Acrylamide in Foods

Background

Following an accident during the construction of a tunnel in Sweden, workers were exposed to acrylamide and N-methylolacrylamide from incomplete polymerization in a grouting used in an attempt to seal water leakage into the construction area. Shortly after that dead fish were observed in a nearby stream and paralyzed cattle from herds that drank from the stream; workers also reported neurotoxic symptoms. This led to monitoring the exposed workers which involved measuring the content of acrylamide-hemoglobin adduct in blood samples. During this process, control subjects (non-smokers, supposedly not previously exposed to acrylamide) were observed to have ‘low’ levels of the acrylamide-hemoglobin adduct.

While investigating the source of these ‘low’ levels, investigators at the University of Stockholm considered the potential for a food-derived source. Heating model food samples, such as meat and potatoes, resulted in the formation of acrylamide, particularly when potatoes were heated at elevated temperatures, i.e. above 120° C. Commercial food samples were obtained in Stockholm and the content of acrylamide determined in each using a newly developed, sensitive analytical technique (liquid chromatography-mass spectrometry) (LC-MS/MS). Acrylamide was found in a number of foods commonly consumed. This was particularly true for carbohydrate-rich foods prepared by heating at high temperature; protein (meat) products contained only small amounts of acrylamide.

These results were announced at a press conference on April 22, 2002 and published several months later (Tareke et al 2002). This was the first report of the occurrence of acrylamide in foods common to diets consumed around the world.

Acrylamide is a well-known industrial chemical whose primary use is the synthesis of polyacrylamide. Polyacrylamide is used as a flocculant in water treatment, a soil conditioner, manufacture of paper, in grouting agents, and in gel electrophoresis.

As a result, the announcement of the occurrence of acrylamide in foods rapidly became a global issue. The results announced in Sweden were confirmed in other countries within a short time. Due to its potential as a public health threat, both as a suspected carcinogen and a neurotoxin, studies were rapidly initiated. Several hundred studies have resulted worldwide. There has been extensive cooperation/collaboration among several countries.
Analysis and Occurrence in Foods

The new procedure, with increased sensitivity, developed at the University of Stockholm for analysis of the acrylamide content of foods, was necessitated by the need to accurately and rapidly determine the amounts (µg/kg, ppb) present in foods. Within a relative short time, two methods were established as being acceptable and comparable (Castle and Erickson, 2005). These were gas chromatography-mass spectrometry (GC-MS) after bromination to 2,3-dibromopropionamide or direct determination with liquid chromatography-mass spectrometry (LC-MS). Liquid chromatography coupled to tandem mass spectrometry (LC-MS/MS) is probably the preferred method, but the equipment required is expensive and not readily available to all who want to determine the acrylamide content of foods. These methods and subsequent studies on extraction and separation can be applied to both ‘routine’ and ‘difficult’ (i.e., chocolate and coffee) food matrices (Castle, 2006).

Acrylamide occurs in carbohydrate (reducing sugar)-containing foods prepared by heating above 120°C, i.e. frying, grilling, baking, broiling. Acrylamide is not present in the native (raw) ingredients (i.e., raw potato) and is not formed during boiling or microwaving (although some exceptions appear to occur for the latter). Potato and cereal food products tend to have the highest amounts of acrylamide among commonly consumed foods. Meat products are very low in acrylamide content, lacking the precursors required for its formation. Acrylamide formation essentially is a surface reaction; as temperature increases and moisture content decreases, acrylamide formation increases. In general, the darker in color the food product (burnt toast, darker French fries), the higher the acrylamide content. The acrylamide content of food(s) varies widely within the same food product, within the same manufacturing facility at different times, and between manufacturers (for which different recipes and processing conditions may be used).

Some examples of foods and their acrylamide contents follow.

