Risk Assessment Studies
Report No. 11

Chemical Hazard Evaluation

Acrylamide in Food

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Abstract

Acrylamide is a toxic and potentially carcinogenic chemical. Following the announcement by the National Food Administration in Sweden that acrylamide was found in many types of food, especially starch-containing food with high-temperature treatment, the Food and Environmental Hygiene Department took some 450 food samples available in the local market for acrylamide analysis to assess the situation in Hong Kong. Local staple food of steamed rice, soup noodles and congee were not found to contain appreciable amount of acrylamide. The acrylamide levels in the more commonly consumed food items in the food groups rice and rice products, noodles, bakery and batter-based products which were subject to frying, baking and grilling were generally less than 60 μg/kg. Higher levels were found in the food groups biscuit related products and crisps. The highest levels were detected in potato crisps (1500 to 1700 μg/kg). The present data on acrylamide are not sufficient to warrant changes in basic dietary advice on healthy eating, i.e., have a balanced and varied diet, eat more fruits and vegetables, and should moderate consumption of fried and fatty foods.

Risk Assessment Studies –

Acrylamide in Food

An investigation of acrylamide in Asian Food available in Hong Kong

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INTRODUCTION

Background

In April 2002, the Swedish National Food Administration (NFA) and researchers from Stockholm University released a study finding that acrylamide was detected in a variety of common foods cooked at high temperature such as chips (French fries), potato crisps, breakfast cereals and cookies etc. Subsequent studies from Norway, Switzerland, United Kingdom and United States had also found elevated levels of acrylamide in such foods. The discovery of acrylamide in food is a public health concern because acrylamide is a potential carcinogen and genotoxicant.

2. In view of the findings, an expert consultation convened jointly by the Food and Agriculture Organisation of the United Nation (FAO) and the World Health Organisation (WHO) in June 2002. The Consultation recognized that the issue is a major concern and acknowledged the potential link between acrylamide and carbohydrate-rich foods cooked at high temperature. The Consultation considered that the existing data is insufficient to allow a

quantitative estimate of cancer risks from dietary acrylamide. Besides, data in food consumed in regions other than Europe and North America is lacking and called for more research in this area.

3. In view of the public health risk of this issue, the Food and Environmental Hygiene Department (FEHD) thus considered that there is a need to conduct a study to determine the acrylamide levels in foods of our local diets especially Asian food (e.g. fried rice, fried noodles, fried dim sum (點心) and yau-hei (i.e. deep-fried dough) (油器) etc.).

Use of acrylamide

4. Acrylamide is an odourless, white, crystalline organic solid with melting point of 84-86°C.[1] It readily undergoes polymerization to form polyacrylamide, which is a highly cross-linked gel polymer with many uses in industry. Polyacrylamides are used as a coagulant aid in the treatment of drinking water and waste water. It is also used in paper, textile and plastic industries, and synthesis of dyes, as a grouting agent in the construction of dam foundation, tunnels and sewers.

Source of exposure

5. Prior to NFA's announcement, the major health concerns associated with acrylamide were the exposure through drinking water and in occupational exposure, while acrylamide from diet is not known as an exposure.

Polyacrylamide is used as a coagulant aid in drinking water treatment and trace amounts of non-polymerized acrylamides may present in drinking water.[2] The WHO Guideline for Drinking Water Quality has established a guideline value of 0.5 μg/litre for acrylamide in drinking water. Residual acrylamide from packaging material contributes a negligible exposure.[3]

Health implications of acrylamide

6. Ingested acrylamide is readily absorbed from the gastrointestinal tract and mainly excreted via urine, with small amounts eliminated via faeces and exhalation.

7. Acute toxicity caused by acrylamide is rarely encountered in humans. Neurotoxicity is the only recognized adverse effect of oral acrylamide exposure for humans, affecting sensory and/or motor functions. The WHO Consultation in June 2002 supported the "No Observed Adverse Effect Level" (NOAEL) for acrylamide neurotoxicity of 0.5 mg per kg body weight per day previously established. The LD_{50} values ranged from 107 – 203 mg/kg body weight was shown in rats.[4]

8. Acrylamide is genotoxic in vivo, therefore acrylamide has the potential to induce heritable damage at gene and chromosome level.

9. Acrylamide is carcinogenic in experimental animals producing increased incidences of a number of benign and malignant tumours in various organs, including thyroid, adrenal, brain, lung, skin, etc. For humans, the

relative potencies of cancer causation due to acrylamide in food are not known.[5]

10. In 1994, International Agency for Research on Cancer (IARC) evaluated acrylamide and considered that there was sufficient evidence of carcinogencity in experimental animals but inadequate evidence of carcinogenicity in humans and classified it as Group 2A (probably carcinogenic to humans). This classification was endorsed by the WHO Consultation in 2002.

