European Commission

Food Quality and Safety

Project no. 506820 HEATOX

Heat-Generated Food Toxicants; Identification, Characterisation and Risk Minimisation

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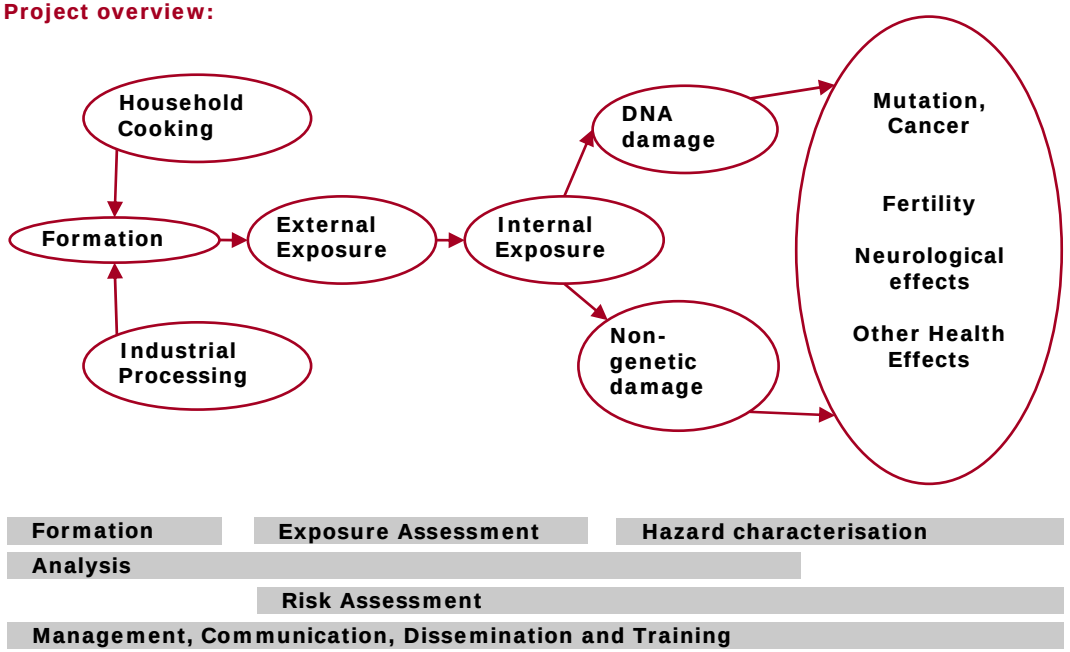
Project overview:



theheatoxproject

Heat-Generated Food Toxicants

Modern science has showed that heating food can generate various kinds of potentially hazardous compounds. Some of these compounds can damage the human genetic material or can cause cancer.

In the last decades, new knowledge e.g. related to polycyclic aromatic hydrocarbons and heterocyclic amines has been followed up by advice related to smoking and frying of meat products to reduce the formation of harmful compounds.

Recent research has established the fact that other hazardous compounds like acrylamide is also formed during heating of food, thus challenging the state-of-the-art in this research field. The need for cutting-edge research as the basis for sound risk management has again been acknowledged.

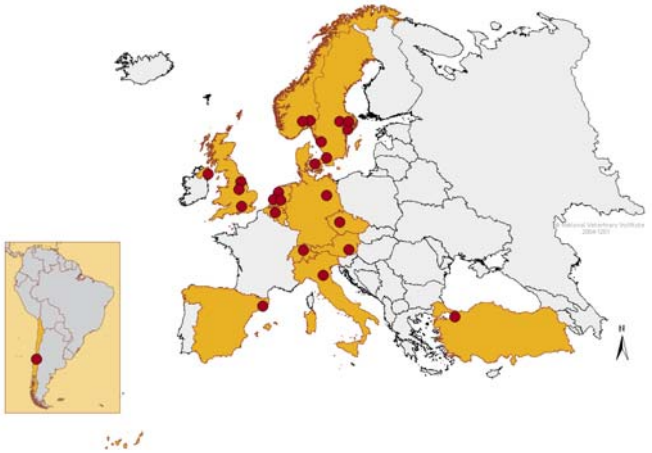
However, heating foods gives many advantages. It adds taste, colour and texture. Furthermore heating in general enhances the microbiological quality thus minimises the risk for harmful germs being present in the final product.