<table>
<thead>
<tr>
<th>Food Product</th>
<th>Acrylamide Content (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato chips (crisps)</td>
<td>117 – 4215</td>
</tr>
<tr>
<td>French fries (potato chips)</td>
<td>59 – 5200</td>
</tr>
<tr>
<td>Bakery products and biscuits</td>
<td>18 – 3324</td>
</tr>
<tr>
<td>Bread</td>
<td>&lt;10 - 397</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>&lt;10 – 1649</td>
</tr>
<tr>
<td>Chocolate products</td>
<td>&lt; 2 - 826</td>
</tr>
<tr>
<td>Roasted coffee</td>
<td>45 - 935</td>
</tr>
<tr>
<td>Coffee extract/powder</td>
<td>87 – 1188</td>
</tr>
</tbody>
</table>

These only serve as general indications, since the actual acrylamide contents will vary with product, manufacturer and country. Large databases of occurrence data are maintained by the European Commission (European Union Acrylamide Monitoring Database) (European Commission 2006) and the U.S. Food and Drug Administration (Survey Data on Acrylamide in Food: Individual Food Products) (U.S. FDA 2006).

Mechanism of Formation

Within a few months following the 2002 announcement, attention became focused on the Maillard Reaction (MR) when it was reported from England (Mottram et al), Switzerland (Stadler et al 2002) and Canada, that acrylamide was formed from the reaction of reducing sugars and the amino acid asparagine. In subsequent studies, it was confirmed that the primary mechanism of formation is the reaction of glucose (and/or fructose) with asparagine during heating via the MR. Formation of acrylamide is favored by high temperatures and low moisture content; it is primarily a surface reaction, i.e. acrylamide in bread is primarily located in the crust with very low or no amounts in the crumb. One reason for the high acrylamide content of potato chips (crisps) is that a chip primarily is two surfaces with very little space between them.

The MR is a complex series of reactions occurring during the heating of reducing carbohydrates and amine compounds (generally amino acids). It is primarily responsible for the brown colors, flavors and aromas in many foods, i.e browning during toasting and in frying potatoes. In addition to these and many other beneficial
compounds, numerous compounds with potential adverse health benefits also are formed. However, normally these are not consumed in sufficient amounts to be a danger to humans. Thus, it is clear that, even though we did not know or suspect it, acrylamide has been part of our daily diets ever since foods were first prepared by cooking (heating) thousands of years ago.

The reducing sugars (glucose, fructose) and asparagine are natural (native) components of plants (plant-derived ingredients) used in preparation of the foods we eat daily. They are particularly prevalent in cereals and potatoes. As it turns out, the reducing sugars (glucose, fructose) are the limiting factors (so far as acrylamide formation is concerned) in potatoes, while asparagine appears to be the limiting factor in cereal products (Stadler 2006).

Later studies indicated that one other chemical compound (3-aminopropionamide) can be formed during the Maillard Reaction and can be converted to acrylamide under aqueous conditions (Schieberle et al 2005). It is an effective precursor of acrylamide and was confirmed as a transient intermediate in its formation during cocoa roasting (Granvogl and Schieberle 2007). It has been identified in cocoa beans, coffee and cereal products (such as popcorn). The extent to which it may be involved as an intermediate in acrylamide formation in foods, is not known at this time. It has been identified as a minor precursor in the formation of acrylamide in potatoes (Granvogl et al. 2004).

**Exposure**

Estimation of acrylamide exposure from the diet began shortly after the original announcement and as soon as the data required (acrylamide content of foods and the amount of each consumed) for a preliminary estimate could be obtained. Exposure data is normally calculated for gender, age groupings and for average (mean) and high consumers in each age group. It can be aggregated for estimation of a national average. For France, Germany, the Netherlands, Norway, Sweden, the U.K. and the U.S., acrylamide exposures range from 0.3 – 3.2 µg/kg bw\(^{-1}\) day\(^{-1}\) with considerable variation in the estimations. Children may have acrylamide intakes two to three times those of an adult on a body weight basis. Even though the estimates may be done in different ways and dietary habits differ between countries, an average mean intake can be considered to be about 0.4 µg/kg bw\(^{-1}\) day\(^{-1}\) and the average intake for a high-level consumer to be about 1.0 µg/kg bw\(^{-1}\) day\(^{-1}\) (Mills et al 2009).

Foods contributing the most to these exposures will vary between different countries and according to the daily diet. In the U.S., the foods contributing the largest amount to the daily consumption include French fries, potato chips, cereal products (breakfast cereal, cookies, toast, pies and cakes, crackers and bread), and brewed coffee (DiNovi 2006). In many European countries, potato products (French fries, crisps and comparable products), bread (toast and soft bread) and coffee also are major contributors.

