Canadian Food Inspection Agency | Agence canadienne d'inspection des aliments

Acrylamide in selected foods - April 1, 2013, to March 31, 2015

Food chemistry - Targeted surveys - Final report

Canada

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Summary

Targeted surveys provide information on potential food hazards and enhance the Canadian Food Inspection Agency's (CFIA's) routine monitoring programs. These surveys provide evidence regarding the safety of the food supply, identify potential emerging hazards, and contribute new information and data to food categories where it may be limited or non-existent. They are often used by the agency to focus surveillance on potential areas of higher risk. Surveys can also help to identify trends and provide information about how industry complies with Canadian regulations.

Acrylamide may be unintentionally formed in carbohydrate-rich foods that are cooked at high temperatures (e.g. fried, baked, toasted, grilled or roasted), and/or processed at lower temperatures (e.g. sterilized, dried, preserved)[1,2]. Acrylamide is classified as 'possibly carcinogenic to humans' by the International Agency for Research on Cancer (IARC)[3]. Both Health Canada and the Joint Food and Agriculture Organization (FAO)/World Health Organization (WHO) Expert Committee on Food Additives (JECFA) have indicated that the current levels of acrylamide exposure from food may pose a human health risk, but more data and research are needed before a precise risk level can be determined[4,5].

The main objectives of this targeted survey are to generate baseline surveillance data on acrylamide levels in a defined set of food commodities, and to compare these levels to the previous targeted surveys on acrylamide (2010-2011 and 2011-2013) and to similar surveys performed by Health Canada, the U.S. Food and Drug Administration (FDA), and the U.K. Food Standards Agency (UK FSA) and other published data.

Over the course of this targeted survey (April 1, 2013 to March 31, 2015), a total of 1491 products were collected from retail locations in 6 cities across Canada and analyzed for acrylamide. The samples collected included chocolate/cocoa products, coffee products, condiments, flavorings, fruit chips, grain-based products, infant purees, legume-based products, nut/seed products, pork-based snacks, prune-based products, soups, sweet potato products, and vegetable chips. Acrylamide was detected in 1227 samples (82%) and detected levels ranged from 5 parts per billion (ppb) in an infant puree sample, a soft bread sample, and a sample of toasted soy spread, to 4000 ppb in a sample of wheat-based cracker chips.

At the time of this survey, Health Canada had not established a maximum level, tolerance, or standard for levels of acrylamide in food, therefore, compliance with a numerical standard was not evaluated in this survey. Health Canada's Bureau of Chemical Safety (BCS) reviewed all results in this survey and determined that none of the samples posed a concern to human health.

What targeted surveys are

Targeted surveys are used by the CFIA to focus its surveillance activities on areas of highest health risk. The information gained from these surveys provides support for the allocation and prioritization of the agency's activities to areas of greater concern. Originally started as a project under the Food Safety Action Plan (FSAP), targeted surveys have been embedded in our regular surveillance activities since 2013. Targeted surveys are a valuable tool for generating information on certain hazards in foods, identifying and characterizing new and emerging hazards, informing trend analysis, prompting and refining health risk assessments, highlighting potential contamination issues, as well as assessing and promoting compliance with Canadian regulations.

Food safety is a shared responsibility. We work with federal, provincial, territorial, and municipal governments and provide regulatory oversight of the food industry to promote safe handling of foods throughout the food production chain. The food industry and retail sectors in Canada are responsible for the food they produce and sell, while individual consumers are responsible for the safe handling of the food they have in their possession.

Why the survey was conducted

Acrylamide may be formed unintentionally in primarily starchy, sweet, and grain-based foods which are cooked or processed (fried, baked, toasted, grilled, or roasted) at high temperatures before consumption[1,6]. To form acrylamide, food must contain substantial levels of both the amino acid asparagine and sugars, which when heated may react to form acrylamide[1,6,7,8]. In addition to high temperature formation, acrylamide has been detected in foods processed at much lower temperatures (70-80°C), as is the case for many dried, canned, and/or sterilized fruit and vegetable products[2].

Acrylamide is classified as 'probably carcinogenic to humans' by the IARC[3]. Health Canada, governments in other countries, and international committees established by the WHO and the United Nations FAO continue to conduct research and monitor dietary exposure to acrylamide and conduct health risk assessments[1,5]. The European Union has established a set of levels designed to trigger investigations into food products containing elevated levels of acrylamide[9]. Animal studies show evidence that acrylamides may be toxic to the liver and to the nervous, immune, and reproductive systems[6].

Health Canada has an acrylamide reduction strategy and has allowed the addition of the enzyme asparaginase to be used in certain food products sold in Canada since 2012[4], which reduces the amount of acrylamide that forms during cooking by breaking down the asparagine naturally present in the food before it can react with the sugars and starches to form acrylamide. All commodities tested in this survey were selected in consultation with Health Canada's BCS Acrylamide Monitoring Program[13] to address data gaps and/or better characterize the acrylamide levels in certain foods. This targeted survey also adds to baseline data established in the previous targeted surveys.

