Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

Polycyclic aromatic hydrocarbons (PAHs) in selected foods – April 1, 2020, to March 31, 2022

Food chemistry – Targeted surveys – Final report



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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.

Polycyclic aromatic hydrocarbons (PAHs) are products of the incomplete combustion of materials such as coal, oil, gas, wood, and charbroiled meat. They are a common airborne pollutant and often contaminate crops. PAHs can also form in food during thermal processing. This survey analysed for 16 PAHs, including the 4 PAHs that occur in foods that are considered to be the most toxic. These 4 PAHs are benzo[a]pyrene, which has been classified as "carcinogenic to humans" by the International Agency for Research on Cancer (IARC), benz[a]anthracene, benzo[b]fluoranthene, and chrysene, which have been classified as "possibly carcinogenic to humans" by the IARC[1].

This targeted survey generated baseline surveillance data on the occurrence of 16 PAHs in domestic and imported products that are likely to contain PAHs on the Canadian market. CFIA sampled and analyzed 444 products including 150 nuts, seeds, and nut/seed butters, 146 baked goods (crisp and soft-baked), 50 smoked meat/poultry products, 49 smoked fish products, and 49 smoked cheeses. At least one PAH was detected in 99% of samples tested, and at least one of the 4 most toxic PAHs were detected in 35% of samples. Baked goods had the lowest average level of total PAHs and smoked cheese had the highest average level of total PAHs. Smoked fish had the lowest average level of the 4 most toxic PAHs, and the nuts, seeds, and nut/seed butters category had the highest average level of the 4 most toxic PAHs.

There are no regulations in Canada for PAH levels in food, except for olive pomace oils[2], which were not examined in this survey. All levels of PAH found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians.

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

PAHs are natural and unintentional by-products of the incomplete combustion of materials such as coal, oil, gas, and wood[1]. They are a common airborne pollutant and often contaminate crops. PAHs can also form in food during thermal processing, particularly during charbroiling, grilling, smoking, or toasting of foods[1,2]. As such, they can form in food during high-temperature processing and contaminate food through industrial air, soil, and water pollution.

PAHs include a wide range of chemicals with varying levels of carcinogenicity as classified by the IARC; this survey analysed for levels of 16 PAHs. These 16 PAHs are: acenaphthene (Ane), acenaphthylene (Anl), anthracene (Ant), benz[a]anthracene (BaA), benzo[a]pyrene (BaP), benzo[b]fluoranthene (BbF), benzo[g,h,i]perylene (BghiP), benzo[k]fluoranthene (BkF), chrysene (Chr), dibenz[a,h]anthracene (DahA), fluoranthene (Flt), fluorene (Flu), indeno[1,2,3-cd]pyrene (InP), naphthalene (Nap), phenanthrene (Phen), and pyrene (Pyr), many of which have been classified as carcinogenic, probably carcinogenic, or possibly carcinogenic to humans by the IARC[1]. This report will present the levels of the sum of all 16 PAHs analyzed (called Total PAH16 in this report) and the relative toxic potency of the sum of 4 most toxic PAHs that are found in food (BaA, BaP, BbF, and Chr), which is referred to as Toxic PAH4 in this report.

Maximum Limits (MLs) for PAH levels in food have not yet been established by Health Canada, apart from olive pomace oils[2], which were not examined in this survey. This survey was initiated in consultation with Health Canada to establish further baseline surveillance data to complement and expand upon the data previously collected.

What was sampled

A total of 444 domestic and imported food products were sampled between April 1, 2020, and March 31, 2022, including 150 nuts, seeds, and nut/seed butters, 146 baked goods (cookies, crackers, crispbreads, croutons, and soft breads/flatbreads), 50 smoked meat/poultry products, 49 smoked fish products, and 49 smoked cheeses. Samples were collected from local/regional retail locations located in 8 major cities across Canada, encompassing 4 Canadian geographical areas:

- Atlantic (Halifax and Moncton)
- Ontario (Ottawa and Toronto)
- Quebec (Montreal)
- West (Calgary, Vancouver, and Winnipeg)

The number of samples collected from these cities was in proportion to the relative population of the respective areas. Imported samples originated from at least 28 countries.

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
Baked goods	52	47	47	146
Cheese - smoked	33	12	4	49
Fish - smoked	21	21	7	49
Meat - smoked	41	3	6	50
Nuts, seeds, and nut/seed butters	60	64	26	150
Total	**207**	**147**	**90**	**444**

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 ISO/IEC 17025 accredited food testing laboratories under contract with the Government of Canada. The samples were tested as sold, which means the product was tested as is and not prepared according to package instructions.

