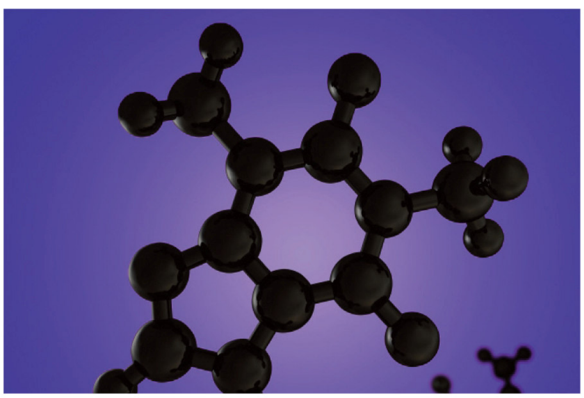
Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

Food Safety Action Plan

REPORT

2010-2011 Targeted Surveys

Chemistry



Dioxins and Dioxin-like Compounds in Vegetable Oils and Cheese

TS-CHEM-10/11-8

Canada

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Executive Summary

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

The main objective of this targeted survey was to provide baseline data regarding the presence and levels of dioxins and dioxin-like compounds in selected high-fat commodities (specifically vegetable oils and cheese) available on the Canadian retail market.

Dioxins and dioxin-like compounds are chemical contaminants that have been associated with a wide range of adverse health effects in laboratory animals and humans. The type and occurrence of these effects typically depend on the level and duration of exposure. Some of the dioxins and dioxin-like compounds have been classified by the International Agency for Research on Cancer (IARC) as known human carcinogens, others as probable human carcinogens, while others are not classifiable as to their carcinogenicity[i] in humans. The World Health Organization (WHO) considers dioxins and dioxin-like compounds a health concern on a global scale, and has recently re-iterated the need to reduce emissions of, and human exposure to, these persistent organic pollutants. Approximately 90% of a person's exposure to dioxins and dioxin-like compounds occurs through the diet, particularly through the consumption of high-fat animal tissues and dairy products. Due to recent food contamination events outside Canada, dioxins and dioxin-like compounds have gained attention in the media.

A total of 451 samples were collected and analyzed in this targeted survey. Samples included 167 domestic and imported vegetable oils and 284 domestic, intra-provincially traded cheeses. All samples were analyzed for dioxins and dioxin-like compounds (furans and polychlorinated biphenyls). All oil and cheese samples had detectable levels of one or more dioxins or dioxin-like compounds. This is not unexpected given their presence and persistence in the environment, as well as their ability to bioaccumulate in fatty tissues and biomagnify through the food chain.

The Canadian *Food and Drug Regulations* (FDR) state that food (with the exception of fish) which contains chlorinated dibenzo-*p*-dioxins is adulterated. The regulation causes enforcement challenges, as it does not reflect the large improvements that have been

[i] IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. *Polychlorinated Dibenzo-para-dioxins and Polychlorinated Dibenzofurans* Volume 69.[online]. Published 1997. Accessed April 2012, http://monographs.iarc.fr/ENG/Monographs/vol69/index.php

made to analytical methods of detection for these substances. This tolerance was established many years ago and is considered to be outdated by Health Canada. Due to the ubiquitous nature of dioxins and dioxin-like compounds in the environment, and the fact that methods of detection are becoming increasingly sensitive, “zero tolerance” is not practical and is not applied by Canada or any major trading partners. No samples in this survey had concentrations of dioxins or dioxin-like compounds in excess of European Union limits for either vegetable oils or dairy products. In fact, the levels detected were well below these limits. The levels of dioxins and dioxin-like compounds observed in this survey are unlikely to contribute significantly to the overall exposure of Canadians to these contaminants, and are not likely to be of human health concern. Follow-up activities were not deemed necessary given that no elevated concentrations were found and the levels were similar to those detected in domestic raw milk monitoring data.

1 Introduction

1.1 Food Safety Action Plan

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

The Canadian Food Inspection Agency's (CFIA's) Food Safety Action Plan (FSAP) is one element of the government's broader FCSAP initiative. The goal of FSAP is to identify risks in the food supply, limit the possibility that these risks occur, improve import and domestic food controls and identify food importers and manufacturers. FSAP also looks to verify that the food industry is actively applying preventative measures, and that there is a rapid response when/if these measures fail.

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

1.2 Targeted Surveys

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

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

The chemical contaminants of focus in this survey, dioxins and dioxin-like compounds, are considered a health concern on a global scale. Dioxins and dioxin-like compounds (polychlorinated dibenzo-p-furans and certain polychlorinated biphenyls) refer to a group of compounds with similar chemical and biological properties. They are persistent organic pollutants, able to travel long distances from the source of emissions, and biomagnify in the food chain. The human health risks associated with exposure to dioxins and dioxin-like compounds have been well-documented. The World Health Organization (WHO) has recently re-iterated the need to reduce emissions of and human exposure to these substances[1]. Many countries, including Canada, have taken efforts to reduce exposure of the public to dioxins and dioxin-like compounds, including through food[2]. It was considered appropriate to perform a dioxin targeted survey to examine whether dioxins and dioxin-like compounds could be detected in products not routinely monitored under the National Chemical Residue Monitoring Program (NCRMP).

1.3 Acts and Regulations

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

Health Canada establishes the health-based maximum levels for chemical residues and contaminants in food sold in Canada. Regulation B.01.046 (1) (p) of the FDAR suggests that any food, with the exception of fish (B.01.046 (f)), containing chlorinated dibenzo-*p*-dioxins is considered adulterated. No similar regulation exists in the FDAR for the dioxin-like compounds. The regulation for dioxins causes enforcement challenges, as the absence of these fat-soluble contaminants from certain animal-based and high-fat foods is difficult to achieve, and it does not reflect the large improvements that have been made to analytical methods of detection for these substances. This tolerance was established many years ago and is considered to be outdated by Health Canada. At the time the Regulation was developed, foods not thought to contain dioxins using the available analytical methods can now be seen, using much more sensitive methods, to actually contain very low levels of dioxins, and the total absence of these compounds is rare.

Health Canada assesses any findings of elevated levels of dioxins and dioxin-like compounds in food on a case-by-case basis using the most current scientific data available to determine if there is a potential health risk. If levels of dioxins and dioxin-like compounds in food are deemed to pose a health concern, appropriate corrective actions (such as public recalls and product detention) may be taken by the CFIA, based on Part 1, Section 4 of the Canadian *Food and Drug Act (FDA).*

Health Canada is currently conducting a re-assessment of the risks posed by, and standards for, dioxins and dioxin-like compounds, and in the interim has adopted the Joint Expert Committee on Food Additives (JECFA) tolerable monthly intake for dioxins and dioxin-like compounds as a guideline for Canadians[3].

The European Union has established maximum levels for total dioxins (which includes dioxins, furans, and dioxin-like polychlorinated biphenyls, or PCBs) in various foodstuffs, including dairy and vegetable oils and fats. Many European countries apply these limits in lieu of establishing domestic regulations. Refer to Table A in the Appendix for a summary of maximum levels for dioxins and dioxin-like compounds in selected commodities in various countries.

2 Survey Details

2.1 Dioxins and Dioxin-Like Compounds

2.1.1 General background and formation

Dioxins and dioxin-like compounds are a group of chemicals with similar biological and chemical properties. Generally speaking, dioxins and dioxin-like compounds consist of three groups of chemicals with related structures. These are polychlorinated dibenzo-*p*-dioxins (referred to as dioxins or PCDDs), polychlorinated dibenzofurans (called furans or PCDFs), and a small group of polychlorinated biphenyls (referred to as dioxin-like PCBs).

There are 75 congeners (different structural forms) of dioxins. Only 17 of these congeners are considered to be of toxicological concern, and seven of these congeners are regarded as highly toxic[4]. The most toxic dioxin congener is 2,3,7,8-tetrachlorodibenzodioxin (TCDD). There are 135 furan congeners, ten of which display "dioxin-like" toxicological properties. Additionally, there are 12 dioxin-like PCB congeners that display "dioxin-like" properties with respect to toxicity.