What was sampled

A total of 1491 domestic and imported chocolate/cocoa products, coffee products, condiments, flavorings, fruit chips, grain-based products, infant purees, legume-based products, nut/seed products, pork-based snacks, prune-based products, soups, sweet potato products, and vegetable chips were sampled between April 1, 2013, and March 31, 2015.

Samples of products were collected from local/regional retail locations in 6 major cities across Canada. These cities encompassed 4 Canadian geographical areas:

- Atlantic (Halifax)
- Quebec (Montreal)
- Ontario (Toronto and Ottawa)
- West (Vancouver and Calgary).

The number of samples collected from these cities was in proportion to the relative population of the respective areas. The shelf life, storage conditions, and the cost of the food on the open market were not considered in this survey.

Table 1. Distribution of samples based on product type and origin

Product type	Number of domestic samples	Number of imported samples	Number of samples of unspecified[a] origin	Total number of samples
Chocolate products	23	130	86	239
Coffee products	13	30	30	73
Condiments, flavorings, and soups	23	119	67	209
Fruit, vegetable, legume, and non-grain products	18	76	17	111
Grain-based products	93	177	246	516
Infant food purees	13	22	28	63
Nut and/or seed products	84	44	60	188
Prune-based foods	3	21	32	56
Sweet potato products	2	27	7	36
Total	**272**	**646**	**573**	**1491**

Table notes

[a] Unspecified refers to those samples for which the country of origin could not be assigned from the product label or available sample information.

How samples were analyzed and assessed

Samples were analyzed by an ISO/IEC 17025 accredited food testing laboratory under contract with the Government of Canada. The laboratory used a Liquid Chromatography Mass Spectrometry (LC-MS) method based on a method developed by Health Canada[10]. The results represent finished food products as sold and not as they would be consumed, whether the product sampled is considered an ingredient or requires preparation prior to consumption.

There are no limits in Canada or internationally for acrylamide levels in food. Elevated levels of acrylamide may be assessed by Health Canada on a case-by-case basis using the most current scientific data available.

Results of the survey

Of 1491 products sampled in this survey, 82% (1227) contained detected levels of acrylamide. Detected levels of acrylamide ranged from 5 ppb in an infant puree sample, a soft bread sample, and a sample of toasted soy spread, to 4000 ppb in a sample of wheat-based cracker chips. The average level found in positive samples was 168 ppb. Table 2 presents the concentrations of acrylamide reported based on product type.

Table 2. Minimum, maximum, and average acrylamide levels detected in assorted food samples

Product type	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[b] (ppb)
Chocolate products	239	215 (90)	6	710	111
Coffee products	73	59 (81)	15	1300	139
Condiments, flavorings, and soups	209	99 (47)	7	830	273
Fruit, vegetable, legume, and non-grain products	111	107 (96)	7	1800	229
Grain-based products	516	474 (92)	5	4000	168
Infant food purees	63	17 (27)	5	76	27
Nut and/or seed products	188	173 (92)	5	940	104
Prune-based foods	56	49 (88)	12	340	101
Sweet potato products	36	34 (94)	12	1600	583
Total	**1491**	**1227 (82)**	**5**	**4000**	**168**

Table notes

[b] Average of positive results only.

Chocolate products

The chocolate products sampled in this survey included 189 samples of ready-to-eat (RTE) chocolate (baking chocolate, chocolate bars, chocolate chips, and chocolate-covered fruits, nuts, and coffee beans), 35 samples of cocoa powder, and 15 samples of powdered hot chocolate mix. Acrylamide was detected in 215 of the 239 samples, or 90%. Unsweetened chocolate samples had the highest average level (422 ppb), and hot chocolate powder samples had the lowest average level (25 ppb). Chocolate-covered coffee beans had the highest detection rate at 100%, and white chocolate had the lowest detection rate at 17%.

Coffee

This survey sampled 34 unbrewed coffee samples (ground and unground roasted beans), 22 instant coffee powders, and 17 ready-to-drink (RTD) coffee beverages. Acrylamide was detected in 81% of the samples. Instant coffee had the highest average level (180 ppb), and RTD beverages had the lowest average level (72 ppb). All of the unbrewed coffee samples and 95% of instant coffee samples contained acrylamide, and the RTD beverages had the lowest detection rate at 24% of samples containing acrylamide.

Condiments, flavorings, and soups

The 209 condiments, flavorings, and soups that were sampled included 150 olive and olive-based pastes or tapenades, 22 dried soup mixes, 15 spice mixtures (powdered or paste), 13 dried gravy mixes, and 9 canned soups. A sweet potato-based canned soup was also sampled but is included in the sweet potato category. Acrylamide was found in 99 (47%) samples. Canned soups had the lowest average level (14 ppb), and dried gravy mixes had the lowest detection rate (8%). Spice mixtures had the second highest average level (289 ppb) and the second highest detection rate (47%). The olive products had the highest average level (314 ppb) and the highest detection rate (52%).

