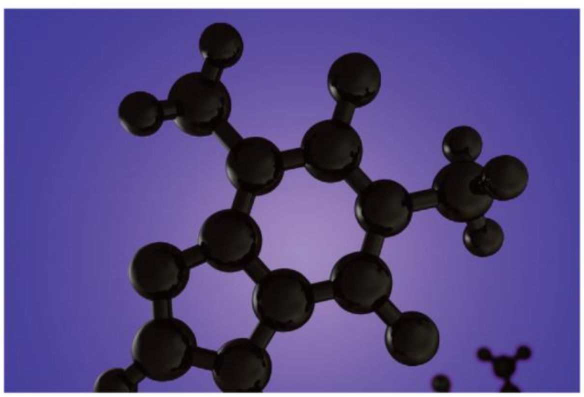
Canadian Food Inspection Agency / Agence canadienne d'inspection des aliments

Food Safety Action Plan

REPORT

2011-2012 Targeted Surveys

Chemistry



Dioxins and Dioxin-like Compounds in Selected Foods

TS-CHEM-11/12

Canada

Table of Contents

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 generate data to evaluate 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 foods (specifically vegetable oils and fats, dairy-containing foods, nut/seed butters, nutritional supplements/meal replacements, and guar gums) 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, as well as the types of compounds involved. 2,3,7,8-Tetrachlorodibenzo-para-dioxin (TCDD), generally considered the most potent dioxin, has been classified by the International Agency for Research on Cancer as a human carcinogen. The World Health Organization considers dioxins and dioxin-like compounds a health concern on a global scale, and has recently reiterated the need to reduce emissions of, and human exposure to, these persistent pollutants. According to the United States Environmental Protection Agency, 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.

A total of 256 samples were collected and analyzed in this targeted survey. Samples included 92 vegetable oils and fats, 52 dairy-containing foods, 49 nut/seed butters, 40 nutritional supplements/meal replacements, and 23 guar gums. Samples were analyzed for dioxins and dioxin-like compounds (which consist of certain polychlorinated dibenzofurans and polychlorinated biphenyls). All of the samples had a detectable level of one or more dioxins and/or dioxin-like compounds. This is expected given their widespread presence and persistence in the environment, their ability to bioaccumulate in fatty tissues and biomagnify through the food chain, and the sensitivity of current analytical methods.

Canada's *Food and Drugs Act* prohibits the sale of food that is adulterated, and 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 made to analytical methods of detection for these substances. This tolerance was established many years ago and is considered to be untenable and out of date 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 of its’ major trading partners.

The levels of dioxins and dioxin-like compounds observed in this survey were evaluated by Health Canada’s Bureau of Chemical Safety and none of the samples were expected to present a safety concern to human health. Appropriate follow-up actions were initiated that reflected the magnitude of the human health concern. No product recalls were warranted.

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 Canada's safety system for food, health, and consumer products. 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 preventive 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.

Within the current regulatory framework, some commodities (such as meat products) traded internationally and interprovincially are regulated by specific Acts. These are referred to as federally registered commodities. Under the current regulatory framework, the non-federally registered commodities encompass 70% of domestic and imported foods that are regulated solely under the *Food and Drugs Act* and *Regulations*. Targeted surveys are primarily directed towards non-federally registered commodities.

1.2 Targeted Surveys

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

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

The chemical contaminants of focus in this survey, dioxins and dioxin-like compounds, are considered a health concern on a global scale. Dioxins (polychlorinated dibenzodioxins) and dioxin-like compounds (polychlorinated dibenzofurans and certain polychlorinated biphenyls) refer to three groups of compounds with similar chemical and toxicological properties. They are persistent pollutants, able to travel long distances from the source of emission, 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 reiterated the need to reduce emissions of and human exposure to these substances[1]. Member countries of the Codex Alimentarius Commission have developed and supported the formal adoption of a Code of Practice for preventing and reducing dioxin and dioxin-like PCB contamination in foods and feed[2].

Two previous FSAP targeted surveys have examined dioxins and dioxin-like compounds in guar gums, vegetable oils, and cheeses[3]. Additionally, the CFIA routinely monitors foods of animal origin (namely meat, poultry, raw milk, and eggs) for dioxins and dioxin-like compounds under the National Chemical Residue Monitoring Program (NCRMP)[4]. It was thus considered appropriate to perform a targeted survey that complements NCRMP monitoring and builds on previous FSAP surveys. The survey examines whether dioxins and dioxin-like compounds were present in food products not routinely monitored under the NCRMP (e.g., vegetable oils and fats, nut and seed butters).

1.3 Acts and Regulations

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

Health Canada establishes the health-based maximum levels for chemical residues, contaminants, and natural toxins in food sold in Canada. Certain maximum levels for chemical contaminants in food appear in the Canadian *Food and Drug Regulations*, where they are referred to as tolerances. There are also a number of maximum levels that do not appear in the regulations, but rather, are on Health Canada's website[5], and are referred to as standards. There are no Canadian regulations for the dioxin-like compounds (i.e. furans and PCBs). Canada's *Food and Drugs Act* prohibits the sale of food that is adulterated[6], and Regulation B.01.046 (1) (p) of the *Food and Drugs Regulations* states that any food, with the exception of fish (B.01.047 (f)), containing chlorinated dibenzo-*p*-dioxins is considered adulterated[7]. This causes enforcement challenges given that the Regulations for dioxins were established many years ago and are considered to be untenable and out of date by Health Canada. The complete absence of dioxins in foods is unrealistic due to the ubiquitous and persistent nature of dioxins and dioxin-like compounds in the environment. Furthermore, highly sensitive analytical methods are now available which are capable of detecting extremely low levels of these compounds. At the time the Regulations were developed, it was believed that food did not generally contain dioxins; however, using the sensitive analytical methods now available, foods are known to actually contain very low levels of dioxins and dioxin-like compounds.

Health Canada is currently updating its risk assessment for dioxins and dioxin-like compounds in foods and, as part of this work, will update the regulations pertaining to these compounds. Specific findings of elevated levels of dioxins and dioxin-like compounds in foods may be assessed by Health Canada on a case-by-case basis using the most current scientific data available. If Health Canada identifies a potential safety concern, the Canadian Food Inspection Agency can exercise follow-up actions under the authority of Section 4 (1) of the *Food and Drugs Act*. Follow-up actions are initiated in a manner that reflects the magnitude of the health concern. Actions may include further analysis, notification to the producer or importer, follow-up inspections, additional directed sampling, and recall of products.

The European Union has established maximum levels for total dioxins (which include dioxins, furans, and some PCBs) in various foodstuffs, including dairy products and vegetable oils/fats. Refer to Table A in the Appendix for a summary of maximum levels for dioxins and dioxin-like compounds in selected foods in various jurisdictions.

2 Survey Details

2.1 Dioxins and Dioxin-like Compounds

2.1.1 Background and Sources

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

There are 75 congeners (different structural forms) of polychlorinated dibenzodioxins, 7 of which are considered to be of toxicological concern. The most potent and studied dioxin congener is 2,3,7,8-Tetrachlorodibenzodioxin (TCDD). There are 135 furan congeners, of which 10 display “dioxin-like” toxicological properties. Additionally, there are 209 PCB congeners, 12 of which display “dioxin-like” properties with respect to toxicity. For the sake of simplicity in this report, these three groups of compounds will hereafter be referred to as dioxins and dioxin-like compounds (furans and PCBs), and will consist of the 29 congeners of most concern to human health[8]. Please refer to Figure A in the Appendix for the general 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. Conversely, PCBs are man-made, and often contain furan contaminants. PCBs were historically used in many industrial applications (e.g. 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.

2.1.2 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. These properties make dioxins and dioxin-like compounds ubiquitous and persistent contaminants. They are recognized as causing adverse effects on humans and the ecosystem by the Stockholm Convention[9] on Persistent Organic Pollutants[1].

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 or dioxin-like compounds have entered the human body, they are sequestered to the liver and to fat tissues, where they are estimated to have a half-life of up to eleven years[10].
Exposure to dioxins and dioxin-like compounds in humans and laboratory animals have been associated with a wide range of health effects, including skin disorders (e.g.

---

[1] An international treaty requiring parties to eliminate or reduce the release of these contaminants into the environment

chloracne), liver and thyroid problems, impairment of the endocrine, nervous, reproductive, and immune systems, developmental effects, and certain types of cancers[11]. The type and occurrence of these health effects typically depend on the level and duration of exposure.

JECFA established a provisional tolerable monthly intake (PTMI) of 70 picograms[2] of dioxins and dioxin-like compounds per kilogram of body weight per month[12]. Health Canada supports the approach taken to derive this PTMI and employs this figure in its health risk assessments for these types of compounds in foods.

2.1.3 Dioxins and Dioxin-like Compounds in Food

Although production and use of dioxins and dioxin-like compounds is prohibited[13], low levels are still detected in many foods because of their persistence and widespread presence in the environment. Food manufacturing and processing (including cooking) does little to reduce, break down, or remove these compounds. For most Canadians, about 90% of overall exposure to dioxins and dioxin-like compounds comes through diet[11,14]. It is generally accepted that 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].

