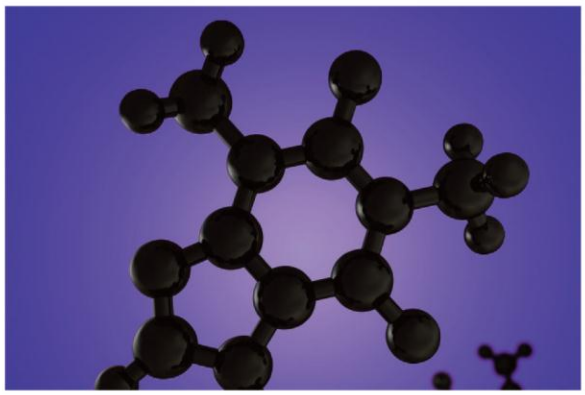
Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

Food Safety Action Plan

REPORT

2010-2011 Targeted Surveys

Chemistry



Acrylamide in Selected Foods

Canada

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Executive Summary

The Food Safety Action Plan (FSAP) aims to modernize and enhance Canada's food safety system. As part of the FSAP enhanced surveillance initiative, targeted surveys are used to test various foods for specific hazards.

Acrylamide is unintentionally formed in high carbohydrate foods that are cooked or processed at high temperatures (e.g., fried, baked, toasted, grilled, and roasted). Acrylamide is classified as 'possibly carcinogenic to humans' by the International Agency for Research on Cancer[1]. Both Health Canada and the Joint Food and Agriculture Organization/World Health Organization (FAO/WHO) Expert Committee on Food Additives (JECFA) have indicated that the current levels of acrylamide exposure from food may pose a human health risk[2].

The main objective of the acrylamide survey was to generate baseline surveillance data on acrylamide levels in high carbohydrate foods which may have been cooked or processed at high temperatures.

There are no regulations in Canada, the European Union, the United States, or Australia/New Zealand for acrylamide in foods. However, the Codex Alimentarius Commission has established an industry code of practice for the reduction of acrylamide levels in food as part of the efforts to limit intake of acrylamide to "As Low As Reasonably Achievable" (ALARA)[3].

A total of 897 samples of high carbohydrate foods, which may have been cooked or processed at high temperatures, were analyzed for acrylamide. Most of the samples (623/897 or 69.5%) contained detectable levels of acrylamide. The acrylamide levels detected ranged from 6 to 2000 parts per billion (ppb). The lowest average acrylamide levels were observed in jams (10 ppb) while the highest average acrylamide levels were observed in molasses (901 ppb).

All the data generated were shared with Health Canada for use in performing human health risk assessments. The levels of acrylamide detected in foods in this survey were determined to be unlikely to pose a human health concern. All acrylamide results were evaluated and appropriate follow-up action was pursued.

1. Introduction

1.1. Food Safety Action Plan

In 2007, the Canadian government launched a five-year initiative in response to a growing number of product recalls and concerns about food safety. This initiative, called the Food and Consumer Safety Action Plan (FCSAP), aims to modernize and strengthen the food safety regulatory system. The FCSAP initiative unites multiple partners in ensuring safe food for Canadians.

The Canadian Food Inspection Agency's (CFIA) Food Safety Action Plan (FSAP) is one element of the government's broader FCSAP initiative. The goal of FSAP is to identify risks in the food supply, limit the possibility that these risks occur, improve import and domestic food controls, and identify food importers and manufacturers.

Within FSAP there are 12 main areas of activity, one of which is risk mapping and baseline surveillance. The main objective of this area is to better identify, assess, and prioritize potential food safety hazards through risk mapping, information gathering, and testing of foods from the Canadian marketplace. Targeted surveys are one tool used to test for the presence and level of a particular hazard in specific foods. Targeted surveys are largely directed towards the 70% of domestic and imported foods that are regulated solely by the *Food and Drugs Act* and *Regulations,* and are generally referred to as non-federally registered commodities.

1.2. Targeted Surveys

Targeted surveys are pilot surveys used to gather information regarding the potential occurrence of chemical residues in defined commodities. The surveys are designed to answer specific questions. Therefore, unlike monitoring activities, testing of a particular chemical hazard is targeted to commodity types and/or geographical areas.

Due to the vast number of chemical hazards and food commodity combinations, it is not possible, nor should it be necessary, to use targeted surveys to identify and quantify all chemical hazards in foods. To identify food-hazard combinations of greatest potential health risk, the CFIA uses a combination of scientific literature, media reports, and/or a risk-based model developed by the Food Safety Science Committee, a group of federal, provincial and territorial subject matter experts in the area of food safety. The Committee deemed acrylamide a high priority[4].

The purpose of this targeted survey was to determine the acrylamide levels in high carbohydrate foods which may have been cooked or processed at high temperatures.

1.3. Acts and Regulations

The *Canadian Food Inspection Agency Act* stipulates that the CFIA is responsible for enforcing restrictions on the production, sale, composition and content of foods and food products as outlined in the *Food and Drugs Act* and *Regulations*.

Health Canada establishes the health-based maximum levels for chemical residues and contaminants in food sold in Canada. Certain maximum levels for chemical contaminants in food appear in the Canadian *Food and Drug Regulations*, where they are referred to as tolerances. Tolerances are established as a risk management tool, and generally only for foods that significantly contribute to the total dietary exposure. There are also a number of maximum levels that do not appear in the regulations and are referred to as standards. Currently, no maximum level, tolerance, or standard has been established by Health Canada for acrylamide levels in food and therefore, compliance with a Canadian numerical standard was not possible. However, all foods sold in Canada must comply with the provisions in section 4(a) of the Food and Drug Act.