In consequence, research related to heat-generated food toxicants is complex. This is in nature a multidisciplinary research area.

The risk assessments given as basis for risk management decisions should always consider risk versus risk and risk versus benefit.

The HEATOX Project

The HEATOX project has been a multidisciplinary research project involving 24 partners in 14 countries. It started in November 2003 and ended in February 2007.



The main objectives were to

- estimate health risks that may be associated with hazardous compounds in heat-treated food.
- find cooking/processing methods which minimise the amounts of these compounds, thereby providing safe, nutritious and high-quality food-stuffs.

The focus has been on health risks associated with hazardous compounds in heat-treated carbohydrate-rich foods. Special emphasis has been put on the most recently discovered heat-generated food toxicant, acrylamide, but HEATOX scientists have also studied other hazardous compounds like Furan and Hydroxymethylfurfural (HMF).

Risk Communication

To support and strengthen the project profile, a risk communication strategy was developed early in the project. A tailored action plan was implemented successively during the whole project period. The ultimate aim was to ensure that project deliverables were as useful and focused as possible and that the dialogue within HEATOX and between HEATOX and the outside world was effective.

The following definition of risk communication has been applied:

"The interactive exchange of information and opinions throughout the risk analysis process as regards hazards and risks, risk-related factors and risk perceptions, among risk assessors, risk managers, consumers, feed and food business, the academic community and other interested parties, including the explanation of risk assessment finding and the basis of risk management decisions."
Regulation No 178/2002 of the European Parliament and of the Council

The risk communication activities of HEATOX have been assessed and evaluated resulting in specific guidelines to Good Risk Communication Practice (GRCP) related to heat-induced toxicants. The Guidelines have been constructed on the basis of experiences from earlier and ongoing risk communication projects and practices, updated risk communication research and experiences from the HEATOX project. It is anticipated that these guidelines could have a crossover effect on similar projects, thus enhancing the integration of risk communication into risk-related research even further.

For details, see D61 at "Deliverables" at www.heatox.org

Heat-Generated Food Toxicants · HEATOX' Main Results
- Identification and Characterisation

Formation and Processing

- Kinetic models have been developed describing the formation as well as the subsequent loss of acrylamide. These are important tools in the applied work to reduce the acrylamide levels in food products.
- Factors influencing acrylamide formation in potato products have been elucidated – from growing conditions to heat transfer during crisp or French fry processing as well as home cooking. Specific options to reduce acrylamide levels in practice have been pointed out, including raw material selection, additives, blanching, and vacuum frying.
- New knowledge on acrylamide formation during bread baking has been developed. The importance of long yeast fermentation has been demonstrated and new baking technologies (i.e. infrared radiation) reducing the acrylamide level have been developed.
- The influence of raw material parameters on acrylamide formation in coffee roasting has been investigated and the importance of the choice of coffee bean and degree of roasting has been demonstrated.
- Two databases, listing toxicity probabilities of chemical compounds formed in food during heating have been compiled. (Maillard browning compounds and products of heated lipid systems respectively.) They are important starting points for future research into potential toxic compounds formed during cooking.