Within the olive category, acrylamide content varied between the types of olives, with black (ripe) olives having both the highest average level (379 ppb) and the highest detection rate (98%). There was no detectable level of acrylamide in any of the 20 kalamata olive samples. Whole, pitted, or sliced olives had a higher average level than spreads/tapenades (349 ppb and 230 ppb, respectively), but the tapenades had a higher detection rate (96%) than the whole, pitted, or sliced olives (44%).

Fruit, vegetable, legume, and non-grain products

Samples in this category consisted of products whose first ingredient was a fruit, legume, or vegetable. In total, 111 samples were tested: 40 samples of roasted legume snacks (broad bean, chickpea, edamame, hummus, lentil, mung bean, pea, pinto beans, and soy nuts), 22 potato-based vegetable-flavored chips/straws, 17 legume chip/crisp/cracker samples (black bean, chickpea, lentil, navy bean, and pea), 12 fruit chip samples (apple, banana, and plantain), 10 samples of beans canned in tomato sauce, 7 root vegetable chip (including beet, carrot, cassava, lotus root, mixed vegetable, and parsnip), 2 pork rind snacks, and 1 kale chip sample.

Sweet potato products were not included in this category because they are part of the sweet potato products category. Acrylamide was found in 107 samples, or 96% of samples. Potato-based chip/straw samples had both the highest average level (710 ppb) and the highest detection rate (100%). Pork rind snacks also had a 100% detection rate but had the lowest average level (10 ppb). The next lowest average level was found in the beans canned in tomato sauce (26 ppb) which had the second lowest detection rate of 90%. The single kale chip sample did not have a detectable level of acrylamide. The overall average of this category was 229 ppb.

Grain-based products

A total of 516 grain-based products whose main ingredient is a grain were sampled in this survey. This included 203 soft baked goods (bagels, breads, cakes, crumpets, English muffins, muffins, naan, pastries, pies, pitas, and tortillas), 183 crispy baked goods and snacks (chips, cookies, crackers, cracker ships, crispbreads, croutons, and toasted/roasted corn snacks), 79 granola or cereal bars, and 51 grain-based beverages (barley tea, buckwheat tea, coffee substitutes, green tea containing roasted rice, and instant malted barley beverage powder). The highest average level was in wheat-based cracker chips (2440 ppb), which included the sample that had the highest level in the entire survey (4000 ppb). A sample of wheat-based crackers had the next highest level at 1600 ppb. The lowest average level was in tortillas (8 ppb). The highest detection rate was in the crisp baked goods and grain-based beverages (98%), and the lowest detection rate was in soft baked goods (83%).

Infant food purees

Fruit and/or vegetable-based infant food purees in jars were sampled in this survey. Sample types included apple, apricot, banana, carrot, green beans, pears, squash, strawberry, and mixtures of assorted fruits and vegetables. Note that samples containing prunes or sweet potatoes are not included in this category, rather they are included in the prune or sweet potato categories below. Acrylamide was found in 17 of the 63 samples (27%), which is the lowest detection rate in the survey. Samples containing only fruit (apple, apricot, banana, mixed fruit, pears, and strawberry) were not found to contain acrylamide. Levels detected ranged between 5 ppb and 76 ppb, with an average level of 27 ppb, which is the lowest average in the survey.

Nut and/or seed products

This survey sampled 188 products containing nuts and/or seeds, including 15 fruit and nut snacking mixtures, 128 nut butters (almond, cashew, hazelnut, and peanut), and 45 seed butters (pumpkin seed, sesame seed/tahini, sunflower seed, and toasted soy). Some of these products contained chocolate/cocoa and/or other flavoring ingredients. Acrylamide was found in 100% of almond butters, peanut butters, tahini samples, and sunflower seed butters, and the lowest detection rate was in soy butters (59%). The overall average level in this category was 104 ppb, with almond butters having the highest average (345 ppb), and pumpkin seed butters and soy butters having the lowest average levels (11 ppb and 14 ppb respectively).

Prune-based foods

Foods made from dried prunes are at risk for acrylamide formation because the sugar and asparagine content in plums can result in acrylamide forming during the drying process[2]. In this survey, 56 prune-based products were sampled, including 21 infant purees, 15 dried/canned prune samples, 10 plum sauces, and 10 prune juice samples. Acrylamide was found in 88% of samples, and the average level for all prune-based foods sampled in this survey was 101 ppb. Plum sauce had both the lowest detection rate (70%) and the lowest average level (30 ppb). Prune juice had both the highest detection rate (100%) and the highest average level (182 ppb).

