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The First Hong Kong Total Diet Study: Acrylamide

Purpose

This paper briefs Members on the main findings of the first Hong Kong total diet study (TDS) on acrylamide.

Background

2. The first Hong Kong TDS aims to estimate the dietary exposure of the Hong Kong population and various population sub-groups to a range of substances and thus assess any associated health risks. The Study commenced in March 2010 and would be completed in 2014. As of December 2013, seven reports, covering "dioxins and dioxin-like polychlorinated biphenyls (PCBs)", "inorganic arsenic", "polybrominated diphenyl ethers (PBDEs)", "pesticide residues", "metallic contaminants", "acrylamide" and "mycotoxins", have been released. In this paper, the main findings of the first Hong Kong TDS on acrylamide are presented.

3. Acrylamide is a processing contaminant which was first discovered in 2002 to be formed in foods, typically plant commodities high in carbohydrates and low in protein, during cooking or processing at high temperature (usually > 120°C). Due to concerns about the possible public health risks associated with dietary exposure to acrylamide, the issue has attracted attention in the international arena. Many researches and studies of

both the toxicity and the occurrence of acrylamide in food have since been conducted around the world. The Food and Environmental Hygiene Department (FEHD) have also conducted several studies on acrylamide levels in local food and the dietary exposure of the local population, as well as methods for reducing acrylamide formation, since 2003. The studies conducted so far focused on food products reported with high acrylamide levels. The findings of the last study conducted in 2010 suggested that there were possible concerns from the angle of the dietary exposure of the local population to acrylamide. We thus further examined this issue in the first TDS with a view to obtaining another estimate of the dietary exposure to acrylamide using a different exposure assessment method from the whole diet.

The Study

4. Acrylamide is an industrial chemical that has been used since mid-1950s in the production of polyacrylamide and also a component of tobacco smoke. Its presence in food was first discovered in 2002 by Swedish researchers who revealed that high levels of acrylamide were formed in food during frying or baking. Acrylamide is mainly formed via the Maillard reaction when the free amino acid asparagine, the most important precursor, reacts with the reducing sugars or other carbonyl compounds that are present in food. The formation of acrylamide usually takes place during high temperature (usually > 120°C) processing such as frying, baking, roasting, toasting and grilling. In contrast, only trace amounts of acrylamide will be formed by boiling. Potato crisps, French fries, biscuits, crisp bread and crackers and coffee were reported to contain acrylamide in significant levels, up to “mg/kg” quantities, in many countries. Vegetables, other than potatoes, cooked at high temperature, such as baking, grilling, roasting and pan-frying, were also reported to contain acrylamide, up to several hundreds “μg/kg”, in some overseas surveys and researches.

5. Acrylamide is a genotoxic carcinogen and may also cause toxic effects on the nervous system, and adverse reproductive and developmental effect in experimental animals. High doses of acrylamide are also found to be toxic to the nervous system of humans. However, epidemiological studies do not provide any consistent evidence to show a positive correlation between the level of dietary exposure to acrylamide and the incidence of cancer in humans.

6. The Joint Food and Agriculture Organization (FAO) / World Health Organization (WHO) Expert Committee on Food Additives (JECFA) evaluated the safety of acrylamide for the first time in 2005 and re-evaluated it in 2010. JECFA considered it appropriate to use the benchmark dose lower confidence limit for a 10% extra risk of tumours ($BMDL_{10}$) in animals for assessing the risk of acrylamide exposure, in which two different end-points in animals with the lowest $BMDL_{10}$ were used. The margins of exposure (MOEs) (i.e. the ratio of $BMDL_{10}$ from animal study to the estimated dietary exposure of the local population to acrylamide) were then determined for providing an indication of the health concern level (i.e. the higher the MOE, the lower the health concern, and vice versa). For genotoxic carcinogens, a MOE value exceeding 10,000, based on a $BMDL_{10}$ from animal study, would be of low concern from a public health point of view.