Analysis

- Optimised extraction procedures have been established, to ensure efficient extraction of acrylamide and furan from food matrices whilst avoiding any extra, artificial, formation that may occur e.g. at high pH for acrylamide.
- Established LC-MS and GC-MS methods capable of testing all food types of interest with regards to acrylamide down to the concentrations of interest.
- A full collaborative trial of two test methods for acrylamide has been published.
- A data base for heat-induced toxicants (acrylamide, ethylcarbamate, furan, heterocyclic amines, HMF, nitrosoamines and PAHs) has been compiled from the literature.
- Data on acrylamide and furan levels in food items in different countries, along with information on the effect of different heating conditions for home-produced and commercial products have been collected.
- Different analytical methods for several other compounds emerging in interest during the project (HMF, 3-APA, and especially furan) in different types of foods have been developed and applied in testing foods.

Hazard Characterisation

- Extrapolation from high doses in animals was addressed by investigating genetic damage and other molecular biomarkers as well as effects on gene expression. Using binding to DNA and haemoglobin and chromosome instability no threshold of effect could be identified indicating that there could be a risk also at low exposures. In testicular cells from mice, glycidamide caused genetic damage at doses much lower than previously reported. In studies on genome wide gene-expression in various cell types, acrylamide and glycidamide caused a plethora of responses.
- Humans exposed to a diet high in acrylamide had a slightly higher level of chromosomal instability than those exposed to a diet containing 100 times less.
- Acrylamide at low doses caused developmental neurotoxicity when given to mice during five days shortly after birth when the growth spurt of the brain takes place. The behavioural effects that were observed were persistent at least up to 6 months of age and got worse with time.
- When given neonatally, glycidamide induced tumours in the intestine of transgenic mice selected as being particularly susceptible to intestinal carcinogens.
- HMF can be converted to a metabolite that caused kidney toxicity in mice and genetic damage in cells. Human enzymes responsible for conversion of HMF were identified by expressing human enzymes in bacteria and cells.

Exposure Assessment

- Intake of acrylamide within the EU varies between 0.3 – 1.4 micrograms per kg body weight per day.
- Brand loyalty can influence high exposure levels of acrylamide depending on market share.
- Scenario analyses illustrate a theoretical reduction in acrylamide exposure based on data generated in HEATOX. The results show a maximal 40% reduction for the Dutch population.
- The relationship between external and internal dose of acrylamide and glycidamide in rats exposed to acrylamide at dose rates applied in the published cancer tests compared to the same relations in man exposed to doses obtained after eating fried foods, show that high dosed rats is a suitable model for low exposed humans.
- Internal exposure was measured as Hb adducts of acrylamide and glycidamide for 430 women with breast cancer and 430 controls from a cohort of 30 000 women. There was an association between acrylamide adducts and oestrogen dependent breast cancer after adjustment for smoking.

Risk Assessment and Risk Characterisation

- Acrylamide has been classified by WHO, World Health organisation. This conclusion is strengthened by the project. Following exposure to acrylamide via food the primary concern is the possible risk of cancer.
- Compared with many regulated food carcinogens, the exposure of acrylamide poses a higher estimated risk to European consumers.
- Risk assessments and recommendations to minimize exposure to acrylamide made by WHO are still valid.
- Other compounds formed during cooking of food, for example HMF, Furan, and a variety of Maillard reactants and lipid oxidation products may also constitute an increased cancer risk for consumers. Approximately 50 substances that would require risk assessment have been theoretically identified within the project.
- Current knowledge does not allow for a risk-benefit assessment of cooking with respect to acrylamide or other heat-induced toxicants.

Risk Minimisation of Acrylamide
– HEATOX Advice to Authorities

The Risk

The risk characterisation carried out in HEATOX concludes that compared with many regulated food carcinogens, the exposure to acrylamide poses a higher estimated risk to European consumers.

The average intake of acrylamide for adults in the countries covered by HEATOX' studies varies between 0.3 and 0.5 micrograms per kg body weight per day and between 0.3 and 1.4 for children and adolescents.

The scenario analyses illustrate a theoretical reduction in acrylamide exposure based on data generated within the project. As an example, the graph below shows a maximal 40% reduction for the Dutch population.

