Chief Scientific Advisor's

Science Report

Issue Two: seeking and acting on independent expert advice on food chemicals

Food Standards Agency
food.gov.uk

"I am pleased to introduce my second report as Chief Scientific Advisor to the Food Standards Agency (FSA). My first report focussed on microbiological risks in the form of foodborne viruses. In this report we turn to chemical risks, and focus on two issues that have required advice from our scientific advisory committees."

Professor Guy Poppy,
FSA Chief Scientific Advisor

The independent expert advice we receive from these committees helps to ensure that FSA policy and advice to consumers is based on the best possible evidence. These issues also highlight how we work with other government departments and advisory committees on topics of mutual interest.

The major topic in this report is acrylamide, which forms in food during cooking. The background to the research that identified acrylamide in food provides an interesting example of how chance observations can be important in scientific discovery. That initial finding has prompted much additional research into how and where acrylamide forms in food, expert assessment of the risks, and consideration of how best to protect the health of consumers.

We also report on an assessment of how an increase in potassium in our diet might affect the health of some consumers. Potassium compounds can be used as alternatives to sodium compounds in efforts to reduce salt (sodium chloride), and if this practice becomes widespread then our total intakes will increase. While potassium is an essential mineral and we cannot live without it, you can have too much of a good thing, and it is important to consider possible risks alongside the benefits of decreased sodium intake.

Consumers are becoming increasingly aware of some of the microbiological risks associated with food. I hope that this report helps to demonstrate that we are working with other government departments and our expert advisory committees to take an holistic approach to food safety that also addresses chemical risks. All of this work supports our aim to deliver food we can trust.

Lead analysis: Acrylamide

What is acrylamide and why is it in food?

Acrylamide is a chemical substance formed by a reaction between amino acids and sugars, typically in foods with high starch content, when cooked at high temperatures such as in frying, roasting and baking. This reaction is called the Maillard reaction.

Acrylamide is not deliberately added to foods, it is a natural by-product of the cooking process.

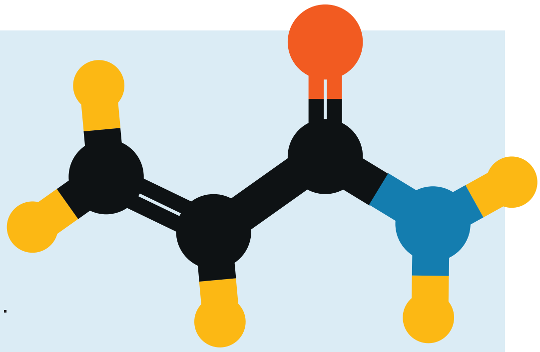
The duration and temperature of cooking determines the amount of acrylamide produced.

The products of the Maillard reaction result in browning of the food (it is also known as 'non-enzymatic browning'), and additional aromas and flavours in the food. This reaction also occurs during the burning of tobacco and therefore acrylamide is found in cigarette smoke.

The duration and temperature of cooking determines the amount of acrylamide produced; long durations and high temperatures form more acrylamide than short durations and lower temperatures.

The amino acid predominantly responsible for the acrylamide formed via the Maillard reaction is asparagine. It is one of the major amino acids found in starchy foods such as potatoes and cereals and hence acrylamide tends to be found in higher levels in these foods when they have been cooked at high temperatures (above 120°C).

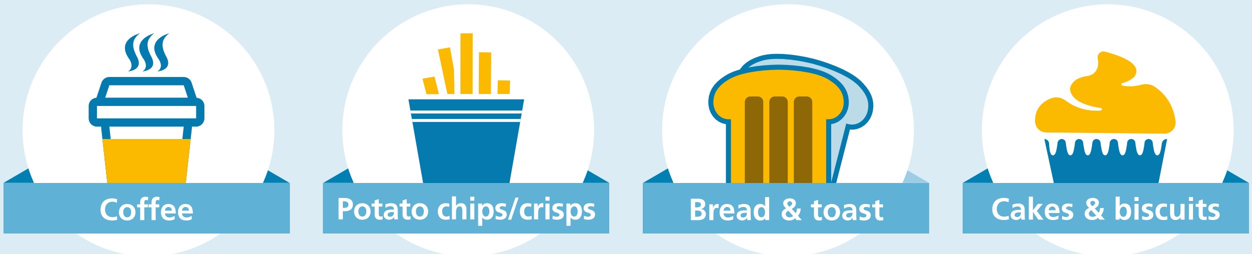
Acrylamide in food



What is acrylamide?