The majority of dietary dioxin intake has been attributed to the consumption of animal (both aquatic and terrestrial) tissues, eggs, and dairy products[15]. These food products are generally highest in animal fat, which is the primary site of storage of dioxins once ingested by an animal. Dioxins and dioxin-like compounds bioaccumulate with continued exposure over the lifetime of an animal as they consume contaminated animal 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 also been found at low levels in feed and plant material due to their deposition on plant surfaces and soil. Food and feed products made from these plants, particularly oily plants[16], may also contain dioxins and/or dioxin-like compounds. Additionally, specific food ingredients (i.e., raw materials containing dioxins) or permitted food additives (e.g., guar gum, known to have dioxin contamination issues in the past) may be the source of dioxins in finished foods[17].

2.1.4 Comparing Dioxins, Furans, and Dioxin-like PCBs

As previously discussed, there are a large number of compounds included in the three groups of dioxins and dioxin-like compounds with varying levels of toxicity. Given the

[2] One picogram is equivalent to one trillionth of a gram

wide range of toxicity associated with individual congeners, it is not appropriate to simply measure the concentration of each congener of concern and add them together to arrive at a total concentration. To facilitate the risk assessment of these compounds, the concept of Toxic Equivalence (TEQ) and the use of World Health Organization (WHO) consensus Toxic Equivalency Factors (TEFs) are applied[8,18].

The dioxin congener 2,3,7,8-TCDD is considered the most toxic form of all dioxins and dioxin-like compounds. In order to compare the toxicity of the 29 congeners of concern, 2,3,7,8-TCDD was assigned a TEF of 1. The other 28 congeners of concern were given a TEF[8] ranging from 0.00003 to 1 with respect to their toxic potency relative to 2,3,7,8-TCDD. Please refer to Table B in the Appendix for a summary of 2005 WHO TEFs used in this survey.

The concentration of each dioxin or dioxin-like compound detected in a sample is multiplied by its respective TEF. This result is referred to as a Toxic Equivalence (TEQ) concentration. Each of the calculated individual TEQ concentrations are then summed to arrive at a total TEQ concentration, which is an estimate of the total potency of all the dioxins and dioxin-like compounds detected in the sample.

2.2 Rationale

This targeted survey was designed to provide a snapshot of the levels of dioxins and dioxin-like compounds in selected foods available to Canadian consumers, and highlight commodities that warrant further investigation. Dioxin and dioxin-like contaminants have gained attention in the media due to their persistence, bioaccumulative and toxicity potential, and industrial accidents/food contamination events outside of Canada. There have been incidents involving dioxin contamination of food products of animal origin directly resulting from the ingestion of dioxin-contaminated animal 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[19]. Other notable cases of dioxin contamination in the food supply have involved pork, chicken, beef, milk, and guar gum[20,21]. Although these incidents generally did not affect food products manufactured or sold in Canada, they highlighted the need for baseline data gathering on select foods available in the Canadian marketplace.

The CFIA routinely monitors foods of animal origin (namely domestic raw milk, selected animal products and fats, and eggs) for dioxins and dioxin-like compounds under the NCRMP. As well, two previous FSAP targeted surveys[3] have investigated the occurrence and levels of dioxins and dioxin-like compounds in guar gum, vegetable oils, and some cheeses. It was considered appropriate to perform a complementary targeted survey to examine whether dioxins and dioxin-like compounds are present in food products not routinely monitored under the NCRMP, specifically vegetable oils/fats, dairy-containing foods, nutritional supplements/meal replacements, nut/seed butters, and guar gums.

As mentioned previously, dioxins and dioxin-like compounds have been found at low levels in foods derived from oily plants, including edible oils[3,16] and nut/seed butters[22], and are known to occur in dairy-containing products. Canadians consume significant quantities of dairy products and oils/fats per year, with over 22 kg (excluding cheese and butter) and 25 kg available for per capita consumption, respectively, in 2009[23,24]. Similarly, more than 8 kg of pulses and nuts were available for per capita Canadian consumption in 2009[24]. For these reasons, vegetable oils, fats, certain dairy-containing foods (including nutritional supplements/meal replacements), and nut/seed butters have been targeted in this survey.

Guar gum is a permitted food additive in Canada, and is commonly used as an emulsifier and stabilizer in many processed foods[25]. It is generally a minor ingredient in foodstuffs but is found in a wide variety of products (e.g. dairy-containing foods, salad dressings, infant formula, bread, etc.). In 2007, the European Commission discovered dioxin contamination of guar gum originating from India[17]. A possible source of contamination of that guar gum was thought to be contact with contaminated processing/transfer materials (e.g. storage containers). This prompted implementation of control measures to prevent recurrence of the dioxin contamination of guar gum, however, the possibility of cross-contamination still exists. Dioxins were detected in guar gum samples in a previous FSAP targeted survey[3], and it was considered appropriate to establish additional baseline data for guar gums in this targeted survey.

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

2.3 Sample Distribution

The 2011-2012 Dioxin and Dioxin-like Compounds survey targeted domestic and imported vegetable oils and fats, dairy-containing foods, nutritional supplements/meal replacements, nut/seed butters, and guar gums. A total of 256 samples were collected from grocery and specialty stores in 11 Canadian cities between June 2011 and March 2012. The samples collected included 92 vegetable oils and fats, 52 dairy-containing foods, 49 nut/seed butters, 25 nutritional supplements, 23 guar gums, and 15 meal replacements. Samples categorized as dairy-containing products had one or more milk/milk ingredients (e.g., buttermilk), sour cream, cream, cheese (e.g., parmesan, ricotta, cream cheese), or yogurt listed as one of the first three ingredients.

For the purposes of this survey, nutritional supplements were considered to be foods sold or represented as a supplement to a diet that may be inadequate in energy and essential nutrients (such as protein, vitamins, or minerals). Nutritional supplements may be found in many forms, such as bars, liquids, extracts, concentrates, or powders. Common examples of nutritional supplements may include protein powders, ready to consume drinks/beverages, or dry beverage mixes. The nutritional supplements sampled in this survey (all but one of which were powders) were more varied than meal replacements with respect to ingredients. Some of the samples contained only milk-based ingredients (e.g., casein, whey protein), some contained only soy ingredients, and others were blends of both. In a few samples, no milk-based or soy ingredients were present, but instead had one or more oils/oilseeds (spice oils, safflower oil, sunflower oil, flaxseed), coconut fats, or guar gum.

Similarly, a meal replacement was considered to be a formulated food that, by itself, can replace one or more daily meals. To be called a meal replacement, a product must meet a variety of compositional and labelling requirements as defined in Division 24 of the *FDR*. These items may be in the form of powders or prepared liquids, and will state “meal replacement” on the label (two of the meal replacements in this survey were ready to consume liquids; the rest were powders). All but one of the meal replacement samples in this survey contained milk-based ingredients (e.g., casein, whey protein; the other contained only soy), and often also contained soy/soybean oil. Several meal replacement samples also contained sunflower, corn, and canola oils.

The 256 survey samples included 82 domestic products, 116 imported products, and 58 products of unspecified origin. In general, an unspecified country of origin refers to those samples for which the origin could not be determined from the product label or sample information. It is important to note that the products sampled often contained the statement “processed in Country X”, “imported for Company A in Country Y” or “manufactured for Company B in Country Z”, and though the labelling meets the intent of the regulatory standard, it does not specify the true origin of the product ingredients. Only those products labelled with a clear statement of “Product of”, “Prepared in”, “Made in”, “Processed in”, and “Manufactured by” were considered as being from a specific country of origin. The samples originated in at least 18 countries, including Canada, with approximately 62% of the samples originating in either Canada or the United States. The distribution of samples collected in this survey with respect to the country of origin (as recorded on the sampling documentation or indicated on the product label) is presented in Table 1.

Table 1. Distribution of samples by category type and origin

Category	Number of Samples of Domestic Origin	Number of Imported Samples	Number of Samples of Unspecified* Origin	Total Number of Samples
Vegetable oils and fats	18	50	24	92
Dairy-containing foods	15	31	6	52
Nut/seed butters	31	12	6	49
Nutritional supplements	6	5	14	25
Guar gum	9	14	0	23
Meal replacements	3	4	8	15

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

2.4 Analytical Methods

Samples in the dioxin targeted survey were analyzed by ISO 17025 accredited laboratories under contract with the Government of Canada. Samples were tested as sold, meaning that the product was not prepared as per the package instructions (if applicable).

Sufficient quantities were collected to allow one or two different analytical methodologies to be conducted on each sample. Determination of dibenzo-*p*-dioxins, dibenzofurans, and polychlorinated biphenyls in various foods of animal and plant origin was by gas chromatography/high-resolution mass spectrometry (GC/HRMS) method. Combined, the methods can analyze for 35 dioxins and dioxin-like compounds, however, this report will focus only on the 29 congeners of most concern that are included in the total TEQ calculations. The additional six PCBs analyzed by the methods do not contribute to the total TEQ calculation and will not be discussed further herein.