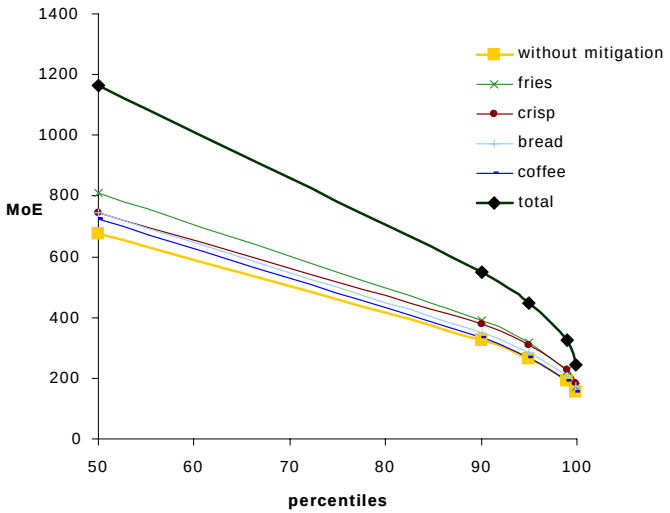


Figure 1. Distribution of Margin of Exposure (MoE) of the acrylamide reduction scenarios over the percentiles.

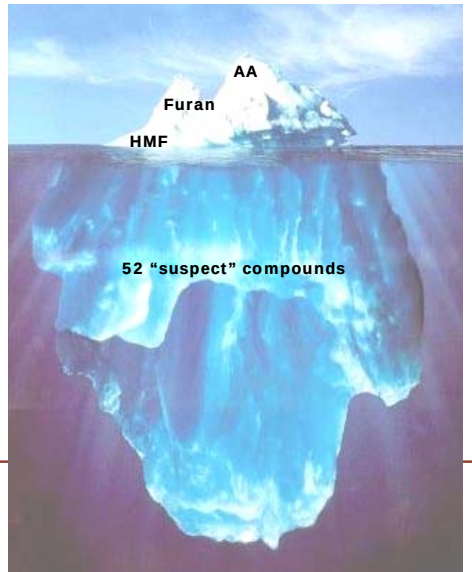
Managing the Risk

The scenario analyses performed indicates a possible maximum reduction of 40% if all known mitigation efforts are applied. It is important that the efforts to find more efficient tools are continued. Meanwhile, advice on consumption can be a complementary way of reducing the intake. This indicates the need to consider a management strategy combining regulatory means with consumption advice and risk communication activities.

Industrial processing and catering are the places in the food chain where mitigation efforts would be most efficient. Industry-based food processing is much more foreseeable as to final results than home cooking due to quality assurance systems and accurate processing equipment.

Product labelling regarding best cooking practices is also a means to enhance public awareness related to industry products.

At the home cooking level, avoiding overcooking is probably by far the most important action to recommend. Authorities must also consider national differences both regarding diet, cooking practices and risk perception. Home cooking advice is probably most efficient when combined with general consumption advice.



Knowledge Gaps

Although the HEATOX project has covered a wide range of topics related to heat-generated food toxicants, there are still major knowledge gaps in this area. HEATOX would particularly draw attention to the following needs for further research related to heat induced toxicants:

- Formation and possible mitigation of toxic compounds other than acrylamide
- Development of methods to attain more dramatic reduction of acrylamide levels in food products
- The relevance to man of neurotoxic effects
- The effects of acrylamide and its active metabolite glycidamide at low doses
- The role of genetic vs non-genetic effects of acrylamide
- Further development and trials of analytical methods for compounds other than acrylamide
- Dietary factors influencing the metabolism of acrylamide
- The risk for intestinal carcinogenesis in man
- Cancer risks in humans using biomarkers of exposure
- The exposure to acrylamide and other heat-induced toxicants in people consuming high amounts of fried foods
- The contribution of heat-induced toxicants other than acrylamide to the observed diet-related risk of cancer in man

Risk-benefit assessments should be performed. There is a special need for establishing agreed protocols including weighting factors for risk-benefit assessments.