In a small duplicate diet study in Switzerland (Swiss 2002), it was found that 8% of the daily intake of acrylamide occurred from breakfast, 21% from lunch, 22% from dinner, 13% from snacks, and 36% from coffee. These values were later corrected for an apparently low consumption of some fried foods in the study, compared to the normal diet. However, the contribution from coffee was still 22%. This illustrates the fact that just because a particular food product contains a high amount of acrylamide, it may not be a major contributor to intake if it is not consumed in large quantities. A food or diet item relatively low in acrylamide content, such as coffee or bread, can make a significant contribution to the dietary intake of acrylamide when it is consumed in larger quantities.

Acrylamide is a food problem, not that of one or a few particular foods. For example, in the U.S., it is estimated that foods containing acrylamide contribute 38% of the daily calories, 33% of the carbohydrates, 36% of the fiber, and more than 25% of a significant number of micronutrients (Petersen and Tran 2005). This is a very important observation, particularly since so much emphasis is placed on the contribution of potato chips and French fries as sources of acrylamide in normal diets.
Health Risks

The primary question globally concerning potential adverse health risks from consuming the acrylamide present in foods common to the normal diet is: Does the presence of acrylamide in food and its consumption constitute a human health hazard, particularly an increase in the risk of cancer?

Toxicology:

Acrylamide is a well-known industrial chemical whose toxicological properties have been studied extensively. It has been found to be carcinogenic in animal studies, primarily rodents, with limited primate studies, using doses higher than typical human dietary exposures, as is common in such studies. The International Agency for Cancer Research (IARC) classifies acrylamide as a ‘probably a human carcinogen (Class 2A)’ based on animal studies (IARC 1994). Acrylamide is genotoxic in a range of assays and is acutely neurotoxic. It is a known human neurotoxin. It is virtually certain that exposure from consumption of acrylamide-containing food is far below the exposure required for neurotoxicity.

The primary metabolite of acrylamide is glycidamide, an epoxide that readily reacts with DNA. This raises concerns about potential genotoxicity. However, at this time, insufficient information is available to address carcinogenicity or genotoxicity in humans from the amount of acrylamide consumed in the normal diet. A major rat and mouse toxicological study has been completed over a period of more than two years at the U.S. National Center for Toxicological Research (NCTR). The data from this are anticipated to be published in the relatively near future. They were shared with JECFA (Joint FAO/WHO Expert Committee on Food Additives) for their 2010 second risk assessment of acrylamide in foods (see JECFA 2010).

Causes of death among a cohort of workers exposed to acrylamide (employed between 1925 and 1976) in four factories (3 in the U.S., 1 in the Netherlands) were investigated (1989). Among exposed workers, mortality from all causes was significantly reduced; a weak indication of increased incidence of pancreatic cancer and Hodgkin’s disease was observed. This same cohort, updated for the period 1984-1994, was again analyzed (1999). For the period 1925-1994, no evidence was obtained for a statistically significant excess of mortality. This led to the conclusion that there is little evidence for a causal relationship between acrylamide exposure and cancer mortality (from Dybing and Sanner 2003). These are probably the most definitive epidemiological studies of human exposure to acrylamide and carcinogenic risk obtained thus far.

Epidemiology:

A group of six case-control and cohort epidemiological studies from the U.S. and Italy were reported during the period 2003-2006. No evidence was found for a positive association (increased risk) between dietary intake of acrylamide and any increase in the relative risk of the cancers studied: large bowel, kidney, bladder, renal cell, oral cavity and pharynx, esophagus, larynx, and ovary. This group of studies was recently reviewed (Mucci and Wilson 2008). No differences were observed in associations among smokers and nonsmokers, although smoking is an important source of exposure to acrylamide. The sensitivity of the results from these studies has been criticized due to the relatively small number of subjects. It is believed that this would not yield the discriminatory power required to detect the small increases in cancer risk that might be anticipated from consumption of the amount of acrylamide encountered in foods comprising the normal diet.

Three recent prospective case-control cohort studies from the Netherlands used a larger number of subjects (Hogervorst et al 2007, Hogervorst et al 2008a, Hogervorst et al 2008b). Findings from these studies include:

- increased risks of postmenopausal endometrial and ovarian cancer with increasing intake of acrylamide among never-smokers. Acrylamide intake was not associated with breast cancer.