For the sake of simplicity in this report, these three groups of compounds will be referred to as dioxins and dioxin-like compounds, and consist of 29 congeners of toxicological concern. Please refer to Figure A in the Appendix for the chemical structures of dioxins, furans, and PCBs.

Dioxins and furans are mainly formed incidentally 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). These contaminants are not deliberately manufactured. However, PCBs are manmade, and often contain polychlorinated dibenzo-p-furan contaminants. PCB production is now banned globally. Dioxins and dioxin-like compounds are ubiquitous contaminants, and are recognized as causing adverse effects on humans and the ecosystem by the Stockholm Convention on Persistent Organic Pollutants[5] (an international treaty requiring parties to eliminate or reduce the release of these contaminants into the environment). Although production and use of dioxins and dioxin-like compounds is prohibited[6], low levels are still detected in many foods because of their persistence and prior, extensive environmental contamination.

2.1.2 Health Effects

Dioxins and dioxin-like compounds are not easily broken down in the environment or by biological processes, which allows them to persist. They are insoluble in water and highly soluble in fat. Dioxins and dioxin-like compounds readily transfer from the environment to smaller, less complex organisms, then successively to larger predators, and consequently increase in concentration as they biomagnify through the food chain. Once dioxins have entered the human body, they are stored in the fat tissue, where they are estimated to have a half-life of seven to eleven years[7].

Toxicological studies show that dioxins and dioxin-like compounds have the potential to produce a range of toxic effects on animals and humans. Human health effects associated with exposure to dioxins and dioxin-like compounds include skin disorders (e.g. chloracne), liver and thyroid problems, impairment of the endocrine, nervous, reproductive, and immune systems, developmental effects, and certain types of cancers[3]. Developmental effects have been noted at very low levels of dioxins and dioxin-like compounds, making children (including the developing fetus) the population most at risk. Breast-fed infants, with rapidly developing organ systems, are particularly vulnerable to the levels of dioxins and dioxin-like compounds in breast milk[8].

JECFA established a provisional tolerable monthly intake (PTMI) of 70 picograms of dioxins and dioxin-like compounds per kilogram of body weight per month[8], aimed at reducing exposure through diet. This dioxin PTMI has been adopted by many countries, including Canada.

2.1.3 Comparing Dioxins, Furans, and Dioxin-Like PCBs

As previously discussed, there are a large number of compounds included in the dioxin family, with varying levels of toxicity. This poses a challenge when trying to quantify the risk posed by a particular mix of dioxins and dioxin-like compounds. It is not appropriate to simply measure the concentrations of each congener of concern and add them together to arrive at a total concentration. To accurately assess the health impact of these compounds, the concept of Toxic Equivalence (TEQ) and the use of Toxic Equivalency Factors (TEFs) are generally applied.

The dioxin congener 2,3,7,8-TCDD is considered the most toxic form of all dioxins and dioxin-like compounds. Relative to 2,3,7,8-TCDD, other congeners of toxicological concern are less toxic. In order to "normalize" the toxicity of the 29 congeners of concern, 2,3,7,8-TCDD was assigned a TEF value of 1. The other 28 congeners of concern were given a TEF[4] ranging from 0.00003 to 1. Please refer to Table B in the Appendix for a summary of WHO TEFs used in this survey.

The concentration of each congener detected is multiplied by its respective TEF. This result is referred to as a Toxic Equivalence (TEQ). The TEQ allows for relevant comparison of the detected congeners. Each of the newly calculated TEQs are then summed to arrive at a total TEQ, which gives a more accurate depiction of all the dioxins and dioxin-like compounds detected.

2.2 Dioxins in Food

For most Canadians, about 90% of overall exposure to dioxins and dioxin-like compounds comes through diet[3]. The majority of dioxin intake has been attributed to the consumption of animal tissues and dairy products. These commodities are highest in animal fat, which is the primary site of storage of dioxins once an animal has ingested this type of contaminant. These contaminants bioaccumulate with continued exposure over the lifetime of an animal as they consume contaminated feed and plants. Consequently, consuming high-fat animal products can contribute significantly to the dietary intake of dioxins and dioxin-like compounds by humans.

Dioxins and dioxin-like compounds have been found at low levels in feed and plant material due to deposition on plant surfaces and soil. Food and feed products made from these plants, particularly oily plants, may also contain dioxins and dioxin-like compounds[9].

There have been recent incidents involving dioxin contamination of food products of animal origin as a direct result of dioxin-contaminated feed. Most recently, high levels of dioxins were found in eggs in Germany, the cause of which was ingestion of dioxin-contaminated feed by laying chickens[10]. Other noted cases of dioxin contamination in the food supply have involved pork, chicken, beef, milk and guar gum (a food additive used in a wide range of food products)[11,12].

2.3 Rationale

Dioxins and dioxin-like compounds are well-documented as being some of the most toxic chemicals known and are detrimental to human health. These contaminants have gained attention in the media due to recent food contamination events. Although these incidents generally did not affect products manufactured or sold in Canada, they highlighted the need for baseline data gathering on select foods available in the Canadian marketplace.

It was considered appropriate to conduct a targeted survey examining levels of dioxins and dioxin-like compounds in high-fat commodities which are outside the scope of normal CFIA monitoring activities (dioxins are monitored in domestic raw milk, select animal fats, and eggs by the CFIA's NCRMP). Canadians consume significant quantities of cheese and oils/fats per year, with approximately 12 kg and 25 kg available for consumption respectively in 2009[13,14]. For these reasons, vegetable oils and cheeses have been targeted.

Currently, Health Canada is comprehensively reassessing the risks posed to Canadians by dioxins and dioxin-like compounds. The oils and cheeses examined in this survey may help Health Canada as they conduct their reassessment of the risks posed by dioxins and dioxin-like compounds.

2.4 Sample Distribution

In 2010-11, a total of 451 samples were collected from 10 different cities across Canada. Of these 451 samples, 167 were domestic and imported vegetable oils. The remaining 284 samples were all domestic, intra-provincially traded cheeses (cheeses produced and sold within the same province). As CFIA does not test intra-provincially traded goods under the NCRMP, the information presented here is complementary to the information available through regular monitoring.

Vegetable oils sampled included a variety of single oil types (e.g. olive, sesame), as well as "vegetable oils", which are marketed as blends of different oil types. Please refer to Figure 2.1 below for details about vegetable oil types collected.