Infant prune puree had the second highest detection rate (95%) in the prune category and the second highest average level (120 ppb), with a range of 57 ppb to 240 ppb. In comparison, the levels of acrylamide in other fruit/vegetable-based infant purees in this survey ranged between 5 ppb and 76 ppb, with an average level of 27 ppb and a detection rate of 27% (see the above section on infant food purees). The prune-based infant food purees had a higher detection rate, higher average level, and a higher range of acrylamide levels than the other fruit and/or vegetable infant food purees.

Sweet potato products

Sweet potatoes, like prunes, are at higher risk of forming acrylamide when cooked at high temperatures because of their high sugar and asparagine content[26]. In this survey, 36 sweet potato products were sampled, including 24 samples of sweet potato chips (or chip mixtures containing sweet potatoes), 11 samples of infant food containing sweet potato, and one canned sweet potato soup. Acrylamide was detected in 34 of these samples, or 94%. All of the sweet potato chips and the sweet potato soup contained acrylamide. The chips had the highest average level at 812 ppb and the soup sample contained 26 ppb. The average level in all sweet potato products was 583 ppb, which is the highest category average in the whole survey.

Acrylamide was detected in 9 of the 11 infant food samples (82%), with results ranging from 12 ppb to 78 ppb and an average level of 33 ppb. In comparison, the levels of acrylamide in other fruit/vegetable-based infant purees in this survey ranged between 5 ppb and 76 ppb, with an average level of 27 ppb and a detection rate of 27% (see the above section on infant food purees). In this survey, the acrylamide levels found in sweet potato infant puree had similar average and range of levels but had a higher detection rate than other infant food purees.

What the survey results mean

The results of the survey were compared with the acrylamide levels reported in previous CFIA targeted surveys[11,12], Health Canada's Bureau of Chemical Safety's exposure assessment (BCS-EA)[13], Health Canada data available on Canadian Laboratory Information Network (CLIN)[14], the United States Food and Drug Administration (FDA) Total Diet Study conducted between 2003 and 2006 (FDA TDS)[15], the FDA Survey (2022 to 2015)[16], and/or other published data[17,18,19,20,21,22,23]. Variation between the compared surveys and studies is expected because acrylamide levels may vary widely from product to product, from brand to brand, and from lot to

lot even within the same brand. In Table 3 through Table 15, the results from the current survey are bolded for easier identification, and the data is listed in each table with the newest survey end-date to the oldest survey end-date.

Chocolate products

The acrylamide levels found in this survey were compared to Health Canada's BCS-EA data[13], FDA data[15,16], and a study from Germany published in 2018 (Raters et al.[17]) as shown in Table 3. The results found in this survey are comparable to the results found in the other studies and surveys. Differences between the results may be explained by the types of products sampled in each survey. For example, darker chocolate products, such as cocoa powder or dark chocolate, had higher levels in the current survey, and the German study also concluded that the higher the cacao content in the product, the higher the level of acrylamide present in the sample[17]. The FDA Survey included mostly milk chocolate (31 of 33 samples), and the FDA TDS sampled only milk chocolate products, which may have contributed to the lower results found in those surveys.

Table 3. Comparison of acrylamide levels detected in chocolate products in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[c] (ppb)
Chocolate[d]	**CFIA**	**2013 to 2015**	**189**	**176 (93)**	**6**	**710**	**107**
Chocolate[d] and candy	FDA Survey	2002 to 2015	33	13 (39)	10	210	67
Chocolate[d]	BCS-EA	2012	28	28 (100)	19	650	183
Chocolate bars/syrups	FDA TDS	2003 to 2006	34	32 (94)	11	50	21
Cocoa drink powders	Raters et al.	2018	9	0 (0)	<LOD[e]	<LOD[e]	<LOD[e]
Hot chocolate powder	**CFIA**	**2013 to 2015**	**15**	**12 (80)**	**8**	**100**	**25**
Hot chocolate powder	FDA Survey	2002 to 2015	14	7 (50)	20	100	48
Cocoa powder	Raters et al.	2018	25	25 (100)	40	440	180
Cocoa powder	**CFIA**	**2013 to 2015**	**35**	**27 (77)**	**8**	**500**	**179**
Cocoa powder	FDA Survey	2002 to 2015	4	3 (75)	58	909	428
Cocoa powder	BCS-EA	2012	23	23 (100)	234	578	456

Table notes

[c] Average of positive samples only
[d] "Chocolate" refers to baking chocolate and RTE chocolate products, with/without other ingredients such as nuts/fruit/coconut, and includes a mixture of dark, milk, semi-sweet, and unsweetened chocolate.
[e] <LOD: less than the limit of detection (LOD) of 30 ppb.

Coffee

Table 4 presents a comparison of the acrylamide levels for coffee and coffee-based beverages in the current survey to a previous CFIA survey[12], Health Canada data[14], and FDA data[15,16]. Roast coffee (whole bean and ground samples) and instant coffee granules sampled in this survey had lower average levels than similar products in the FDA Survey but nearly the same as the previous CFIA survey. None of the previous surveys or studies sampled RTD coffee beverages, so for comparison Table 4 shows the most similar product in the other surveys, which was brewed coffee (made from ground coffee) in the Health Canada and FDA data. These studies do not indicate whether the coffee used was dark or light roast, nor are there any indications of strength or brewing method, and these factors may contribute to the lower acrylamide levels seen in those samples compared to the bottled beverages that were sampled in this survey.