Consistent with international reporting practice, sample results are calculated and reported in terms of both lower bound and upper bound levels of dioxin and dioxin-like compounds. 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 (LB) represent solely the sum of all detected forms multiplied by their respective TEFs (congeners not detected are given a value of zero). Upper bound levels (UB) represent the sum of detected forms multiplied by their respective TEFs, plus the sum of the limit of detection (LOD) contributions for all forms that were not detected, also multiplied by their relevant TEFs. As noted in the Overview section below, only lower bound levels will be discussed in this report.

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 method detection limits and applicable 2005 WHO TEFs for the 29 congeners of concern.

2.5 Limitations

This targeted survey was designed to provide a snapshot of the levels of dioxins and dioxin-like compounds in selected foods available to Canadian consumers, and highlight commodities that warrant further investigation. The limited sample sizes analyzed represent a small fraction of the products available to consumers. Therefore, care must be taken when interpreting and extrapolating these results.

Analysis was completed on products as available on the Canadian retail market. Some of the products sampled in this survey are considered ingredients (i.e. guar gum) or require preparation prior to consumption (i.e. mixing with liquid). However, the results represent finished food products as sold and not necessarily as they would be consumed.

Distribution of samples by origin (as recorded by the sampler or indicated on the label) is presented to provide a general sense of the origin of samples. It is important to note, however, that Canadian companies may import raw or intermediate materials (i.e. raw guar gum) for use as ingredients, for blending, or for further processing for resale into Canadian and export markets. In some of these cases, products may be considered to be of Canadian, or domestic, origin. Determination of country of origin is further complicated by the fact that ingredients are often sourced from different or multiple countries. Country of origin was assigned for 189 samples (otherwise designated as "Unspecified") based on information provided on the documentation accompanying the sample or indicated on the product label. As a result, few inferences or conclusions were made regarding the data with respect to country of origin. Regional differences, impact of product shelf-life, packaging and storage conditions, or cost of the commodity on the open market were also 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 picograms/g fat unless otherwise stated (i.e., guar gums are reported on a whole weight basis), 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[8]. The use of 2005 WHO TEF values was taken into consideration when comparing results from this survey with other dioxin datasets and surveys that used previous (1998) TEF values.

3.1 Overview of Survey Results

In part due to the complexity of the food matrices and the high proportion of samples in which some congeners of concern were not detected, the upper bound estimates were considered overly conservative, thus the lower bound estimates were the primary focus in this survey. The entire dataset of dioxins and dioxin-like compounds observed in this survey was forwarded to Health Canada for an assessment of the potential human health concern. From these results, they have determined that none of the samples would be expected to pose an unacceptable human health concern. Appropriate follow-up actions were initiated that reflected the magnitude of the human health concern. No product recalls were warranted.

As previously mentioned, the total absence of dioxins and dioxin-like compounds in food is rare. Of the 256 samples analyzed in this survey, 251 had at least one of the 29 congeners of concern detected. The remaining five samples still had at least one of the additional six PCBs detected that do not contribute to the total TEQ.

Comparing the five product types in the survey, the maximum LB total TEQ value was lowest in guar gums and the average LB total TEQ value was lowest in vegetable oils/fats. The maximum and average LB total TEQ values were highest in dairy-containing foods (see Table 2). These findings are consistent with plant fats bioaccumulating fewer dioxins and dioxin-like compounds than animal fats.

Table 2. Maximum and average LB total TEQ values by product type

Product Type	Number of Samples	Maximum Total TEQ Value (pg TEQ/g fat)	Average Total TEQ Value‡ (pg TEQ/g fat)
		LB	**LB**
Dairy-Containing Foods	52	2.52189	0.17227
Nutritional Supplements/Meal Replacements	40	1.56032	0.12370
Nut/Seed Butters	49	1.04921	0.03856
Vegetable Oils/Fats	92	0.86357	0.02302
Guar Gums*	23	0.17434	0.02763

‡Average values calculated using positive results only; *Guar gums are reported in pg TEQ/g sample since they contain no fat or only trace amounts of fat

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 main contributors for each product type were then gathered and compared. There did not appear to be a dominant contributor to the LB total TEQ for most of the food categories sampled in this survey (i.e. the percentages of each contributor type were similar, some slightly more or less frequent than others). This was in contrast to the case for guar gums, where dioxins appeared to be the dominant contributor to the total TEQ (refer to Figure 1 below).

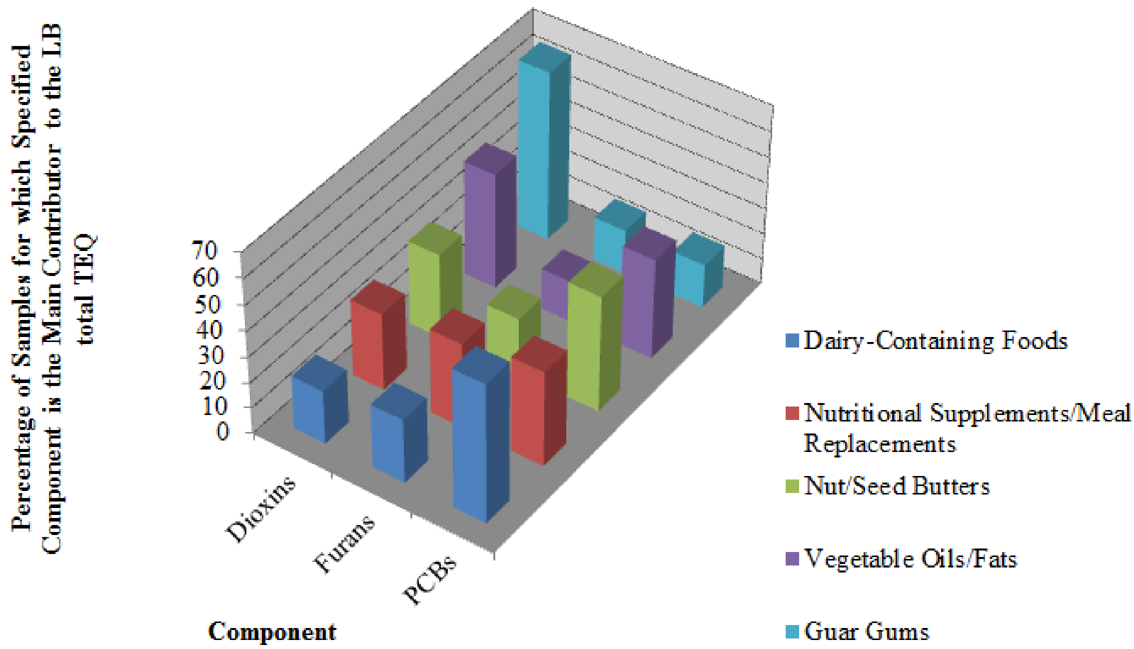


Figure 1. Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by product type

The following sections present the analysis results for dioxins and dioxin-like compounds in each of the five product types, with the lower bound total TEQ values the focus of the discussion.

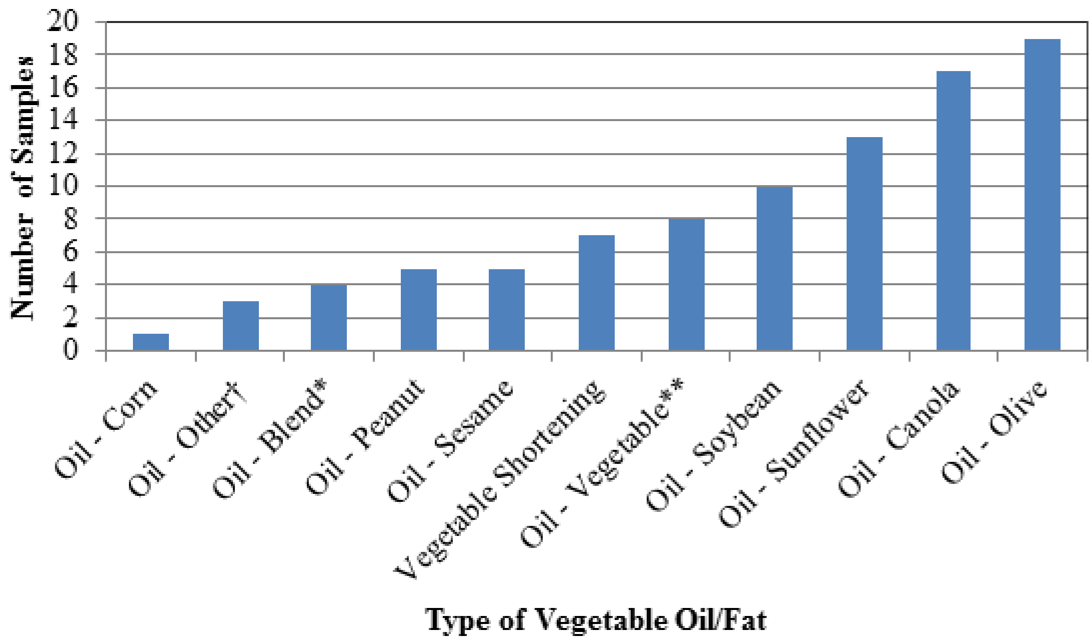
3.2 Results by Product Category and Product Type

Each of the five product types are discussed in the sections below, with comparison to other relevant CFIA data (where possible). Canadian Total Diet Study (TDS) results[26] produced by Health Canada report dioxin and dioxin-like compound concentrations on a whole weight basis rather than a fat weight basis, and therefore cannot be directly compared to the data generated in this survey.