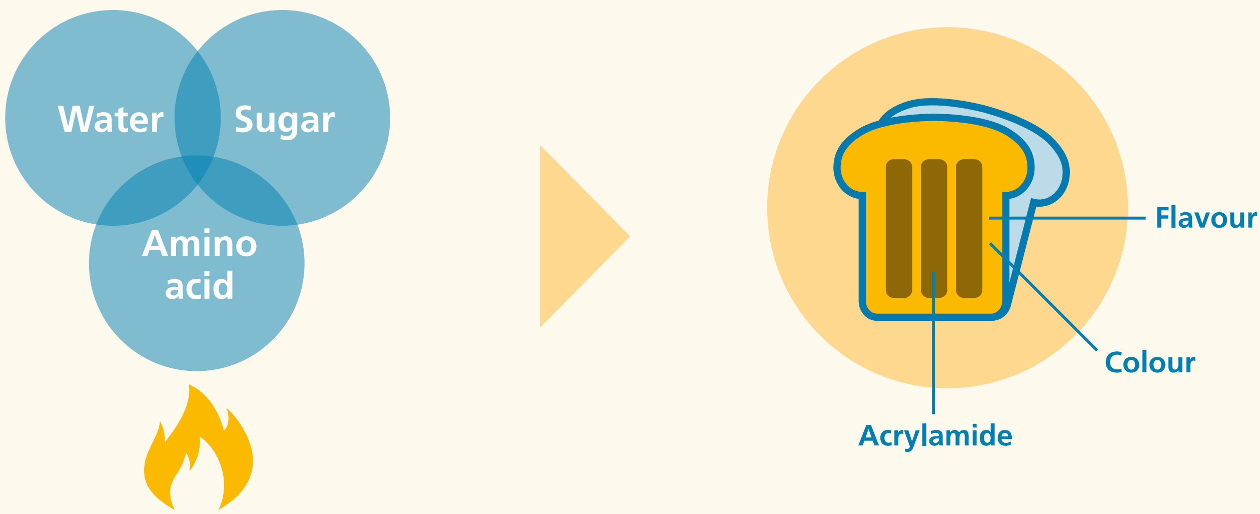
Acrylamide is a chemical produced naturally as a result of cooking starch-rich food at high temperatures, such as when baking or frying. It is also likely to be produced by grilling and roasting food.

What foods is it generally found in?



How does it form when food is cooked?

In a process called the Maillard reaction, the naturally present water, sugar and amino acids combine to create colours, aromas and flavour. This also causes browning of the food and produces acrylamide.



How was acrylamide discovered in food?

In October 1997 dead cows and fish were found in south-western Sweden near to a large railway tunnel being built through a rocky ridge. The tunnel was being lined with a polyacrylamide sealant which had not set properly and allowed acrylamide to leak into the environment.

Acrylamide can be measured in the blood bound to the haemoglobin, the molecule that transports oxygen round the body. Swedish researchers measured acrylamide in the blood of the workers and expected to see higher levels of acrylamide in the blood of the workers compared to levels in non-occupationally exposed people. However unexpected high levels were also found in the non-exposed people leading the researchers to hypothesise that people might be exposed through their diet.

In order to investigate the theory the researchers measured the acrylamide levels in a range of foods, publishing the results in 2002. They found that high levels were found in foods typically rich in carbohydrates, such as potatoes and crispbreads that had been cooked at high temperatures. However, acrylamide was either not detected or present at very low levels in uncooked or boiled food.

