Acrylamide in Foods: An Important International Issue

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College Park, MD
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Acrylamide in Foods

- Acrylamide - industrial chemical
- Listed as ‘potentially a human carcinogen” (Class 2A, IARC, 1994), primarily based on animal (rodent) studies
- Presence in common foods first reported (Sweden) in April 2002
- Rapidly verified; worldwide attention
What’s the problem?

- Core question: Does the consumption of foods containing acrylamide represent a risk to public health, particularly an increased risk of cancer?
- Has resulted in extensive research involving worldwide cooperation
- Hundreds of publications since 2002
Occurrence and Content
<table>
<thead>
<tr>
<th>Food/Product Group</th>
<th>Acrylamide range</th>
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</thead>
<tbody>
<tr>
<td>Potato chips/crisps</td>
<td>117 - 4,215 µg/kg</td>
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<tr>
<td>French fries/chips</td>
<td>59 - 5,200</td>
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<tr>
<td>Bakery products/ biscuits</td>
<td>18 - 3,324</td>
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<tr>
<td>Bread</td>
<td>&lt;10 - 397</td>
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<tr>
<td>Breakfast cereals</td>
<td>&lt;10 - 1,649</td>
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<tr>
<td>Coffee, roasted</td>
<td>45 - 935</td>
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<tr>
<td>Coffee, extract/powder</td>
<td>87 - 1,188</td>
</tr>
<tr>
<td>Chocolate products</td>
<td>&lt;2 - 826</td>
</tr>
<tr>
<td>Meats, Dairy products</td>
<td>&lt;10 - 116</td>
</tr>
</tbody>
</table>
Calories and Nutrient Intake

Foods tested (U.S.) and found to contain acrylamide constitute:

- 38% of calories
- 33% of carbohydrates
- 36% of fiber
- 28% of fat
- 20% of calcium
- 47% of iron
- 25 to 35% of other micronutrients
- 15% of vitamin A
- 34% of vitamin E
- 22 to 44% of B, C and folate vitamins
Acrylamide in Foods

- No single food contributes a majority of acrylamide to the average diet.
- Foods with low acrylamide content, when consumed in large quantities, can be important dietary sources.
Analysis
Analytical Methods for Acrylamide

- Gas chromatography – mass spectrometry (GC/MS) with or without derivatization (bromination)
- *Liquid chromatography with tandem mass spectrometry (LC/MS/MS)*
- Liquid chromatography – mass spectrometry (LC/MS) with derivatization
- LC with UV detection
Liquid Chromatography with Tandem Mass Spectrometry (LC/MS/MS)

- High sensitivity; avoids derivatization
- Extract clean-up: SPE or chemical deproteinization
- A number of different LC columns (stationary-phase chemistries)
- No differences in results. Graphitic carbon most frequently used.
Liquid Chromatography with Tandem Mass Spectrometry (LC/MS/MS) (2)

- Most LC/MS/MS methods use ESI in the positive ion mode.
- Better sensitivity and improved confidence in identification of analyte compared to LC/MS
- LOD 3-20 µg/kg; LOQ 10-50 µg/kg; linear over range of 10-10,000 µg/kg
Proficiency Testing Results

- Performance - generally acceptable in terms of accuracy
- No significant difference between results from GC and LC methods.
- No method dependency on the use of internal standards or sample size
- Direct (underivatized) GC methodology may present problems (more data required).
- Broader variation of AA for samples with low AA concentration

General Observations of Analytical Methods Working Group*

- The analysis of foods for acrylamide is at a relatively advanced level compared to the other factors.
- Improvements in analytical methods appear not to greatly affect exposure data and associated risk assessments.

(*JIFSAN Acrylamide in Foods Workshop, Chicago, IL, April 2004)
Formation
A process-formed compound

- Produced via the Maillard Reaction
- Formed in foods during thermal processing (frying, baking, roasting, grilling, toasting); not boiling.
- Favored by low water content, temperatures above 120 °C (248 °F).
- Formed mostly in plant-based foods (potato and cereal products)
Most Common Mechanism for Formation of Acrylamide

Asparagine + Sugar → Acrylamide

+ Heat

Sugar = glucose or fructose
Summary of AA Formation

- Asparagine + reducing sugars [glucose/fructose (carbonyl source)] are major precursors in food products.
- In potato systems, reducing sugars limit acrylamide formation; in cereal systems, asparagine limits.
- Probably is not possible to cook food without forming at least some acrylamide.
- Processing methods/conditions have significant influence.
Potential Health Concerns – Toxicology/Epidemiology
Toxicology of Acrylamide