The list of compounds reported as part of this survey are shown in Table A-1 in the Appendix of this report. All samples were reported in parts per billion (ppb) in whole sample weight (also called wet weight). Total PAH16 levels were determined by summing the concentrations of all detected analytes in each sample. A breakdown of the frequency of each PAH found in this survey is in Table A-2 in the Appendix of this report.

The 4 most toxic PAHs (BaA, BaP, BbF, and Chr) are also reported as the calculated toxic equivalency (TEQ). This is calculated by multiplying the concentration of each of these PAHs detected in a sample (in ppb) by its respective Toxic Equivalency Factor (TEF) proposed by Nisbut and LaGoy[3]. Refer to Table A-1 in the Appendix for the TEFs used in this survey. PAHs not detected or found below the analytical method's limit of detection are assigned a value of 0 ppb. The calculated TEQ concentrations of the 4 individual PAHs were added together to arrive at a Toxic PAH4 level expressed as 'ppb TEQ', which is an estimate of the total relative toxic potency of these 4 most toxic PAHs detected in the sample.

Health Canada has established a ML of 3 ppb TEQ for PAHs in olive-pomace oils (a unique type of oil, distinct from other olive oils such as virgin olive oil)[2] which were not examined in this survey. In the absence of established tolerances or standards for PAHs in foods, elevated levels in specific foods may be assessed by Health Canada on a case-by-case basis using the most current scientific data available.

Results of the survey

A total of 444 domestic and imported food products were tested in this survey. Of these samples, 439 (99%) contained detectable levels of at least one PAH, allowing a Total PAH16 value to be determined. Additionally, 155 samples (35%) contained detectable levels of a toxic PAH, resulting in a Toxic PAH4 value. The levels of Total PAH16 ranged from 0.283 to 737 ppb and the levels of Toxic PAH4 ranged from 0.0003 to 51.0 ppb TEQ.

The highest detection rate of Total PAH16 (100%) was found in smoked cheese, smoked fish, and baked goods. Nuts, seeds, and nut/seed butters had the lowest detection rate of Total PAH16 (97%). Smoked cheese had the highest average level of Total PAH16 (115 ppb), and baked goods had the lowest average level of Total PAH16 (9.06 ppb).

The highest detection rate of Toxic PAH4 was found in smoked fish (63%) and the lowest detection rate was found in smoked cheese (27%). Nuts, seeds, and nut/seed butters had the highest average Toxic PAH4 level (1.41 ppb TEQ), and smoked fish had the lowest average level (0.218 ppb TEQ) of Toxic PAH4.

The highest levels of both Total PAH16 (737 ppb) and Toxic PAH4 (51.0 ppb TEQ) were found in a domestic tahini sample. This sample contained detectable levels of all 16 PAHs analyzed and had substantially higher concentrations than other tahini and nut/seed products in the survey, suggesting that these levels may not be typical of tahini samples. The next highest level of Total PAH16 was similar (715 ppb), found in a sample of smoked herring. In contrast, the next highest level of Toxic PAH4 was considerably lower (9.50 ppb TEQ) which was found in a sample of gluten-free cookies.

In general, samples in this survey that contained a greater number of detectable PAH compounds also tended to have higher average Total PAH16 levels. They also showed higher detection rates and average levels of Toxic PAH4 compounds, as shown in the Appendix, in Table A-3, Figure A-1, Table A-4, and Figure A-2. This pattern is expected, as higher-temperature processing increases both the rate of formation and the diversity of PAH compounds. Toxic PAH4 compounds, in particular, tend to

form at higher temperatures than other PAHs. As a result, products exposed to more intense heat are more likely to contain elevated PAH levels[13,14].

When foods are deliberately smoked, producers can carefully control processing conditions, such as temperature, smoke source, oxygen levels, and equipment type, to achieve a smoky flavour while minimizing the formation of Toxic PAH4 compounds[1,3,14]. In contrast, other heat-processed foods, such as the crisp baked products and roasted or toasted nuts and seeds analyzed in this survey, can form PAHs during baking, drying, and frying. Because these processes are typically less tightly controlled than smoking, some of these products may contain PAH4 levels comparable to those found in smoked foods.

In addition to heat processing and smoking, foods may also become contaminated through environmental sources such as water, soil, and air, which can come into contact with ingredients, the final product, or processing equipment. This may account for exceptions to the overall trend.