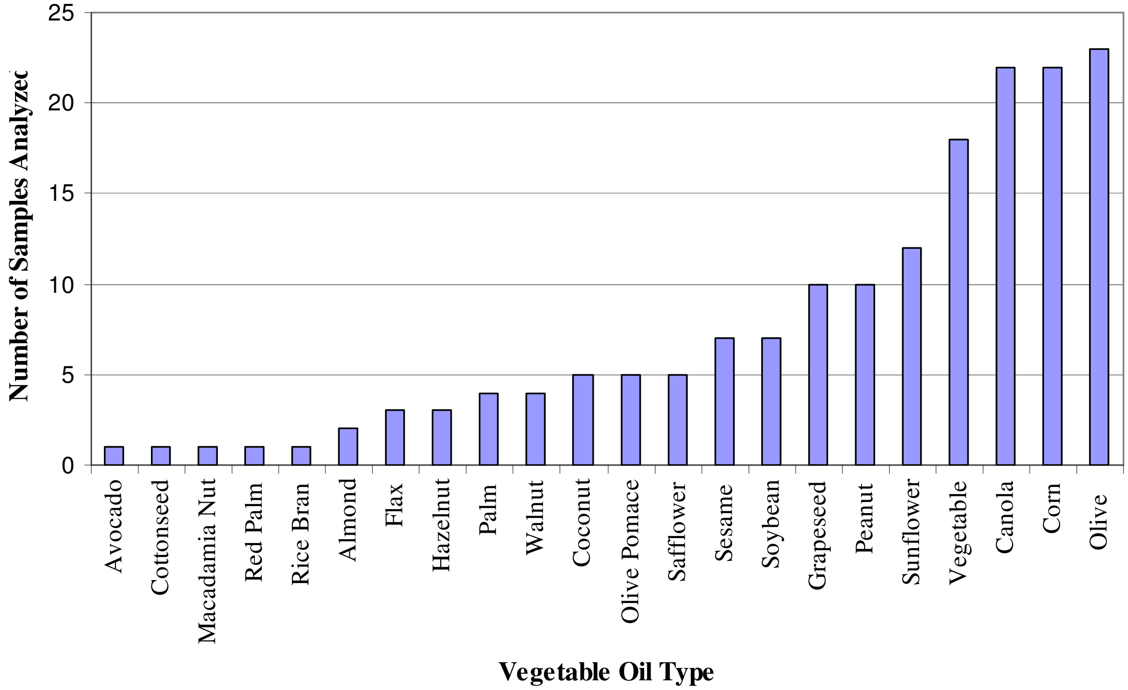


Figure 2.1 – Distribution of samples by vegetable oil type

A wide variety of cheese types were collected but it was not possible to unequivocally categorize the samples. Cheese varieties are often grouped according to texture, moisture and fat content, source of the milk (i.e. animal species), ageing, production method, and origin; however, no single method of classification is universally used. The grouping most commonly used is based on moisture content, which is then followed by fat content and ripening method. The following Table 2.1 generally describes some of the categories of cheeses sampled in this survey[15].

Table 2.1 - Approximate fat content of cheese and typical examples

Approximate fat content of cheese	Description	Examples of cheeses by fat content
0.5-30%	Fresh (coagulated) or stretched curd (“Fresh”)	Ricotta, curds, cottage, paneer, cream, quark, Neufchâtel, mascarpone, chèvre, bocconcini, haloumi, mizithra
20-32%	Soft-ripened (“Soft”)	Brie, Camembert, feta, blue, Gorgonzola
24-31%	Semi-hard washed (“Semi-soft”)	Colby, Gouda, brick, Edam, fontina, Havarti, Munster, raclette
21-34%	Hard (low temperature) (“Semi-hard”)	Oka, mozzarella, Cheddar, provolone, Manchego, Emmental, Gruyère, Tilsit
25-30%	Hard (high temperature) (“Hard”)	Parmesan, Asiago, Romano, Swiss, pecorino

Please refer to Figure 2.2 below for details about categories of cheese analyzed. Note that for some cheeses sampled, it was not possible to verify which category of cheese was appropriate to use, so these were grouped as “Unverifiable”.

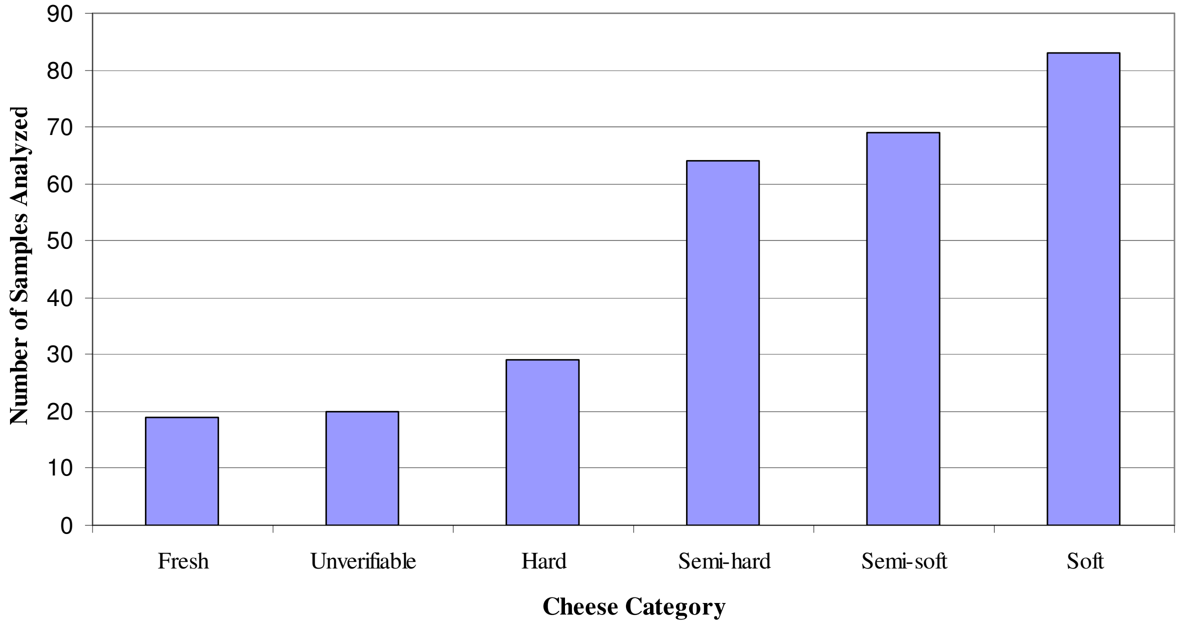


Figure 2.2 – Distribution of samples by cheese category

2.5 Method Details

Samples in the dioxin targeted survey were analyzed by laboratories under contract to the Government of Canada. These laboratories are accredited to ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories* (or its equivalent) by the Standards Council of Canada (SCC).

Two methods were used to analyze for dioxins and dioxin-like compounds in vegetable oils and cheeses. The first method used was developed for the determination of dibenzo-*p*-dioxins and dibenzofurans in beans, fish, eggs, dairy, solid vegetation, and other sample matrices by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS), and cites the United States Environmental Protection Agency (US EPA) reference method 1613B. The second method used has been validated for the determination of polychlorinated biphenyls in meat, fish, eggs, dairy products, and solid vegetation also by HRGC/HRMS, and cites the US EPA reference method 1668a. Both methods were used for all samples.

Consistent with international reporting practice, the methods calculate and report dioxin results in terms of both lower bound and upper bound levels. This allows for interpretation of both a best-case (lower bound) and a more conservative, worst-case scenario (upper bound) estimate of the actual total TEQ of a sample. Lower bound levels represent solely the sum of all detected congeners multiplied by their respective TEFs (non-detected congeners are given a value of zero). Upper bound levels represent the sum of detected congeners multiplied by the relevant toxic equivalency factor (TEF), plus the sum of the limit of detection (LOD) contributions for non-detected congeners, also multiplied by their relevant TEFs. See Figure B in the Appendix for a visual depiction of the lower bound/upper bound concept. Please refer to Table B in the Appendix for detection limits and applicable 2005 WHO TEFs for the 29 congeners of concern.

2.6 Limitations

The dioxin survey was designed to provide a snapshot of the levels of dioxins and dioxin-like compounds in vegetable oils and intra-provincially traded cheeses available to Canadian consumers. In comparison to the total number of oils and cheeses in the Canadian market, 451 samples represent a small fraction of products available to consumers. Therefore, care must be taken with interpretation and extrapolation of these results. Regional (country or province of origin) differences, year-to-year trends, impact of product shelf life, or cost of the commodity on the open market are not examined in this survey.

3 Results and Discussion

All total TEQ concentrations are reported as the sum of dioxins and dioxin-like PCBs (WHO-PCDD/F-PCB-TEQ) in pg/g fat unless otherwise stated, and will be noted as pg TEQ/g hereafter for simplicity. As previously mentioned, calculations were made on the basis of the 2005 WHO TEFs[4]. The use of 2005 TEF values was taken into consideration when comparing results from this survey with other dioxin datasets that use 1998 TEF values.

3.1 Vegetable Oil Results

A total of 167 samples of vegetable oil were collected over the course of the 2010-11 sampling year. Thirty-four samples were of domestic origin, 106 were imported products, and 27 samples were of unverifiable origin. Table 3.1 below shows the total TEQ average and maximum values calculated as both the lower bound (LB) and upper bound (UB) limit for each oil type tested.