Methodology

7. Three samples of 150 TDS food items (involving 15 food groups) were collected on four occasions from March 2010 to February 2011. The food samples were prepared in the form as they would normally be consumed. For example, most leafy vegetables were stir-fried after washing and soaking. With reference to the general food preparation procedures in the overseas TDS, no cooking oil was added during frying of food samples in this study. The prepared foods were then combined into well-defined food composites,

homogenised and analysed for selected substances.

8. Taking into account the way in which acrylamide is formed in food (i.e. occurring mainly through high temperature processing), the 17 fruit items were excluded for the testing of acrylamide. Hence, only 133 TDS food items (involving 14 food groups) were tested for acrylamide. A total of 1,596 individual samples were combined into 532 composite samples for testing.

Main Findings

9. Among the 14 food groups, food group "snack foods" contained the highest acrylamide level (mean: 680 μg/kg), followed by "vegetables and their products" (mean: 53 μg/kg), and "legumes, nuts and seeds and their products" (mean: 40 μg/kg). On the other hand, the majority (95%) of samples for "fish and seafood and their products", and all samples of "eggs and their products" and "beverages, alcoholic" were not detected with acrylamide. At food item level, potato chips, which was the only item in "snack foods" food group, was found to contain the highest level (mean: 680 μg/kg), followed by fried potato (mean: 390 μg/kg) and zucchini (mean: 360 μg/kg).

10. For the average and high consumer, the dietary exposure of the local population to acrylamide was 0.21 and 0.54 μg/kg bw/day, respectively, and their MOEs (847 – 1,459 for the average population, 334 – 576 for the high consumers) were all far below 10,000. It may indicate human health concern because of the relatively low figures for a genotoxic carcinogen.

11. The main dietary source of acrylamide was "vegetables and their products" (52.4% of the total exposure), particularly the stir-fried vegetables (44.9%), followed by "cereals and their products" (14.7%) and "mixed dishes" (9.4%). The contributions to the total dietary exposure from various food

groups are shown in Figure 1. In addition, fried potato products such as fried potato (7.2% of the total exposure) and potato chips (3.4%), biscuits (5.3%) and breakfast cereals (2.3%) were also significant sources of exposure due to the high level of acrylamide found in these food items (mean: 390 μg/kg for fried potato; 680 μg/kg for potato chips; 150 μg/kg for biscuits; 160 μg/kg for breakfast cereals).