Table 2. Summary of targeted survey results of PAHs in selected products

Product type	Total number of samples	Number of samples with detected levels of Toxic PAH4 (%)	Average[b] Toxic PAH4 value (range[c]) in ppb TEQ	Number of samples with detected levels of Total PAH16 (%)	Average[b] Total PAH16 value (range[c]) in ppb
Baked goods	146	42 (29)	0.338 (0.0003 to 9.49)	146 (100)	9.06 (0.307 to 242)
Cheese - smoked	49	13 (27)	0.270 (0.0030 to 0.604)	49 (100)	115 (0.644 to 406)
Fish - smoked	49	31 (63)	0.218 (0.0023 to 1.21)	49 (100)	73.8 (2.79 to 715)
Meat - smoked	50	25 (50)	0.306 (0.0100 to 1.70)	49 (98)	33.3 (0.283 to 295)
Nuts, seeds, and nut/seed butters	150	44 (29)	1.41 (0.0010 to 51.0)	146 (97)	19.2 (0.291 to 737)
Total	**444**	**155 (35)**	**0.607 (0.0003 to 51.0)**	**439 (99)**	**34.2 (0.283 to 737)**

Table notes:

[b] Average of positive results.
[c] Range of positive levels.

Baked goods

This survey sampled 146 samples of baked goods, including 88 samples of crisp products (cookies, crackers, crispbreads, and croutons) and 58 samples of soft bread products (bagels, breads, crumpets, English muffins, naan, pita, pizza crusts, roti, and tortillas). PAHs can form during the baking process and/or be present in the ingredients used to prepare them[12].

Detectable levels of Toxic PAH4 were found in 42 (29%) of baked goods samples, with crisp products having a higher detection rate of Toxic PAH4 (36%) than soft products (17%). Crisp products also had a higher average level of Toxic PAH4 (0.421 ppb TEQ) than soft products (0.0738 ppb TEQ). The highest level of Toxic PAH4 (9.49 ppb TEQ) was found in a sample of gluten-free hemp cookies. In comparison, the highest level found in soft products was 0.525 ppb TEQ, found in a sample of rye bread containing flax and sunflower seeds. The overall average level for baked goods was 0.338 ppb TEQ of Toxic PAH4.

Detectable levels of Total PAH16s were found in all baked goods samples. Crisp products had a higher average level of Total PAH16 (11.5 ppb) than soft products (5.34 ppb). The highest level of Total PAH16 (242 ppb) was found in the same sample of gluten-free hemp cookies that also contained the highest level of Toxic PAH4. The lowest level of Total PAH16 was found in a sample of chocolate walnut cookies (0.307 ppb). The overall average level for baked goods was 9.06 ppb of Total PAH16.

Cheese - smoked

Cheeses labelled as “smoked” can be made in two main ways. The first is traditional smoking, where the cheese is exposed to smoke from burning wood or other materials like straw. The second is by adding smoke flavouring, which can be applied by soaking, spraying, or mixing it into the cheese. Smoke flavourings are produced by collecting smoke from burning wood and processing it into a concentrated liquid or crystal form. Both traditional smoking and added smoke flavourings can introduce PAHs into cheese, because PAHs form during the burning process[8,10,11]. However, commercially manufactured smoke flavourings are produced and refined under controlled conditions, which typically results in lower PAH levels compared to traditional wood smoking[8]. This survey sampled a total of 49 cheeses including 35 samples that had been traditionally smoked and 14 samples that had smoke flavouring added. The cheese varieties sampled included cheddar, firm ripened cheeses, gorgonzola, gouda, Havarti, mozzarella, processed cheese, and provolone.

Toxic PAH4s were detected in 13 of the 49 cheese samples (27%). Traditionally smoked cheese had a higher detection rate of Toxic PAH4s (10 of 35 samples, or 29%) than cheese that had smoke flavour added (3 of 14 samples, or 21%). The average level of Toxic PAH4s found in the smoke-flavoured cheeses (0.328 ppb TEQ) was higher than in traditionally smoked cheeses (0.253 ppb TEQ). The average level of Toxic PAH4 that was detected in all smoked cheese samples was 0.270 ppb TEQ. The highest Toxic PAH4 levels were found in a sample of traditionally smoked cheddar (0.604 ppb TEQ) and a smoke-flavoured gouda sample (0.593 ppb TEQ).

Total PAH16 was detected in all of the cheese samples (100%). The highest and lowest Total PAH16 levels were found in 2 different samples of smoke-flavoured gouda cheese. Cheese that was traditionally smoked had a higher average level of Total PAH16 than cheese that had smoke flavouring added (145 ppb and 41.9 ppb, respectively). The average level of Total PAH16 in all cheese samples was 115 ppb, which was the highest average level among the categories in this survey.

