Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

Dioxins and dioxin-like compounds in selected foods – April 1, 2021, to March 31, 2024

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.

Dioxins and dioxin-like compounds are chemical contaminants found in the environment and consequently in food products. These compounds are separated into 3 groups of chemicals with toxicological and chemical similarities. These groups are polychlorinated dibenzo-p-dioxins (also known as dioxins or PCDDs), polychlorinated dibenzofurans (PCDFs or furans) and polychlorinated biphenyls (dioxin-like PCBs or DL-PCBs). Dioxins and dioxin-like compounds are found mainly in dairy products, animal tissues/fats and eggs[1,2,3]. They can also be found in products made from oily plants due to their accumulation in soil and on plant surfaces[2]. These compounds accumulate in the liver and fat tissues of humans through consumption of food products containing dioxins and dioxin-like compounds[1,3,4,5,6]. Dioxins and dioxin-like compounds are associated with various health effects such as skin disorders (for example, chloracne), liver and thyroid problems, impairment of the endocrine, nervous, reproductive and immune systems, developmental effects and certain types of cancers[3,4,6]. The type and occurrence of these health effects typically depend on the level and duration of exposure. The best method of minimizing dietary exposure to dioxins and dioxin-like compounds is prevention and reduction of contamination in foods and animal feeds[2,3,7]. This survey focused on pine nuts, seaweed products, edible seeds, and seed butters available on the Canadian retail market.

A total of 183 samples were collected from retail stores in Canada between April 1, 2021, and March 31, 2024. Dioxins and/or dioxin-like compounds were found in 66% of samples tested. In this survey, the highest proportion of samples with detected levels of dioxins and dioxin-like compounds was found in seeds and seed butters (73%), and the lowest proportion of samples with detected levels was in pine nuts (59%).

There are no Canadian regulations for total levels of dioxins and dioxin-like compounds in food, however the levels observed in this survey were evaluated by Health Canada's Bureau of Chemical Safety and none of the samples were determined to pose a safety 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

There are over 400 different structural forms of dioxins and dioxin-like compounds. The compounds are separated into three groups of chemicals with toxicological and chemical similarities. These groups are polychlorinated dibenzo-p-dioxins (also known as dioxins or PCDDs), polychlorinated dibenzofurans (PCDFs or furans) and polychlorinated biphenyls (dioxin-like PCBs or DL-PCBs). Only some of these compounds are of concern to human health; 29 of these (also known as targeted congeners) are the focus of this report[2].

Dioxins and furans are mainly formed as by-products of industrial processes (manufacturing of chemicals, pulp and paper bleaching processes, exhaust emissions and incineration, etc.) but can also occur naturally (such as through volcanic activity or forest fires)[3]. These contaminants are not deliberately manufactured. PCBs are also man-made and often contain furan contaminants. PCBs were historically used in many industrial applications (such as for their electrical insulating properties), but their production is now banned globally. PCBs are still present in certain types of electrical equipment and, despite strict controls on handling, storage and disposal of existing PCBs, accidental release into the environment is still possible. When released into the environment, dioxins, furans, and PCBs can be transported long distances from their source[2,3,6].

The primary exposure to dioxins and dioxin-like compounds is through the consumption of foods of animal origin. These pollutants enter the livestock food chain through foraging and animal feed contamination and accumulate in the fatty tissues of the livestock[1,2]. They then enter the human food chain through the consumption of contaminated foods of animal origin, particularly higher fat foods, such as dairy products, meat, and some fish and shellfish[4].

Dioxins and dioxin-like compounds are associated with various health effects such as skin disorders (for example, chloracne), liver and thyroid problems, impairment of the endocrine, nervous, reproductive and immune systems, developmental effects and certain types of cancers[3,4,6]. The type and occurrence of these health effects typically depend on the level and duration of exposure.