In the following sections, it should be noted that a value of zero for the TEQ does not imply that dioxins and dioxin-like compounds were not detected. Rather, a TEQ of zero means that either the compounds detected do not contribute to the TEQ or the extremely small TEQ value has become zero by virtue of rounding. In addition, for all product types discussed below, the average values reported were calculated using positive results only (and it is worth noting that, while positive, a high proportion of the survey samples had few congeners of concern detected).

3.2.1 Vegetable Oils and Fats

A total of 92 samples of vegetable oils and shortenings were collected for the 2011-2012 Dioxin and Dioxin-like Compounds targeted survey. Vegetable oils included a variety of single oil types (e.g. olive, sesame), as well as blends. Some solid vegetable shortenings and margarines were also sampled. Please refer to Figure 2 below for the types of vegetable oils and fats sampled.



Note: Oil - Other† includes grapeseed and safflower oils; Oil - Blend* includes canola/sunflower oil and sesame/soybean oil blends; Oil - Vegetable** includes samples labelled simply as vegetable oils

Figure 2. Distribution of samples by vegetable oil/fat type

All but two of the vegetable oils/fats analyzed in this survey had at least one of the 29 congeners of concern detected. The remaining two samples still had at least one of the additional six PCBs detected that do not contribute to the total TEQ. Table 3 below presents the range of values found (minimum and maximum) for the lower bound (LB) total TEQ by the type of vegetable oil/fat tested. Additionally, the table gives the average value for the LB total TEQ by the type of vegetable oil/fat.

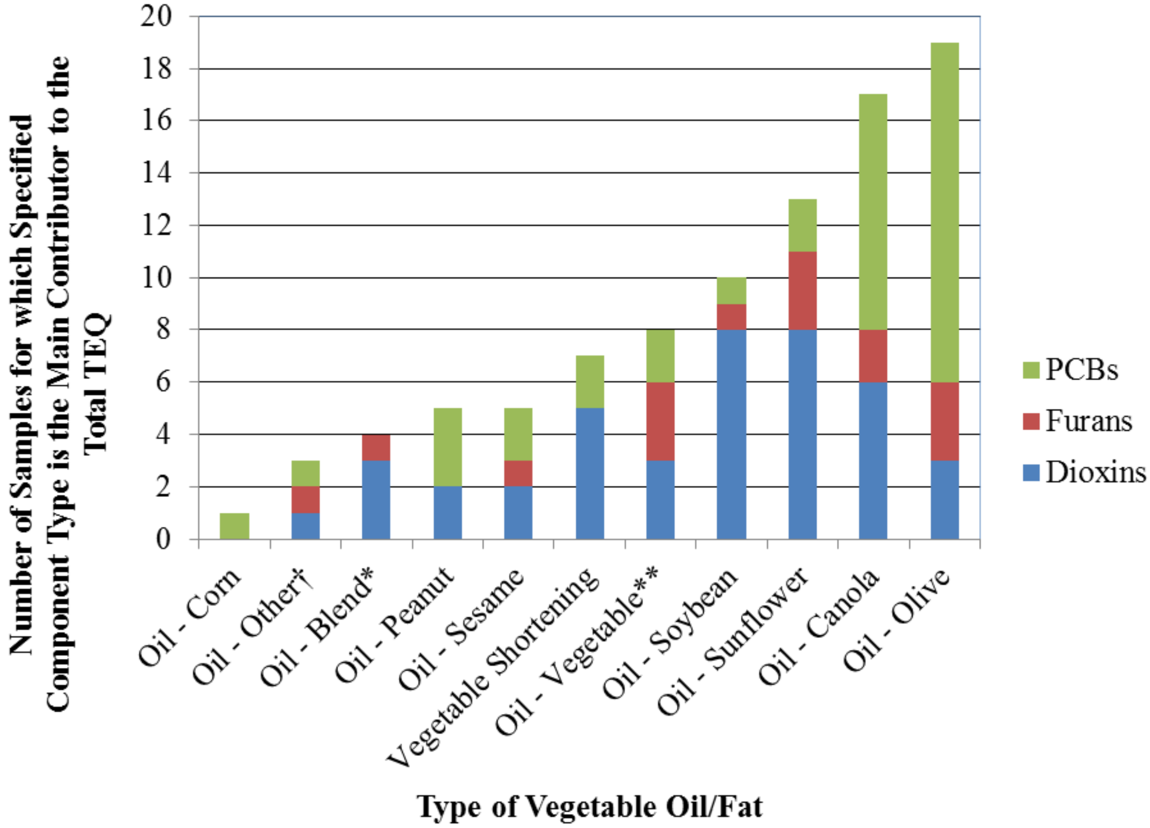
Table 3. Range and average total TEQ values in samples by vegetable oil/fat type (arranged in order of decreasing average LB total TEQ value)

Vegetable Oil/Fat Type	Number of Samples	Total TEQ Value Range (Minimum - Maximum) (pg TEQ/g fat)	Average Total TEQ Value‡ (pg TEQ/g fat)
		LB	LB
Oil - Sunflower	13	0.00002 - 0.53609	0.08074
Oil - Olive	19	0.00006 - 0.86357	0.06901
Oil - Canola	17	0.00000 - 0.39614	0.05733
Oil - Blend*	4	0.00064 - 0.18832	0.05003
Oil - Vegetable**	8	0.00001 - 0.12753	0.01999
Oil - Soybean	10	0.00002 - 0.07829	0.00999
Vegetable Shortening	7	0.00002 - 0.01083	0.00468
Oil - Sesame	5	0.00005 - 0.01286	0.00397
Oil - Peanut	5	0.00001 - 0.00442	0.00155
Oil - Other†	3	0.00002 - 0.00232	0.00141
Oil - Corn	1	0.00053 - 0.00053	-
Total	**92**		
Overall Range		**0.00000 - 0.86357**	
Overall Average			**0.02302**

‡Average values calculated using positive results only; Oil - Other† includes grapeseed and safflower oils; Oil - Blend* includes canola/sunflower oil and sesame/soybean oil blends; Oil - Vegetable** includes samples labelled simply as vegetable oil

The three highest LB total TEQ values were found in one imported pomace olive oil (0.86357 pg TEQ/g) and two sunflower oil (0.53609 pg TEQ/g and 0.39944 pg TEQ/g) samples (one imported and one of unspecified origin). Sunflower oil had the highest average LB total TEQ value, 0.08074 pg TEQ/g, while grapeseed/safflower oils had the lowest average LB total TEQ values at 0.00141 pg TEQ/g.

The relative contribution of each compound type (dioxin, furan, and PCB) to the LB total TEQ was considered (refer to Section 3.1). There was 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. However, furans were less frequently the main contributor compared to dioxins and PCBs for all types of oils/fats (see Figure 3 below).



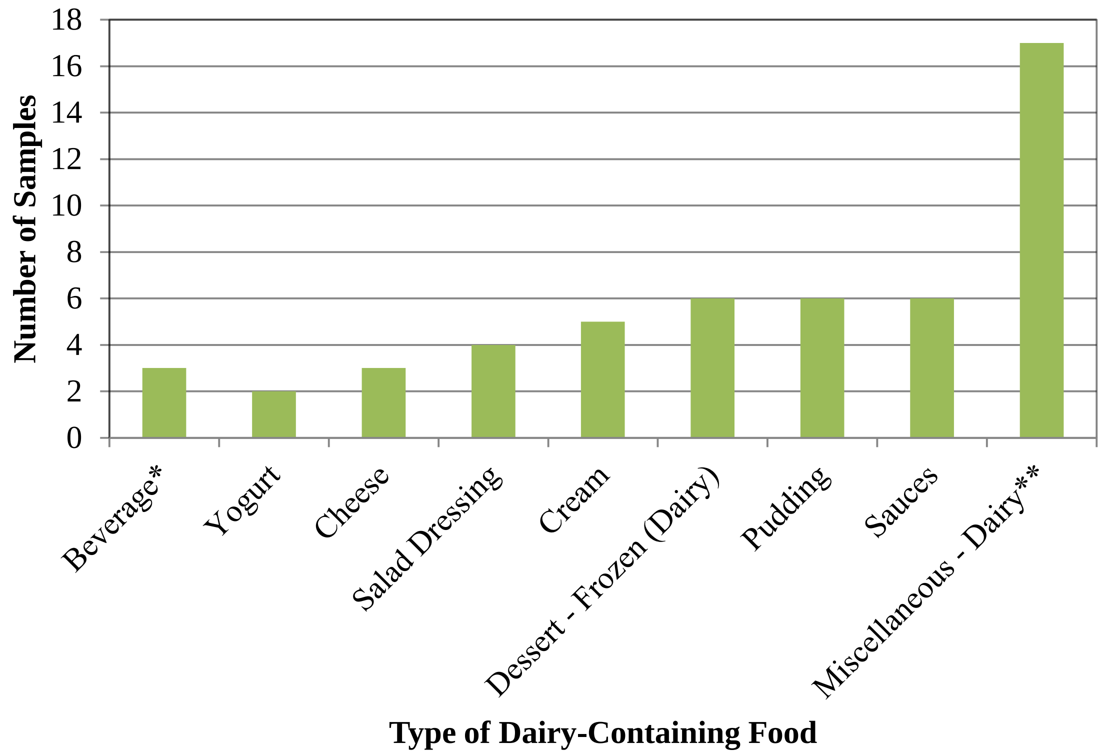
Note: Oil - Other† includes grapeseed and safflower oils; Oil - Blend* includes canola/sunflower oil and sesame/soybean oil blends; Oil - Vegetable** includes samples labelled simply as vegetable oil