- no positive associations were found between acrylamide intake and increased risk of bladder and prostate cancer. However, the authors reported some indications for a positive association between intake of dietary acrylamide and renal cell cancer risk.
• Acrylamide intake was not associated with colorectal, gastric, pancreatic and esophageal cancer risk, but some subgroups deserve further attention.

The preponderance of these epidemiological studies show no correlation between consumption of acrylamide-containing foods and increased risk for a number of cancers. However, it is clear that some differences exist in findings between the studies. It is considered unlikely that epidemiological evidence will be able to prove or disapprove an association between consumption of acrylamide-containing foods and an increased risk of cancer, i.e. a cause-effect relationship.

Risk Assessment:

In 2005, the Joint Expert Committee on Food Additives (JECFA) conducted a risk assessment of acrylamide in foods (JECFA 2005). Analytical data on the occurrence of acrylamide in foods from different countries was obtained from 24 countries with most of the samples from Europe (67.6%) and the U.S. (21.9%); the remainder were from Asia (8.9%) and the Pacific (1.6%). No analytical data were received from Latin America and Africa.

The Committee recommended that:

1. Acrylamide be re-evaluated when results of ongoing carcinogenicity and long-term neurotoxicity studies become available.
2. Work should be continued on using PBPK modeling to better link human biomarker data with exposure assessments and toxicological effects in experimental animals.
3. Appropriate efforts to reduce acrylamide concentrations in food should continue.
4. In addition, the Committee noted that it would be useful to have occurrence data on acrylamide in foods as consumed in developing countries. This information will be useful in conducting intake assessments as well as considering mitigation approaches to reduce human exposure.

With additional data available on occurrence, mitigation, and dietary exposure together with the data previously considered in 2005 (JECFA 2005), new epidemiological studies, and results from recently completed toxicological studies (metabolism, genotoxicity, neurodevelopmental and long-term carcinogenicity), JECFA conducted the second risk assessment at its 72nd Meeting (Rome, 16-25 February 2010). A Summary and Conclusions report was reissued on 16 March 2010 (JECFA 2010) with the final report to be published in the next several months. Conclusions and comments, as taken/quoted from the report, include:

1. Since 2003, mitigation efforts have been reported “for food types with high acrylamide levels or single products with higher levels than those within a food type.” While this may “significantly reduce exposure for some individuals or population subgroups,” it “will have little effect on the average dietary exposure for the general population.” This essentially validates and is consistent with early comments that reducing the acrylamide content in or eliminating any one food product will have no impact on overall exposure to acrylamide.
2. The estimated average dietary exposure acrylamide exposure for the general population and the exposure for consumers with high dietary exposure had not changed since the 2005 JECFA meeting.
3. “While adverse neurological effects are unlikely at the estimated average exposure, morphological changes in nerves cannot be excluded for individuals with a high dietary exposure to acrylamide.” This is consistent with the observations made in 2005.
4. “For a compound that is both genotoxic and carcinogenic,’ results from toxicology studies in rats and mice are indicative of a health concern. The extensive new data from the cancer bioassays in mice and rats support the previous evaluation (JECFA 2005).

5. It was also noted that “worker cohort epidemiological studies did not provide any evidence that exposure to acrylamide resulted in an increase in the incidence of cancer.”

6. “There was a poor correlation between the estimated dietary exposure and internal biological markers of acrylamide exposure adducts in humans.” To better estimate the cancer risk from acrylamide in food for humans, it was recommended that longitudinal studies on intra-individual levels of acrylamide and glycidamide hemoglobin adducts be measured over time in relation to concurrent dietary exposure. This would provide a better estimate of exposure to acrylamide for subsequent epidemiological studies.

It is to be noted that the comments and conclusions essentially indicate that the 2005 Risk Assessment is still valid and the findings are consistent with the language used at that time.

It is anticipated that the final recommendations probably will include that regulators continue to develop risk management approaches to reduce acrylamide formation in food. This would be consistent with the approach that currently is being used in many countries and reflects an ALARA (as low as reasonably achievable) approach. The inherent difficulty with this approach is: who determines/defines what ‘reasonably’ is.