Similarly, regulations for acrylamide in food have not been established internationally, or by Canada's major trading partners (the United States, the European Union, or New Zealand/Australia). However, the Codex Alimentarius Commission has established an industry code of practice for the reduction of acrylamide levels in food as part of the efforts to limit intake of acrylamide to "As Low As Reasonably Achievable" (ALARA)[3].

Elevated levels of acrylamide in specific foods may be assessed by Health Canada on a case-by-case basis using the most current scientific data available. Follow-up actions are initiated in a manner that reflects the magnitude of the health concern. Actions may include further analysis, notification of the producer or importer, follow-up inspections, additional directed sampling, and recall of products.

2. Survey Details

2.1. Acrylamide

Acrylamide is an industrial chemical produced for a variety of uses such as water treatment, and the production of glue, paper and cosmetics. It may also be formed unintentionally in high carbohydrate foods which are cooked or processed at high temperatures before consumption (e.g., fried, baked, toasted, grilled, and roasted). To form acrylamide, food must contain appreciable levels of both the amino acid asparagine and sugars. When heated, the asparagine and sugars may react to form acrylamide[3,5,6,7].

Acrylamide is classified as 'possibly carcinogenic to humans' by the International Agency for Research on Cancer[1]. Some studies have indicated correlations between dietary intake of acrylamide and an increased risk of endometrial and ovarian cancers[8], increased risk of breast cancer in post-menopausal women with higher acrylamide

consumption[9], and positive association between dietary acrylamide and the risk of renal cell cancer[10]. A recent review of epidemiological studies found no conclusive link between dietary acrylamide and cancers in humans[11]. Health Canada and other international partners (including Codex) continue to monitor dietary exposure to acrylamide and work with industry to reduce acrylamide levels in processed foods[12].

A variety of national and international organizations (including the World Health Organization (WHO), the United Nations Food and Agriculture Organization (FAO), and Health Canada) have been working to determine the degree of acrylamide exposure in humans and whether these levels pose a human health risk. Both Health Canada and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) have indicated that the current levels of exposure to acrylamide may pose a human health risk but a tolerable daily intake level for acrylamide in food has not been set[13].

2.2. Rationale

Acrylamide is commonly detected in high carbohydrate foods like French fries, potato chips, breakfast cereals, pastries, cookies, breads, rolls, cocoa and roasted coffee. High levels of acrylamide have been found in deep-fried French fries and potato chips[6]. As these foods are commonly consumed by the vast majority of Canadians, Health Canada has called for consumers and the food industry to implement acrylamide reduction strategies[14,15,16,17].

The current targeted survey was run concurrently with Health Canada's Acrylamide Monitoring Program[18] and complements the Program by examining a wider range of products and brands that are likely to contain high levels of acrylamide.

This survey examined acrylamide levels in high carbohydrate foods such as molasses/syrups, vegetable chips/sticks, pretzels, tortilla/corn chips, breakfast cereals, cookies, crackers/crispbreads/croutons, infant biscuits, and nut butters. These commodities were selected in consultation with Health Canada.

2.3. Sample Distribution

The 2010-2011 acrylamide survey targeted domestic and imported high carbohydrate foods. All foods were sampled at grocery and specialty stores in 11 Canadian cities. A total of 897 samples (478 domestic, 292 imported, and 127 of unverifiable origin) were tested for acrylamide. These samples originated in at least 32 countries. It is important to note that the products sampled often contained the statement "processed in Country X", "imported for Company A in Country Y" or "manufactured for Company B in Country Z". Although the labelling is accurate, it does not unambiguously identify the true origin of the product ingredients. Only those products labelled with a clear statement of "Product of Country A" were considered as being from a specific country of origin. Domestic products may indicate that they are manufactured or processed in Canada with domestic and/or imported ingredients.

Samples were divided into fruit and/or vegetable-based, grain-based, and assorted foods. The fruit- and/or vegetable-based foods (390 samples) included samples of dried fruits and vegetables, corn/potato/vegetable chips or sticks, jam, prunes, popcorn, and dehydrated potato mixes. The grain-based foods (303 samples) included breakfast and infant cereals, cookies, crackers, crispbreads, croutons, infant biscuits and pretzels. The assorted foods (204 samples) included condiments, dehydrated foods (e.g., dip mix, gravy mix, sauce mix, soup powder, taco seasonings, dry meals (burrito kits/noodle kits/chow mein/biryani)), molasses, syrups, and nut butters. Table 1 illustrates the distribution of samples by category and by country of origin.

Table 1. Distribution of survey samples by category and by country of origin (in order of decreasing number of samples)

Country of Origin	Number of Fruit and Vegetable-Based Samples	Number of Grain-Based Samples	Number of Assorted Food Samples	Total Number of Samples
Canada	172	201	105	478
USA	99	46	44	189
Unverifiable	78	24	25	127
China	6	7	2	15
United Kingdom	1	6	6	13
Turkey	11	1		12
Thailand	4		4	8
Italy	2	4		6
Switzerland	1	5		6
India	1		3	4
Iran	3	1		4
Malaysia		1	3	4
Philippines	3		1	4
Guatemala			3	3
Ecuador	2			2
Germany		2		2
North Korea			2	2
Pakistan	1		1	2
Poland		2		2
Singapore	1	1		2
Algeria	1			1
Belgium	1			1
Chile	1			1
Costa Rica			1	1
France	1			1
Indonesia	1			1
Japan			1	1
Korea			1	1
Lebanon			1	1
Paraguay			1	1
Spain		1		1
Sweden	1			1

*****Unverifiable refers to those samples for which the country of origin could not be determined from the label or sample information

2.4. Method Details

Samples were analyzed for acrylamide by a laboratory under contract with the Government of Canada. Contracted laboratories are accredited to ISO/IEC 17025,

General Requirements for the Competence of Testing and Calibration Laboratories (or its equivalent) by the Standards Council of Canada (SCC). The laboratory was required to use analytical methods that met or exceeded the requirements and limits of detection (LOD) of the equivalent Health Canada method (*The Determination of Acrylamide in Foods by LC-ESI-MS-MS*)[17]. This method is a liquid chromatography-tandem mass spectrometry (LC-MS-MS) method. The LODs are listed in Table 2.