Table 3.1 - Maximum and average total TEQ values in vegetable oil samples
(Sample types are arranged in order of decreasing average LB total TEQ values)

Vegetable Oil Type	Number of Samples	Maximum Total TEQ Value (pg TEQ/g fat)		Average Total TEQ Value (pg TEQ/g fat)	
		LB	UB	LB	UB
Rice Bran	1	0.5654	0.8628	0.5654	0.8628
Olive Pomace	5	0.6515	0.8968	0.2152	0.5261
Almond	2	0.2622	0.6094	0.1756	0.5409
Safflower	5	0.5935	0.8837	0.1629	0.5136
Walnut	4	0.4234	0.6468	0.1621	0.4890
Sesame	7	0.3916	0.6957	0.1553	0.4957
Grapeseed	10	0.6273	0.8867	0.1519	0.5179
Olive	23	0.4495	0.8108	0.1473	0.5035
Peanut	10	0.6697	1.0130	0.1063	0.4815
Corn	22	0.2835	0.6400	0.0810	0.4477
Canola	22	0.5859	0.9093	0.0800	0.4510
Flax	3	0.1516	0.5017	0.0771	0.4560
Soybean	7	0.2317	0.5049	0.0764	0.4286
Hazelnut	3	0.1026	0.4520	0.0730	0.4384
Vegetable	18	0.5829	0.8983	0.0673	0.4465
Sunflower	12	0.2450	0.6003	0.0483	0.4279
Cottonseed	1	0.0385	0.4220	0.0385	0.4220
Coconut	5	0.0758	0.4190	0.0279	0.4044
Macadamia Nut	1	0.0271	0.4006	0.0271	0.4006
Palm	4	0.0499	0.4123	0.0230	0.4041
Red Palm	1	0.0201	0.4134	0.0201	0.4134
Avocado	1	0.0104	0.4028	0.0104	0.4028
Total	167				
Overall Maximum		0.6697	1.0130		
Overall Average				0.1027	0.4673

The three highest LB total TEQ concentrations detected were found in peanut oil (0.6697 pg TEQ/g), olive pomace oil (0.6515 pg TEQ/g), and grapeseed oil (0.6273 pg TEQ/g). The three highest UB total TEQ concentrations detected were found in peanut oil (1.0130 pg TEQ/g), canola oil (0.9093 pg TEQ/g), and vegetable oil (0.8983 pg TEQ/g).

Olive pomace oil had the highest average LB total TEQ concentration detected at 0.2152 pg TEQ/g, while palm oil had the lowest average LB total TEQ concentration at 0.0230 pg TEQ/g (excluding oil types with only a single sample). Almond oil had the highest average UB total TEQ concentration detected at 0.5409 pg TEQ/g, while macadamia nut oil had the lowest average UB total TEQ concentration at 0.4006 pg TEQ/g (excluding oil types with only a single sample).

The relative TEQ contribution of each compound type (dioxin, furan, and PCB) to the LB total TEQ was considered. The detected dioxin TEQs were summed for each sample. Similar sums were obtained for furans and PCBs. For each sample, the main contributor, or "driver", to the sample's overall total TEQ was deemed to be the highest of these three summed TEQ values. The drivers for each vegetable oil type were collated. There appeared to be no distinct pattern with respect to a single type of compound (dioxin, furan, or PCB) being the main contributor/driver to the overall total TEQ for any type of vegetable oil, or for vegetable oils in general (see Figure 3.1 below).

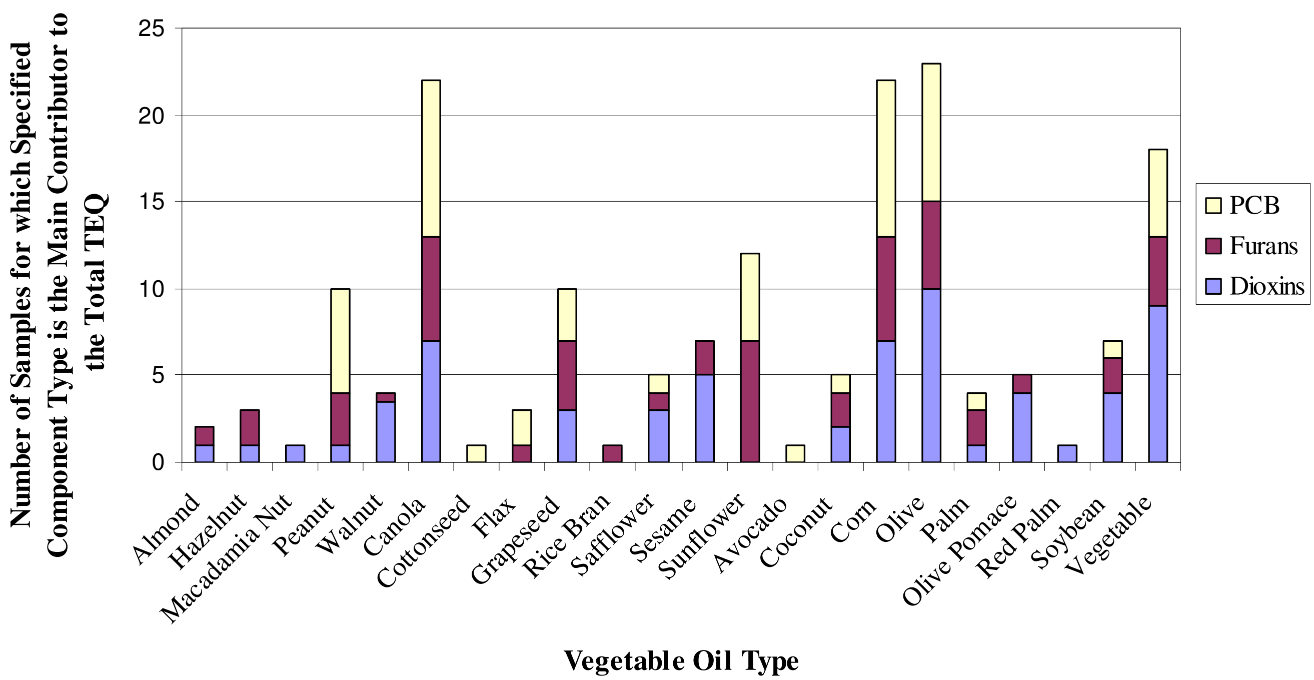


Figure 3.1 - Main contributor (dioxins, furans, or PCBs) to the LB total TEQ per vegetable oil type

None of the vegetable oil samples analyzed in this survey contained dioxins and dioxin-like compounds in excess of the 1.25 pg TEQ/g European Union limit[16] for the sum of dioxins and dioxin-like compounds in vegetable oils and fats (which is conservatively based on a worst-case exposure scenario), and in fact were well below this limit. This was true for both the lower bound and upper bound total TEQ concentrations. See Figure 3.2 below, in which both the vegetable oil type maximum LB and UB concentrations are depicted.