Table 4. Comparison of acrylamide levels detected in coffee products in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[f] (ppb)
Coffee beverage - RTD	**CFIA**	**2013 to 2015**	**17**	**4 (24)**	**15**	**96**	**72**
Coffee - brewed	CLIN	2010	4	4 (100)	2	4	3
Coffee - brewed	FDA TDS	2003 to 2006	26	7 (27)	11	28	17
Coffee - instant	**CFIA**	**2013 to 2015**	**22**	**21 (95)**	**21**	**1300**	**180**
Coffee - instant	FDA Survey	2002 to 2015	12	12 (100)	172	539	337
Coffee - instant	CFIA	2011 to 2013	32	32 (100)	64	360	181
Coffee - unbrewed[g]	**CFIA**	**2013 to 2015**	**34**	**34 (100)**	**38**	**300**	**122**
Coffee - unbrewed[g]	FDA Survey	2002 to 2015	124	124 (100)	27	1080	235
Coffee - unbrewed[g]	CFIA	2011 to 2013	102	102 (100)	53	310	140

Table notes

[f] Average of positive samples only
[g] "Coffee - unbrewed" refers to roasted coffee beans and ground roasted coffee.

Condiments, flavorings, and soups

The acrylamide levels found in the canned soup, dried gravy mix, dried soup mix, olive products, and spice mixtures were compared to similar products sampled in previous CFIA surveys[11,12], Health Canada data[13], FDA data[15,16], and published studies from China (Mo et al.[23], 2014) and the Netherlands (Konings et al.[22], 2003), as shown in Table 5. The results from this survey were similar to or less than the other studies' results, except for the spice mixes/pastes. This is likely due to the types, ingredients and/or the processing procedures of spice mixes that were sampled in each survey or study. In the olive category, the comparison studies had the lowest average levels in kalamata olives and the highest average levels in black (ripe) olives, as was also found in the current survey.

Table 5. Comparison of acrylamide levels detected in condiments, flavorings, and soups in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[h] (ppb)
Canned soups	**CFIA**	**2013 to 2015**	**9**	**2 (22)**	**10**	**18**	**14**
Canned soups and chilis	FDA Survey	2002 to 2015	30	12 (40)	20	260	98
Canned soups and chilis	FDA TDS	2003 to 2006	80	30 (38)	10	210	57
Dried gravy mixes	**CFIA**	**2013 to 2015**	**13**	**1 (8)**	**23**	**23**	**23**
Dried gravy mixes	CFIA	2010 to 2011	12	3 (25)	16	37	24
Gravy powder	Konings et al.	2003	2	NR[i]	NR[i]	NR[i]	15
Dried soup mixes	**CFIA**	**2013 to 2015**	**22**	**11 (50)**	**7**	**260**	**43**
Dried soup mixes	FDA Survey	2002 to 2015	6	5 (83)	22	1184	297
Dried soup mixes	CFIA	2010 to 2011	25	15 (60)	7	260	59
Olives and olive products	**CFIA**	**2013 to 2015**	**150**	**78 (52)**	**9**	**820**	**314**
Olives	CFIA	2011 to 2013	50	22 (44)	15	970	336
Olives	BCS-EA	2012	27	21 (78)	50	668	259
Spice mixes/pastes	**CFIA**	**2013 to 2015**	**15**	**7 (47)**	**12**	**830**	**289**
Spice rubs/liquid smoke	FDA Survey	2002 to 2015	4	3 (75)	38	151	81
Curry powders/pastes	Mo et al.	2014	12	12 (100)	32	155	72
Spice mixes/pastes/sauces	CFIA	2010 to 2011	52	36 (69)	5	420	100

Table notes

[h] Average of positive samples only
[i] NR: Not reported

Fruit, vegetable, legume, and non-grain products

The acrylamide levels found in this survey were compared to previous CFIA surveys[11,12], Health Canada data[13], and FDA data[15,16] as shown in Table 6. Note that products containing sweet potatoes are not included in this category (see the sweet potato category). The average levels found in this survey are comparable to, or lower than, the results found in the other surveys. The maximum level found in roasted legume snacks was higher than the maximum levels found in the other studies, and this difference could be explained by the types of products sampled in each survey, including the legume varieties, processing procedures, and/or coatings, spices, or flavourings in some products. All levels of acrylamide found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians.