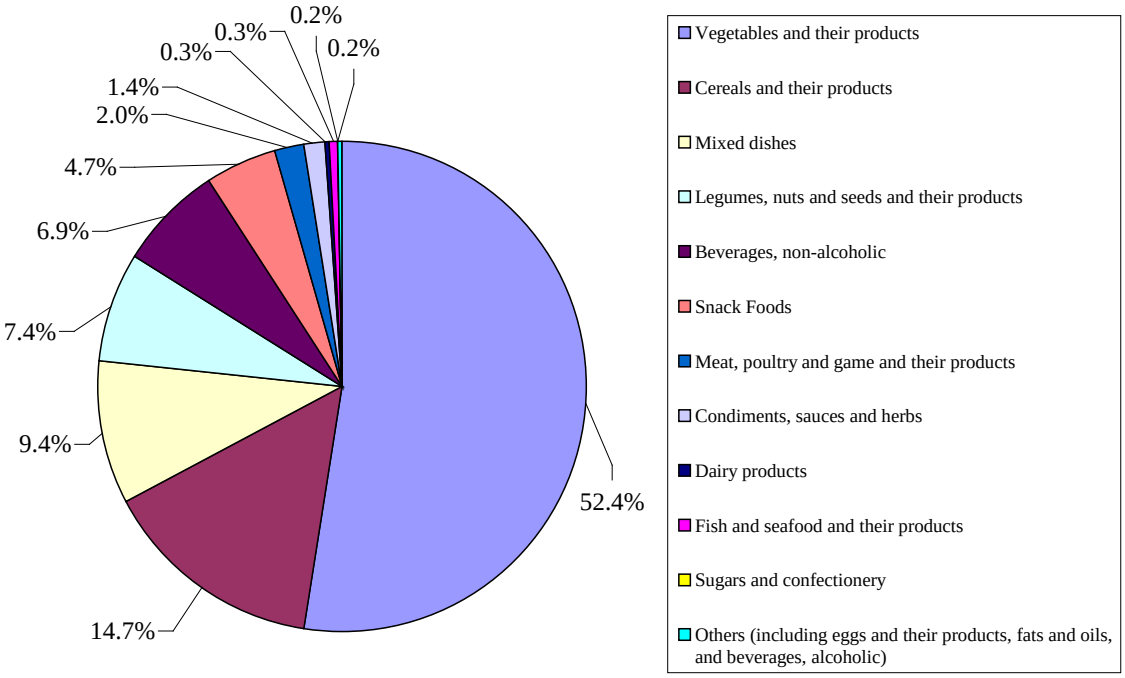

Figure 1: Percentage Contribution to Dietary Exposure to Acrylamide by Food Group

12. The dietary exposure estimated in our Study is around the lower end of the range of the exposure estimates obtained from other places. Our findings are similar to the results of the 2007 Chinese TDS. The 2007 Chinese TDS revealed that the dietary exposure to acrylamide of the average and high consumer among adults was 0.286 μg/kg bw/day (MOE: 621 – 1,069) and 0.490 μg/kg bw/day (MOE: 367 – 633) respectively. The major contributor was vegetables (48.4%).

13. The Study findings showed that stir-fried vegetables contained relatively high levels of acrylamide and their levels varied among vegetables of the same kinds. In contrast, no acrylamide was detected in any raw or boiled vegetables, and only low levels of acrylamide were found in some kinds of stir-fried vegetables such as Chinese spinach, watercress, spinach and Chinese lettuce. The acrylamide levels in the 22 stir-fried vegetable items are provided in **Annex I**. The formation of acrylamide may be affected by many factors such as the presence of asparagine and reducing sugars in the vegetables, and the frying temperature and time. In this Study, the vegetable samples were fried without cooking oil added, which may not truly reflect the situation of domestic cooking on stir-frying vegetables and may introduce bias in the test results.

14. Further investigation on the formation of acrylamide in stir-frying vegetables was conducted. Four types of vegetables, which were found to be the major contributors to dietary acrylamide exposure, were selected for testing, namely, Chinese flowering cabbage, water spinach, zucchini and onion. They were stir-fried with and without cooking oil added under different combinations of cooking power (i.e. medium (induction cooker at 1200 W) and medium-high power (induction cooker at 1600 W)) and cooking time (i.e. 3 and 6 minutes). In addition, three samples each of three vegetable types (i.e. Chinese flowering cabbage, water spinach and zucchini) prepared by restaurants were taken for testing of acrylamide.

15. The findings revealed that a higher acrylamide level was formed where the vegetables were fried at a higher temperature and for a longer time, and in general, less acrylamide was formed in two leafy vegetables i.e. Chinese flowering cabbage and water spinach than zucchini and onion. No obvious associations were observed in acrylamide level for frying with or without cooking oil added. Lower acrylamide levels were found in these experiments

and in the vegetables sampled from restaurants as compared with the TDS samples of the same kinds. Therefore, the estimated dietary exposure to acrylamide from fried vegetables in the TDS study might be overestimated. Moreover, it should be noted that many variables may affect the formation of acrylamide, such as batch to batch variation, food composition (e.g. contents of reducing sugars and amino acid) and processing conditions (e.g. cooking temperature and time), etc.

16. Since lower acrylamide level was detected in fried vegetables from restaurants, further investigation was carried out. It was found that it was common for restaurant chefs to blanch leafy vegetables for about 1 minute or less before frying. Based on these findings, blanching of vegetables may help to reduce the formation of acrylamide.