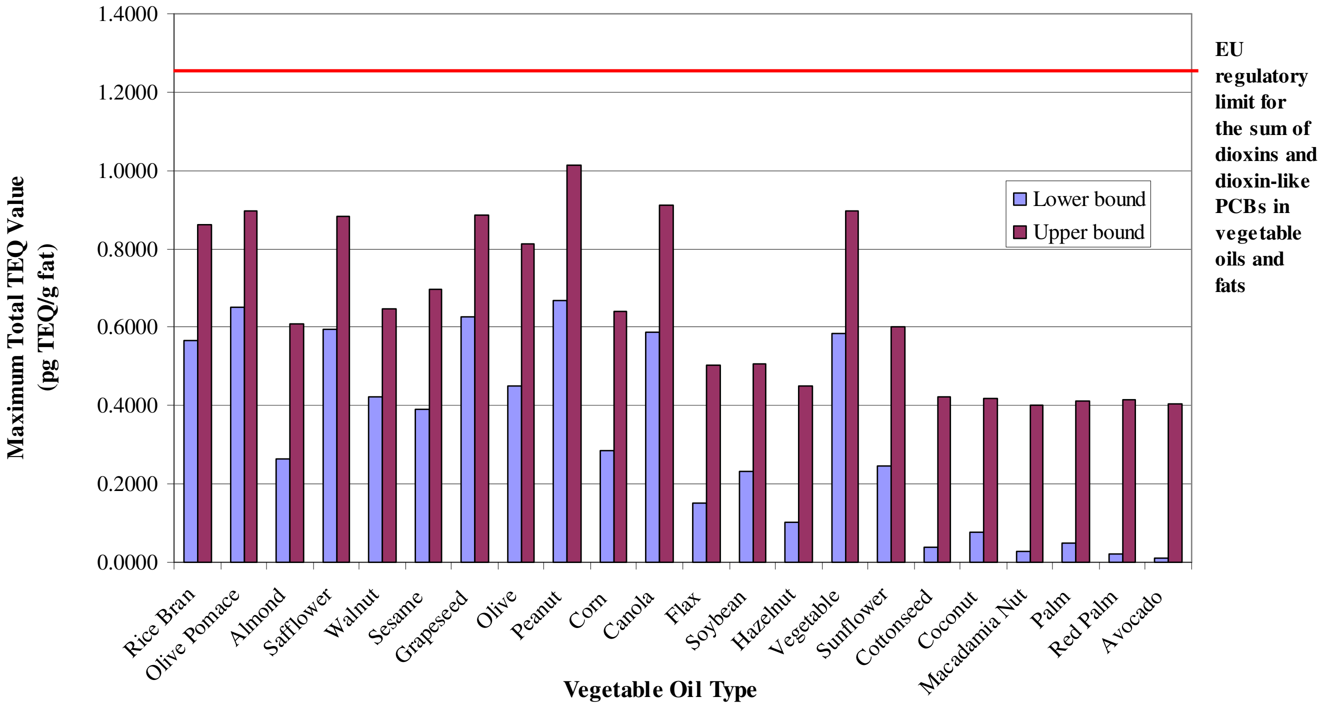


Figure 3.2 - Maximum lower bound and upper bound total TEQ detected per vegetable oil type

3.2 Cheese Results

A total of 284 domestic cheese samples were collected during the 2010-11 sampling year. The intent of the survey was to sample cheeses that were both manufactured and sold within the same province (i.e. intra-provincially traded), as these types of products are not generally monitored on a national scale. However, some inter-provincially traded cheeses may have been sampled during the survey unintentionally.

A wide variety of cheese was sampled, and given that no single method of classification is universally used, the grouping was based on approximate moisture/fat content. Cheese categories included fresh/curd ("fresh", e.g. cottage, curds, ricotta), soft-ripened ("soft", e.g. Brie, Camembert, feta), semi-hard washed ("semi-soft", e.g. Edam, Havarti, raclette), hard low-temperature ("semi-hard", e.g. Oka, Cheddar, Emmental), and hard high-temperature ("hard", e.g. Asiago, Romano, Parmesan). Many artisan-style cheeses were included in each category. Table 3.2 below shows the total TEQ average and maximum values calculated as both the LB and UB limit for each cheese category tested.

Table 3.2 - Maximum and average total TEQ values in cheese samples
(Sample types are arranged in order of decreasing average LB total TEQ values)

Cheese Type	Number of Samples	Maximum Total TEQ Value (pg TEQ/g fat)		Average Total TEQ Value (pg TEQ/g fat)	
		LB	**UB**	**LB**	**UB**
Semi-soft	69	3.2476	3.5328	0.2817	0.6144
Hard	29	1.1631	1.4785	0.2707	0.5893
Semi-hard	64	0.9390	1.1184	0.2674	0.5992
Soft	83	1.7492	2.0305	0.2159	0.5525
Unverifiable	20	0.4894	0.7371	0.1739	0.5188
Fresh	19	0.8760	1.1994	0.1551	0.5060
Total	284				
Overall Maximum		3.2476	3.5328		
Overall Average				0.2421	0.5763

The three highest LB total TEQ concentrations detected were found in a Port Salut-type semi-soft cheese (3.2476 pg TEQ/g), an organic goat feta soft cheese (1.7492 pg TEQ/g), and a mini Friulano-type hard cheese (1.1631 pg TEQ/g). The three highest UB total TEQ concentrations detected were found in the same cheeses: Port Salut-type semi-soft cheese (3.5328 pg TEQ/g), organic goat feta soft cheese (2.0305 pg TEQ/g), and mini Friulano-type hard cheese (1.4785 pg TEQ/g).

Semi-soft cheeses had the highest average LB total TEQ concentration detected at 0.2817 pg TEQ/g, while fresh cheeses had the lowest average LB total TEQ concentration at 0.1551 pg TEQ/g. Semi-soft cheeses had the highest average UB total TEQ concentration detected at 0.6144 pg TEQ/g, while fresh cheeses again had the lowest average UB total TEQ concentration at 0.5060 pg TEQ/g.

As with vegetable oils, the relative TEQ contribution of each compound type (dioxin, furan, and PCB) to the lower bound total TEQ in each cheese sample was considered. The detected dioxin TEQs were summed for each sample. Similar sums were obtained for furans and PCBs. For each sample, the main contributor, or “driver”, to the sample’s overall total TEQ was deemed to be the highest of these three summed TEQ values. The drivers for each cheese category were collated.

In contrast to the case in vegetable oils (where no dominant contributor was apparent), dioxins generally appeared to be the dominant contributor across all cheese types, this being the case in approximately 57% of the cheese samples. In addition, dioxins, furans, and PCBs were all present as drivers in each cheese category. There does not appear to be an obvious relationship between the category of cheese sampled and the level of dioxins and dioxin-like compounds detected (on a fat basis) (Figure 3.3).

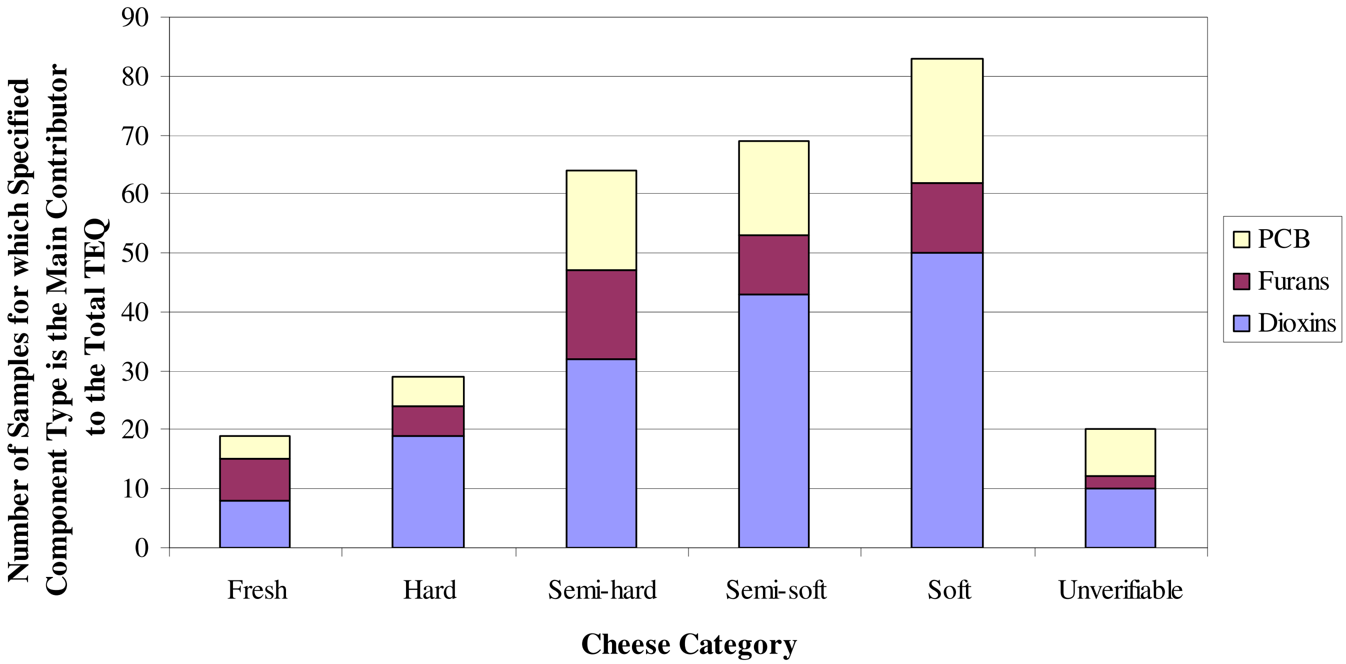


Figure 3.3 - Main contributor (dioxins, furans, or PCBs) to the LB total TEQ per cheese category