Fish - smoked

The 49 samples of traditionally smoked fish that were sampled in this survey included 24 smoked salmon, 8 smoked mackerel, 7 smoked herring, 7 smoked sardine, and 3 smoked trout samples. None of these samples contained added smoke flavour. Smoked fish was sampled because smoking foods is known to be a source of PAH contamination in food[1,14].

The average level of Toxic PAH4 in smoked fish was 0.218 ppb TEQ, which was the lowest average among the categories in this survey. The detection rate of Toxic PAH4 in smoked fish was the highest in the entire survey at 63% (31 of 49 samples). The highest Toxic PAH4 result was 1.21 ppb TEQ in a sample of smoked sardines. Between the species of fish, smoked sardines had the highest average level (0.400 ppb TEQ), and smoked salmon had the lowest average level (0.0717 ppb TEQ).

The average level of Total PAH16 in smoked fish was 73.8 ppb and the detection rate was 100%. The highest Total PAH16 level was 715 ppb, found in a sample of smoked herring fillets and the lowest level was found in a sample of smoked mackerel (2.79 ppb). Between the species of fish, smoked herring had the highest average level (220 ppb), and smoked trout had the lowest average level (37.6 ppb).

Meat/poultry - smoked

This survey sampled 50 smoked beef, chicken, pork, and/or turkey products, such as Montreal smoked meat, ham, bacon, smoked chicken/turkey, smoked deli meats, and smokie-style sausages. Of these 50 samples, 45 were traditionally smoked, 3 were traditionally smoked and also had added smoke flavour, and 2 contained smoke flavouring only.

Toxic PAH4s were detected in 50% of smoked meat and poultry samples, with an average level of 0.306 ppb TEQ. The traditionally smoked products had a detection rate of 47% (21 samples), and an average Toxic PAH4 level of 0.328 ppb TEQ. The samples with both traditional smoke and smoke flavouring had a detection rate of 67% (2 samples) and had an average level of 0.328 ppb TEQ, the same as the traditionally smoked products. Both of the smoke-flavoured meats contained Toxic PAH4s (100%), but their average level was much lower at 0.0532 ppb TEQ. The highest Toxic PAH4 levels were found in a sample of traditionally smoked black forest ham (1.70 ppb TEQ).

Total PAH16s were detected in 49 of the 50 meat/poultry samples (98%) with an overall average level of 33.3 ppb. The traditionally smoked products had a detection rate of 98% (44 samples), and an average Total PAH16 level of 28.8 ppb. The samples that were both traditionally smoked and contained smoke flavouring had a detection rate of 100% (3 samples) and had an average level of 113 ppb. Both of the smoke-flavoured meats contained Total PAH16s (100%) with an average level of 11.7 ppb. The highest level of Total PAH16 was 295 ppb, found in a sample of traditionally smoked ham sausage.

Nuts, seeds, and nut/seed butters

This survey sampled 84 samples of nuts and/or seeds and 66 nut/seed butters, for a total of 150 samples of a variety of nut and seed products. PAHs may be present in these samples due to contaminated growing conditions or may be formed during the drying or roasting processes[4].

Toxic PAH4s were detected in 29% of nut, seeds, and nut/seed butter samples (44 samples) and the average level was 1.41 ppb TEQ, which is the highest average level among the categories in this survey. The highest level of Toxic PAH4 was 51.0 ppb TEQ, found in a sample of tahini (sesame seed paste) and the next highest level found was 3.58 ppb TEQ in a sample of chestnuts. There were 7 other tahini products sampled in this survey, and 5 of these contained detectable levels of Toxic PAH4s, ranging between 0.0031 and 0.732 ppb TEQ. This might indicate that this elevated tahini sample may not be in the range that would typically be found in tahini samples. All levels of PAH found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians, including this elevated tahini sample.

Total PAH16s were detected in 97% of nut, seed, and nut/seed butter samples (146 samples), and the average level was 19.2 ppb. The highest level of Total PAH16 (737 ppb) was found in the same tahini sample that had the highest level of Toxic PAH4 discussed above. The next highest level of Total PAH16 was 175 ppb in a sample of Brazil nuts, and the next highest level of Total PAH16 in a tahini sample was 77.9 ppb, which again may indicate that this elevated tahini sample is not typical of tahini products in general. All levels of PAH found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians, including this elevated tahini sample.

What the survey results mean

The primary objective of this targeted survey was to obtain additional baseline data on PAH levels in selected foods available in the Canadian retail market. Of the 444 samples tested, 439 (99%) contained detectable levels of at least one PAH (Total PAH16) and 155 (35%) contained detectable levels of at least one toxic PAH (Toxic PAH4). All levels of PAH found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians.