Table 6. Comparison of acrylamide levels detected in fruit, vegetable, legume, and non-grain products in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[j] (ppb)
Canned beans in sauce	**CFIA**	**2013 to 2015**	**10**	**9 (90)**	**11**	**57**	**26**
Canned legumes/beans	FDA Survey	2002 to 2015	32	12 (38)	10	160	54
Baked/refried/dried beans	FDA TDS	2003 to 2006	31	13 (42)	10	26	18
Fruit chips[k]	**CFIA**	**2013 to 2015**	**12**	**11 (92)**	**13**	**360**	**140**
Fruit chips[k]	FDA Survey	2002 to 2015	14	14 (100)	50	740	263
Fruit chips[k]	CFIA	2010 to 2011	5	5 (100)	150	270	184
Legume chips/crackers[l]	**CFIA**	**2013 to 2015**	**17**	**16 (94)**	**29**	**380**	**145**
Legume chips/crackers[l]	FDA Survey	2002 to 2015	14	12 (86)	10	500	109
Legume chips/crackers[l]	CFIA	2011 to 2013	5	5 (100)	31	310	216
Pork rind snacks	**CFIA**	**2013 to 2015**	**2**	**2 (100)**	**7**	**13**	**10**
Pork rind snacks	FDA Survey	2002 to 2015	12	1 (8)	12	12	12
Roasted legume snacks	**CFIA**	**2013 to 2015**	**40**	**40 (100)**	**9**	**590**	**71**
Roasted soy nut	FDA Survey	2002 to 2015	1	1 (100)	91	91	91
Roasted beans/chickpeas	BCS-EA	2012	4	4 (100)	38	71	51
Dried peas/chickpeas	CFIA	2010 to 2011	5	3 (60)	16	35	26
Vegetable chips[m]	**CFIA**	**2013 to 2015**	**30**	**29 (97)**	**18**	**1800**	**606**
Vegetable chips[m]	FDA Survey	2002 to 2015	31	26 (84)	30	3244	621
Vegetable chips[m]	CFIA	2011 to 2013	46	45 (98)	9	3400	872

Table notes

[j] Average of positive samples only
[k] "Fruit chips" include apple, banana, and plantain chips.
[l] "Legume chips/crackers" include chip and cracker products whose first ingredient is a legume (adzuki bean, black bean, chickpea, fava bean, lentil, navy bean, pea/snow pea, soybean).
[m] "Vegetable chips" includes baked, deep-fried, and extruded products whose first ingredient is a vegetable (batata, beet, carrot, cassava, lotus root, kale, parsnip, potato, taro).

Grain-based products

This survey sampled a wide variety of grain-based products, including crisp baked goods, granola/cereal bars, grain-based beverages, and soft breads. The results were compared to previous CFIA surveys[11,12], Health Canada data[13], and the FDA Survey[16]. Barley tea, buckwheat tea, and tea containing roasted rice were not included in any of these surveys, so they were compared to other published studies. The barley tea was compared to 2 studies published in Japan in 2003 (Takatsuki et al.[18] and Ono et al.[19]). The teas containing green tea leaves and roasted rice were compared to a study that examined green tea (Liu et al.[20], 2008) and a study that examined roasted rice for use in teas in South Korea (Kim et al.[21], 2021). To our knowledge, buckwheat tea has not been studied for acrylamide formation and so there is no peer-reviewed information about roasted buckwheat tea. These comparisons are shown in Table 7.

The average levels found in this survey were similar to or lower than the levels found in equivalent products in the other studies. The green tea with roasted rice had an average level that was between the levels for green tea and roasted rice individually, as might be expected in a mixture of those two products. Buckwheat tea had similar average levels to the other roasted grain beverages, although no direct comparison data was available. The maximum level in soft breads in this survey is higher than the other surveys which is due to a single whole grain pumpernickel rye bread containing 910 ppb acrylamide. The next highest level in this category is 150 ppb in a whole grain rye bread, which was similar to the maximum levels found in the comparison data.

Table 7. Comparison of acrylamide levels detected in grain-based products in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[n] (ppb)
Barley tea	**CFIA**	**2013 to 2015**	**4**	**4 (100)**	**220**	**460**	**308**
Barley tea	Takatsuki et al.	2003	2	2 (100)	256	270	263
Barley tea	Ono et al.	2003	2	2 (100)	218	578	398
Buckwheat tea	**CFIA**	**2013 to 2015**	**2**	**2 (100)**	**20**	**470**	**245**
Coffee substitute	**CFIA**	**2013 to 2015**	**27**	**27 (100)**	**27**	**1000**	**481**
Coffee substitute	FDA Survey	2002 to 2015	2	2 (100)	3747	5399	4573
Coffee substitute	CFIA	2011 to 2013	1	1 (100)	720	720	720
Crisp baked goods/snacks	**CFIA**	**2013 to 2015**	**183**	**179 (98)**	**7**	**4000**	**299**
Crisp baked goods/snacks	CFIA	2011 to 2013	623	618 (99)	6	7100	295
Crisp baked goods/snacks	CFIA	2010 to 2011	217	215 (99)	6	2000	298
Granola/cereal bars	**CFIA**	**2013 to 2015**	**79**	**76 (96)**	**11**	**250**	**57**
Granola/cereal bars	FDA Survey	2002 to 2015	76	52 (68)	10	960	179
Granola/cereal bars	CFIA	2011 to 2013	144	139 (97)	5	880	91
Roasted brown rice	Kim et al.	2021	8	8 (100)	225	423	315
Green tea with roasted rice	**CFIA**	**2013 to 2015**	**18**	**17 (94)**	**18**	**280**	**103**
Green tea	Liu et al.	2008	10	7 (70)	3	94	48
Soft baked goods	**CFIA**	**2013 to 2015**	**203**	**169 (83)**	**5**	**910**	**32**
Soft baked goods	FDA Survey	2002 to 2015	431	190 (44)	10	220	34
Soft breads	CFIA	2011 to 2013	98	81 (83)	17	120	31
Soft baked goods	BCS-EA	2012	103	86 (83)	10	199	47

