FOOD SURVEY
INFORMATION SHEET

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ANALYSIS OF TOTAL DIET STUDY SAMPLES FOR ACRYLAMIDE

Introduction

Since the initial 2002 discovery of unexpectedly large amounts of acrylamide in some foods, research has continued internationally to improve understanding of the toxicology, analytical methodology, formation and potential methods of reducing acrylamide levels in foods. More than 200 research projects have been initiated around the world and this survey has been conducted as part of that international effort. The results of the survey form part of the wider international body of evidence and will be fed into the February 2005 Joint FAO/WHO Expert Committee on Food Additives safety evaluation of acrylamide in food. The results of this survey do not affect Agency advice on what people should eat.

Summary

The aim of this study was to estimate the amount of acrylamide people are exposed to from food and to identify whether previously unconsidered food categories contributed significantly to acrylamide exposure. Acrylamide levels were measured in Total Diet Study samples; these food samples represent the average UK diet and sampled foods are prepared according to normal domestic practice. The results have been used to estimate dietary exposure to acrylamide for average and high level UK consumers and identify those foods that contribute to total dietary exposure.

UK consumers' estimated exposure to dietary acrylamide, based on the survey results, was similar to exposure estimates in other countries.

Acrylamide is known to cause cancer in animals. It is considered probable that it could also cause cancer in humans, although this is not certain. Overall the estimated levels of exposure that the survey found were at least 1000 times lower than the doses reported to cause cancer in laboratory rats. Since 2002 the food industry and other researchers have been working to reduce acrylamide levels in food.

Acrylamide was quantified in 7 of the 20 food groups tested. The dietary exposure estimates show that cereal-based products and potatoes are the main sources of acrylamide in the UK diet. Quantifiable amounts of acrylamide were found in the following groups; bread, miscellaneous cereals (includes products such as biscuits and breakfast cereals), poultry, meat and meat products, sugars and preserves and potatoes (which includes a range of cooked fresh and processed potatoes). Where appropriate food in these groups had been prepared for consumption. No new sources of dietary acrylamide were identified.

This survey was commissioned to feed into the international research efforts to improve our understanding of acrylamide. The results of the survey do not affect Agency advice on what people should eat. The Food Standards Agency continues to recommend that people should eat a balanced healthy diet, including plenty of fruit and vegetables, bread, other cereals and potatoes and should limit the amount of sugary and fatty foods they eat, including fried food such as chips and crisps.

Background

Acrylamide in Food

In April 2002, researchers in Sweden discovered unexpectedly large amounts of the chemical acrylamide in foods rich in starch that had undergone high temperature cooking or processing e.g. crisps, chips, breads and crispbreads[1]. Following the initial survey the Agency conducted its own research which confirmed the findings in Sweden[2].

Acrylamide is known to cause cancer in animals and has been classified by the World Health Organisation's (WHO) International Agency for Research on Cancer (IARC) as probably carcinogenic to humans[3]. The European Commission's Scientific Committee on Food concluded that because acrylamide is carcinogenic in animals and is genotoxic, dietary exposure should be as low as reasonably achievable[4].

Since the initial discovery, research on acrylamide in food has continued internationally, with the aim of understanding more about the toxicology, analytical methodology, formation and potential methods of reducing acrylamide levels in foods. The main mechanism of formation of acrylamide in food is thought to be via a reaction between the amino acid asparagine and reducing sugars, e.g. glucose, during high temperature cooking, for example frying, baking and microwaving[5,6,7].

This survey was conducted to provide data for an estimate of dietary exposure to acrylamide for UK consumers, and to identify any unknown sources of acrylamide in the diet. This will also assist in highlighting the contribution of different food groups and inform which groups contribute most to dietary acrylamide exposure. The information provided by this survey has been supplied to the Joint FAO/WHO Expert Committee on Food Additives (JECFA) for use in the assessment of acrylamide in February 2005.