Figure 3. Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by increasing number of samples

The current survey results for vegetable oils/fats were compared to levels found in the previous 2010-2011 FSAP Dioxin survey[3]. Fewer samples of, and types of, vegetable oils were sampled in the current survey. The overall maximum LB total TEQ value was slightly higher in the current survey (0.86357 pg TEQ/g in a pomace olive oil compared to 0.6697 pg TEQ/g in a peanut oil in the 2010-2011 survey). However, the average LB value was lower in the current survey than in the previous survey (0.02302 pg TEQ/g for vegetable oils compared to 0.1027 pg TEQ/g for oils in the 2010-2011 survey). The main contributor and the types of congeners detected for a given type of vegetable oil did not appear to be consistent year-to-year.

3.2.2 Dairy-containing Foods

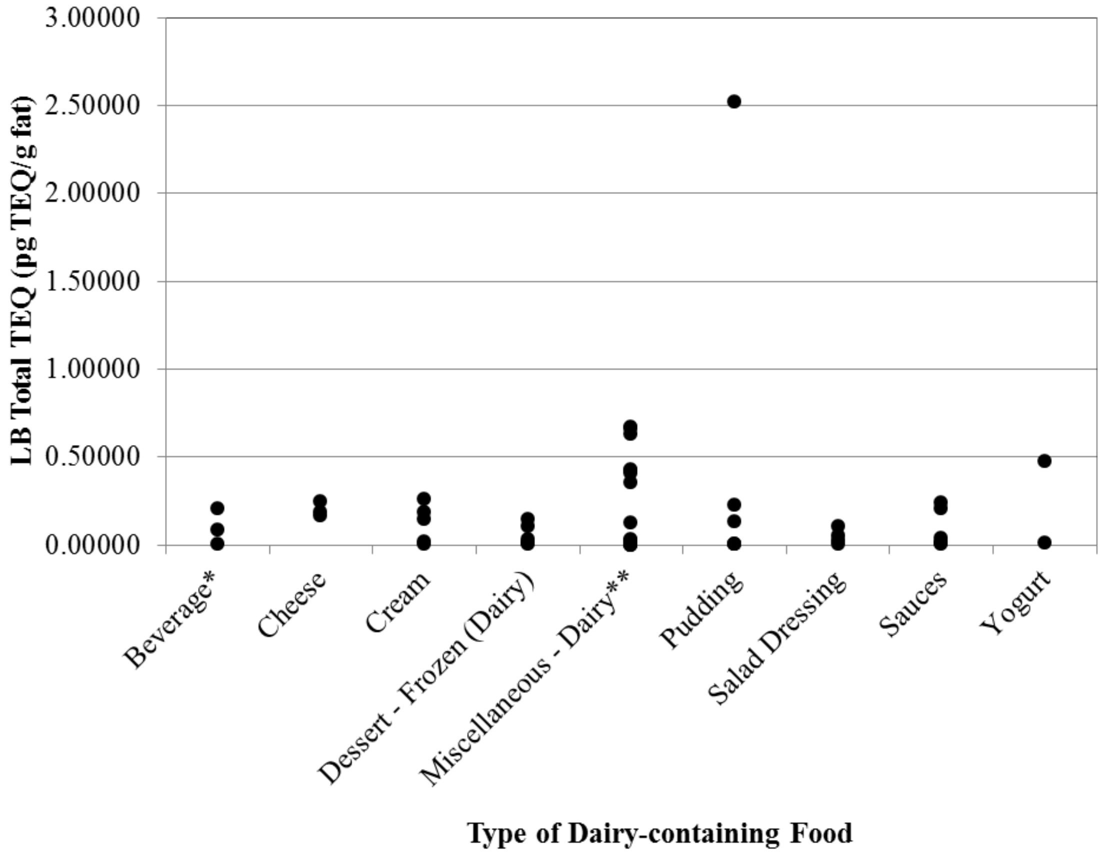
Fifty-two samples of dairy-containing foods were collected for this targeted survey. As previously mentioned, dairy-containing products had one or more cow's milk/milk-based ingredients as one of the first three ingredients. Sauce samples included cooking and pasta sauces. Beverage and pudding samples were ready-to-consume, and frozen dairy desserts were limited to cheesecakes. Please refer to Figure 4 below for the types of dairy-containing foods sampled.



*Beverage includes ready-to-consume coffee, tea, and yogurt products; **Miscellaneous - Dairy includes ready-to-consume custards, chip/veggie dips, and cream-based products

Figure 4. Distribution of samples by dairy-containing food type

All of the dairy-containing foods analyzed in this survey had at least one of the 29 congeners of concern detected. Figure 5 below shows the range of values found for the lower bound (LB) total TEQ by the type of dairy-containing food tested.

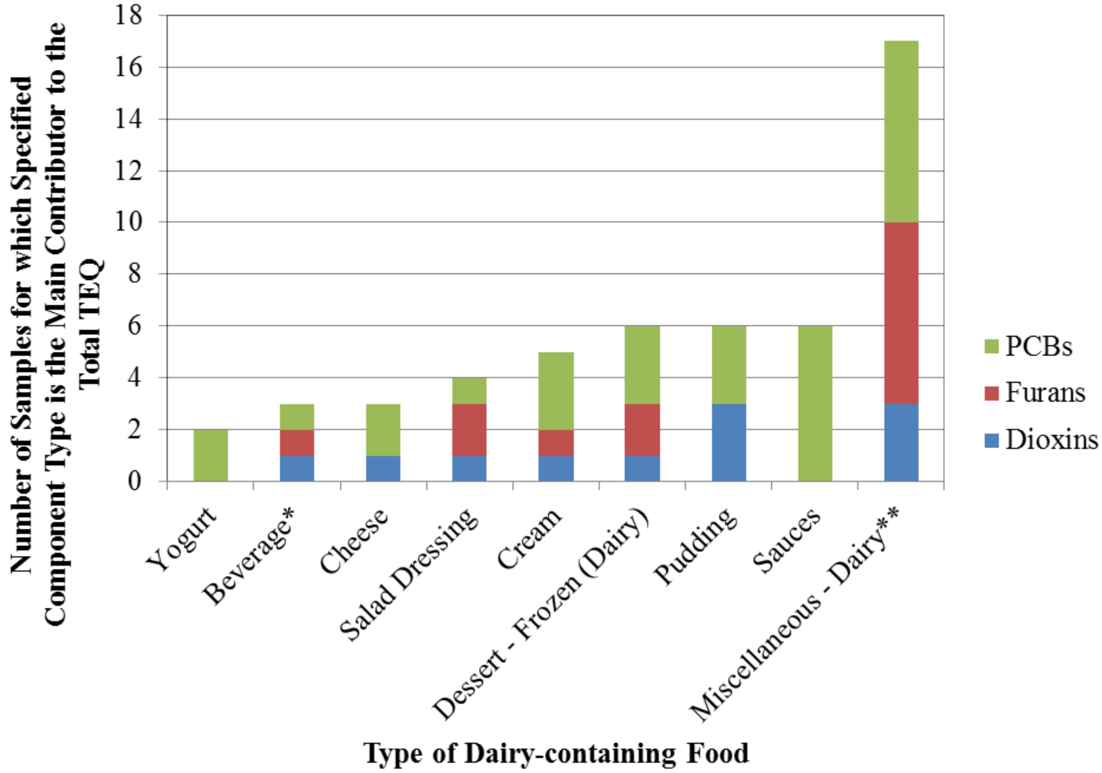


*Beverage includes ready-to-consume coffee, tea, and yogurt products; **Miscellaneous - Dairy includes ready-to-consume custards, chip/veggie dips, and cream-based products

Figure 5. LB total TEQ values in dairy-containing foods by product type

The three highest LB total TEQ values were found in an imported vanilla pudding (2.52189 pg TEQ/g) and two imported English Devon Style custards (0.67310 pg TEQ/g and 0.66600 pg TEQ/g) samples. Puddings had the highest average LB total TEQ value, 0.48157 pg TEQ/g (mainly due to a single, relatively elevated sample; see Figure 5 above), while salad dressings had the lowest average LB total TEQ values at 0.04479 pg TEQ/g.

The relative contribution of each compound type (dioxin, furan, and PCB) to the LB total TEQ was considered (refer to Section 3.1). There was 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 dairy-containing food, or for these samples in general. However, PCBs were more frequently the dominant contributor compared to dioxins and furans for all types of dairy-containing foods (see Figure 6 below).