Table notes

[n] Average of positive samples only

Infant food purees

The acrylamide levels that were found in the infant purees sampled in this survey were compared to levels found in a previous CFIA survey[12] and FDA data[15,16]. The result of this comparison is shown in Table 8. For all of these sources, the samples included only fruit and/or vegetable purees and excluded purees that contained prune or sweet potato, which are included in their respective categories later in this report. The levels found in this survey are comparable to the levels found in the other surveys.

Table 8. Comparison of acrylamide levels detected in infant fruit and/or vegetable purees in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[o] (ppb)
Infant puree	**CFIA**	**2013 to 2015**	**63**	**17 (27)**	**5**	**76**	**27**
Infant puree	FDA Survey	2002 to 2015	33	6 (18)	17	40	29
Infant puree	CFIA	2011 to 2013	121	37 (31)	7	110	32
Infant puree	FDA TDS	2003 to 2006	90	50 (56)	10	89	30

Table notes

[o] Average of positive samples only

Nut and/or seed products

Table 9 summarizes the acrylamide levels found in nut and/or seed products in the current survey, past CFIA surveys[11,12], Health Canada data[13], and the FDA Survey[16]. The current survey is the first CFIA survey to test mixtures of nuts and dried fruit and there were no published surveys found that tested these specific products, so they are compared with the results of whole nuts and dried fruits from other surveys. Almond butter is compared separately from the other nut/seed butters because almonds and almond butters have historically had higher levels of acrylamide, as is discussed below.

When comparing nut products, it is important to note that almonds naturally contain higher levels of the amino acid asparagine, which leads to higher acrylamide levels when the almonds are roasted or otherwise treated at high temperatures[2,5]. The acrylamide levels in roasted almonds will be higher than other nuts, but raw or blanched almonds generally contain very low levels of acrylamide. As shown in Table 9, the maximum and average levels between the nut studies vary greatly, and the higher levels appear to correlate with larger proportion of almond samples in a survey. For example, in the Health Canada BCS-EA[13] survey, the maximum and average levels of acrylamide found were 749 ppb and 258 ppb, respectively. The samples in that survey included 15 roasted almond samples that had an average level of 636 ppb, but the other 25 samples were cashews (11) and peanuts (14), which together had an average level of 30 ppb. Thus, the elevated average level of that survey was due to the relatively high proportion of roasted almonds (38% of samples) included in the survey. Where the proportion of roasted

almond samples was available in each study, it is shown in Table 9. The proportion of roasted almonds in the mixtures of nuts and fruit sampled in the current survey is unknown.

The average levels from the current survey are comparable to the average levels found in the other surveys. The current survey had a higher maximum level in non-almond butters than the other studies. This high level (610 ppb) was found in a sample of sunflower seed spread, and the next highest level was 220 ppb in a peanut butter sample, which is similar to the maximum levels found in the other studies.

Table 9. Comparison of acrylamide levels detected in nut and/or seed products in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[p] (ppb)
Almond butter	**CFIA**	**2013 to 2015**	**29**	**29 (100)**	**15**	**940**	**345**
Almond butter	CFIA	2011 to 2013	31	29 (94)	6	1800	349
Almond butter	CFIA	2010 to 2011	4	4 (100)	140	1100	398
Fruit and nut mixtures	**CFIA**	**2013 to 2015**	**15**	**11 (73)**	**9**	**150**	**43**
Nuts (19% roasted almonds)	FDA Survey	2002 to 2015	52	25 (48)	10	457	93
Nuts (3% roasted almonds)	CFIA	2011 to 2013	31	15 (48)	7	220	37
Nuts (38% roasted almonds)	BCS-EA	2012	40	40 (100)	17	749	258
Dried fruit	CFIA	2010 to 2011	72	14 (19)	9	96	39
Nut/seed butter - other[q]	**CFIA**	**2013 to 2015**	**144**	**133 (92)**	**5**	**610**	**56**
Nut/seed butter - other[q]	CFIA	2011 to 2013	98	82 (84)	5	240	69
Peanut butter	BCS-EA	2012	14	14 (100)	60	133	102
Nut/seed butter - other[q]	CFIA	2010 to 2011	10	3 (30)	37	75	55

Table notes

[p] Average of positive samples only
[q] Nut and/or seed butters not containing almonds

Prune-based foods

Prune-based foods are included as a separate category because these products have been associated in the past with particularly elevated levels of acrylamide, due to their sugar and asparagine content and heat treatment during processing[2]. This survey sampled prunes (dried and/or canned), prune juice, prune infant puree, and plum sauce. The acrylamide levels were compared to previous CFIA surveys[11,12] and Health Canada data[13], as shown in Table 10. The average levels and detection rates found in the current survey were comparable to or less than these other surveys.