Risk Minimisation of Acrylamide
- HEATOX Advice to Industry and Catering

HEATOX approach

Industry and catering represent important food chain levels where effective risk minimisation initiatives could contribute to reducing the intake of acrylamide. This was acknowledged early in the HEATOX project.

HEATOX was planned and initiated in a situation when the fact that acrylamide is present in many carbohydrate-rich heated food products had just been established. The knowledge at that time was very limited. HEATOX took a very broad approach and adopted as a guiding rule that new knowledge should come into practical use as soon as possible. Parallel to the HEATOX project, many HEATOX researchers have therefore engaged in fast track research initiated by other interested parties and have taken active part in research networks.

Important industry based networks and research projects frequented by HEATOX researchers

- ILSI Acrylamide Taskforce, ILSI Europe
- CIAA Toolbox project, Belgium
- NORDACRYL, Nordic Industry Network
- Bund für Lebensmittelrecht und Lebensmittelkunde – BLL, Germany

The CIAA Acrylamide Toolbox

The Acrylamide Toolbox has been developed by the Confederation of the Food and Drink Industries of the EU, the CIAA. The Toolbox is based on work performed within industry as well as findings from the research community, including HEATOX. The Toolbox provides brief descriptions of intervention steps evaluated and, in several cases, implemented by food manufacturers and other players in the food chain.

There has been active and close contact between CIAA and HEATOX during the entire project period. The first version of the Toolbox was evaluated internally within HEATOX by relevant research groups prior to the decision to build further on this basis rather than developing an alternative HEATOX system. Following advice from the HEATOX External Panel and the outcome of the HEATOX Workshop in 2006, HEATOX results relevant to industry and catering sector are being fed into the CIAA Toolbox.

For detailed advice and further information, see www.ciaa.be

HEATOX research

Many HEATOX results are of direct relevance to industry and supporting the Toolbox.
HEATOX research covers many aspects related to the three main food sectors in the Toolbox.

Potato products; from growing conditions to crisp or French fry processing
Cereal products; mainly focused on bread and baking
Coffee; roasting process and influence of raw material parameters.

For details regarding HEATOX research relevant to industry and catering sector, see D60 at "Deliverables" at www.heatox.org

Semi-industrial fryer for catering use.
Photo: University of Bologna (Italy)

Risk Minimisation of Acrylamide
- HEATOX Advice to Authorities and Consumer Organisations on Home Cooking and Consumption

Intake from Home Cooking

Acrylamide formation and minimisation strategies have been quite extensively studied in the laboratory and in industrial environments where the processing/heating conditions are better controlled than in home cooking. HEATOX researchers have conducted a number of experiments related to deep-fried French fries, crisps, oven-roasted potato wedges and toasted bread.

The general intake of acrylamide for adults is quite similar across Europe. Due to the fact that a large number of foods contributing to acrylamide intake are industrially produced the contribution from home cooking is probably quite small in the general population.

Exposure from home cooking comes primarily from potato products with some addition of toasted and homemade bread. Home cooking, especially potato products, can generate a very large and almost unpredictable variation even for the same product and for the same cook, which makes it difficult to predict the real intake from home cooked foods. Individuals with a high consumption and preference for specific hard fried foods might constitute high exposure risk groups.

National Differences

The HEATOX Workshop in Graz 2006 identified significant differences in home cooking methods and availability of ingredients within countries and certainly across the different European regions and member states. The national differences in dietary habits and cooking practices, as well as the different availability of ingredients, need to be taken into account by national authorities and consumer organisations when developing material like brochures, web pages, and presentations for consumers.

The HEATOX Guidelines to authorities and consumer organisations on home cooking conclude by given advices both related to home cooking practices and to consumption.