The levels of PAHs found in this targeted survey were compared to previous CFIA surveys[4,5,6] and to levels reported in scientific literature in similar product types from China (2017[7]), Italy (2015[8]), Korea (2018[9]), Poland (2020[10], 2022[11]), Serbia (2008[12]), Spain (2018[13]), and Sweden (2010[14]). The results of these reports are summarized in Table 3 (Toxic PAH4) and Table 4 (Total PAH16) below. The results of the current survey are bolded in the tables for ease of identification.

Table 3. Minimum, maximum, and average levels of Toxic PAH4 from various published studies and surveys

Product type	Study and year	Total number of samples	Number of samples (%) with detected levels	Minimum[d] Toxic PAH4 levels (ppb TEQ)	Maximum Toxic PAH4 levels (ppb TEQ)	Average[e] Toxic PAH4 levels (ppb TEQ)
Baked goods	**CFIA 2020 to 2022**	**146**	**42 (29)**	**0.0003**	**9.49**	**0.338**
Cookies and crackers	CFIA 2018	142	51 (36)	0.0011	1.68	0.155
Cookies and crackers	CFIA 2014 to 2018	50	21 (42)	0.0019	3.56	0.362
Grain-based foods	Spain 2018	22	6 (29)	0.0035	4.55	1.85
Cheese - smoked	**CFIA 2020 to 2022**	**49**	**13 (27)**	**0.0030**	**0.604**	**0.270**
Smoked cheese	Poland 2022	10	10 (100)	0.419	0.927	0.705
Smoked cheese	Poland 2020	12	6 (50)	0.166	5.88	2.72
Smoked mozzarella	Italy 2015	40	26 (65)	0.09	35.5	5.16
Fish - smoked	**CFIA 2020 to 2022**	**49**	**31 (63)**	**0.0023**	**1.21**	**0.218**
Smoked fish and seafood	CFIA 2014 to 2018	52	43 (83)	0.0031	109	4.68
Smoked fish	Korea 2018	15	NR[f]	NR[f]	NR[f]	1.06
Smoked fish	Sweden 2010	39	31 (79)	0.0030	18.7	3.84
Meat/poultry - smoked	**CFIA 2020 to 2022**	**50**	**25 (50)**	**0.0100**	**1.70**	**0.306**
Smoked meat and poultry	CFIA 2014 to 2018	25	10 (40)	0.0022	2.01	0.279
Smoked meat and poultry	Sweden 2010[g]	38	22 (58)	0.003	47.7	9.39
Smoked meat	Serbia 2008	32	32 (100)	0.101	1.51	0.576
Nuts, seeds, and butters	**CFIA 2020 to 2022**	**150**	**44 (29)**	**0.0010**	**51.0**	**1.41**
Nuts, seeds, and butters	CFIA 2019	114	44 (39)	0.0010	2.93	0.166
Nuts, seeds, and butters	CFIA 2014 to 2018	408	157 (38)	0.0015	8.58	0.252
Nuts and seeds	China 2017	38	38 (100)	NR[f]	NR[f]	2.58

Table notes:

[d] Minimum positive value found.
[e] Only positive results were used to calculate the average Toxic PAH4 levels.
[f] NR = not reported in the study.
[g] This study included traditional Swedish “sauna” smoking, which smokes the meat over a burning log fire; this smoking method results in higher PAH levels overall[14].

The detection rates and average levels of Toxic PAH4 found in this study were comparable to, or lower than, the detection rates reported in other studies. The average level found in nuts, seeds, and nut/seed butters is lower than the literature but is higher than previous CFIA surveys. This high average level is due to the elevated level found in 1 tahini sample (51.0 ppb TEQ). When this tahini sample is excluded, the average level of Toxic PAH4 in the other 149 nut, seed, and nut/seed butter samples is 0.254 ppb TEQ, which is similar to the average levels found in previous CFIA surveys. Overall, the differences between the study results are likely due to the specific types of products that were sampled and the smoking, roasting, and/or drying methods used on the samples in each survey or study.

Table 4. Minimum, maximum, and average levels of Total PAH16 from various published studies and surveys