Table 10. Comparison of acrylamide levels detected in prune-based foods in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[r] (ppb)
Prunes - dried/canned	**CFIA**	**2013 to 2015**	**15**	**12 (80)**	**12**	**120**	**42**
Prunes - dried/canned	CFIA	2011 to 2013	102	96 (94)	6	390	45
Prunes - dried	CFIA	2010 to 2011	15	15 (100)	15	140	58
Prune juice	**CFIA**	**2013 to 2015**	**10**	**10 (100)**	**83**	**340**	**182**
Prune juice	CFIA	2011 to 2013	79	78 (99)	20	910	264
Prune juice	BCS-EA	2012	43	43 (100)	33	916	200
Infant puree - prune/prune mixture[s]	**CFIA**	**2013 to 2015**	**56**	**49 (88)**	**57**	**240**	**120**
Infant puree - prune/prune mixture[s]	CFIA	2011 to 2013	144	138 (96)	24	380	120
Infant puree - prunes	BCS-EA	2012	20	20 (100)	75	265	154
Infant puree - prune	CFIA	2010 to 2011	14	14 (100)	51	580	226
Plum sauce	**CFIA**	**2013 to 2015**	**10**	**7 (70)**	**21**	**45**	**30**
Plum sauce	CFIA	2011 to 2013	1	0 (0)	n/a[t]	n/a[t]	n/a[t]
Plum sauce	CFIA	2010 to 2011	9	6 (67)	11	32	17

Table notes

[r] Average of positive results only
[s] "Prune mixture": purees containing prunes mixed with apple, banana, carrot, grape/raisin, and/or oats.
[t] n/a: not applicable; no positive results.

Sweet potato products

As with prunes, products containing sweet potatoes are included as a separate category because these products have been associated in the past with particularly elevated levels of acrylamide, due to their sugar and asparagine content and heat treatment during processing[24]. Table 11 summarizes the levels of acrylamide in sweet potato products in the current targeted survey as well as a previous CFIA survey[12], Health Canada data[13], and FDA data[15,16]. Overall, the detection rates, maximum levels and average levels of the current survey are comparable to or lower than the other studies in equivalent products.

Table 11. Comparison of acrylamide levels detected in products containing sweet potato in this survey and other published studies

Product type	Survey author	Year	Number of samples	Number (%) of positive samples	Minimum (ppb)	Maximum (ppb)	Average[u] (ppb)
Sweet potato chips/crisps[v]	**CFIA**	**2013 to 2015**	**24**	**24 (100)**	**14**	**1600**	**812**
Sweet potato chips/crisps[v]	CFIA	2011 to 2013	75	75 (100)	14	3300	1091
Sweet potato chips	BCS-EA	2012	4	4 (100)	1419	2924	1893
Sweet potato soup	**CFIA**	**2013 to 2015**	**1**	**1 (100)**	**26**	**26**	**26**
Sweet potato - frozen	FDA Survey	2002 to 2015	18	14 (78)	14	724	206
Sweet potato - canned/frozen/soup	CFIA	2011 to 2013	9	7 (78)	5	110	25
Sweet potato - canned	FDA TDS	2003 to 2006	12	12 (100)	21	153	55
Sweet potato infant puree	**CFIA**	**2013 to 2015**	**11**	**9 (82)**	**12**	**78**	**33**
Sweet potato infant puree	CFIA	2011 to 2013	28	27 (96)	20	140	58
Sweet potato infant puree	BCS-EA	2012	23	23 (100)	32	69	59

Table notes:

[u] Average of positive results only.
[v] Some products contained other root vegetables (i.e. beet, carrot, cassava, parsnip, potato, taro) in addition to sweet potatoes.

Currently, no maximum level, tolerance, or standard has been established by Health Canada for acrylamide levels in food and therefore compliance with a numerical standard could not be evaluated in this survey. All levels of acrylamide found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians, therefore no product recalls were required.

When comparing this survey to previous years and other studies, the positive rate, maximum level, and average levels of acrylamide were reasonably consistent year-to-year, where comparisons were possible. Where no comparisons were possible, CFIA has added these results to its baseline data for future enforcement decisions.

How to access the survey data

The data associated with this report will be accessible on the Open Government Portal.

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