How are we exposed?

Unless you work in the polyacrylamide production industry, or are a smoker, the main source of acrylamide exposure is the consumption of acrylamide-rich foods or beverages. The average level of acrylamide bound to haemoglobin in the blood of smokers is three to four times higher than in non-smokers. This indicates that smoking exposes people to higher levels of acrylamide than their diet.

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Uses of acrylamide in industry

Polyacrylamide, which is produced industrially, consists of a large number of acrylamide molecules linked together by a process known as polymerisation. It is used as grout on the linings of tunnels to make them waterproof.

Polyacrylamide is used in water purification to remove particulate material by the process of flocculation. The polyacrylamide interacts with the particles, allowing them to congregate until they reach sufficient size to sink to the bottom of the solution to form a layer.

Polyacrylamide and acrylamide can also be used in the production of paper, dyes, food packaging, cosmetics and polyacrylamide can be used as a soil stabiliser.

Exposures from food

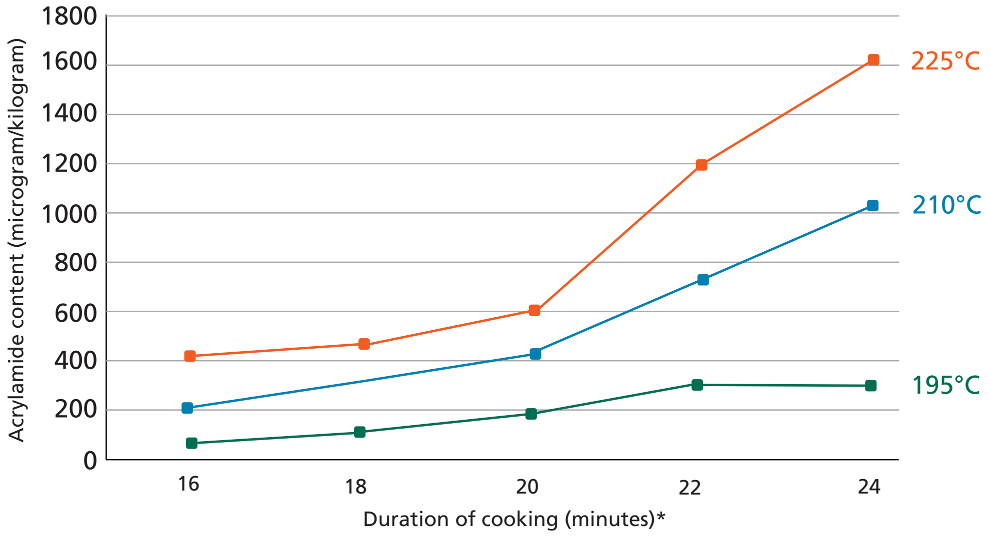
Dietary exposure to acrylamide differs with age and body weight. The main contributors to total dietary acrylamide for different age groups are as follows:

- Infants – potato and cereal based baby foods and products.
- Toddlers, children and adolescents – fried potato products, bread, biscuits, crackers, crisp bread, other products based on cereals.
- Adults – potato products, bread, coffee, porridge, breakfast cereals, cakes and pastries, biscuits, crackers and crisp bread.

Further cooking of carbohydrate rich foods, for example the grilling of bread to make toast, causes more acrylamide to be produced.

Some foods are rich in acrylamide due to the way they are produced. Further cooking of carbohydrate rich foods, for example the grilling of bread to make toast, causes more acrylamide to be produced. This browning process is indicative of acrylamide production; levels are higher in well-cooked dark brown chips compared to lighter brown cooked chips (**see figure 1**).

Figure 1 – Influence of cooking temperature and duration on the acrylamide content of chips (Source: EFSA, 2015, modified)



**Manufacturers of oven chips advise cooking times and temperatures on packets, these typically range between 15 and 20 mins at 200-220°C.*

What are the key health effects of acrylamide?