Table 2. Limits of detection (LOD) for acrylamide in the current targeted survey

Product	Limit of Detection (LOD, ppb)
Dried pineapple	2.40
Dehydrated mashed potato mix	2.91
Dehydrated vegetable soup mix	3.66
Dried cranberries	4.05
Soy sauce	4.08
Ketchup (prepared)	5.10

Samples were tested as sold, meaning that the product was not prepared as per the package instructions, if applicable. Most of the samples were considered ready-to-consume.

2.5. Limitations

The current targeted survey was designed to provide a snapshot of acrylamide levels in selected foods available on the Canadian retail market. In comparison to the total number of such products available to Canadian consumers, a sample size of 897 is considered small. Therefore, care must be taken when interpreting and extrapolating these results. It is important to note that the products sampled often contained the statement "processed in Country X", "imported for Company A in Country Y" or "manufactured for Company B in Country Z". Although the labelling is accurate, it does not unambiguously identify the true origin of the product ingredients. Only those products labelled with a clear statement of "Product of Country A" were considered as being from a specific country of origin. Domestic products may indicate that they are manufactured or processed in Canada with domestic and/or imported ingredients. Regional differences, impact of product shelf-life, packaging and storage conditions, or cost of the commodity on the open market were not examined in this survey.

3. Results and Discussion

3.1. Overview of Acrylamide Results

The samples were separated into three product groups of processed products: fruit and/or vegetable-based, grain-based, and assorted. Of the 897 samples tested for acrylamide, 274 samples (30.5%) did not have detectable levels of acrylamide. Figure 1 illustrates the number of samples with detectable acrylamide residues as a function of product group (i.e. fruit and/or vegetable-based, grain-based and assorted foods) and by product type (e.g. potato chips, corn chips). All chip (potato, corn, vegetable), pretzel, infant biscuit, cracker and molasses samples had detectable levels of acrylamide. Jams were associated with the lowest positive rate (4%).

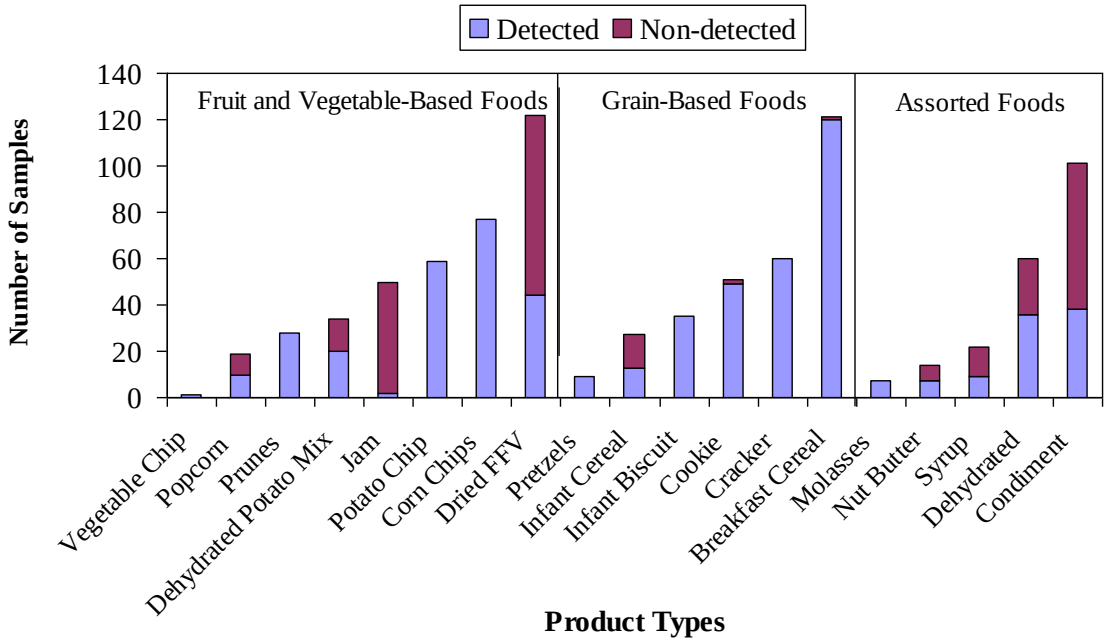

Figure 1. Number of samples with acrylamide detected (arranged in order of increasing number of samples)

Table 3 shows the minimum, maximum, and average levels of acrylamide by product type. All product types were associated with detectable levels of acrylamide. The measured levels of acrylamide ranged from 6 ppb to 2000 ppb. The average acrylamide level ranged from 10 ppb in jams to 901 ppb in molasses.