In food, dioxins and dioxin-like compounds are found mainly in dairy products, animal tissues/fats and eggs[1,2,3,4]. They can also be found in products made from oily plants due to their accumulation in soil and on plant surfaces[2]. These compounds accumulate in the liver and fat tissues of humans through consumption of food products containing dioxins and dioxin-like compounds[1,3,4,5]. Dioxins and dioxin-like compounds are not destroyed by heating or cooking. The best method of minimizing dietary exposure to dioxins and dioxin-like compounds is prevention and reduction of contamination in foods and animal feeds[2,3,7]. This survey focused on pine nuts, dried seaweed products, seeds, and seed butters available on the Canadian retail market.

What was sampled

A variety of pine nuts, seaweed products, edible seeds, and seed butters were sampled between April 1, 2021, and March 31, 2024. Samples of products were collected from local/regional retail locations in 11 major cities across Canada. These cities encompassed 4 Canadian geographical areas:

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

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
Pine nuts	0	16	1	17
Seaweed products	0	91	1	92
Seeds and seed butters	35	32	7	74
Total	**35**	**139**	**9**	**183**

Table note:

[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 17025 accredited food testing laboratories under contract with the Government of Canada and were reported as they were sold (not prepared according to directions prior to analysis). Although the detection methods often test for 35 or more compounds, only 29 of these (also known as targeted congeners) are the focus of this report[2]. The list of compounds reported as part of this survey are shown in Table A-1 in the Appendix of this report. The concentration of each dioxin or dioxin-like compound detected, reported as picograms per gram of sample (pg/g), is multiplied by its respective World Health Organization (WHO) 2005 consensus Toxic Equivalency Factors (TEFs)[8,9] to calculate the individual toxic equivalency (TEQ) concentration in picograms TEQ per gram of sample (pg TEQ/g). Refer to Table A-1 in the Appendix for the TEFs used in this survey. Each of the calculated individual TEQ concentrations are then added together to arrive at a total TEQ concentration, which is an estimate of the total relative potency of all the dioxins and dioxin-like compounds detected in the sample.

Consistent with international reporting practice, total TEQ results are calculated and reported in terms of both lower bound TEQ (LB TEQ) and upper bound TEQ (UB TEQ) levels of dioxins and dioxin-like compounds. This allows for interpretation of both a best-case (LB TEQ) and a more conservative, worst-case scenario (UB TEQ) estimate of the total TEQ of a sample. LB TEQ levels represent solely the sum of all detected congeners multiplied by their respective TEFs, and congeners not detected are given a value of zero. UB TEQ levels represent the sum of detected forms multiplied by their respective TEFs, plus the sum of the limit of detection (LOD) contributions for all congeners that were not detected, also multiplied by their relevant TEFs. This method of calculating the UB TEQ incorporates levels that may be present below the LOD but still contribute to the total toxicity value. The true TEQ value will be somewhere between the LB TEQ and UB TEQ levels. At very low concentrations, the LB TEQ and UB TEQ values can span a larger range due to measurement uncertainty at low toxicity levels, but the higher the concentrations of the congeners, the closer the LB TEQ and UB TEQ values will be. In an abundance of caution, most global guidance and regulations use the UB TEQ value for compliance[1,10,12,13].

There are no Canadian regulations for total TEQ of dioxin-like compounds (furans and PCBs) in food[11]. In the absence of established tolerances or standards for dioxins 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. Currently, Health Canada is using the Joint Expert Committee on Food Additives' (JEFCA) recommended tolerable monthly intake of 70 picograms of dioxins and dioxin-like compounds per kilogram of body weight per month to assess the safety of foods while they are updating their risk assessments for these compounds[6].

Results of the survey

Of the 183 samples analyzed in this survey, 66% (120 samples) contained dioxins and dioxin-like compounds. The range of levels found is presented in Table 2. Among the 3 product types analysed, the highest average LB and UB TEQ levels were found in dried seaweed products (0.0022 pg TEQ/g and 0.224 pg TEQ/g, respectively).