*Beverage includes ready-to-consume coffee, tea, and yogurt products; **Miscellaneous - Dairy includes ready-to-consume custards, chip/veggie dips, and cream-based products

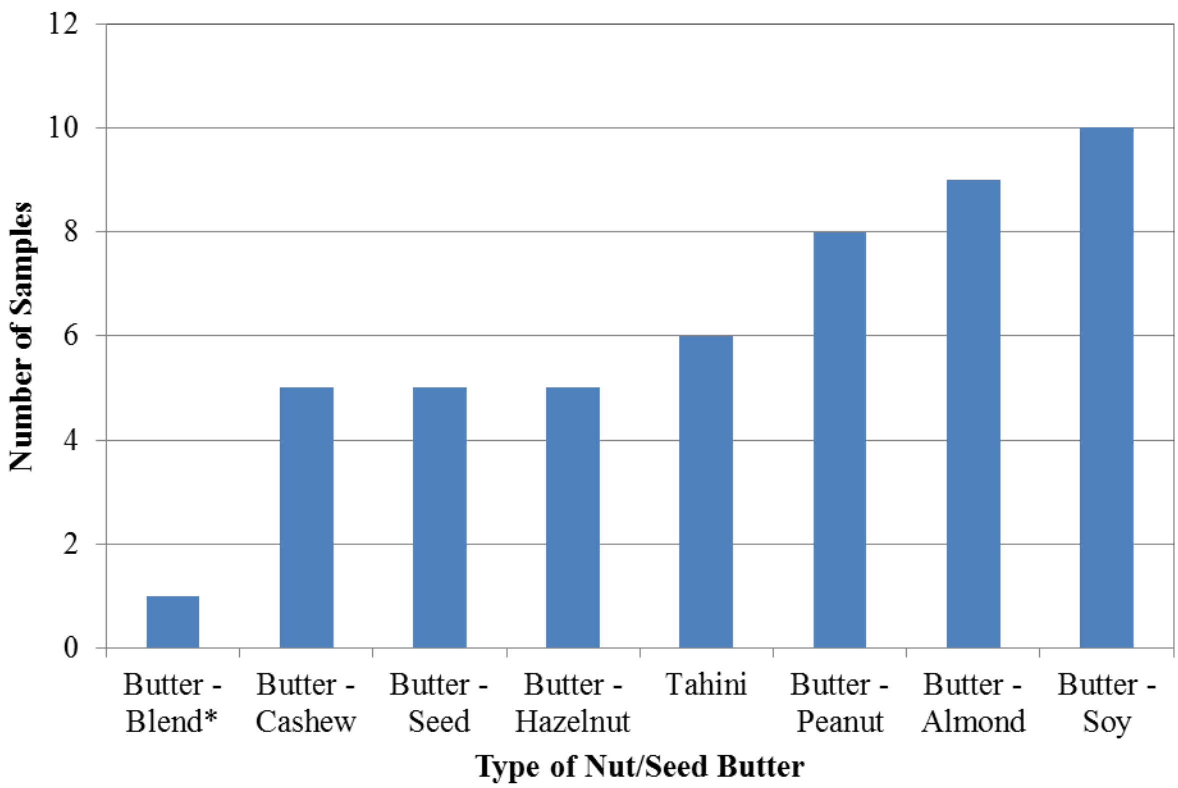
Figure 6. Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by increasing number of samples

The current survey results for cheese samples were compared to those found in the previous 2010-2011 FSAP Dioxin survey[3]. It was noted that only three samples of cheese were taken in the current survey (two cream cheeses and a light ricotta, all considered fresh cheeses) compared to the 284 cheese samples in the previous survey. Given the limited number of similar samples between the two surveys, no comparative conclusions were drawn.

Results for dairy-containing foods sampled in this survey were also compared to the levels of dioxin and dioxin-like compounds in domestic raw cow's milk monitored under the CFIA's NCRMP (from April 1, 2008 to December 31, 2011)[4]. In general, most of the NCRMP raw milk total TEQ values (calculated at a midpoint between the LB and UB level) are below 1 pg TEQ/g fat, with an average value of approximately 0.429 pg TEQ/g fat. The LB total TEQ values for dioxins and dioxin-like compounds in dairy-containing samples in this survey were very similar to the levels seen in domestic raw milk NCRMP monitoring data (i.e., below 1 pg TEQ/g fat), with the exception of the single, relatively elevated pudding sample.

3.2.3 Nut/seed Butters

Forty-nine samples of nut and seed butters were collected for this targeted survey. Please refer to Figure 7 below for the types of nut/seed butters sampled.



Note: Butter - Blend* refers to hazelnut and chocolate spreads

Figure 7. Distribution of samples by nut/seed butter type

All but one of the nut/seed butters analyzed in this survey had at least one of the 29 congeners of concern detected. The remaining sample still had at least one of the additional six PCBs detected that do not contribute to the total TEQ. Figure 8 below shows the range of values found for the lower bound (LB) total TEQ by the type of nut/seed butter tested. Note that almond, cashew, hazelnut, and blended nut butters are represented as “tree nut butter”, and sunflower seed butter/tahini have been combined as “seed butter”.

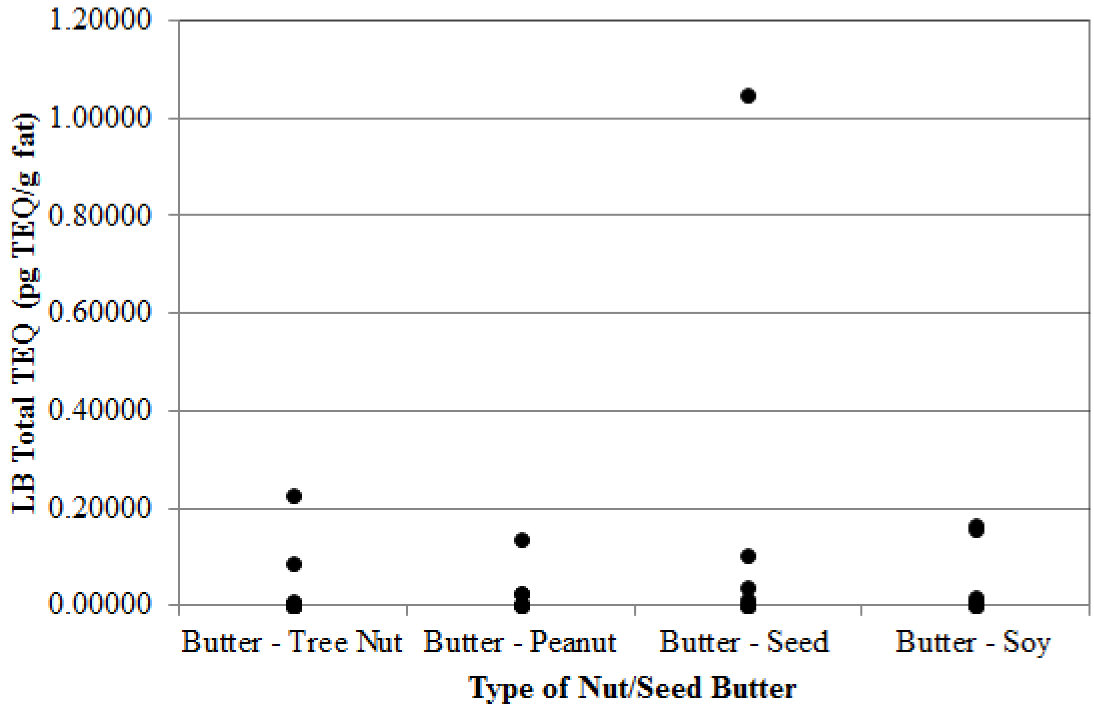


Figure 8. LB total TEQ values in nut/seed butters by product type

The three highest LB total TEQ values were found in a sample of tahini of unspecified origin (1.04921 pg TEQ/g), a domestic almond butter, and a domestic soy butter (0.22573 pg TEQ/g and 0.16509 pg TEQ/g respectively). Seed butters had the highest average LB total TEQ value, 0.12080 pg TEQ/g, driven primarily by a single, relatively elevated tahini sample (see Figure 8 above). Tree nut butters had the lowest average LB total TEQ values at 0.02029 pg TEQ/g.

The relative contribution of each compound type (dioxin, furan, and PCB) to the LB total TEQ was considered (refer to Section 3.1). There was 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 nut or seed butter. However, similar to the case for vegetable oils/fats, furans were less frequently the dominant contributor compared to dioxins and PCBs for these samples in general (see Figure 9 below).