Table 3. Minimum, maximum, and average levels of acrylamide in food samples (arranged in order of decreasing maximum acrylamide levels)

Product Type	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Cracker	60	60	100	6	2000	396
Molasses	7	7	100	380	1600	901
Potato Chip	59	59	100	57	1300	466
Breakfast Cereal	121	120	99	< LOD	1300	168
Corn Chip	77	77	100	11	1200	329
Nut butter	14	7	50	< LOD	1100	251
Vegetable Chip	1	1	100	-	750	-
Cookie	51	49	96	< LOD	620	173
Prune*	28	28	100	15	580	142
Infant Biscuit	35	35	100	20	520	179
Dried Fruit and Vegetable	122	44	36	< LOD	420	95
Popcorn	19	10	53	< LOD	410	146
Dehydrated Foods**	60	36	60	< LOD	380	66
Pretzel	9	9	100	110	290	161
Condiment	101	38	38	< LOD	210	47
Syrup	22	9	41	< LOD	48	27
Infant Cereal	27	13	48	< LOD	26	15
Dehydrated Potato Mix***	34	20	59	< LOD	23	12
Jam	50	2	4	< LOD	10	10

LOD = Limit of detection

* Prunes are included as a separate category as these products have been associated in the past with particularly elevated levels of acrylamide[19].

** Dehydrated foods include: dip mix, gravy mix, sauce mix, soup powder, taco seasonings, dry meals (burrito kits/noodle kits/chow mein/biryani).

*** Dehydrated potato mixes were separated out to allow comparison to potato chips.

More detailed results by product type are presented in the following sections. Where feasible, the results of the survey were compared with ranges of acrylamide levels reported in the scientific literature, with Health Canada's recent exposure assessment for acrylamide[13] (referred to as HC survey throughout the report), and with a recent U.S. Food and Drug Administration (FDA) Survey on acrylamide levels in foods[19] (referred to as FDA survey throughout the report).

3.2. Acrylamide Results by Product Group

3.2.1. Fruit- and/or Vegetable-Based Foods

The fruit- and/or vegetable-based product group included 122 dried fruits and vegetables (e.g., apple, apricot, pineapple, sweet pepper, onion), 77 corn chips, 59 potato chips, one vegetable chip (mixed vegetable), 50 jams (e.g., single fruit, mixed fruits, ginger), 28 prunes (pitted, strained), 19 popcorn, and 34 dehydrated potato mixes. All of the product types were associated with detectable levels of acrylamide. All chip (vegetable, corn and potato) and prune samples had detectable levels of acrylamide. Table 4 shows a summary of the minimum, maximum, and average levels of acrylamide in fruit- and/or vegetable-based foods. Acrylamide levels ranged from 10 ppb in jams to 1300 ppb in potato chips. The levels of acrylamide in fruit- and/or vegetable-based foods in this survey were determined to be unlikely to pose a human health concern. All acrylamide results were evaluated and appropriate follow-up action was pursued.

Table 4. Minimum, maximum, and average levels of acrylamide in fruit- and/or vegetable-based foods (arranged in order of decreasing maximum acrylamide level)

Product Type	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Potato Chip	59	59	100	57	1300	466
Corn Chip	77	77	100	11	1200	329
Vegetable Chip	1	1	100	-	750	-
Prune*	28	28	100	15	580	142
Dried Fruit and Vegetable	122	44	36	< LOD	420	95
Popcorn	19	10	53	< LOD	410	146
Dehydrated Potato Mix**	34	20	59	< LOD	23	12
Jam	50	2	4	< LOD	10	10

LOD = Limit of detection
* Prunes are included as separate category as these products have been associated in the past with particularly elevated levels of acrylamide[19].
** Dehydrated potato mixes were separated out to allow comparison to potato chips.

Each product type was further subdivided by processing method, flavour or type of primary ingredient (e.g., type of corn). Samples for which processing method, product flavour, or primary ingredient could not be determined based on the available information (product label or sampling information) were categorized as "unverifiable". See Appendix A for a summary of the acrylamide results for fruit- and/or vegetable-based product type samples.

Chips were subdivided into potato chips, corn chips or vegetable chips depending on the primary ingredient. The single sample of vegetable chips contained 750 ppb of acrylamide. This falls within the range of acrylamide levels (11 to 1300 ppb) observed in corn and potato chips in this survey. In the HC survey, eight samples of sweet potato chips had acrylamide levels ranging from 1419 to 2924 ppb[13]. The FDA survey[19] showed acrylamide levels ranging from 828 to 1340 ppb in three samples of vegetable chips and acrylamide levels ranging from 647 to 4080 ppb in five samples of sweet potato chips.

Potato chips were separated by processing method: baked, kettle-cooked, cooked in olive oil, cooked in peanut oil, cooked in sunflower oil, and unverifiable. Acrylamide levels in potato chips ranged from 57 ppb (baked chips) to 1300 ppb (chips cooked in olive oil). This falls within the range of acrylamide levels observed in the scientific literature[7], in the HC survey[13] and in the FDA survey[19]. In the scientific literature, the levels of acrylamide ranged from 530 ppb to 3700 ppb in chips from five different manufacturers. In the HC survey, all potato chips sampled had detectable levels of acrylamide. The acrylamide levels ranged from 149 to 319 ppb in baked chips (12 samples), from 278 to 4660 ppb in kettle-cooked chips (13 samples), and from 61 to 808 ppb in other styles/types of potato chips (57 samples)[13]. All potato chip samples analyzed in the FDA survey[19] had detectable levels of acrylamide. Comparable acrylamide levels observed in the FDA survey were as follows: 385 ppb in a single sample of potato chips cooked in olive oil, 1096 ppb in a single sample of baked chips, and a range of 117 to 1265 ppb in kettle-cooked chips (three samples) and of 146 to 2510 ppb in other styles/types of potato chips (37 samples).