HEATOX partner BEUC, European Consumers' Organisation has organised the interaction with consumer representatives.

BEUC national member organisations were represented at the HEATOX Workshop in June 2006 and provided valuable input to HEATOX advice related to home cooking.

Advice

The HEATOX advice is aimed as a tool for National Authorities and Consumer organisations for handling the acrylamide issue in relation to home-cooking. This might include giving cooking advice directly to consumers as well as influencing providers of raw materials, pre-fried products and frying equipment for domestic use.

Home cooking

National authorities should highlight the following:

Potatoes low in sugar

- Low sugar potato varieties
- Maintenance of suitable storage temperature during the supply chain
- Low sugar levels in prefabricated potato products for domestic frying.

Best frying temperature

- Frying temperature in the range 145 to 170°C for deep frying potatoes.
- Clear and accurate cooking instruction on the package of pre-fried products.
- Clear and accurate instruction for fryers for domestic use.

Golden, not brown!

- French fries and roast potatoes cooked to a golden-yellow rather than golden-brown colour.
- Bread toasted to the lightest colour acceptable.

Consumption

Balance the diet as proposed in national dietary recommendations and integrate acrylamide considerations into the "normal" dietary recommendations.

For detailed advice and further information about HEATOX work relevant to home cooking and consumption, see D59 at "Deliverables" at www.heatox.org

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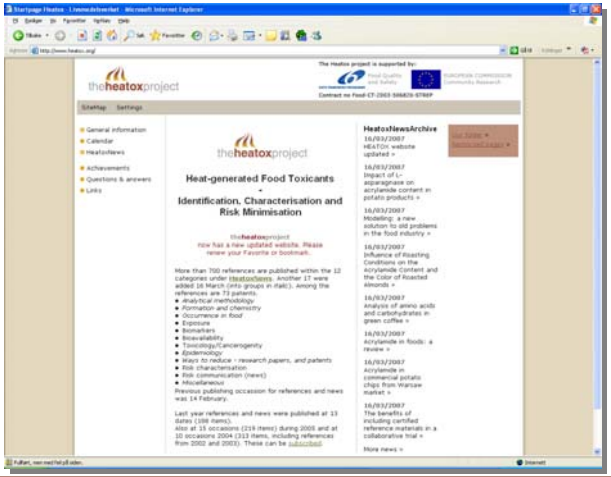
- Chris Elliott

For details regarding HEATOX research, see www.heatox.org



HEATOX External Panel

The External Panel constituted the core risk communication network and provided valuable discussion with HEATOX' stakeholders.
In charge: Karl-Erik Hellenäs.

Members:

Consumer
- Barbara Gallani (from June 2005)/Beate Kettlitz (until March 2005), BEUC, BE

Industry
- Beate Kettlitz (from March 2005)/Domenique Teaymans (until March 2005), CIAA, BE
- Sam Lalljie, ILSI, BE
- Julia Gelbert, BLL/ZUTECH, GE

Research
- David Lineback, JIFSAN, USA
- Erland Bråthen (until 2005), MATFORSK, NO
- Vincenzo Fogliano, COST-927, IT
- Elke Anklam (until July 2006), JRC irmm, BE

Authorities
- Almut Bitterhof (from spring 2006)/Martin Slayne (until spring 2006), DG Sanco, BE
- Claudia Heppner, EFSA, Contam panel, IT
- Lutz Dehne, BfR, DE
- Wendy Matthews (from 2004)/Karen Goonan (until 2004), FSA, UK
- Sara Henry, FDA, USA
- Lauren Jackson, FDA, USA

- 24 partners
- 14 countries
- 25 PhD students
- External Panel

More than
- 100 scientific publications
- 200 posters and oral presentations
- 700 references published on HEATOXNews at www.heatox.org and frequent popular updates in newspapers, on radio and TV

Final meeting in Prague, 2007. Photo: Torbjörn Albert

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