The Total Diet Study

The Total Diet Study (TDS) represents the average UK diet and has been carried out on a continuous annual basis since the 1960s. The results are used to estimate dietary exposures of the general UK population to chemicals in food, to identify trends in exposure and make assessments on the safety and nutritional quality of food.

The TDS is made up of 119 categories of foods purchased from 24 locations throughout the UK each year (total of 480 samples) which are combined into 20 groups of similar foods. Shoppers are asked to select and purchase a single product from each food category in each location without reference to products purchased in other locations. Foods are prepared according to normal domestic practice. Once combined the groups are thoroughly homogenised. The types of food included in each group and their relative proportions reflect consumption data, largely based on household food purchases, recorded in Defra's Expenditure and Food Survey[8]. This is updated annually to reflect changes in eating habits.

Methodology

Analysis was carried out at the Central Science Laboratory (CSL).

Homogeneity

The 2003 TDS samples were tested to ensure sufficient homogeneity by measuring the content of water-soluble metals. The entire portion of each sample was homogenised and divided into four parts for analysis. The method of homogenisation varied according to sample type: oils and fats were stirred; milk and beverages were shaken; cereals and sugars were ground using a coffee grinder; and the remaining groups were homogenised in a blender. Each homogenised sample was then tested for sodium, magnesium, potassium, calcium and manganese using acid digestion followed by inductively coupled plasma mass spectrometry (ICP-MS).

Acrylamide analysis

The TDS samples were analysed for acrylamide in duplicate using a United Kingdom Accreditation Service (UKAS) accredited GC-MS method. A third sub-sample was spiked with a known amount of acrylamide, to determine the analytical recovery. All data were corrected for recovery. The full method is given in the laboratory report[9].

The quality control criteria used were as follows:

- Results of duplicate analysis were accepted if they had a relative standard deviation of less than or equal to 20 per cent.

- Acrylamide data were accepted only if the recovery of spikes lay in the range 60 to 140 per cent with at least 75 per cent of the spiked samples lying in the range 80 to 120 per cent.
- Food Analysis Proficiency Assessment Scheme (FAPAS®) Series 30 (acrylamide) Round 1 (Crispbread) and Round 3 (Breakfast cereal) samples were used as reference materials. The acceptance criterion was that the results should be within the range that would give a z-score of plus or minus 2.

Analytical results have a variability known as measurement uncertainty (MU). For any analytical method each result is reported as the best estimate for the sample and it is always qualified by a measurement of uncertainty (e.g. x micrograms/kilogram ± y micrograms/kilogram). For this survey the calculation of MU was carried out by CSL using z-scores calculated from the measurement of FAPAS test materials.

The limit of quantification (LOQ) varied from 1-5 micrograms/kg dependent on the food group. Where samples contained acrylamide below the LOQ the results are reported as less than the LOQ.

The level of acrylamide quantified in the 2003 TDS potato group sample was lower than expected. On investigation of the composition of this group it was found that, no crisps or fried potato products were purchased in the potato products category in 2003 and only a third of the potato and potato products included were baked, grilled or microwaved. The rest of the sample was either boiled, steamed or prepared from instant mash potato. Therefore, the sample underrepresented foods consumed in the UK that are known to contain acrylamide. Since 2002 various initiatives to try and reduce acrylamide levels in food have been explored by the food industry and other researchers. Although the impact of such initiatives will not be reflected in the 2001 TDS potato group sample it was found to be more representative, in that it did include crisps and baked potatoes/potato products. Therefore, the 2001 sample was analysed to supply a more accurate acrylamide occurrence estimate for this food group. This latter occurrence level has been used in an acrylamide dietary exposure estimate.

Results

Homogeneity

It was concluded that the TDS samples are sufficiently homogeneous. The relative standard deviation for the metals analysis was in the range of 0–17 per cent with an average of 5.6 per cent. This precision measurement is within the historical data for ICP-MS metal analysis and is smaller than the repeatability of acrylamide measurements. Full results are given in the laboratory report[9].