Product type	Study and year	Number of PAHs analyzed	Total number of samples	Number of samples (%) with detected levels	Minimum[h] Total PAH16 levels (ppb)	Maximum Total PAH16 levels (ppb)	Average[i] Total PAH16 levels (ppb)
Baked goods	**CFIA 2020 to 2022**	**16**	**146**	**146 (100)**	**0.307**	**242**	**9.06**
Cookies and crackers	CFIA 2018	16	142	138 (97)	0.286	41.0	6.91
Cookies and crackers	CFIA 2014 to 2018	16	50	50 (100)	0.833	120	10.0
Grain-based foods	Spain 2018	16	22	20 (91)	0.168	22.3	5.03
Cheese - smoked	**CFIA 2020 to 2022**	**16**	**49**	**49 (100)**	**0.644**	**406**	**115**
Smoked cheese	Poland 2022	15	10	10 (100)	28.3	53.3	37.1
Smoked cheese	Poland 2020[k]	16	12	12 (100)	40.9	4010	1279
Smoked mozzarella	Italy 2015	6	40	30 (75)	0.20	144	18.7
Fish - smoked	**CFIA 2020 to 2022**	**16**	**49**	**49 (100)**	**2.79**	**715**	**73.8**
Smoked fish and seafood	CFIA 2014 to 2018	16	52	50 (100)	1.19	2044	232
Smoked fish	Korea 2018	8	15	NR[j]	NR[j]	NR[j]	11.6
Smoked fish	Sweden 2010	8	39	32 (82)	0.30	168	33.2
Meat/poultry - smoked	**CFIA 2020 to 2022**	**16**	**50**	**49 (98)**	**0.283**	**295**	**33.3**
Smoked meat and poultry	CFIA 2014 to 2018	16	25	25 (100)	0.223	79.3	11.9
Smoked meat and poultry	Sweden 2010[l]	15	38	21 (55)	0.6	390	76.6
Smoked meat	Serbia 2008	16	32	32 (100)	1.5	22.7	8.38
Nuts, seeds, and butters	**CFIA 2020 to 2022**	**16**	**150**	**146 (97)**	**0.291**	**737**	**19.2**
Nuts, seeds, and butters	CFIA 2019	16	114	112 (98)	0.702	121	25.0
Nuts, seeds, and butters	CFIA 2014 to 2018	16	408	406 (99.5)	0.196	265	18.6
Nuts and seeds	China 2017	16	38	38 (100)	81.8	402	190

Table notes:

[h] Minimum positive level.

[i] Only positive results were used to calculate the average Total PAH16 levels.

[j] NR = not reported in the study

[k] This study surveyed 3 cheeses that were commercially smoked and 9 cheeses that were produced in small family farms; the cheeses that were made by small farms had a higher range of Total PAH16 levels (76.2 to 4010 ppb) than the commercially produced smoked cheeses (40.9 to 50.3 ppb), indicating the difference in smoking protocols[10].

[l] This study included traditional Swedish “sauna” smoking, which smokes the meat over a burning log fire; this smoking method results in higher PAH levels overall[14].

The detection rates and average levels of Total PAH16 were comparable to or lower than the values in previous surveys and the scientific literature. The maximum level of Total PAH16 in nuts, seeds, and nut/seed butters was higher than in the other surveys. This difference is due to the elevated level of Total PAH16 found in 1 tahini sample (737 ppb). When this tahini sample is excluded, the maximum level of Total PAH16 in all other nuts, seeds, and nut/seed butters is 175 ppb, which is similar to the comparison surveys. Overall, the differences between the study results are likely due to the specific types of products that were sampled and the smoking, roasting, and/or drying methods used on the samples in each survey or study.

There are no regulations in Canada for PAH levels in food, except for olive pomace oils[2], which were not examined in this survey. All levels of PAHs found in the products tested in this survey were evaluated by Health Canada and deemed safe for consumption by Canadians.

How to access the survey data

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

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Appendix

Table A-1. PAHs included in this survey, their TEFs, and their detection limits

PAH	Abbreviation	In Total PAH16?	In Toxic PAH4?	TEF[m]	Limit of detection[n] (ppb)
Acenaphthene	Ane	Yes			0.02 to 0.14
Acenaphthylene	Anl	Yes			0.05 to 0.21
Anthracene	Ant	Yes			0.003 to 0.1
Benz[a]anthracene	BaA	Yes	Yes	0.1	0.03 to 0.06
Benzo[b]fluoranthene	BbF	Yes	Yes	0.1	0.03 to 0.06
Benzo[a]pyrene	BaP	Yes	Yes	1	0.031 to 0.12
Benzo[g,h,i]perylene	BghiP	Yes			0.012 to 0.14
Benzo[k]fluoranthene	BkF	Yes			0.009 to 0.09
Chrysene	Chry	Yes	Yes	0.01	0.04 to 0.171
Dibenz[a,h]anthracene	DahA	Yes			0.018 to 0.12
Fluoranthene	Flt	Yes			0.01 to 0.11
Fluorene	Flu	Yes			0.006 to 0.16
Indeno[1,2,3-cd]pyrene	InP	Yes			0.07 to 0.12
Naphthalene	Nap	Yes			0.004 to 0.15
Phenanthrene	Phen	Yes			0.016 to 0.15
Pyrene	Pyr	Yes			0.002 to 0.11

Table notes:

[m] Toxic Equivalency Factor (TEF) proposed by Nisbut and LaGoy[3].
[n] Limit of detection depends on the laboratory, method used, and sample type.