Table 1. Levels of dioxins and dioxin-like compounds in selected foods

Product type	Total number of samples	Number of samples with detected levels (%)	LB TEQ Average[b] value (range[c]) (pg TEQ/g)	UB TEQ Average[b] value (range) (pg TEQ/g)
Pine nuts	17	10 (59)	0.0006 (<LOD to 0.0045)	0.110 (0.0656 to 0.139)
Seaweed products	92	56 (61)	0.0022 (<LOD to 0.0632)	0.224 (0.222 to 0.281)
Seeds and seed butters	74	54 (73)	0.0016 (<LOD to 0.0474)	0.114 (0.0341 to 0.222)
Total	**183**	**120 (66)**	**0.0018 (<LOD to 0.0632)**	**0.169 (0.0341 to 0.281)**

Table notes:

[b] Only positive results were used to calculate averages.
[c] <LOD = Below the Limit of Detection (dependant on the analyte and analysis method).

Pine nuts

Dioxins and dioxin-like compounds were found in 10 of the 17 pine nut samples tested (59%). The average LB TEQ was 0.0006 pg TEQ/g and the average UB TEQ was 0.110 pg TEQ/g. Pine nuts had the lowest average level and the lowest maximum level of both LB TEQ and UB TEQ among the categories in this survey.

Seaweed products

Seaweeds naturally absorb many substances from the surrounding water and sediment, including both beneficial nutrients and harmful contaminants. When seaweed grows in polluted areas, it can accumulate dioxins, dioxin-like compounds, and other environmental contaminants[17]. The seaweed products tested in this survey were dried, grilled, or roasted seaweed products including seaweed snacks, sushi nori, and dried kelp. Dioxins and dioxin-like compounds were found in 56 of the 92 samples, or 61% of samples. Seaweed products had the highest average levels and the highest maximum levels of both LB TEQ and UB TEQ among the categories in the survey. Health Canada evaluated the levels found in these products and has determined that the products are safe for consumption.

Seeds and seed butters

This survey tested 38 samples of chia, flax, hemp, pumpkin, sesame, and sunflower seeds and 36 samples of pumpkin seed butter, sunflower seed butter, and tahini, for a total of 74 seed product samples. Dioxins and dioxin-like compounds were found in 54 of the 74 samples (73%), and the detection rate in seeds (31 of 38 samples, or 82%) was higher than the detection rate in seed butters (23 of 36 samples, or 64%). The average LB TEQ level in all seed products was 0.0016 pg TEQ/g, and seeds and seed butters had similar average LB TEQ levels (0.0017 pg TEQ/g and 0.0015 pg TEQ/g, respectively). The overall average UB TEQ level was 0.114 pg TEQ/g, and seed butters had a higher overall average UB TEQ level than seed samples (0.134 pg TEQ/g and 0.0957 pg TEQ/g, respectively).

What the survey results mean

Table 3 presents current survey data compared with other surveys where dioxins and dioxin-like compounds were analyzed in similar commodities, including previous CFIA targeted surveys[15,16] and results from 2 international studies that tested seaweed samples[17,18].

Table 3. Minimum, maximum, and average results of dioxins and dioxin-like compounds across various studies

Product type	Survey and year	Total number of samples	Number of samples with detected levels (%)	Average[d] LB TEQ value (pg TEQ/g)	Average[d] UB TEQ value (pg TEQ/g)
Pine nuts	**CFIA 2021 to 2024**	**17**	**10 (59)**	**0.0006**	**0.110**
Pine nuts	CFIA 2014 to 2019	14	13 (93)	0.0141	0.197
Seaweed products - dried	**CFIA 2021 to 2024**	**92**	**56 (61)**	**0.0022**	**0.224**
Fresh seaweed[e]	Hahn et al. 2015	43	32 (74)	0.0441	0.816
Other vegetables, mushrooms, and seaweed[f]	Mato et al. 2007	205	111 (54)	0.0006	NR[g]
Seeds and seed butters	**CFIA 2021 to 2024**	**74**	**54 (73)**	**0.0016**	**0.114**
Seeds and seed butters	CFIA 2014 to 2019	42	41 (98)	0.0046	0.0990
Seeds and seed butters	CFIA 2011	11	11 (100)	0.0662	0.240

Table notes:

[d] Only positive results were used to calculate averages.
[e] Hahn et al. reported PCDD/PCDF in fresh seaweed and did not include DL-PCBs.
[f] The Japanese Total Diet Study reported by Mato et al. combined data from seaweed with mushrooms and non-green vegetables.
[g] NR: Not reported.