Reduction/Mitigation of Acrylamide in Foods

Beginning shortly after the announcement in Sweden, there has been extensive study devoted to the mitigation/reduction of acrylamide in foods where possible without changing consumer acceptability of the resulting food product or increasing food safety concerns. Much of this work has been done in the food(s) industries, but also has involved academic and government scientists/technologists. Members of the European food industry freely shared the results of their studies through a collaboration coordinated by the Confederation of the Food and Drink Industry of the EU (CIAA).

Reduction/mitigation of acrylamide in foods can be approached through (a) removing reactants (fructose, glucose, asparagine) before the heating process, (b) disrupting the reaction (addition of amino acids, food grade acids, changing reaction conditions) and (a) removing acrylamide after its formation during heat processing. The latter approach has not proved to be viable.

Efforts, ranging from laboratory through industrial scale, have focused on (a) changing ingredients (decreasing glucose, fructose, asparagine), (b) altering processing conditions (lower heating temperatures, decreased heating time, blanching, use of the enzyme asparaginase), (c) changes in equipment, and (d) agronomic practices (storage practices, breeding of cultivars with lower glucose, fructose and/or asparagine content, selection of current cultivars with lower glucose, fructose and/or asparagine contents).

Some practices (tools) that have been used successfully to reduce the acrylamide content of French fries, potato chips, or bread (on an industrial scale production) are shown below as illustrations. It is suggested that manufacturers select those most suitable to their product and process.

- French fries - (a) Select potato varieties with low sugar (glucose, fructose) contents. Don’t use potatoes stored below 44°F (6°C), (b) Blanch potato strips in hot water (for a longer period of time) to lower reducing sugar levels (at or near the surface) and control color. Addition of sodium acid pyrophosphate during the last stage of blanching can reduce acrylamide levels in the final product. (c) Cut the potatoes into thicker strips (French fries). (d) Par fry the French fries. Acrylamide is formed mostly during the final stages of frying. Little or no acrylamide is found in par-fried French fries. (e) Fry smaller amounts of potatoes each time. (f) Control the temperature/time of final frying. (g) Aim for a lighter golden final color.
• Potato chips (crisps) – (a) Select potato varieties with low sugar (glucose, fructose) contents. Don’t use potatoes stored below 44°F (6°C). (b) Control the temperature/time of frying. Optimize settings to produce a crisp product with a golden yellow color. (c) Control the final moisture content. For fabricated chips, some other practices may be used to reduce the acrylamide in the final product.

• Bread – (a) Control the baking time and temperature to prevent excessive browning in the crust. (b) Avoid adding reducing sugars in the recipe. (c) Addition of calcium salts, e.g. calcium carbonate and sulphate. Two additional tools that also may be used, but have the potential for affecting product quality, include selection of flours produced from cereals with low levels of asparagine, and extending fermentation times.

Some approaches (tools), that have been used to reduce acrylamide formation in the laboratory or pilot plant, have not been successfully scaled to industrial production yet.

A relatively recent development has been the use of the enzyme asparaginase which converts asparagine to aspartic acid. The latter can not form acrylamide. Asparaginase is commercially produced from *Aspergillus niger* (DSM’s Preventase) or *Aspergillus oryzae* (Novozyme’s Acrylaway). Both have been approved in several countries for use in reducing acrylamide in selected food products. They are particularly effective in dough products (e.g., cereal products or fabricated chips), but can be applied in soaking (blanching) (e.g., potato strips) where they can reduce asparagine concentrations on the surface. Reduction of acrylamide contents in selected products made from doughs has ranged up to 90+ %. The use of asparaginase is now included in the CIAA Acrylamide Toolbox (see following paragraphs).

After several years of cooperative research and testing, the results were compiled into the CIAA Acrylamide ‘Toolbox,” first released in 2005 (CIAA 2009a). This publication is not meant as a prescriptive manual or as formal guidance. It gives brief descriptions of intervention steps that have been tried, evaluated, and have been successful in reducing acrylamide formation in specific classes of products. It is also indicated when the intervention steps have the potential for producing decreased product quality or acceptance. The Toolbox is meant for individual manufacturers including small and medium size industries. It can also provide useful leads for catering, retail, restaurants, and domestic cooking to aid in the reduction of acrylamide. It allows potential uses to access, assess and evaluate which reduction measures are appropriate for their product(s). In many cases, intervention steps have already been implemented commercially.