Biological effects of acrylamide exposure include cancer and damage to the nervous and reproductive systems. Most of the evidence is based on effects seen in experimental animals or cells studied in a laboratory. Whether or not acrylamide will cause these effects in humans will depend upon the level of exposure. It has long been known that acrylamide causes neurotoxicity in humans and it caused nerve damage in the occupationally exposed tunnel workers. However, the data for cancer and reproductive system effects in humans are not conclusive.

Chemicals can be altered (metabolised) in the body to become more toxic or less toxic. Acrylamide can be detoxified by binding to glutathione, before being eliminated from the body. Alternatively it can be activated by metabolism to glycidamide. Glycidamide can bind to DNA leading to mutations, and this is most likely to be the cause of the cancers observed in animal studies. The neurological and reproductive system effects are more likely to be due to acrylamide itself, rather than to the glycidamide metabolite.

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The FSA relies on advice from expert committees

Because the science is complex we have sought the views of the UK scientific advisory committees.

Three committees have provided advice on the possible toxic effects of acrylamide:

- The Committee on Mutagenicity of Chemicals in Food, Consumer Products and the Environment (COM).
- The Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC).
- The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT).

The COM reviewed the genotoxicity data available on acrylamide in 2009 and concluded that acrylamide has the potential to damage DNA, through multiple mechanisms, and that ‘there is no level of exposure to this genotoxic carcinogen that is without some risk’.

In 2014 the European Food Safety Authority (EFSA) released a Draft Scientific Opinion on Acrylamide in Food for public consultation, which reflected the COM views on the genotoxicity of acrylamide.

We invited the COT and COC to respond to the consultation in order to help improve the draft EFSA opinion and to check whether they agreed with it.

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The COC reviewed the sections relevant to carcinogenicity. They largely agreed with EFSA, and recommended further work to understand the differences between inhaled and oral exposures.

The COT agreed with the draft EFSA conclusions and recommended further clarification on the sources and calculation of exposure, some of the ascribed effects in humans and the potential for transgenerational effects.

The finalised EFSA Opinion was published on June 4th, 2015.

Risk assessment

The risk assessment indicates that at the levels we are exposed to from food, acrylamide could be increasing the risk of cancer but not effects on the nervous and reproductive systems. We cannot avoid exposure to acrylamide and actual exposure will vary depending on diet, lifestyle and environment.

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Risks of acrylamide consumption

Acrylamide occurs when starch-rich ingredients such as potatoes, cereal grains and coffee beans are cooked at high temperatures. Regularly eating food containing high levels of acrylamide can increase the risk of cancer. Other possible, but unlikely, consequences are damage to the nervous and reproductive systems.

How we assess the risk

We often use data from studies in animals to assess the risk of chemicals to humans. This is because it's often difficult to assess the risks from human exposure to chemicals because we don't always know how much of a chemical people are exposed to and whether it is that chemical that has made people ill.

We then use statistical models to analyse the animal response to chemicals. We use these data to generate a benchmark dose (BMD) and its lower confidence limit (BMDL). We use the BMDL as a reference point because it takes into account uncertainty in the data we are using. We then use the BMDL as a starting point to determine what the risks to humans from exposure to this chemical might be.

The BMDL is divided by estimated human exposure to produce a "Margin of Exposure" (MOE).

- A large MOE indicates a low risk
- A small MOE indicates a higher risk
- Interpreting the size of the MOE has to take into account the nature of the effects under consideration and other issues such as important gaps in the available knowledge.

Based on data on how much acrylamide is in different foods and on surveys across Europe of how much food and what people eat, EFSA estimated the acrylamide exposure for average and high-level consumers across European countries, for a range of age groups.

When assessing the carcinogenic risk from acrylamide, the calculated MOEs range from 50 for high level consumers in the toddler age group (1-3 years) up to 425 for average adult age groups.

For substances that are genotoxic and carcinogenic, EFSA considers that an MOE of 10,000 represents a low concern for public health. The MOEs for acrylamide are considerably lower than the value of 10,000, indicating a cancer risk. However as noted above there is always uncertainty in interpreting an MOE because of gaps in our knowledge about the effects of chemicals on humans.