Table A-2. Frequency and average levels of individual PAHs in detected samples in the survey

PAH	Number of positive samples (%)	Category with the highest proportion of positive samples (%)	Minimum level[o] (ppb)	Maximum level (ppb)	Average level[p] (ppb)	Category with highest average[p] level (average, ppb)
Acenaphthene	264 (59)	Smoked fish (94)	0.03	25.2	1.65	Smoked cheese (5.29)
Acenaphthylene	298 (67)	Smoked fish (94)	0.03	104	5.25	Smoked cheese (13.0)
Anthracene	179 (40)	Smoked fish (84)	0.03	24.9	3.05	Smoked cheese (6.38)
Benz[a]anthracene	93 (21)	Smoked fish (47)	0.02	17.7	0.906	Baked goods (1.31)
Benzo[b]fluoranthene	54 (12)	Smoked fish (20)	0.02	45.9	1.27	Nuts/seeds (2.59)
Benzo[a]pyrene	68 (15)	Smoked meat (26)	0.02	44.5	1.41	Nuts/seeds (3.76)
Benzo[g,h,i]perylene	42 (9)	Baked goods (12)	0.02	82.4	2.30	Nuts/seeds (5.55)
Benzo[k]fluoranthene	47 (11)	Smoked fish (14)	0.02	29.3	1.20	Nuts/seeds (2.35)
Chrysene	127 (29)	Smoked fish (57)	0.02	27.9	0.858	Nuts/seeds (1.36)
Dibenz[a,h]anthracene	17 (4)	Smoked meat (14)	0.05	3.37	0.752	Nuts/seeds (1.36)
Fluoranthene	321 (72)	Smoked fish (90)	0.05	102	1.86	Smoked fish (2.66)
Fluorene	346 (78)	Smoked fish (100)	0.04	89.8	5.38	Smoked cheese (20.1)
Indeno[1,2,3-cd]pyrene	25 (6)	Baked goods (8)	0.02	35.1	1.71	Nuts/seeds (3.79)
Naphthalene	399 (90)	Smoked cheese (98) Smoked fish (98)	0.192	375	16.7	Smoked cheese (63.2)
Phenanthrene	404 (91)	Smoked fish (96)	0.11	110	5.52	Smoked cheese (13.7)
Pyrene	326 (73)	Smoked cheese (92) Smoked fish (92)	0.06	107	1.64	Nuts/seeds (2.35)

Table notes:

[o] Minimum detected level in the whole survey.
[p] Only detected samples used to calculate averages.

Table A-3 Number of detected PAHs compared to Total PAH16 levels

Number of PAHs detected	Number of samples	Average[q] (range[r]) Total PAH16 (ppb)
1	22	0.921 (0.283 to 2.83)
2	30	2.15 (0.644 to 12.1)
3	22	4.18 (0.739 to 21.8)
4	39	6.53 (1.04 to 66.5)
5	45	6.37 (0.580 to 19.2)
6	47	9.2 (1.59 to 28.8)
7	47	13.9 (1.43 to 39.1)
8	71	71.1 (1.54 to 373)
9	26	53.6 (3.84 to 351)
10	29	50.3 (3.06 to 402)
11	22	91.6 (1.89 to 406)
12	10	47.6 (5.48 to 131)
13	9	117 (1.65 to 715)
14	6	20.5 (3.86 to 35.8)
15	9	72.6 (1.80 to 279)
16	5	198 (5.89 to 737)

Table notes:

[q] Only detected samples used to calculate averages.
[r] Range of positive levels.
[s] N/A = Not applicable; no samples contained only 1 or 2 detected Toxic PAH4 compounds.