None of the cheese samples analyzed in the 2010-2011 survey contained dioxins and dioxin-like compounds in excess of the 5.5 pg TEQ/g European Union limit[16] for the sum of dioxins and dioxin-like compounds in dairy products (which is conservatively based on a worst-case exposure scenario), and were actually well below this limit. This was true for both the lower bound and upper bound total TEQ concentrations. See Figure 3.4 below, in which both maximum lower bound and upper bound concentrations are depicted for each cheese category.

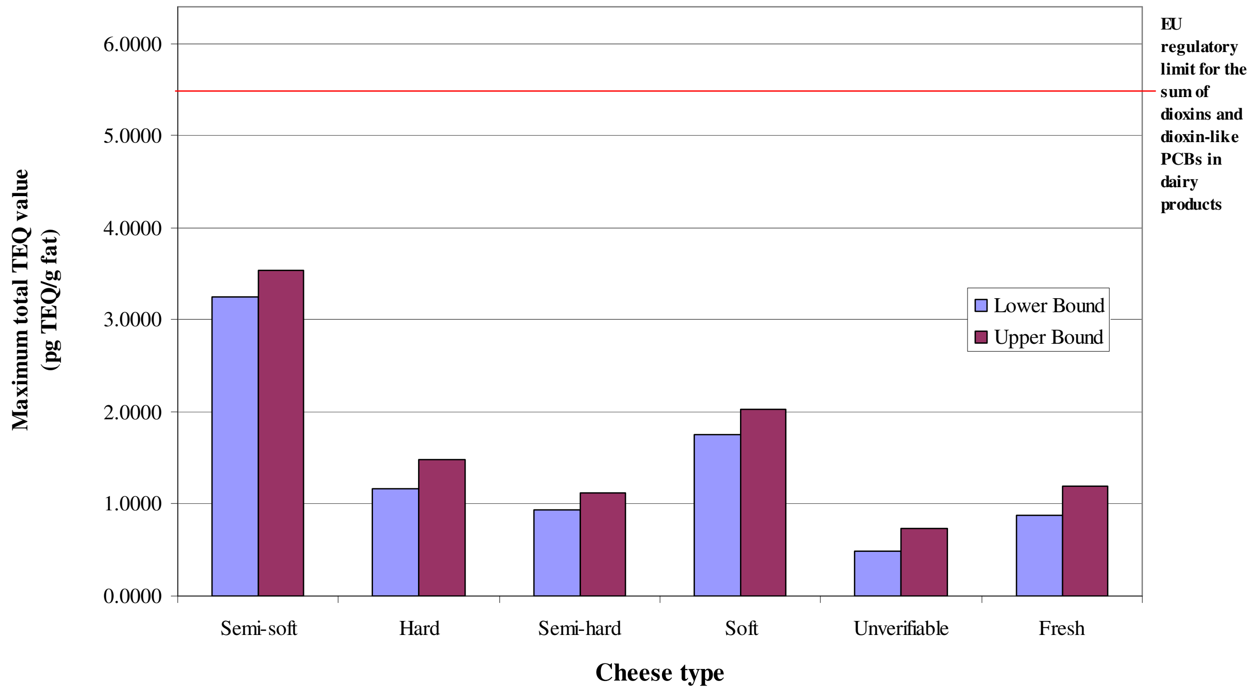


Figure 3.4 Maximum lower bound and upper bound total TEQ detected per cheese type

3.3 Comparison and Discussion of Oil and Cheese Results

In general, the average total TEQ levels were lower in vegetable oils than in cheese samples on a fat basis. This is consistent with animal fats (i.e. milk fat) bioaccumulating more dioxins and dioxin-like compounds than plant fats. As mentioned previously, there did not appear to be a consistent driver for the total TEQ (lower bound) in the case of vegetable oils (i.e. the percentages of each driver type were similar). This was in contrast to the case for cheese, where dioxins appeared to be the dominant contributor across all cheese types. This is not unexpected given the wide range of raw sources for the vegetable oils analyzed (e.g. nuts, seeds, vegetables), which contrasts sharply with the distinct source for cheese production, milk.

Dioxin levels in domestic raw cow's milk monitored under the CFIA's National Chemical Residue Monitoring Program (from April 1, 2008 to December 31, 2011)[17] were compared to the results of this survey. The intent of the comparison to the milk data was to investigate whether any relationship exists between the type of commodity (plant or animal origin) and the dioxin compounds observed/drivers. Overall, the average concentrations of dioxins, furans, and PCBs were similar in the current survey samples relative to domestic raw milk samples.

It appeared that dioxins and PCBs tended to be the greatest contributors to the lower bound total TEQ in milk and cheese, relative to oil (refer to Figure 3.5 below). The apparently sharp contrast between the furan driver proportion in raw milk and in cheese may be due to slight differences in the minimum concentrations that can be detected by a given laboratory (cheeses were analyzed by laboratories under contract with the Government of Canada and milk was analyzed at a CFIA laboratory). The contrast may also be affected by the fact that the cheeses sampled were produced from various types of milk, and the domestic raw milk was sampled from cow only.

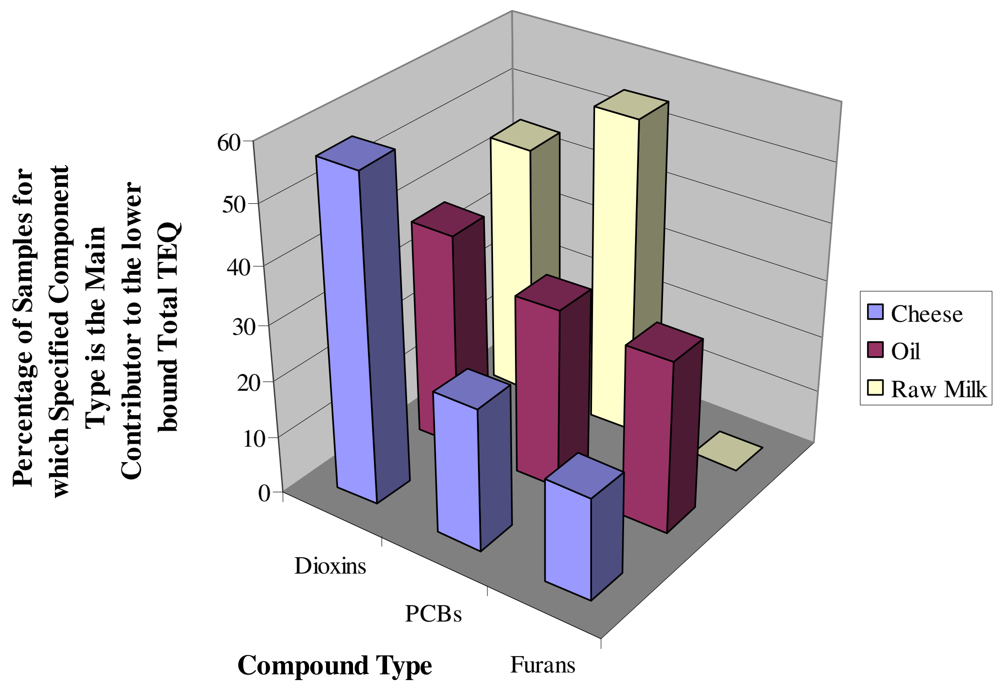


Figure 3.5 Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by commodity

Canadian Total Diet Study (TDS) results[18] produced by Health Canada (which include some samples of oil and cheese) report dioxin and dioxin-like compound concentrations on a whole weight basis, not a fat weight basis, and therefore cannot be easily compared to the survey data.