As regards the possible effects of acrylamide on the nervous and reproductive systems, the calculated MOEs ranged between 126 for high level consumers in the toddler age group to 1,075 for average adult age groups. An MOE of 100 is commonly considered of low concern for non-cancer effects, indicating no, or low concern for such effects as a result of dietary exposure to acrylamide.

Are there regulatory limits for acrylamide in food?

There are currently no regulatory maximum limits for acrylamide in food. However, the European Commission (EC) has introduced ‘indicative values’ (European Commission Recommendation 2013/647/EU) for those food groups considered to contribute the most to consumer dietary exposure to acrylamide. Indicative values are not statutory maximum limits and are intended only as a guide to prompt investigation of higher levels to understand how to reduce levels of acrylamide in food.

There is however a regulatory limit of 0.1 µg/L for the amount of acrylamide that can be present in drinking water in the EU. This value is based on the amount of acrylamide that could be released from polyacrylamide used in water purification.

Advisory

Mandatory

Analogy: advisory and mandatory speed limits

Maximum limits are the equivalent of mandatory speed limits – it is illegal to exceed them. The *indicative values* are the equivalent of advisory warning signs you sometimes see on sharp bends – for safety reasons it is advisable to comply with these, but not actually illegal to exceed them. Similarly, exceeding *indicative values* for acrylamide gives a warning that levels are high, and you should look to reduce them. In the food industry this may also involve a visit from a local authority representative.

How has the FSA reacted to the concerns relating to acrylamide?

We want to help people to make informed choices about the food they eat and give advice on the best available evidence.

Reducing acrylamide levels in foods will not be easy, as acrylamide forms naturally in some foods when they are cooked or heat treated. There are many variables that can impact on the final level of acrylamide in a given food, ranging from crop variety, storage conditions, agronomic factors, seasonal variation and then the processing or cooking conditions.

We are working to understand more about acrylamide, reduce the risk that it presents and provide helpful advice to both industry and consumers. We are doing this through:

- Supporting food manufacturers' initiatives to reduce acrylamide in retail foods. We are in regular dialogue with food industry representatives such as the UK Food and Drink Federation (FDF) and Food and Drink Europe (FDE) who maintain an acrylamide reduction toolbox and provide acrylamide reduction advice for smaller companies.
- Conducting and publishing annual monitoring data for acrylamide in a range of retail products. The most recent publication can be found here http://www.food.gov.uk/news-updates/news/2014/12970/acrylamide-and-furan-survey-results-published

The FSA is committed to helping people make informed choices about the food they eat and to giving advice based on the best available evidence.

- Undertaking a broad programme of research such as the recent study on how consumer behaviours affect acrylamide from home cooking (See case study 1 http://www.food.gov.uk/science/research/chemical-safety-research/pc-research/fs102070) to inform any actions taken, and advice the FSA provides and to inform the debate on next steps for acrylamide reduction.
- Supporting industry led projects to develop new varieties of crops such as wheat or potatoes that will form less acrylamide when cooked (**see case study 2**).
- Undertaking a new UK Total Diet Study on acrylamide in food.
- Producing advice for consumers on minimising acrylamide https://www.food.gov.uk/science/acrylamide and following NHS guidance on a balanced diet http://www.nhs.uk/livewell/healthy-eating/Pages/Healthyeating.aspx
- Taking a lead in discussions in Europe on how best to support acrylamide reduction and increase consumer safety.

Success of these efforts

To understand how acrylamide levels in UK products might be changing over time and how successful efforts by food manufacturers to reduce acrylamide have been, we conducted some statistical trend analysis of the FSA retail product sampling to date (2007- 2013). This indicated some evidence of a downward trend of acrylamide in potato crisps and snacks, pre-cooked French fries/potato products for home cooking, biscuits and roasted coffee. There is also some evidence of a recent decrease in acrylamide levels in processed cereal-based baby food. However, further data are required to establish whether these apparent trends are continuing and whether they only apply for the products included in the FSA survey. It is not currently possible to completely control raw materials and acrylamide levels can vary with the season and year.