The Toolbox is a ‘living’ document and is frequently updated as results become available; essentially annually. Information from the U.S. GMA (formerly Grocery Manufacturer’s Association which had previously merged with the U.S. National Food Producers Association) and its food industry members has been included in the 2009 update, expanding coverage to the U.S. industry. This is a step towards making the Toolbox a global effort. Information generated during the EC-funded acrylamide-oriented HEATOX research project (see Suggested Reading for the Final Report) has been included in the Toolbox, particularly with respect to the domestic audience. The three examples above are excerpted from the Toolbox and the Acrylamide Pamphlets (CIAA 2009b) produced for classes of food products for use by Small and Medium Enterprises (SME).)

The Acrylamide Toolbox is organized into 4 compartments (Agronomic, Recipe, Process, Final Preparation) with 13 parameters. The Agronomic compartment contains the parameters Sugars and Asparagine. The Recipe compartment contains the parameters NH$_4$HCO$_3$, pH, Minor ingredients, Dilution, and Rework. The Process compartment contains the parameters Fermentation, Thermal input, and Pre-treatment. The Final Preparation compartment contains the parameters Color Endpoint, Texture/Flavour, Product Storage/Shelf Life/Consumer Preparation. In the body of the Toolbox, the practices (tools) to be considered are described and discussed under the compartments and parameters listed.

The Codex Alimentarius Commission (CAC) adopted a Code of Practice for the Reduction of Acrylamide in Foods in July 2009 (CAC 2009). The Code of Practices is intended 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. The guidance covers three strategies (where information is available) for reducing acrylamide formation in particular products. The three strategies, aligned with those approaches previously noted for mitigation/reduction, include (a) raw materials, (b) control/addition of other ingredients, and (c) food processing and heating. Its use should enable nations and their food processing organizations to facilitate mitigation/reduction of acrylamide in those food products where it is possible without loss of consumer acceptance of the product or generation of additional food safety or health concerns. Along these same lines, the U.S. FDA is considering issuing guidance concerning the reduction of acrylamide content in foods. As part of this process, it has requested comments and data from the food industry on practices they have adopted for their products and what reductions they have achieved (U.S. FDA 2009).

Regulations and/or Recommendations

At this time, no country has established regulations setting limits on the amount of acrylamide allowed in the diet or in specific food products. There is insufficient scientific evidence, particularly concerning toxicology, epidemiology, and potential adverse health issues, to warrant this action.

Germany is the only nation, so far, that has adopted a formal scheme as a goal/recommendation concerning acrylamide limits in foods. This system, known as the German Minimization Concept, does not have regulatory status but is a voluntary system of collaboration between the government and the food industry, a soft management approach. Foods are classified into certain food groups. Data concerning the amount of acrylamide in a food product are collected from official surveillance laboratories of the federal states and the Federal Institute of Risk Assessment. The products which constitute the top 10% of acrylamide content in each food group are identified. The lowest value among that 10% is the ‘signal value’ for the group. This is the goal for reduction of acrylamide content of the products in that 10%. Data on acrylamide content for that category is collected annually and the listing again prepared. If the signal value is greater than 1,000 µg/kg, it will then automatically remain at that value (i.e., 1,000 µg/kg). The Signal Value is then recalculated (annually). It can only be decreased, not increased. This practice has been in progress since the first values were set in late 2002. At that time, a decision was made that all food products with an acrylamide content of 1,000 µg/kg or greater should, in principle, be included in the reduction efforts. Some successes have resulted, but a number of the products have not been successful in meeting the signal value. The Signal Value for breakfast cereals, bakery wares, specialty biscuits, French fries (prepared), potato patties, and roasted coffee beans have been reduced from 2002 values to those listed for the Seventh calculation (2008). No progress has been made in lowering the Signal Value of 1000 for potato chips or gingerbread. The system has been modified to include an ‘observed value.’ This is calculated basically in the same way as the signal value, but without the condition that it must not be increased and must not exceed 1,000 µg/kg. In several cases, the observed value within a food category remained above the signal value in the 2008 listing. Germany is the only nation currently using this system, although some others have discussed it and not proceeded further.