Formation of acrylamide in food

11. At present, research findings revealed that raw food and foodstuffs that are prepared by boiling do not contain appreciable levels of acrylamide.[6] Acrylamide is formed when food, particularly those rich in carbohydrate are cooked at above 120°C.[5] Current evidence suggests that acrylamide may be formed in food in chemical reaction which requires the presence of the amino acid, asparagines and reducing sugars under certain conditions.

12. The mechanism involved in acrylamide formation during the food processing is still uncertain. Researches are underway in many parts of the world to find out the exact mechanism of formation of acrylamide in food.

OBJECTIVE

13. This study aims to determine the levels of acrylamide in food

available in local market.

METHODS

Sampling

14. For the purpose of this study, a wide range of carbohydrate-rich food was taken for acrylamide analysis. These food were subjected to high-temperature cooking, principally >120°C such as grilling, roasting, baking, barbecuing, frying and deep-frying. Asian style foods such as Chinese, Japanese, Indian, Indonesian, Malaysian, Thai, Vietnamese style, as well as some Western foods were included. They might be in a form of ready-to-eat, mixed dishes and pre-packaged. Food samples were collected from various restaurants, supermarkets, bakeries and other retail outlets.

15. The popularity and availability of the food / products formed the major selection criteria. Mixed dishes were mainly in a form of "composite sample". Samples collected randomly from three to four sources were mixed and homogenized, otherwise, food samples were analysed individually. The food groups are shown in Annex I.

Laboratory analysis

16. Laboratory analyses were conducted by the Food Research Laboratory (FRL) of the FEHD.

17. The edible portion of the food sample was homogenized and an appropriate test portion (1-4 g) was taken. The acrylamide in the test portion was extracted by water and then, cleaned up by solid phase extraction, and subsequently determined by Liquid Chromatograph-Tandem Mass Spectrometry (LC-MS/MS) technique. Acrylamide-1,2,3-C^{13} was used as an internal reference (surrogate) for the analysis. The test method was validated by single-laboratory validation. The limit of detection and the limit of quantification were 3μg/kg and 10μg/kg respectively.

RESULTS AND DISCUSSION

18. Some 450 food samples were collected and sent to the FRL for acrylamide analysis. A total of 156 analyses had been conducted. The results are listed in Annex II.

19. On the whole, high-temperature treated carbohydrate-rich foods contained acrylamide. The levels of acrylamide in the more commonly consumed Asian style food items in the food groups rice and rice product dishes, noodles, bakery products and batter-based products were low and generally less than 60 μg/kg, except for deep-fried sizzling rice (guo-ba) and Japanese fried noodle (teppan-yaki soba) with levels up to 67 μg/kg and 84 μg/kg respectively. Similar levels were found in most of the food items in the Asian delicacies food group, which included Chinese dim sum and other deep-fried products. Higher levels

were detected in deep-fried taro meat dumpling at 190 μg/kg and Chinese fried fritters with range 95 to 170 μg/kg. On the other hand, staple food of steamed rice, soup noodles and congee were not found to contain appreciable amount of acrylamide.

20. Higher acrylamide levels up to above 1000 μg/kg were found in the two food groups biscuit related products and crisps. The ranges of acrylamide content in some of the subgroups were quite wide, probably due to the variation in food processing conditions. The highest levels were found in potato crisps with range 1500 to 1700 μg/kg. Apart from banana crisp (770 μg/kg) and taro crisp (320 μg/kg), the acrylamide levels in other fruit/vegetable-based crisps were quite low, ranging from less than 3 to 86 μg/kg. The acrylamide levels in rye flour-based crisps (440 μg/kg) were considerably lower than those in the potato ones, followed by corn-based (65 to 230 μg/kg) and wheat flour-based crisps (61 to 200 μg/kg), and then rice flour-based crisps (17 to 42 μg/kg). The products in these two food groups are crispy with low moisture content. Moreover, the crisps are in thin slice forms with large specific surface area. As the amount of acrylamide was measured per unit weight of food and the acrylamide would be formed mainly on the food surface during heating, these two factors of low moisture content and large specific surface area would contribute to the generally higher acrylamide level.

21. In general, the acrylamide level in processed meat and seafood products was very low, less than 3 μg/kg. The exception was grilled fish slice in Indonesian style with acrylamide at a level of 93 μg/kg. This might require further investigation as to the ingredients and processing conditions of the food

product.