FSA advice

We do not advise people to stop eating particular foods but you should follow Department of Health advice from the NHS Choices website on eating a healthy, balanced diet.

It is also recommend that:

- When making chips at home, they are cooked to a light golden colour.
- Bread should be toasted to the lightest colour acceptable.
- Manufacturers' instructions for frying or oven-heating foods, (such as chips), should be followed carefully.

Our plans for the future

As part of our ongoing efforts to support acrylamide reduction and to protect consumers we will:

- Renew our UK acrylamide strategy; Review the outcomes of our research (such as the UK Total Diet Study on acrylamide), to inform EU discussions and advice to consumers and industry.
- Attend the EU Commission expert committee on environmental and industrial contaminants meeting at the EU Commission in Brussels, where the findings of the recent EFSA opinion on acrylamide will be considered and they will discuss what action is needed to reduce consumer exposure to acrylamide. Our updates on these meetings can be found at https://www.food.gov.uk/enforcement/regulation/europeleg/euupdates
- Consider longer-term solutions that can have a significant impact on acrylamide both in retail and home cooked foods. This could include the development of new crop varieties with lower asparagine and various researchers are already working on this around the world including in the UK. It is likely that it will take a long time to develop varieties with all the correct traits for different uses, particularly if limited to traditional breeding technologies. Interestingly, this process could be potentially quicker in countries where genetic modification (GM) can be used to accelerate varietal development. In the United States a low acrylamide producing genetically engineered (GE) potato has been developed and declared as safe by the U.S. Food and Drug Administration. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm439121.htm

Case study

1. Acrylamide in the Home

Exploring the impact of consumer behaviours on acrylamide in home cooked foods.

- **What is the science telling us?** While the FSA has undertaken annual monitoring of retail products for acrylamide in the UK since 2007 (similar studies have been undertaken in other EU countries) the levels of acrylamide, and more importantly how consumers behave in the home, is less well understood. This is something that had been identified as an evidence gap by EFSA in their recent opinion on acrylamide.
- **What is the FSA doing about it?** The FSA has commissioned research to assess consumer behaviours when cooking certain foods at home and the potential impact this can have on acrylamide levels. It will also increase our understanding of consumer awareness of acrylamide and the range of ways that certain foods are prepared.
- **How was this research undertaken?** This research consisted of an observational study and interview in the homes of consumers while they prepare foods such as roast potatoes, chips and toast and recording how this was done, and why they prepared food in specific ways. A representative portion of the final food was sent for analysis for acrylamide and also photographed to record final product colour. Where ovens were used the temperature was also recorded throughout the process.

What will this enable the FSA to do?

The result of this work will inform the discussions within Europe on how to reduce consumer exposure to acrylamide from food. It will help to identify the types of interventions that might be required, and advice that can be provided to consumers.

What further information is needed?

Whilst EFSA has produced advice to consumers when preparing food at home, the level of consumer engagement on this issue remains low. The FSA needs to understand the impact their advice had on consumer choices and how best to communicate their advice clearly and effectively.

Case study

2. Acrylamide mitigation in French Fries

Potato processors in Europe have supported the development of FoodDrinkEurope's acrylamide mitigation toolbox, which represents more than a decade of collaboration between the food industry and EU national authorities in investigating the pathways of acrylamide formation in foods and potential intervention steps to reduce consumer exposure.

The industry is committed to ensuring that acrylamide in food is kept as low as reasonably achievable (the ALARA principle) and supports the monitoring and reporting of acrylamide occurrence data. Part-cooked French Fries, chips and potato products do not contain detectable levels of acrylamide and average levels in cooked products (fried or oven-cooked) are well below the Indicative Level set by the European Commission (600 parts per billion for ready to eat fries). The FSA monitoring data (2007- 2013) suggest a downward trend in acrylamide levels for products intended for home cooking, corresponding to the adoption of the mitigation steps in the toolbox.