- Carcinogenic in animal (rodent) studies
- Genotoxic in a range of assays
- Neurotoxic (in humans)
- Metabolized to the epoxide glycidamide; forms DNA adducts
Health Risks - Epidemiology

- Approximately 40 human studies address acrylamide contents of foods and their consumption by different groups.
- Most: No evidence of a positive association between dietary intake and increased relative risk for a number of cancers
- A few: Positive association with postmenopausal endometrial, ovarian, and renal cell cancer
Health Risks - Epidemiology

- A meta analysis (586 publications identified; 25 relevant) indicated a lack of an increased risk for most types of cancer; kidney cancer requires further monitoring.

- Relative Risks for an increase of 10 µg/day of acrylamide intake were close to 1.0 for all cancers considered. No associations were statistically significantly increased.

(Pelucchi et al. 2011. Annals of Oncology, January)
For a compound both genotoxic and carcinogenic, the MOEs indicate a human health concern.

Mitigation/reduction successes in some foods/products may reduce exposure for some individuals or subgroups, but little effect on average dietary exposure for general population.

2005 Risk assessment still valid
Risk Management
Progress on Mitigation Techniques

- Broad cooperation (government, academia, industry) to develop (implement) ways to reduce acrylamide in foods, where possible.
  - Food Drink Europe Acrylamide “Toolbox” (2011)- summarizes agronomic, processing and ingredient mitigation techniques, including enzyme treatments.
- Elimination or reduction unlikely for some foods
Risk Management

- No country has used regulatory action yet to set limits on acrylamide content of foods.
- Germany developed and introduced a voluntary “Minimization Scheme” (2002), using a Signal Value; limited success.
- Codex Alimentarius Commission adopted a Code of Practice for Reduction of Acrylamide in Foods (July 2009)
Risk Management

- EU monitored (2007-2009, 2010-2012) acrylamide content of selected foods (higher acrylamide content or contributing significantly to the diet).
- Products exceeding the Signal (Germany) or Indicative (EU) Values lead to consultations to determine why this occurs.
EC Indicative values for acrylamide contents in 10 food categories

<table>
<thead>
<tr>
<th>Food category</th>
<th>Indicative Value (µg/kg)</th>
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<tbody>
<tr>
<td>French fries, ready-to-eat</td>
<td>600</td>
</tr>
<tr>
<td>Potato crisps</td>
<td>1,000</td>
</tr>
<tr>
<td>Soft bread</td>
<td>150</td>
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<tr>
<td>Breakfast cereals (excluding muesli and porridge)</td>
<td>400</td>
</tr>
<tr>
<td>Biscuits, crackers, wafers, crisp bread, and similar, excluding ginger bread</td>
<td>500</td>
</tr>
<tr>
<td>Roast coffee</td>
<td>450</td>
</tr>
<tr>
<td>Instant (soluble) coffee</td>
<td>900</td>
</tr>
<tr>
<td>Baby foods, other than processed biscuits and rusks</td>
<td>80</td>
</tr>
<tr>
<td>Biscuits and rusks for infants and young children</td>
<td>250</td>
</tr>
<tr>
<td>Processed cereal-based foods for infants and young children, excluding biscuits and rusks</td>
<td>100</td>
</tr>
</tbody>
</table>

*From Commission Recommendation on 10/1/2011 on Investigations into the Levels of Acrylamide in Foods (EC 2011)*
Risk Management

- U.S. FDA, Canada, FSA, EFSA have surveyed acrylamide contents in foods.
- FDA and Canada “plan” to issue Draft Guidance – ‘supposedly’ now ‘in review’.
- No Values (limits) to be established: will monitor - then take action (if necessary).
- EFSA now evaluating 2009-2012 results – then take further action, if necessary.
- EFSA will conduct a risk assessment in 2013.
Concluding Remarks
Is acrylamide in food a problem?

- **Might** be a problem; we don’t know yet.
- There is insufficient evidence to allow a definitive science-based decision to be made at this time.
- It will not be possible to remove or reduce acrylamide from all foods.
- The situation is being actively monitored in the EU, Canada and US. (Other countries)
- A commonly recommended approach is ALARA (as low as reasonably achievable)