22. The results for potato crisps, corn crisps, potato chips and batter-based products were within the ranges reported by some European countries and the USA in the FAO/WHO consultation meeting in June 2002.[5] For the case of Asian foods, the results for spring roll, rice cracker and battered fried vegetables (tempura) were comparable to those reported elsewhere.[7]

Estimation of dietary exposure

23. Dietary exposure to acrylamide in the local population was estimated by combining the results of the present study and data from the Hong Kong Adult Dietary Survey 1995 [8] and the Food Consumption Survey in Secondary School Student 2000 [9]. The result revealed that dietary exposure to acrylamide of an average citizen in Hong Kong is about 0.3 μg/kg body weight /day while that for an average secondary school student is about 0.4 μg/kg body weight /day. Both of them fell within the lower end of the range of dietary intake of acrylamide in the western diet (i.e. 0.3 to 0.8 μg/kg body weight /day) as estimated by the WHO at the expert consultation meeting in June 2002.

CONCLUSIONS AND RECOMMENDATIONS

24. Acrylamide was found present in heated carbohydrate-rich foods such as those prepared by grilling, roasting, baking, frying and deep-frying. The

levels varied according to the food material and processing conditions. The study on Asian indigenous foods available in Hong Kong showed that the levels of acrylamide in the commonly consumed foods such as rice, noodles, bakery and batter-based products were in general low, while higher levels were present in snack foods such as biscuits, chips and crisps. Local staple foods of steamed rice, soup noodles and congee were not found to contain appreciable amount of acrylamide. Dietary exposure to acrylamide in the local population is on the low side when compared with dietary intake of acrylamide in the western diet.

25. At present, the data on acrylamide are not sufficient to warrant changes in basic dietary advice on healthy eating, i.e., have a balanced and varied diet, eat more fruits and vegetables, and should moderate consumption of fried and fatty foods.

26. To minimize the risk of acrylamide in food, food should not be cooked excessively, i.e. for too long or at too high temperature. However, all food particularly meat and meat products should be cooked thoroughly to destroy foodborne pathogens.

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Food Groups for acrylamide analysis

Food Group	Characteristics	Sub- group	
Rice	Refers to pre-cooked rice (except steamed/boiled rice) that undergoes stir-frying, pan-frying, deep-frying, grilling, baking.		Fried rice/baked rice/deep-fried rice/ grilled rice/ steamed rice/ boiled rice
Noodles	Refers to pre-boiled noodles/pasta (except boiled soup noodles) that undergoes stir-frying, pan-frying, deep-frying.	Wheat based	Fried noodles/ Instant noodles/ cup noodles/ fried spaghetti//baked spaghetti/ boiled noodles
		Rice based	Fried rice noodles/ Fried flattened noodles
Oriental delicacies	Refers to some Chinese dumplings, wraps, roll stuffed with meat, that undergoes pan-frying, deep-frying.	Wheat-based Taro-based Rice-based	Deep fried dumpling/ fried dumpling/ deep-fried roll Deep fried dumpling Deep-fried rice roll/fried turnip cake
	Refers to wheat-flour dough that undergoes deep-frying. No stuffing is required.	Yau-hei (油器)	Yau-hei (Deep-fried dough without stuffing)
Bread	Refers to a fermented/leavened dough that undergoes baking, toasting, pan-frying, deep-frying, steaming.		Soft bread/ toast (medium) / fried bun/ deep-fried bun/ steamed bun
Confectionery	Refers to dough (but not bread) that undergoes baking.		Cake Tart Pastry
Biscuits	Refers to shaped dough that undergoes baking.	Rice flour based	Rice cracker
		Wheat flour based	Cracker (e.g soda, cream cracker)/ Biscuit (e.g wafer, cookie, digestive, shortbread)
		Rye flour based	Crispbread
Crisps	Refers to either sliced whole potato, shaped flour-based cereal /fruit/ vegetable that undergoes baking, deep-frying, roasting, freeze drying.	Cereal based	Potato crisps/ corn crisps/ wheat crisps/ rice crisps/ rye crisps/ mix of potato/corn/wheat crisps/ starch crisps Fruit crisps (e.g jackfruit crisps, apple crisps, banana crisps)
Potatoes	Refers to potato undergoes either deep-frying or baking.		Deep-fried potato/roasted potato
Vegetables (other than potato) and fruits	Refers to starchy vegetable/fruit that undergoes roasting, battered deep-frying, deep-frying.	Vegetable	Roasted yam/ roasted chestnut/ tempura (battered-fried vegetables) Taro crisps/ green pea
		Fruit	Jackfruit crisps/ banana crisps/ apple crisps
	Refers to fresh starchy vegetable/ fruit.	Vegetable / Fruit	Fresh taro/ banana/ jackfruit
Breakfast Cereals Products	Refers to pre-packed processed cereal products that often serve in breakfast.	Corn based	Cornflakes
		Oat based	Instant oat meals
		Mix of wheat/ rice	Instant cereal drink
Meat, fish and seafood products	Refers to meat/processed meat products that undergo deep-frying, grilling.	Meat	Crumbled-fried pork chop/ barbecued pork jerky/ deep fried sausage
	Refers to processed fish and seafood products that undergo deep-frying, grilling.	Processed fish and Seafood	Deep-fried fish ball/ grilled fish slice Deep–fried shrimp/ Battered-fried octopus/deep-fried shrimp cake
Batter-based Products	Refers to batter that undergoes pan-frying. Refers to batter that undergoes grilling, toasting.		Pancake/ grilled egg roll/ waffle/ egg custards
Miscellaneous			
Pizza			
Black Coffee, ready to drink			
Instant Chinese Soup			