4 Conclusions

Dioxins and dioxin-like compounds are associated with a range of adverse health effects. Health Canada is re-assessing the risks posed by these contaminants and will consider any further risk management measures that may be necessary for these contaminants. The

Canadian regulation for chlorinated dibenzo-*p*-dioxins causes enforcement challenges, as the absence of these fat-soluble contaminants from certain animal-based and high-fat foods is difficult to achieve, and it does not reflect the large improvements that have been made to analytical methods of detection for these substances. This tolerance was established many years ago and is considered to be outdated by Health Canada. Due to the ubiquitous nature of dioxins and dioxin-like compounds in the environment, and the fact that methods of detection are becoming increasingly sensitive, “zero tolerance” is not practical and is not applied by Canada or any major trading partners. The CFIA considered it appropriate to examine levels of dioxins and dioxin-like compounds in retail products, specifically certain vegetable oils and domestic cheeses, as these products are directly consumed by Canadians on a daily basis and are not routinely monitored under the National Chemical Residue Monitoring Program (NCRMP).

One or more dioxins or dioxin-like compounds were detected in all samples of vegetable oils and domestic cheese tested in the 2010-2011 FSAP targeted survey. This is not unexpected given the presence and persistence of dioxins and dioxin-like compounds in the environment. The concentrations of dioxins and dioxin-like compounds in the oil and cheese samples tested were similar to those reported in raw milk samples tested under the CFIA’s regular NCRMP monitoring program. For all oil and cheese samples tested, the total TEQ concentrations (lower bound and upper bound) were well below regulatory limits established by Canadian trading partners, such as the European Union.

The levels of dioxins and dioxin-like compounds observed in this survey are not likely to be of concern to human health. Follow-up activities were not deemed necessary given that no elevated concentrations were found and the levels were similar to those detected in domestic raw milk monitoring data.

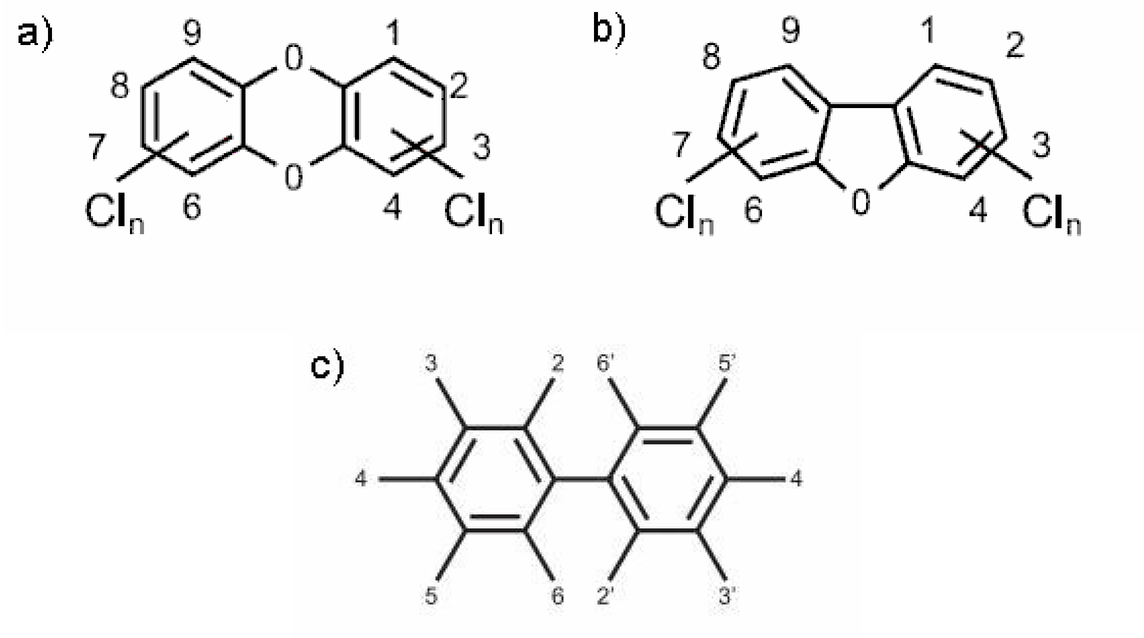
5 Appendix

Table A - Various regulatory limits for dioxins and dioxin-like compounds in selected commodities

Country/Organization	**Commodity**	**Sum of Dioxins (WHO-PCDD/F-TEQ)**	**Sum of Dioxins and Dioxin-like PCBs (WHO-PCDD/F-PCB-TEQ)**	**Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180**
European Union[16]	Raw milk and dairy products	2.5 pg/g fat	5.5 pg/g fat	40 ng/g fat
European Union[16]	Vegetable oils and fats	0.75 pg/g fat	1.25 pg/g fat	40 ng/g fat
Australia/FSANZ – Total PCBs[19]	Milk and milk products	N/A	0.2 mg/kg	N/A
Canada - Chlorinated dibenzo-*p*-dioxins[20] (Dioxins and dioxin-like compounds)	All foods	Zero tolerance /Assessed on case-by-case basis; if a health concern is identified and corrective action considered necessary, it is taken under the authority of the FDA		
United States*	Milk and milk products or vegetable fats/oils	N/A	N/A	N/A

*Note: Action levels exist in the US for PCBs in red meat[21] and for 2,3,7,8-TCDD in drinking water[22]

Figure A - General structures of a) dioxins (PCDDs), b) furans (PCDFs), and c) PCBs



a) Polychlorinated dibenzo-*p*-dioxins (referred to as dioxins or PCDDs) – there are 75 congeners of dioxins that vary in both the number and arrangement of chlorine atoms around an identical central structure (two benzene rings joined by two oxygen atoms)

b) Polychlorinated dibenzofurans (referred to as furans or PCDFs) - there are 135 furan congeners consisting of different arrangements of chlorine atoms around two benzene rings connected by a single oxygen atom

c) Polychlorinated biphenyls (referred to as dioxin-like PCBs) - there are 12 dioxin-like PCB congeners (lacking any chlorine or oxygen atoms)

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

Compound	Congener	LOD* (pg/g fat)	TEF**
Dioxins	2,3,7,8-TCDD	0.1	1
	1,2,3,7,8-PeCDD	0.1	1
	1,2,3,4,7,8-HxCDD	0.2	0.1
	1,2,3,6,7,8-HxCDD	0.2	0.1
	1,2,3,7,8,9-HxCDD	0.2	0.1
	1,2,3,4,6,7,8-HpCDD	0.2	0.01
	1,2,3,4,6,7,8,9-OCDD (or OCDD)	0.5	0.0003
Furans	2,3,7,8-TCDF	0.1	0.1
	1,2,3,7,8-PeCDF	0.2	0.03
	2,3,4,7,8-PeCDF	0.1	0.3
	1,2,3,4,7,8-HxCDF	0.1	0.1
	1,2,3,6,7,8-HxCDF	0.2	0.1
	1,2,3,7,8,9-HxCDF	0.2	0.1
	2,3,4,6,7,8-HxCDF	0.2	0.1
	1,2,3,4,6,7,8-HpCDF	0.2	0.01
	1,2,3,4,7,8,9-HpCDF	0.2	0.01
	1,2,3,4,6,7,8,9-OCDF (or OCDF)	0.2	0.0003
Dioxin-like PCBs	3,3',4,4'-TeCB (PCB 77)	0.5	0.0001
	3,4, 4',5-TeCB (PCB 81)	0.5	0.0003
	2,3,3',4,4'-PeCB (PCB 105)	0.5	0.00003
	2,3,4,4',5-PeCB (PCB 114)	0.5	0.00003
	2,3',4,4',5-PeCB (PCB 118)	0.5	0.00003
	2',3,4,4',5-PeCB (PCB 123)	0.5	0.00003
	3,3',4,4',5-PeCB (PCB 126)	0.1	0.1
	2,3,3',4,4',5-HxCB (PCB 156)	0.5	0.00003
	2,3,3',4,4',5'-HxCB (PCB 157)	0.5	0.00003
	2,3',4,4',5,5'-HxCB (PCB 167)	1	0.00003
	3,3',4,4',5,5'-HxCB (PCB 169)	0.1	0.03
	2,3,3',4,4',5,5'-HpCB (PCB 189)	1	0.00003