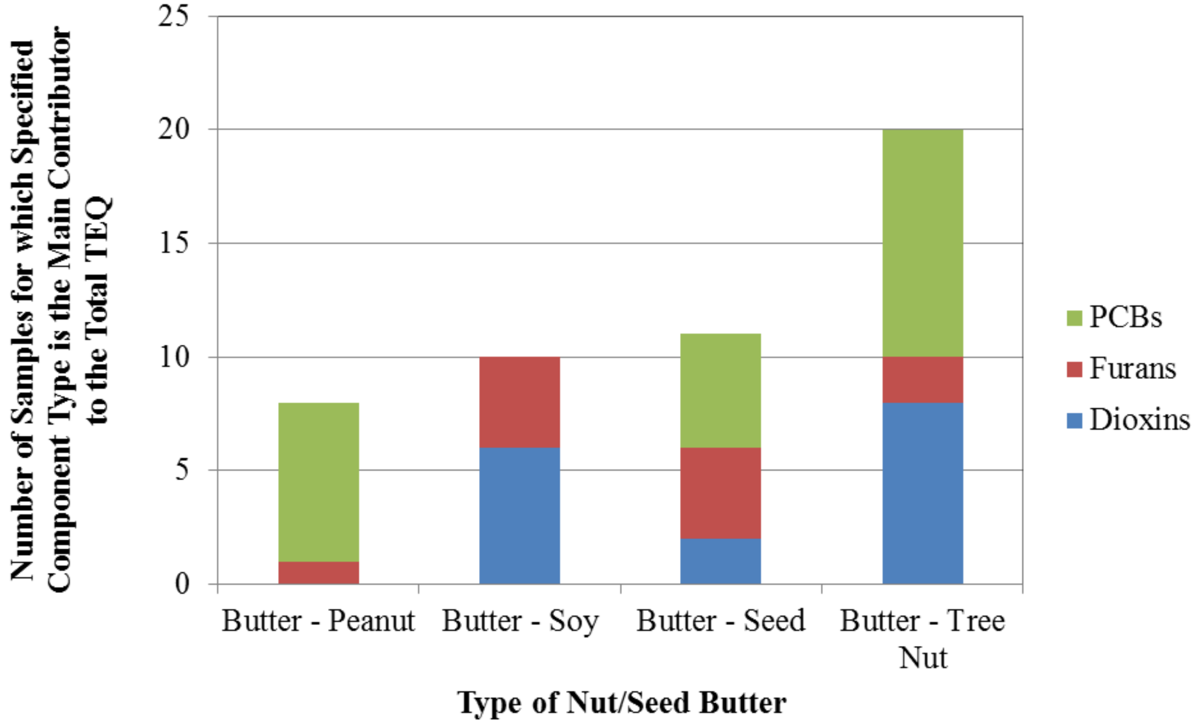


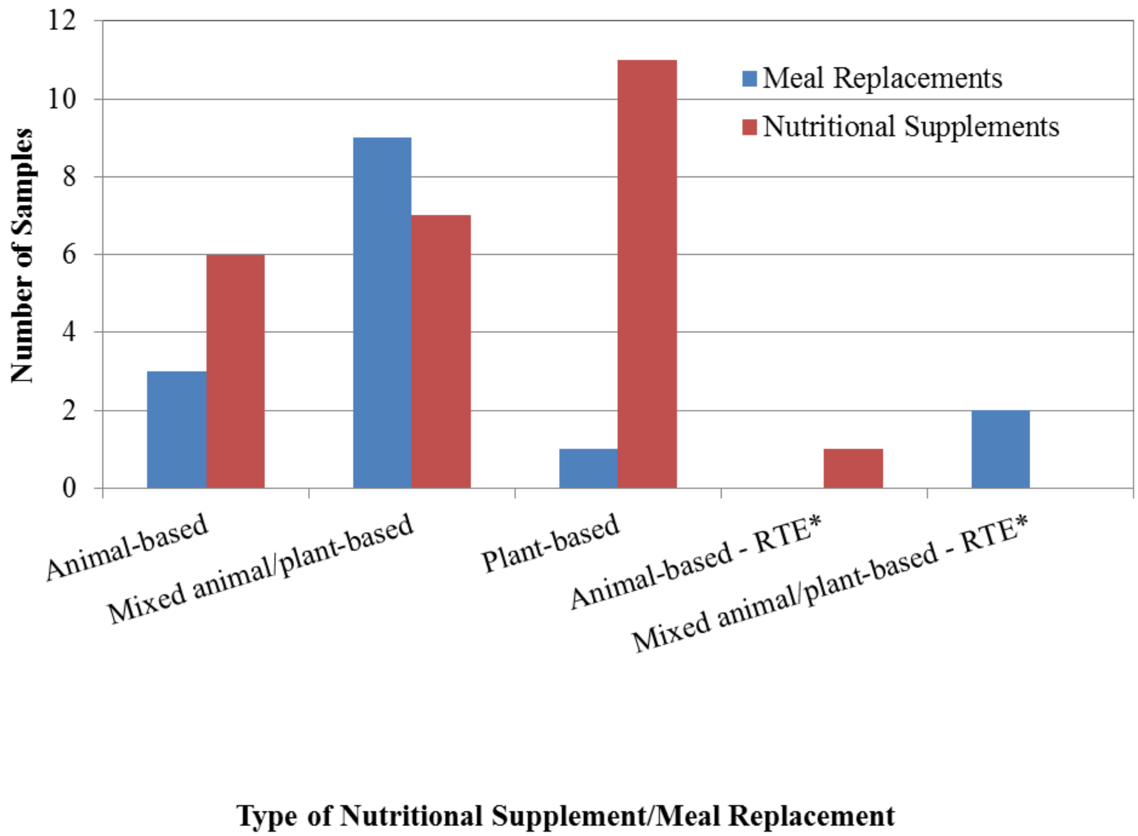
Figure 9. Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by increasing number of samples

Nut and seed butters were not sampled in either of the previous FSAP Dioxin surveys, nor are they monitored under the CFIA's NCRMP, or included in the Canadian Total Diet Study (TDS) results[26] produced by Health Canada.

Little comparative data was available in the literature for dioxins and dioxin-like compounds in nut or seed butters. The US FDA has reported dioxin analysis results/exposure estimates in various foodstuffs under their own TDS, including peanut butter[27]. The Dioxins in Food Dietary Exposure Assessment and Risk Characterisation results[22] produced by Food Standards Australia New Zealand also sampled peanut butters. Similar to the case with Health Canada TDS results, they report dioxin and dioxin-like compound concentrations on a whole weight/fresh weight basis, not a fat weight basis, and therefore cannot be directly compared to the data generated in this survey.

3.2.4 Nutritional Supplements and Meal Replacements

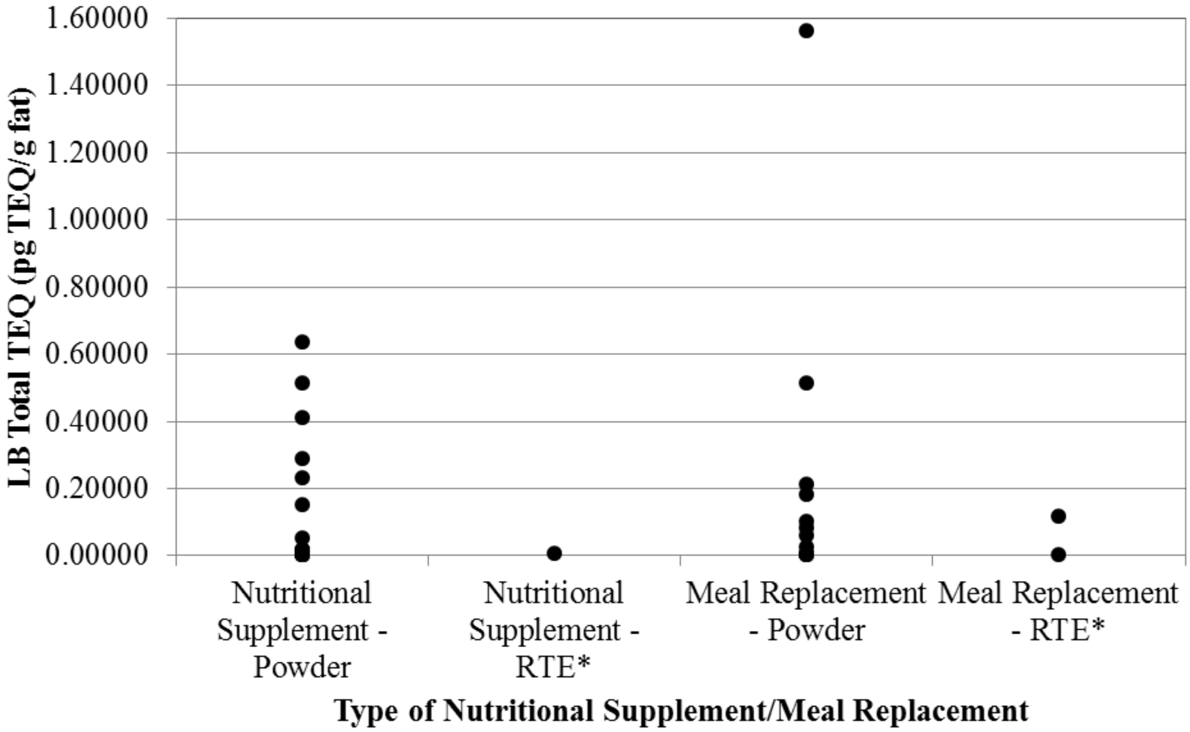
Forty samples of nutritional supplements and meal replacements were collected for this targeted survey. Samples were either powder shake mixes (meant to be mixed with liquid prior to consumption) or ready-to-consume drinks. Animal-based proteins consisted of dairy or goat milk products. Plant-based proteins consisted of plant oil or soy products. Mixed animal/plant-based proteins were mainly dairy and soy-containing, sometimes with plant oil or guar gum. Please refer to Figure 10 below for the types of nutritional supplements/meal replacements sampled.