Figure A-1 Number of detected PAHs compared to Total PAH16 levels

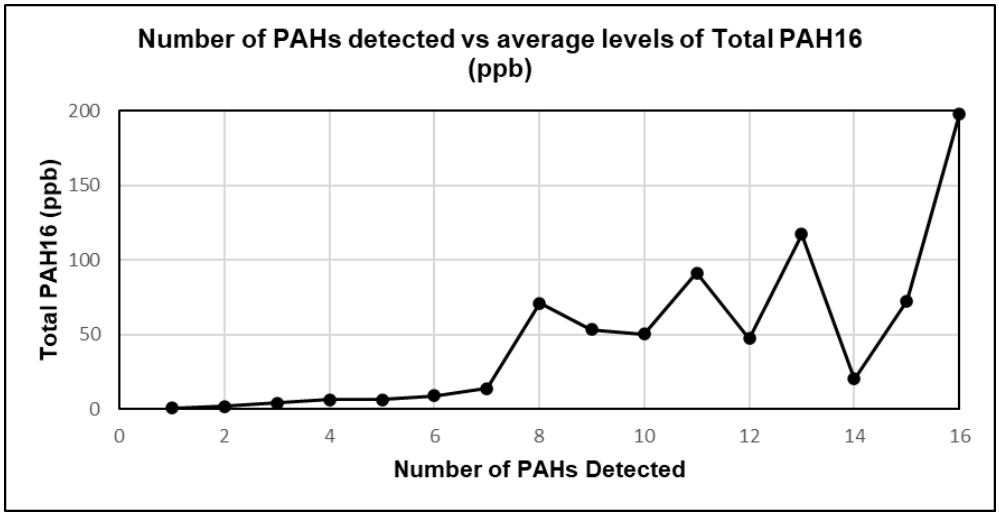


Figure note:

This is a graphical representation of the data in Table A-3.

Table A-4 Total number of detected PAHs compared to detected Toxic PAH4 compounds and average Toxic PAH4 TEQ levels

Number of Total PAH16s detected	Average number (range) of Toxic PAH4s detected	Average[t] Toxic PAH4 (ppb TEQ)
3	1 (1 to 1)	0.0213
4	1 (1 to 2)	0.174
5	1 (1 to 2)	0.124
6	1 (1 to 1)	0.0791
7	1 (1 to 2)	0.0800
8	1 (1 to 2)	0.120
9	1 (1 to 3)	0.119
10	2 (1 to 3)	0.0777
11	3 (2 to 3)	0.241
12	3 (3 to 4)	0.315
13	4 (3 to 4)	0.626
14	4 (4 to 4)	0.597
15	4 (4 to 4)	1.25
16	4 (4 to 4)	11.2

Table notes:

[t] Only detected samples used to calculate averages.

Figure A-2 Total number of detected PAHs compared to the number of detected Toxic PAH4 compounds and the average Toxic PAH4 TEQ levels

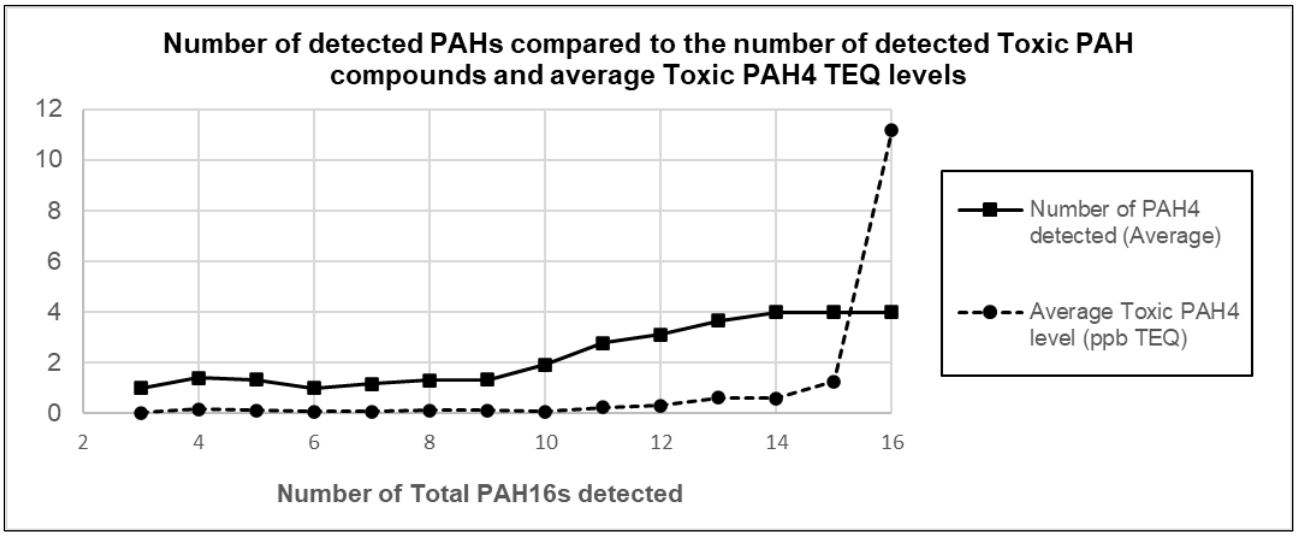


Figure note:

This is a graphical representation of the data in Table A-4.