In contrast, dehydrated potato mixes contained lower levels of acrylamide (6 to 23 ppb) than the range found in potato chips (57 to 1300 ppb). Acrylamide was not detected in any of the four samples of mashed potato mixes analyzed in the FDA survey[19].

Corn chips were further subdivided by type of corn (yellow, white, blue, multigrain, and unverifiable). Blue corn chips had the highest (1200 ppb) and multigrain corn chips the lowest (310 ppb) maximum acrylamide levels. Acrylamide levels in the corn chip samples ranged from 11 ppb (unverifiable) to 1200 ppb (blue corn) which was larger than the range of 34 to 495 ppb observed in the HC survey[13] (5 samples). The acrylamide levels in corn chip samples in the FDA survey ranged from 185 to 282 ppb (four samples)[19]. All corn chip samples analyzed in the current survey, the HC survey and the FDA survey had detectable levels of acrylamide.

Popcorn samples were separated by processing method into popped, unpopped, and unverifiable (could not unambiguously classify the sample as popped or unpopped based on available sampling information). The maximum level of acrylamide was higher in popped (410 ppb) than in unpopped (14 ppb) popcorn. Acrylamide was not detected in any of the unverifiable popcorn samples. The thirteen samples of popped popcorn in the HC survey had acrylamide levels ranging from 145 to 303 ppb[13] while the single popcorn sample in the FDA survey had an acrylamide level of 446 ppb[19]. All samples of popped popcorn in the HC survey[13] and in the FDA survey[19] had detectable levels of acrylamide. Unpopped popcorn was not examined in either study.

Prunes were divided into pitted prunes and strained (jarred) prunes for infants. Acrylamide levels in prunes ranged from 15 ppb (pitted) to 580 ppb (strained). The acrylamide levels in strained prunes in this survey were generally higher than those observed in the 28 samples of strained prunes in the HC survey[13] (74 to 265 ppb). The acrylamide levels in pitted prunes in the current survey were comparable to the two samples of pitted prunes examined in the FDA survey (31 to 87 ppb)[19]. All prune samples

analyzed in the current survey, the HC survey[13] and the FDA survey[19] had detectable levels of acrylamide.

The dried fruit and vegetable samples included apple, apricot, banana, cranberry, currant, date, mango, papaya, pear, pineapple, plantain, raisin, strawberry, cassava, garlic, chili pepper, pea, sweet pepper, and tomato. Detectable levels of acrylamide ranging from 12 to 420 ppb were only observed in samples of dried papaya, pea, strawberry, garlic, chili pepper, onion, banana, cassava, date, sweet pepper, and plantain. The results for bananas (150-200 ppb) and prunes (15-580 ppb) in this survey are somewhat higher than the results reported in the literature for bananas (60 ppb) and for dried plums (160 ppb)[20]. The results in this survey for pears (not detected) are lower than those noted in the literature (< LOD to 2060 ppb)[20]. To our knowledge, the levels of acrylamide in the other types of dried fruits and vegetables analyzed in this survey have not been examined in the scientific literature, including the HC survey[13] or the FDA survey[19].

Jam flavours included apricot, blueberry, cherry, ginger, grape, mixed fruit, orange, peach, plum, raspberry, strawberry, wildberry, and unverifiable. Only one sample of mixed fruit jam and one sample of strawberry jam contained detectable levels of acrylamide (10 ppb each). Jams/jellies were not included in the HC survey[13]. Acrylamide was not detected in any of the three samples of jams and jellies analyzed in the FDA survey[19].

3.2.2. Grain-Based Foods

The grain-based product group included 121 breakfast cereals, 27 infant cereals, 51 cookies, 60 crackers, 35 infant biscuits and nine pretzels. All of the product types were associated with detectable levels of acrylamide. All cracker, infant biscuit and pretzel samples had detectable levels of acrylamide. See Table 5 for a summary of minimum, maximum, and average levels of acrylamide in grain-based foods. Acrylamide levels ranged from 6 to 2000 ppb, both observed in cracker samples. The levels of acrylamide in general in grain-based foods in this survey were determined to be unlikely to pose a human health concern. All acrylamide results were evaluated and appropriate follow-up action was pursued.

Table 5. Minimum, maximum, and average levels of acrylamide in grain-based foods (arranged in order of decreasing maximum acrylamide level)

Product Type	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Cracker	60	60	100	6	2000	396
Breakfast Cereal	121	120	99	< LOD	1300	168
Cookie	51	49	96	< LOD	620	173
Infant Biscuit	35	35	100	20	520	179
Pretzel	9	9	100	110	290	161
Infant Cereal	27	13	48	< LOD	26	15

LOD = Limit of detection

Each product type was subdivided by processing method, flavour or type of primary ingredient (e.g., type of grain). Samples for which processing method, product flavour, or primary ingredient could not be determined based on the available information (product label or sampling information) were categorized as "unverifiable". See Appendix B for a summary of the acrylamide results for grain-based product type samples.