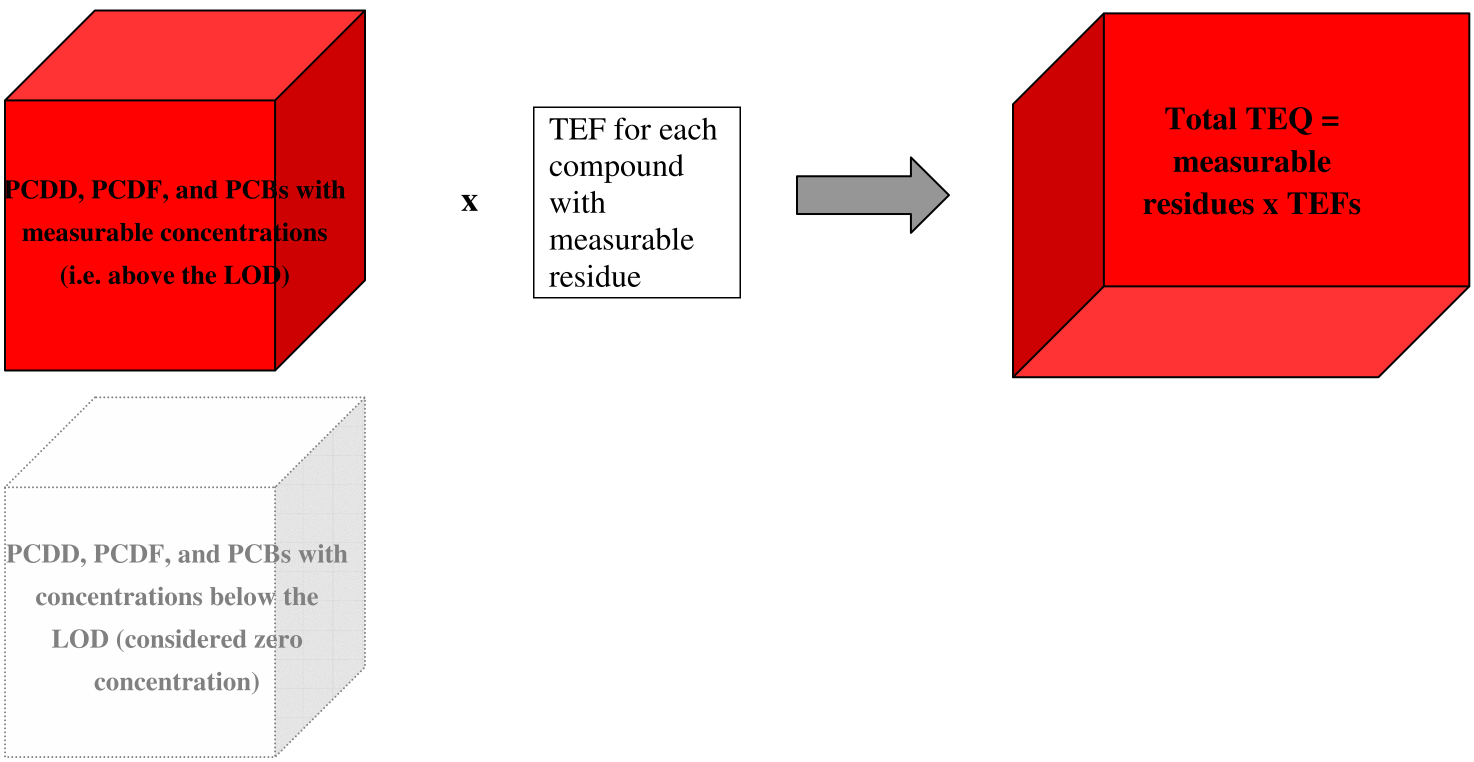
* LOD= Method limit of detection

** TEF = Toxic Equivalency Factor (2005 WHO TEF values)[4]

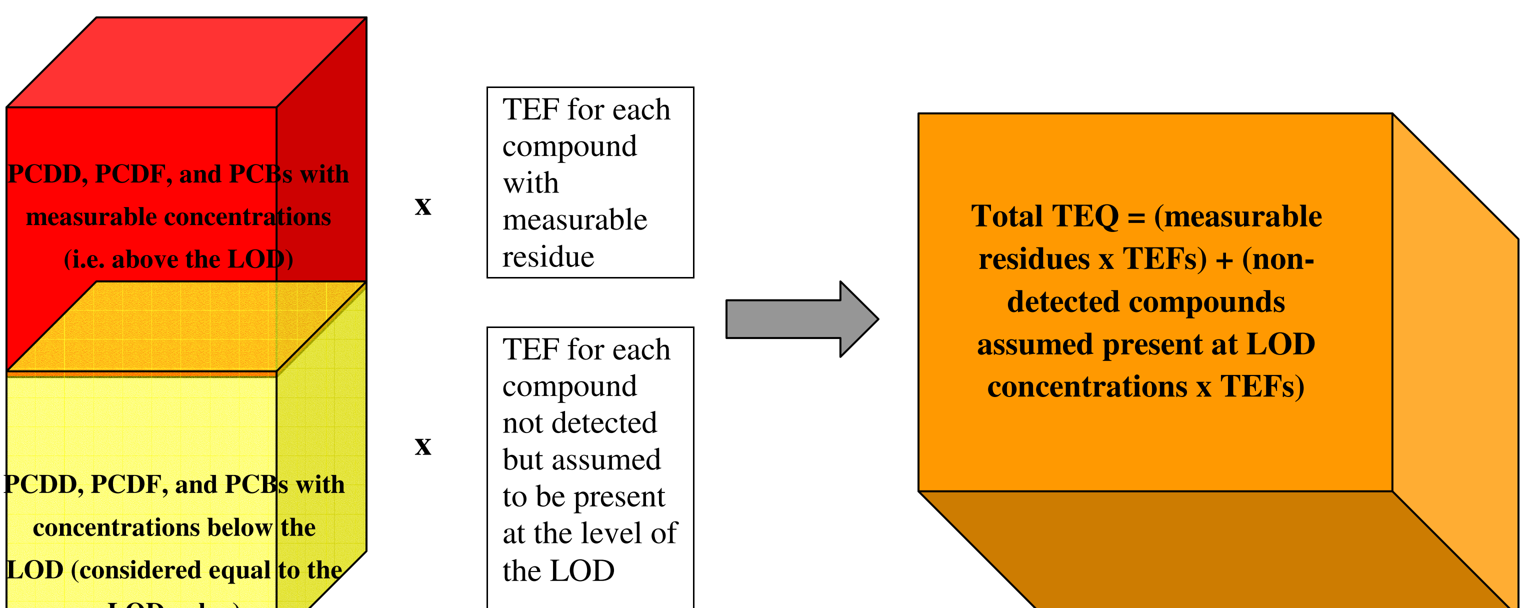
Figure B - Depiction of the lower bound/upper bound concept

Lower bound levels (best-case scenario)

What's included in calculations? **What's the resulting Total TEQ?**



Upper bound levels (worst-case scenario)



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