Levels of acrylamide in various food groups

Food Group	Total no. of analysis		Sub-group†	No. of analysis	Range of conc. (µg/kg)	Media conc*. (µg/kg)	Mean conc*. (µg/kg)
Rice	11		Fried rice	4	<3- 15	<3	9
			Baked rice	2	<3		
			Deep-fried rice	1	67		
			Grilled rice	1	<3		
			Steamed rice	2	<3		
			Boiled rice	1	<3		
Noodles	13	Wheat based	Fried noodles	5	<3-84	<3	21
			Instant noodles	1	<3		
			Cup noodles	1	<3		
			Boiled noodles	1	<3		
			Fried spaghetti	1	56		
			Baked spaghetti	1	<3		
		Rice based	Fried noodles	1	<3		
			Fried flattened noodles	2	38-43		
Bread	12		Soft Bread	2	<3-18	<10	13
			Toast (medium)	3	<10-38		
			Fried bun	3	<10-33		
			Deep-fried	4	<3-18		
Oriental delicacies	11	Wheat-based dim sum	Deep-fried dumpling	1	<3	27	44
			Fried dumpling	1	<3		
			Deep-fried roll	2	27-59		
		Taro-based dim sum	Deep-fried dumpling	1	190		
		Rice-based dim sum	Fried rice roll	1	<3		
			Fried turnip cake	1	<3		
		Yau-hei	Deep-fried Dough	4	<3-170		
Confectionery	7		Cake	4	<3-14	<10	14
			Tart	1	<10		
			Pastry	2	14-57		
Biscuits	26	Rice flour based	Rice cracker‡	3	15-23	185	268
		Wheat flour based	Crackers‡	10	33-660		
			Wafer‡	2	110-290		
			Biscuit stick‡	4	47-1100		
			Cookie‡	2	71-240		
			Digestive‡	2	110-340		
			Shortbread‡	1	12		
		Rye flour based	Crispbread‡	2	270-740		
Crisps	32	Cereal based	Potato crisps‡	3	1300-1700	110	251
			Corn crisps‡	6	65-230		
			Wheat crisps‡	10	61-200		
			Rice crisps‡	2	17-42		
			Rye crisps‡	1	440		
			Mix of potato/ corn/ wheat‡	3	260-460		
			Starch‡	7	<3-26		
Potatoes	4		Deep-fried‡	3	100-340	220	220
			Roasted	1	240		
Vegetable (other than potato) and fruit	12	Vegetable	Vegetable tempura	1	32	25	110
			Roasted chestnut	1	28		
			Roasted sweet potato	1	66		
		Fruit	Battered fried banana	1	21		
		Fruit based	Fruit crisps‡	3	<3-770		
		Vegetable based	Vegetable crisps‡	2	86-320		
			Fresh vegetable/ fruit	3	<3		
Meat, fish and seafood products	11	Meat	Crumbed-fried pork chop	1	<3	<3	10
			Barbecued pork jerky	1	<3		
			Deep-fried pork chop	1	<3		
			Grilled sausage	1	<3		
		Fish and seafood	Deep-fried shrimp	1	<3		
			Battered-fried octopus	1	<3		
			Deep-fried fish ball	3	<3		
			Deep-fried shrimp cake	1	<3		
			Grilled fish slice	1	93		
Breakfast cereals products	3	Corn based	Cornflakes	1	100	<10	36
		Oat based	Instant Oat meals	1	<3		
		Mix of wheat/ rice	Instant Cereal Drink	1	<10		
Batter- based Products	5		Grilled egg roll	1	<3	<10	10
			Grilled waffle	1	<3		
			Grilled egg custard	1	<3		
			Pan-cake	2	16-26		
Miscellaneous							
Pizza‡	3				11-51	42	35
Black Coffee, ready to drink‡	3		-	-	<3-13	<3	5
Instant Chinese Soup‡	3		-	-	<3	<3	1.5
Total	**156**			**156**			

***** 1/2 LOD and 1/2(LOD+ LOQ) were assigned to non-detects and results below quantification respectively for the calculation of median and mean levels

† Composite sample,

‡ Single sample .