Crackers were separated into mixed grain, rice, animal crackers, wheat, and unverifiable. The level of acrylamide in crackers ranged from 6 to 2000 ppb, both observed in wheat cracker samples. The range of acrylamide levels is greater in this survey than in either the HC survey[13] or the FDA survey[19]. All the cracker samples in the HC survey[13] were wheat-based; the acrylamide levels ranged from 10 to 511 ppb (46 samples). The FDA survey[19] observed acrylamide levels in rice (two samples; 242 to 248 ppb), rye (five samples, 96 to 620 ppb), wheat (ten samples; 26 to 300 ppb), graham (three samples; 266 to 1540 ppb), animal (three samples; 60 to 342 ppb) and oyster crackers (3 samples; 141 to 189 ppb). All samples of crackers in this survey, the HC survey and the FDA survey contained detectable levels of acrylamide.

Infant biscuits were divided into arrowroot, graham, rice, and teething biscuits. The level of acrylamide in infant biscuit samples ranged from 20 ppb (rice biscuit) to 520 ppb (graham biscuit) and falls within the range of acrylamide levels (31 to 1900 ppb) observed in infant biscuits (rice, arrowroot, and teething biscuits) in the HC survey (69 samples)[13]. The FDA survey[19] included a single sample of teething biscuits (130 ppb) and

a single sample of arrowroot biscuits (113 ppb). All samples of biscuits in this survey, the HC survey[13] and the FDA survey[19] contained detectable levels of acrylamide.

Cookies were separated into arrowroot, chocolate, coconut, cream-filled, fruit/nut-filled, oatmeal, and plain. The level of acrylamide in cookie samples ranged from 16 ppb (fruit/nut-filled cookie) to 620 ppb (plain cookie). This falls within the range of acrylamide levels observed in the HC survey[13] and the FDA survey[19]. The HC survey included 72 samples of chocolate, cream-filled, ginger, oatmeal, and plain cookies with acrylamide levels ranging from 12 to 665 ppb[13]. The FDA survey included 29 samples of cookies whose acrylamide levels ranged from 34 to 955 ppb.

Breakfast cereals intended for adults and children were subdivided by type of grain (wheat, wheat bran, corn, corn bran, flax, granola, kamut, mixed grain, mixed bran, muesli, oat, oat bran, rice, and unverifiable cereals). Acrylamide was not detected in the single sample of oat bran cereal. The level of acrylamide detected in breakfast cereal samples ranged from 11 ppb (oat cereal) to 1300 ppb (mixed grain cereal). This range is higher than that observed for breakfast cereals in the HC survey (35 to 407 ppb)[13] or in the literature (100 to 170 ppb)[7]. The FDA survey[19] analyzed 59 breakfast cereals, which included oat, corn, wheat bran, rice, wheat, muesli/granola, mixed, oat bran and unverifiable breakfast cereals. The acrylamide levels observed in the FDA survey ranged from 20 to 1057 ppb. The difference in acrylamide levels in the present survey and in the other studies may be due to different grain types and/or brands of cereals being analyzed.

Infant cereals included barley, mixed grain, oat, rice and wheat cereals. Acrylamide was not detected in the infant rice cereals. The acrylamide levels ranged from 11 ppb (barley cereal) to 26 ppb (mixed grain cereal). This is similar to the results of the HC survey in which only two of the six samples contained detectable levels of acrylamide (18 and 20 ppb)[13]. The FDA survey[19] included six samples of infant cereal (oatmeal, rice and mixed grain) which did not contain detectable acrylamide levels.

All samples of pretzels analyzed in this survey contained detectable levels of acrylamide. The levels of acrylamide ranged from 110 to 290 ppb. This is comparable to the levels observed in the HC survey[13] (131 to 210 ppb, 18 samples) and the FDA survey (46 to 386 ppb, 10 samples)[19].

3.2.3. Assorted Foods

The assorted foods product group included 101 condiments (e.g., sauces, chutneys, salsa), 60 dehydrated foods (e.g., dip mix, gravy mix, sauce mix, soup powder, taco seasonings, dry meals (burrito kits/noodle kits/chow mein/biryani)), 14 nut butters (almond, cashew, macadamia, pecan, pistachio, walnut), seven molasses, and 22 syrups (corn and unverifiable). The condiments included steak sauce, grill sauce, salsa, curry, barbeque sauce, chili/hot/pepper sauce, plum sauce, chutney, dipping sauce, ketchup, mustard, soy sauce, and wing sauce. All product types had samples with detectable levels of acrylamide. All molasses samples contained detectable levels of acrylamide. See Table 6 for a summary of minimum, maximum, and average levels of acrylamide in the assorted food samples. Acrylamide levels ranged from 48 ppb in syrup to 1600 ppb in molasses.

The levels of acrylamide in assorted foods in this survey were determined to be unlikely to pose a human health concern. All acrylamide results were evaluated and appropriate follow-up action was pursued.

Table 6. Minimum, maximum, and average levels of acrylamide in assorted foods (arranged in order of decreasing maximum acrylamide level)

Product Type	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Molasses	7	7	100	380	1600	901
Nut Butter	14	7	50	< LOD	1100	251
Dehydrated Food	60	36	60	< LOD	380	66
Condiment	101	38	38	< LOD	210	47
Syrup	22	9	41	< LOD	48	27

Each product type was subdivided by processing method, flavour or type of primary ingredient (e.g., type of nut). Samples for which processing method, product flavour, or primary ingredient could not be determined based on the available information (product label or sampling information) were categorized as "unverifiable". See Appendix C for a summary of the acrylamide results for assorted food product type samples.

Acrylamide was detected in all molasses samples. The level of acrylamide in molasses ranged from 380 to 1600 ppb. Other studies have reported acrylamide levels ranging from 10 to 297 ppb in molasses[21,22]. Molasses was not examined in either the HC survey[13] or the FDA survey[19].