Acrylamide levels

Table 1 gives the mean concentrations of acrylamide quantified in each of the twenty 2003 TDS food group samples and the 2001 TDS potato group sample. The measurement uncertainties for these analyses are plus or minus 28 per cent and 32 per cent respectively. The acrylamide level quantified in the 2001 TDS potato sample has been used to estimate acrylamide dietary exposure.

Acrylamide was quantified in 7 of the 20 food groups: bread (12 micrograms/kg), miscellaneous cereals, which includes products such as biscuits and breakfast cereals (57 micrograms/kg), carcass meat, the majority of which were baked (10 micrograms/kg), meat products, including sausages and pies, which were all prepared for consumption (13 micrograms/kg), poultry which have been mostly baked or grilled (6 micrograms/kg), sugars and preserves, including chocolate and confectionery (23 micrograms/kg) and potatoes, which contains a range of cooked fresh and processed potatoes (112 micrograms/kg).

Acrylamide was not quantified in samples of offal, fish, oil & fats, eggs, green vegetables, other vegetables, canned vegetables, fresh fruit, fruit products, beverages, milk, dairy products and nuts.

These results are generally consistent with what is known about the formation of acrylamide in food and the results of other international research, such as those recorded in the European Commission's Joint Research Centre database [15,16].

Discussion

Levels of acrylamide quantified in the bread group were lower than expected when compared with levels generally found in bread and toast; for example, bread has been shown to contain an average of 30 micrograms/kg, whereas toasted bread can contain approximately 200 micrograms/kg[2,16,17]. No toast was present in this 2003 TDS sample which may explain these findings. However, including this level of acrylamide in toast in the overall acrylamide exposure does not significantly effect the exposure estimate.

High levels of acrylamide were quantified in the sugar and preserves group; the likely source of this acrylamide is chocolate. Chocolate has been found to contain acrylamide levels of 20 micrograms/kg[16].

The current understanding of the formation of acrylamide suggests that acrylamide is mainly formed in starch-rich foods; however, acrylamide was also quantified in the carcass meat and poultry groups, these groups will therefore contribute to acrylamide dietary exposure. Previous research has measured similar levels of acrylamide in meat products[1]. The inclusion of breadcrumb and other ingredients may also contribute to the levels of acrylamide quantified in this sample.

No new food groups were identified as containing significant levels of acrylamide. The estimated dietary exposures to acrylamide given in Table 2 are at least 1000 times lower than the doses reported to cause cancer in laboratory rats[4]. The dietary exposure estimates show that cereal-based products and potatoes are the main sources of acrylamide in the UK diet. Since 2002 various initiatives to reduce acrylamide levels in food have been explored by the food industry and other researchers. Any impact of such initiatives on acrylamide in potatoes and potato products will not be reflected in these dietary exposure estimates. Dietary acrylamide exposure estimates carried out by the WHO, Sweden, the Netherlands and Australia give estimates in the range of 0.3 to 0.8 micrograms/kg bw/day dependent on age group[18,19,20,21]. The estimated UK exposure for average consumers lies in a similar range. However, it should be noted that these dietary exposures are not directly comparable because of the different methods used, for example: different age groups; whole populations or consumers of particular products; using limited food groups rather than the whole diet.

Conclusions

The results from this survey will be fed into the international research efforts to improve our understanding of acrylamide. The results of the survey do not affect Agency advice on what people should eat. The Food Standards Agency continues to recommend that people should eat a balanced healthy diet, including plenty of fruit and vegetables, bread, other cereals and potatoes and should limit the amount of sugary and fatty foods they eat, including fried food such as chips and crisps.

