils with a high TPC level also contain higher levels of acrylamide," it says.

The 25% TPC level is a rough guide as the limits in Europe are different, according to Gertz. In Switzerland, for example, the level is 27%, while it is 24% in Germany.

"In reality, the problem is much more complex," says Gertz. "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 way less than 25% leads to products of low quality and off-flavours. Levels of 12-18% can already be a problem depending on the application and product, such as pastries, for example."

Klipspringer outlines a few pieces of advice for any business in the food industry 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 rough 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 and higher, 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 in which oil acts as transfer medium for heat.

After food is immersed in oil, a sharp superficial crust region is immediately formed. The thickness of the crust increases with the frying time to about 0.3mm-2mm.

Heat is transferred from the frying oil to the core centre of the food via the crust region. Water is evaporated 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 100-104°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 makes the pressure drop, and the heat transfer raises the temperature of the material to above 100°C very quickly.

At the moment, when no more water can escape through the crust, the temperature increases and reaches a point above 120°C, when acrylamide starts to form. This reaction is at its optimum between 170°C to 180°C.

## 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 – such as mono- and di-acylglycerols or medium chain triacylglycerols – than oils such as rapeseed oil, sunflower oil, or groundnut oil. It is possible that more polar compounds reduces 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 at the oil-food interface, meaning the water in the food evaporates faster and the time the temperature exceeds 100-104°C is shorter.

This suggests that frying with palm olein and tallow can give a higher level of acrylamide in comparison to vegetable oils like 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," he says.

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, temperature, product moisture and acidity.

Gertz says that 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 coming 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 soyabean – help to 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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