As a result of recent evaluations of acrylamide as an industrial chemical, some recommendations have been made that can impact concerns about acrylamide in foods. It must be remembered that the evaluations were part of a process being undertaken, particularly in the EU, Canada and the U.S., to review a much larger listing of chemicals that are used commercially.

1. The European Chemicals Agency’s (ECHA) Member State Committee identified acrylamide as one of 15 new chemicals for the Candidate List of substances of very high concern (SVHC) (ECHA 2009). Acrylamide has been included in that list (ECHA 2010). Decisions as to whether Acrylamide needs to be subjected to authorization will be made at a later date.

2. The U.S. Department of Health and Human Services’ (DHHS) Agency for Toxic Substances and Disease Registry (ATSDR) has called for public comments concerning a Draft Toxicological Profile for acrylamide, “a toxic substance produced during heating of certain foods.” The profile “provides interpretation of available toxicological and epidemiological information and identification of toxicologic testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects to humans” (ATSDR 2009).
3. Acrylamide was one of 19 substances included in Batch 5 of the Chemicals Management Plan of Canada. This is part of Canada’s continuing review of about 200 chemicals of widespread industrial use that have not been through a thorough risk analysis. When the final screening assessments and proposed risk management plans was released, it was recommended that acrylamide be added to the government’s list of toxic chemicals. The decision to do so means that the Government of Canada will have to take steps to ensure that exposure of its citizens to acrylamide from food sources is kept as low as possible (ALAP). A three pronged management approach to achieving this has been initiated and includes (a) working with the food industry to develop and implement acrylamide reduction strategies that can be used by food processors and the food service industry, (b) regularly updating consumption advice, and (c) working with international partners (EU, US, Japan) to coordinate risk management efforts (Government of Canada 2009).

These conclusions are not surprising since acrylamide, as an industrial chemical, is recognized as a probable human carcinogen, an animal genotoxin, and neurotoxic.

Recommendations have essentially been to maintain the diets currently recommended by the national health agency of the country. For the U.S., the FDA recommendation has been and continues to be that the public eat a balanced diet, choosing a variety of foods that are low in trans fat and saturated fat, and rich in high-fiber grains, fruits, and vegetables. The U.S. Environmental Protection Agency (USEPA) recommendation is (a) Avoid eating a lot of carbohydrate-rich foods that are cooked at high temperatures (e.g. French fries). (b) Foods with higher protein content appear to have lower amounts of acrylamide. (c) Avoid overcooking foods. Dietary recommendations from other countries are similar to these. The Norwegian government, however, went a bit further by recommending a decrease in consumption of potato chips for those consumers who consume excessive amounts. The Food Standards Agency (FSA) of the U.K. indicated that “total intakes are so low that the Food Standards Agency advises not to alter diets or cooking methods of consumers.”

Thus, progress is being made in the reduction of the acrylamide content of some products. There are some commercial successes for a limited number of food products that have been reported so far. No single method of reduction works universally. Reduction still must be addressed on a case-by-case or category-by-category basis. It is unlikely that it will be possible to reduce the acrylamide content in many foods without changes in the food (color, flavor, texture) and consumer acceptability. Food safety concerns must also be considered, as also any potentially involving diet-nutrition-health consequences.

References Cited


**Suggested Reading**


Prepared by Dr. David Lineback, Senior Fellow, Joint Institute for Food Safety and Applied Nutrition (JIFSAN), IAFoST Fellow and Past President IUFoST on behalf of and approved by the IUFoST Scientific Council.

The International Union of Food Science and Technology (IUFoST) is the global scientific organisation representing over 200,000 food scientists and technologists from more than 65 countries. It is a federation of national food science organisations linking the world’s food scientists and technologists. IUFoST has four regional groupings: ALACCTA representing Central and South America, EFFoST representing Europe, WAAFoST representing Western Africa and FIFSTA representing the countries in the ASEAN region.
IUFoST Contact: J. Meech, Secretary-General, IUFoST, P O Box 61021, No. 19, 511 Maple Grove Drive, Oakville, Ontario, Canada, L6J 6X0, Telephone: +1 905 815 1926, Fax: +1 905 815 1574, e-mail: jmeech@iufost.org