Syrups were divided into corn syrups and unverifiable syrups (syrups were identified only as "syrup" in the product description and the ingredient list was unavailable). The level of acrylamide per syrup sample ranged from 30 ppb (unverifiable syrup) to 48 ppb (corn syrup). The acrylamide levels in most syrups have not been well studied in the scientific literature, including the HC survey[13] and the FDA survey[19], so direct comparisons were not possible. The difference in acrylamide levels between the molasses and syrup samples may be related to different raw materials, different processing methods and temperatures, or a combination of these factors.

Nut butters were subdivided by type of nut: almond, cashew, macadamia, pecan, pistachio, and walnut. Detectable levels of acrylamide ranging from 37 to 1100 ppb were observed in all samples of almond, cashew, and pistachio nut butters. There is little

scientific literature on the levels of acrylamide in nuts and nut butters with the exception of peanut butter. The HC survey[13] reported acrylamide levels of 60 to125 ppb in peanut butter (four samples), 542 to 749 ppb in roasted and salted almonds (two samples), and 17 to 48 ppb in roasted or salted cashews (two samples). The HC survey[13] indicated that chocolate products containing almonds (4 samples, 513-650 ppb acrylamide) were associated with higher acrylamide levels than plain chocolate products (8 samples, 65-91 ppb acrylamide). The FDA survey[19] reported acrylamide levels of 236-457 ppb in roasted almonds (four samples) and 64-144 ppb in peanut butter (five samples). Acrylamide was not detected in the single sample of cashews in the FDA survey[19].

Dehydrated food products were divided into dip mixes, gravy mixes, meals (burrito kits/noodle kits/chow mein/biryani), sauce mixes, soup powders, and taco seasonings. The level of acrylamide in dehydrated food samples ranged from 11 ppb (dip mix) to 380 ppb (dry taco seasoning mix). Acrylamide was not detected in any of the ten samples of dehydrated products analyzed in the FDA survey[19].

Condiments included barbeque sauce, chili/hot/pepper sauce, chutney, curry, dipping sauce, grill sauce, ketchup, mustard, plum sauce, salsa, soy sauce, steak sauce, and wing sauce. The level of acrylamide in condiment samples ranged from 9 ppb (chutney) to 210 ppb (steak sauce). Tomato-based sauces and ketchup are known to have very low levels of acrylamide (less than 50 ppb)[23]. The acrylamide levels in most condiments have not been well studied in the scientific literature, including the HC survey[13] and the FDA survey[19], so direct comparisons were not possible.

4. Conclusions

A total of 897 samples were tested for acrylamide. Of these samples, 69.5% (623 samples) had detectable levels of acrylamide. The detected acrylamide levels ranged from 6 to 2000 ppb. The lowest average acrylamide levels were observed in jams (10 ppb) while the highest average acrylamide levels were observed in molasses (901 ppb).

Currently, no maximum level, tolerance, or standard has been established by Health Canada for acrylamide levels in food and therefore, compliance with Canadian regulations was not evaluated in this survey. All the data generated were shared with Health Canada for use in performing human health risk assessments. The levels of acrylamide detected in foods in this survey were determined to be unlikely to pose a human health concern. All acrylamide results were evaluated and appropriate follow-up action was pursued.

5. Appendix A

Minimum, maximum, and average levels of acrylamide in fruit-and vegetable-based samples by product type (arranged in decreasing maximum acrylamide levels, per product type)

Product Type	Flavour, primary ingredient, or processing method	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Vegetable Chip	Mixed Vegetables	1	1	100	-	750	-
Potato Chip	Cooked in Olive oil	5	5	100	220	1300	508
	Baked	8	8	100	57	1200	615
	Kettle-Cooked	12	12	100	150	900	388
	Cooked in Peanut oil	4	4	100	290	870	657
	Unverifiable	28	28	100	96	860	446
	Cooked in Sunflower Oil	1	1	100	-	220	-
Dehydrated Potato Mix	-	34	20 (59)	59	< LOD	23	12
Corn Chip	Blue corn	12	12	100	62	1200	408
	Yellow corn	3	3	100	380	890	607
	Unverifiable	24	24	100	11	860	272
	White corn	33	33	100	49	480	326
	Multigrain	5	5	100	86	440	323
Popcorn	Popped	10	9	90	< LOD	410	161
	Unpopped	7	1	14	< LOD	14	-
	Unverifiable	2	0	0	-	< LOD	-
Prune	Strained	15	15	100	51	580	218
	Pitted	14	14	100	15	140	56
Dried Fruit and/or Vegetable	Chili pepper	9	8	89	70	420	248
	Banana	3	3	100	150	200	167
	Garlic	4	3	75	< LOD	140	88
	Cassava	1	1	100	-	49	-
	Date	8	8	100	12	83	40