Risk Reduction

17. International bodies and many national authorities have made efforts to explore ways to reduce the acrylamide in foods subsequent to the reports on the formation of acrylamide in food. Authorities in overseas authorities such as the USA, Canada and the European Commission are also implementing monitoring programme on the acrylamide levels in food. In 2009, the Codex Alimentarius Commission has adopted a Code of Practice for Reduction of Acrylamide in Foods. This Code of Practice aims 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. CFS also issued in 2011 and revised in 2013 the Trade Guidelines on Reducing Acrylamide in Food (**Annex II**) to provide recommendations to help the trade minimise the formation of acrylamide in food, especially in potato and cereal based products and stir-fried vegetables.

18. JECFA mentioned in its 2010 evaluation that the exposure to

Acrylamide for some individuals or population subgroups might significantly be reduced, further to the mitigation work carried out after 2003. The mitigation was reported mainly for food types with comparably high acrylamide levels or single products with acrylamide levels in the high end within their food types. However, it would have little effect on the dietary exposure for the general population in most countries. JECFA recommended the pursuit of further efforts on developing and implementing mitigation methods for acrylamide in foods as a subject of major importance for dietary exposure.

Conclusions and Recommendations

19. The study findings indicated that the low figures of MOEs for acrylamide, determined from the increase in cancer risk of animals, may indicate human health concern arising from the dietary exposure of the local population to acrylamide. However, at present, there is no consistent evidence on the association between dietary exposure and cancer in humans from epidemiological studies. Nevertheless, efforts should continue to be made in the interest of reducing acrylamide levels in food locally.

20. The food trade is advised to seek ways to reduce the level of acrylamide in food. The food trade may make reference to the said trade guidelines on reduction in acrylamide level during the selection of raw materials and the formulation of recipes and food processing conditions.

21. The public is advised to have a balanced and varied diet, consume at least three servings of vegetables a day, and moderate the consumption of fried foods such as potato chips and fried potatoes. The public is also advised not to cook food for too long or at too high a temperature, in order to reduce the formation of acrylamide. To reduce the level of exposure to acrylamide from vegetables, the public may consider blanching the vegetables before frying vegetables, or cooking them by boiling or steaming. Some vegetables may also

be eaten raw after washing.

22. International bodies and many national authorities have endeavoured to explore ways for reducing the acrylamide in foods. CFS will keep in view latest developments on the subject.

Advice sought

23. Members are invited to note and comment on the main findings of the first Hong Kong TDS on acrylamide.

Centre for Food Safety
Food and Environmental Hygiene Department
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Annex I

Acrylamide levels in the 22 stir-fried vegetable items of the first Hong Kong TDS

Stir-fried vegetables	Mean (μg/kg)*	Range (μg/kg)
Zucchini	360	[160 – 480]
Garlic	200	[120 – 300]
Onion	150	[62 – 240]
Water spinach	140	[50 – 310]
Sweet pepper	140	[94 – 180]
Eggplant	77	[36 – 110]
Chinese kale	61	[22 – 140]
Sponge gourd	60	[43 – 88]
Celery	54	[24 – 110]
Leaf mustard	52	[4 – 160]
Cabbage, Chinese flowering	46	[34 – 70]
Cabbage, Chinese	29	[18 – 46]
Tomato	24	[3 – 39]
Broccoli	20	[4 – 38]
Mung bean sprout	19	[1 – 35]
Cabbage, Petiole Chinese	15	[3 – 37]
Cabbage, European variety	12	[7 – 19]
Bitter melon	6	[2 – 12]
Chinese spinach	5	[1 – 10]
Watercress	5	[1 – 14]
Spinach	4	[ND – 15]
Lettuce, Chinese	1	[ND – 1]

ND denotes not-detects.

* Half of limit of detection (LOD) is used for ND results in calculating the mean.