The average LB TEQ and UB TEQ levels of dioxins and dioxin-like compounds found in this survey are comparable to, or lower than, the comparison studies. Differences can likely be attributed to the types of samples tested in each survey period and/or the amount of environmental contamination present in different parts of the world where the samples originated[1,7]. Another possible cause is that the dioxins and dioxin-like compound contamination of the environment is decreasing after Canada and many other countries began implementing regulations to prevent emissions and monitor environmental levels of these contaminants in the 1990s[6,14].

The levels observed in this survey were evaluated by Health Canada's Bureau of Chemical Safety and none of the samples were determined to pose a safety concern to human health.

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. Limits of detection and WHO Toxic Equivalency Factors (TEFs) for dioxins and dioxin-like compounds

Compound	Congener	LOD range[h] (pg/g)	TEF[i]
Dioxins	2,3,7,8-TCDD	0.01 to 0.047	1
	1,2,3,7,8-PeCDD	0.043 to 0.05	1
	1,2,3,4,7,8-HxCDD	0.03 to 0.084	0.1
	1,2,3,6,7,8-HxCDD	0.02 to 0.059	0.1
	1,2,3,7,8,9-HxCDD	0.035 to 0.04	0.1
	1,2,3,4,6,7,8-HpCDD	0.03 to 0.083	0.01
	1,2,3,4,6,7,8,9-OCDD (or OCDD)	0.202 to 0.31	0.0003
Furans	2,3,7,8-TCDF	0.01 to 0.036	0.1
	1,2,3,7,8-PeCDF	0.03 to 0.053	0.03
	2,3,4,7,8-PeCDF	0.054 to 0.06	0.3
	1,2,3,4,7,8-HxCDF	0.03 to 0.099	0.1
	1,2,3,6,7,8-HxCDF	0.03 to 0.093	0.1
	1,2,3,7,8,9-HxCDF	0.05 to 0.093	0.1
	2,3,4,6,7,8-HxCDF	0.01 to 0.087	0.1
	1,2,3,4,6,7,8-HpCDF	0.03 to 0.098	0.01
	1,2,3,4,7,8,9-HpCDF	0.04 to 0.069	0.01
	1,2,3,4,6,7,8,9-OCDF (or OCDF)	0.09 to 0.162	0.0003
Dioxin-like PCBs	3,3',4,4'-TeCB (PCB 77)	0.008 to 0.4	0.0001
	3,4, 4',5-TeCB (PCB 81)	0.14 to 0.36	0.0003
	2,3,3',4,4'-PeCB (PCB 105)	0.11 to 0.35	0.00003
	2,3,4,4',5-PeCB (PCB 114)	0.13 to 0.35	0.00003
	2,3',4,4',5-PeCB (PCB 118)	0.07 to 0.42	0.00003
	2',3,4,4',5-PeCB (PCB 123)	0.14 to 0.48	0.00003
	3,3',4,4',5-PeCB (PCB 126)	0.09 to 0.42	0.1
	2,3,3',4,4',5-HxCB (PCB 156)	0.14 to 0.41	0.00003
	2,3,3',4,4',5'-HxCB (PCB 157)	0.14 to 0.42	0.00003
	2,3',4,4',5,5'-HxCB (PCB 167)	0.06 to 0.39	0.00003
	3,3',4,4',5,5'-HxCB (PCB 169)	0.1 to 0.38	0.03
	2,3,3',4,4',5,5'-HpCB (PCB 189)	0.09 to 0.32	0.00003

Table notes:

[h] LOD: Method limit of detection depends on the analyte and analysis method.
[i] TEF: Toxic Equivalency Factor (2005 WHO TEF values)[8,9].