Summary of Units

Microgram (µg): one thousandth of a milligram (mg)

Milligram (mg): one thousandth of a gram

Kilogram (kg): one thousand grams

Micrograms per kilogram (µg/kg)

Kilograms body weight (kg bw)

Micrograms per kilogram body weight per day (µg/kg bw/day)

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Further information

Further information on this survey can be obtained from:

Dr Karen Goonan
Chemical Safety Division
Room 707c, Aviation House
125 Kingsway
London, WC2B 6NH
Tel: +44 (0) 20 7276 8714
Fax number: +44 (0) 20 7276 8717
Email: karen.goonan@foodstandards.gsi.gov.uk

The full report of this survey is held in the Elsie Widdowson Library at Aviation House, 125 Kingsway, London WC2B 6NH Tel: +44 (0) 20 7276 8181. If you would like to consult a copy, please contact the Library giving at least 24 hours notice or, alternatively, copies can be obtained from the Library; a charge will be made to cover photocopying and postage.

Table 1 – Mean concentrations of acrylamide in the Total Diet Study samples

Food group	Acrylamide[a] (micrograms/kg)	Acrylamide levels used in exposure assessment (micrograms/kg) and rationale	
1. Bread	12	12	
2. Miscellaneous cereals	57	57	
3. Carcass meat	10	10	
4. Offal	<3	3	Acrylamide quantified in poultry and carcass meat therefore potential to form in offal[1]
5. Meat products	13	13	
6. Poultry	6	6	
7. Fish	<5	5	Food group may contain breaded and battered products which may contain acrylamide[18]
8. Oils and fats	<3	0	
9. Eggs	<1	0	
10. Sugars and preserves	23	23	
11. Green vegetables	<2	0	
12. Potatoes 2003 Group	53		
2001 Group	112	112	
13. Other vegetables	<5	5	Food group may contain roasted vegetables, which may contain acrylamide
14. Canned vegetables	<5	0	
15. Fresh fruit	<1	0	
16. Fruit products	<1	1	Food group may contain cooked components, which may contain acrylamide[16,18]
17. Beverages	<1	1	Food group may contain coffee which may contain acrylamide[16]
18. Milk	<1	0	
19. Dairy products	<1	0	
20. Nuts	<3	3	Food group may contain peanut butter and roasted nuts, which may contain acrylamide[16]

[a] Mean of duplicate analyses and corrected for the analytical recovery. Analytical recoveries lay in the range 60-140 per cent.

Table 2 – Exposure[b] to acrylamide from food groups of the Total Diet study (all food groups combined)

Dietary Survey[a]	Age Range (years)	Exposure estimate[b] (micrograms/kg bw/day)[c]	
		Average consumer[d]	High level consumer[d]
Adults	19 – 64	0.3	0.6
Female		*0.3*	*0.6*
Male		*0.4*	*0.6*
Young People	15 – 18	0.5	0.9
	11 – 14	0.6	1.1
	7 – 10	0.8	1.4
	4 – 6	1.0	1.6
Toddlers	1.5 – 4.5	1.0	1.8
Elderly Free-Living	65 and over	0.3	0.6
Elderly Institutional		0.4	0.7
Vegetarians	–	0.3	0.7

[a] To calculate dietary exposure to acrylamide, the occurrence data from the analysis of the TDS samples was used together with consumption data from the following dietary surveys; the National Diet and Nutrition Survey of British adults[10], young people aged 4-18 years[11], toddlers aged 1.5-4.5 years[12] and people aged 65 years and over[13] and the British Marketing Research Bureau's dietary survey of vegetarians[14].

[b] To estimate these dietary exposures the following acrylamide levels were used: For food groups where acrylamide was quantified, the quantified level was used. For food groups where acrylamide was not quantified but where it is known to be present in components of that group or has the potential to form in that group, an acrylamide level of the LOQ was presumed. Food groups where acrylamide was not quantified and where the group does not have the potential for acrylamide formation, it has been assumed that acrylamide is present at 0 micrograms/kg.

[c] Body weight consumption is calculated using each dietary survey participant's body weight.

[d] Consumer estimates are based only on those people who ate the food in question. The term "average consumer" refers to UK consumers who eat an average amount of food, (for the UK). "High level consumers", also referred to as 97.5th percentile consumers, are UK consumers who eat in excess of the average amount of food.