- **What can the industry do to mitigate acrylamide?** This starts with the selection of potato varieties with lowest reducing sugars suitable for each product. Growing varieties best suited to the local growing conditions, appropriate field selection and using best agronomic practice ensures that good quality raw potatoes are used for processing. After harvesting, sugar levels are managed by keeping potatoes in dedicated potato stores, under controlled climate and temperature conditions.

  The industry applies strict quality control procedures for all potatoes, including testing for fry colour of every delivery from the farm, before acceptance. Part of standard potato processing is the blanching of cut potatoes to precook and to remove approximately 50% of sugars, resulting in lower levels of acrylamide in the final cooked product.

- **How is the industry helping consumers?** To help professional end-users in restaurants and consumers in the home to prepare potato products while controlling acrylamide formation to acceptable levels, the industry has modified its cooking recommendations. The industry voluntarily lowered cooking temperatures on all product packaging as of 2004, on a global scale, recommending frying at max. 175°C and typically 200-220°C for oven-cooked products (depending on product type, cut size, type of oven and fan assistance), so that products are cooked until a light golden colour. This reduced cooking temperature achieves an optimal sensory quality, without increasing the fat content significantly, while limiting the potential formation of acrylamide in the cooked product as consumed.
- **What is being done to inform restaurateurs how to prepare products?** The European potato industry has developed the www.goodfries.eu website, which is available in 28 languages and provides crucial information on how to prepare French Fries in a healthy way with respect to acrylamide formation and oil quality. The website contains a simple training video, as well as printable instructions, which can be placed in professional kitchens.

The potato processing industry continues to support professional end-users by informing them on the importance of this topic and offering training through webinars and other tools, working closely with trade associations within the UK and across Europe.

The potato processing industry continues to support professional end-users.

Also of interest...

Potassium salt replacers

The Department of Health (DH) has introduced salt reduction targets to encourage food businesses to lower the salt content of everyday foods, as eating too much salt can have a serious impact on people's health. In order to meet these salt reduction targets, some food businesses would like to use potassium-based replacements for sodium chloride (table salt) and sodium-based additives. The DH has not recommended this practice as their aim is to allow consumers' palates to adjust to lower salt levels and due to concerns over the impact that increased potassium intakes could have on the health of vulnerable population groups. However, as there are technical limitations with reducing salt in certain foods, the potential benefit of replacing sodium with potassium has prompted a review. As part of this review, the Scientific Advisory Committee on Nutrition (SACN) has been asked to assess the potential benefits of potassium-based replacements, while the COT has been asked to advise on possible adverse effects of the increased potassium intakes that could occur as a result of widespread potassium-based replacement.

Potassium is an essential nutrient that is particularly important for the function of nerve and muscle cells in the heart. In the healthy adult, the serum concentration of potassium is tightly regulated within a narrow range by the excretion of excess potassium via the kidneys. Significantly increased serum potassium concentrations are defined as hyperkalaemia; severe hyperkalaemia can lead to an abnormal heartbeat or heart rate, and in extreme cases, cardiac arrest. After discussions assisted by an NHS renal consultant, the COT concluded that widespread potassium-based replacement would not be a concern for most healthy individuals, but could threaten the health of people with major renal impairment as these individuals would not be able to efficiently excrete excess potassium. While many of these individuals would be aware of their condition and could be advised to decrease their potassium intake accordingly, there may be a subset of the population with undiagnosed kidney impairment that could be at risk of developing hyperkalaemia. The COT recommended that, as part of its review, the SACN would need to consider this risk against the expected health benefits of decreased salt intakes.

Further Reading

COT (2014). COT response to the EFSA Consultation on a draft scientific opinion on the risks to public health related to the presence of acrylamide in food TOX/2014/36. This document can be found at http://cot.food.gov.uk/sites/default/files/tox2014-36.pdf

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