Product Type	Flavour, primary ingredient, or processing method	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
	Sweet Pepper	1	1	100	-	32	-
	Plantain	2	2	100	150	270	210
	Onion	9	8	89	< LOD	86	29
	Pea	5	3	60	< LOD	35	26
	Papaya	9	1	11	< LOD	24	-
	Strawberry	5	3	60	< LOD	17	12
	Apple	14	0	0	-	< LOD	-
	Apricot	10	0	0	-	< LOD	-
	Cranberry	5	0	0	-	< LOD	-
	Currant	2	0	0	-	< LOD	-
	Mango	5	0	0	-	< LOD	-
	Pear	3	0	0	-	< LOD	-
	Pineapple	4	0	0	-	< LOD	-
	Raisin	12	0	0	-	< LOD	-
	Tomato	7	0	0	-	< LOD	-
Jam	Mixed Fruit	4	1	25	< LOD	10	-
	Strawberry	18	1	6	< LOD	10	-
	Unverifiable	1	0	0	-	< LOD	-
	Apricot	1	0	0	-	< LOD	-
	Blueberry	1	0	0	-	< LOD	-
	Cherry	1	0	0	-	< LOD	-
	Ginger	1	0	0	-	< LOD	-
	Grape	2	0	0	-	< LOD	-
	Orange	2	0		-	< LOD	-
	Peach	1	0		-	< LOD	-
	Plum	1	0		-	< LOD	-
	Raspberry	16	0		-	< LOD	-
	Wildberry	1	0		-	< LOD	-

LOD = Limit of Detection

Note: Samples for which processing method, product flavour, or primary ingredient could not be determined based on the available information (product label or sampling information) were categorized as “unverifiable”.

6. Appendix B

Minimum, maximum, and average levels of acrylamide in grain-based samples by product type (arranged in decreasing maximum acrylamide levels, per product type)

Product Type	Flavour, primary ingredient, or processing method	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Cracker	Wheat	37	35	100	< LOD	2000	448
	Mixed Grain	5	5	100	160	1800	654
	Unverifiable	4	4	100	57	1300	572
	Animal Cracker	11	11	100	13	440	174
	Rice	4	4	100	15	300	155
Infant Biscuit	Graham	1	1	100	-	520	-
	Arrowroot	20	20	100	56	380	215
	Teething	9	9	100	38	380	140
	Rice	5	5	100	20	61	39
Cookie	Plain	14	14	100	26	620	303
	Cream-Filled	9	7	78	< LOD	430	103
	Fruit/Nut-Filled	7	7	100	16	390	56
	Coconut	1	1	100	-	390	-
	Arrowroot	2	2	100	55	240	148
	Chocolate	17	17	100	61	230	112
	Oatmeal	1	1	100	-	210	-
Breakfast Cereal	Mixed Grain	33	32	97	< LOD	1300	229
	Wheat Bran	9	9	100	110	880	399
	Kamut	1	1	100	-	630	-
	Wheat	25	25	100	13	320	186
	Oat	14	14	100	11	230	101
	Corn	11	11	100	26	230	90
	Muesli	10	10	100	23	210	99
	Corn Bran	3	3	100	82	160	124
	Mixed Bran	1	1	100	-	110	-
	Granola	7	7	100	19	110	42
	Rice	5	5	100	35	84	49
	Flax	1	1	100	-	63	-

Product Type	Flavour, primary ingredient, or processing method	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
	Unverifiable	1	1	100	-	45	-
	Oat Bran	1	0	0	-	< LOD	-
Infant Cereal	Mixed Grain	8	6	75	< LOD	26	16
	Wheat	1	1	100	-	20	-
	Oat	9	5	56	< LOD	18	13
	Barley	3	1	33	< LOD	11	-
	Rice	6	0	0	-	< LOD	-
Pretzel	-	9	9	100	110	290	161

LOD = Limit of Detection

Note: Samples for which processing method, product flavour, or primary ingredient could not be determined based on the available information (product label or sampling information) were categorized as “unverifiable”.

7. Appendix C

Minimum, maximum, and average levels of acrylamide in assorted food samples by product type (arranged in decreasing average acrylamide levels, per product type)

Product Type	Flavour, primary ingredient, or processing method	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Molasses	-	7	7	100	380	1600	901
Syrup	Corn	10	7	70	< LOD	48	28
	Unverifiable	12	2	17	< LOD	30	23
Nut Butter	Cashew	2	2	100	53	75	64
	Almond	4	4	100	140	1100	398
	Pistachio	1	1	100	-	37	-
	Macadamia	4	0	0	-	< LOD	-
	Pecan	2	0	0	-	< LOD	-
	Walnut	1	0	0	-	< LOD	-
Dehydrated Food	Taco Seasoning	1	1	100	-	94	-
	Dry Meals*	18	14	78	< LOD	380	89
	Soup Powder	24	14	58	< LOD	260	63
	Gravy Mix	9	2	22	< LOD	37	28
	Dip Mix	3	3	100	11	45	23
	Sauce Mix	5	2	40	< LOD	23	12
Condiment	Steak Sauce	10	9	90	< LOD	210	119
	Grill Sauce	3	3	100	7	130	51
	Salsa	9	3	33	< LOD	74	34
	Curry	1	1	100	-	33	-
	BBQ Sauce	12	9	75	< LOD	51	25
	Chili/Hot/Pepper Sauce	10	3	30	< LOD	26	20
	Plum Sauce	9	6	67	< LOD	32	17
	Chutney	9	4	44	< LOD	9	6
	Dipping Sauce	1	0	0	-	< LOD	-
	Ketchup	17	0	0	-	< LOD	-
	Mustard	11	0	0	-	< LOD	-

Product Type	Flavour, primary ingredient, or processing method	Number of Samples	Number of Samples with Detectable Levels	Percentage of Samples with Detected Levels	Minimum (ppb)	Maximum (ppb)	Average (ppb)
	Soy Sauce	7	0	0	-	< LOD	-
	Wing Sauce	1	0	0	-	< LOD	-

* Dry meals implies burrito kits/noodle kits/chow mein/biryani
LOD = Limit of Detection
Note: Samples for which processing method, product flavour, or primary ingredient could not be determined based on the available information (product label or sampling information) were categorized as “unverifiable”.

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