*RTE: ready-to-consume/eat; the rest of the product types are powder shake mixes

Figure 10. Distribution of samples by nutritional supplement/meal replacement type

Thirty-nine nutritional supplements/meal replacements analyzed in this survey had at least one of the 29 congeners of concern detected. The remaining sample still had at least one of the additional six PCBs detected that do not contribute to the total TEQ. Figure 11 below shows the range of values found for the lower bound (LB) total TEQ by the type of nutritional supplement/meal replacement type tested.



*RTE: ready-to-consume/eat; the rest of the product types are powder shake mixes

Figure 11. LB total TEQ values in nutritional supplements/meal replacements by product type

The levels of dioxins and dioxin-like compounds in nutritional supplements, while a bit more variable, were very similar to those found in meal replacements regardless of whether the protein source was animal-based, mixed animal/plant-based, or plant-based. A single meal replacement powder shake mix was slightly elevated compared to the rest of the supplement/replacement samples.

The three highest LB total TEQ values were found in a domestic meal replacement sample (1.56032 pg TEQ/g; dairy and soy-containing powder shake mix), a nutritional supplement of unspecified origin (0.63542 pg TEQ/g; goat milk-based powder shake mix), and a domestic nutritional supplement (0.51399 pg TEQ/g; dairy and soy-containing powder shake mix). Overall, dairy and soy-containing meal replacement samples had the highest average LB total TEQ value, 0.23847 pg TEQ/g, while plant oil only-based nutritional supplements had the lowest average LB total TEQ value at 0.00744 pg TEQ/g.

The relative contribution of each compound type (dioxin, furan, and PCB) to the LB total TEQ was considered (refer to Section 3.1). There was 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 specific type of nutritional supplement or meal replacement (see Figure 12 below). The contributors were found with near equal frequency for nutritional supplement/meal replacement samples, regardless of whether the product base was animal-based, mixed animal/plant-based, or plant-based.

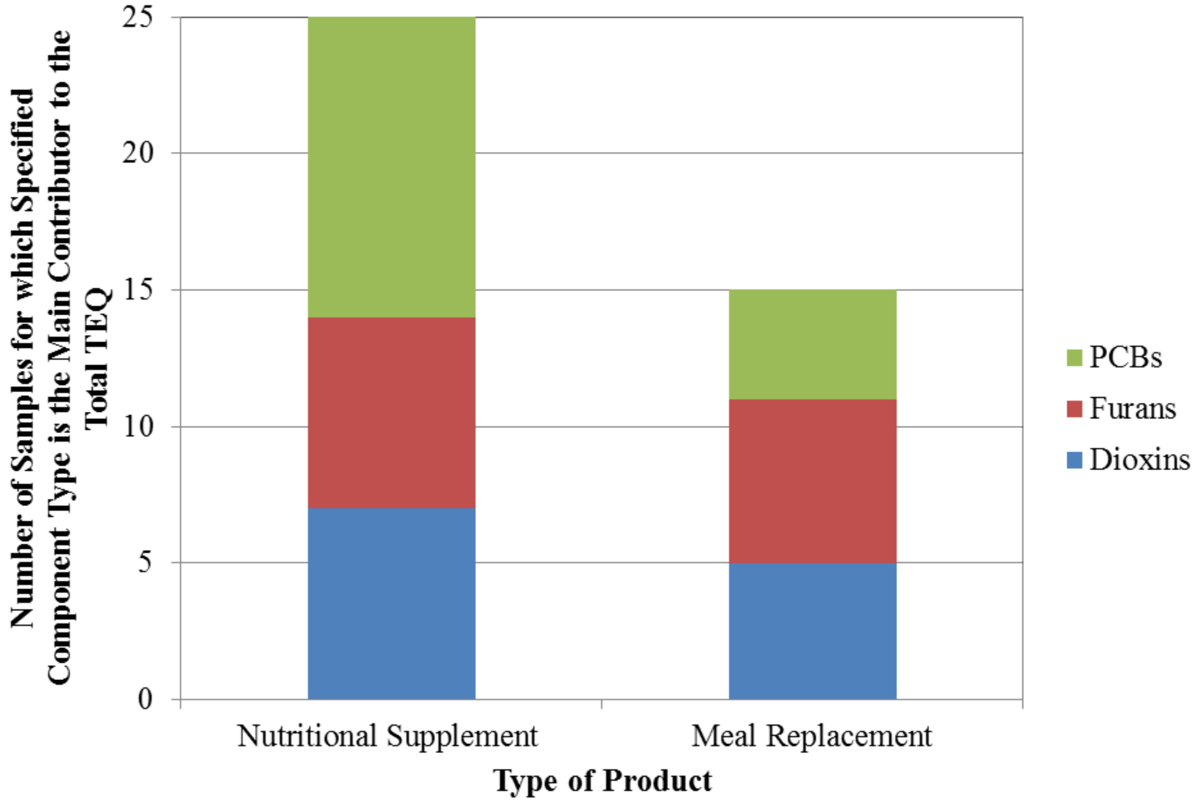


Figure 12. Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by product type

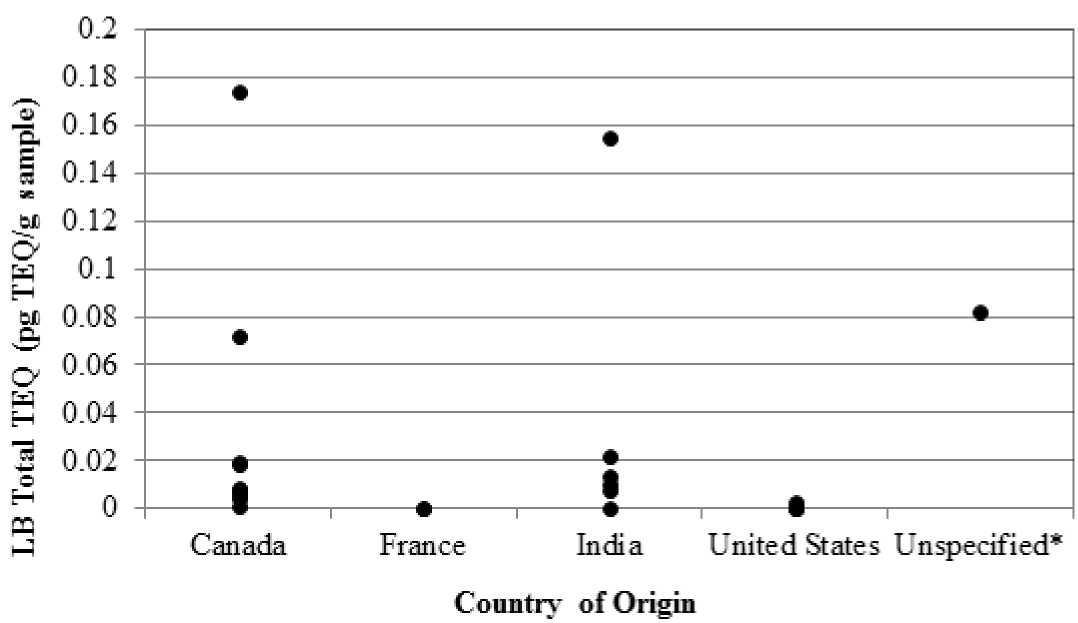
Nutritional supplements and meal replacements were not sampled in either of the previous FSAP Dioxin surveys, nor are they monitored under the CFIA's NCRMP, or included in the Canadian Total Diet Study (TDS) results[26] produced by Health Canada.

Little comparative data was available in the literature for dioxins and dioxin-like compounds in nutritional supplements and meal replacements. The US FDA has reported dioxin analysis results/exposure estimates in various foodstuffs under their own TDS, including ready-to-consume, liquid meal replacements[27]. Few of these types of products were sampled in this survey. Similar to the case with Health Canada TDS results, the US FDA reports dioxin and dioxin-like compound concentrations on a whole weight basis rather than a fat weight basis. For these reasons, direct comparison of the US FDA results to the data generated herein was not carried out.

3.2.5 Guar Gum

Twenty-three samples of guar gum were collected for this targeted survey. Nine of these samples were labelled as domestic product (Canada), thirteen were imported (6 from India, 5 from the United States, and 2 from France), and one sample was of unspecified origin (though likely imported; refer to the Limitations section for more information on country of origin).

All but one of the guar gums analyzed in this survey had at least one of the 29 congeners of concern detected. The remaining sample still had at least one of the additional six PCBs detected that do not contribute to the total TEQ. Figure 13 below shows the range of values found for the lower bound (LB) total TEQ by country of origin of the guar gum. It should be noted that, unlike other sample types presented in this reported which are reported on a fat basis, guar gums are reported in pg TEQ/g sample (i.e., on a whole weight basis) since they contain no fat or only trace amounts of fat.



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

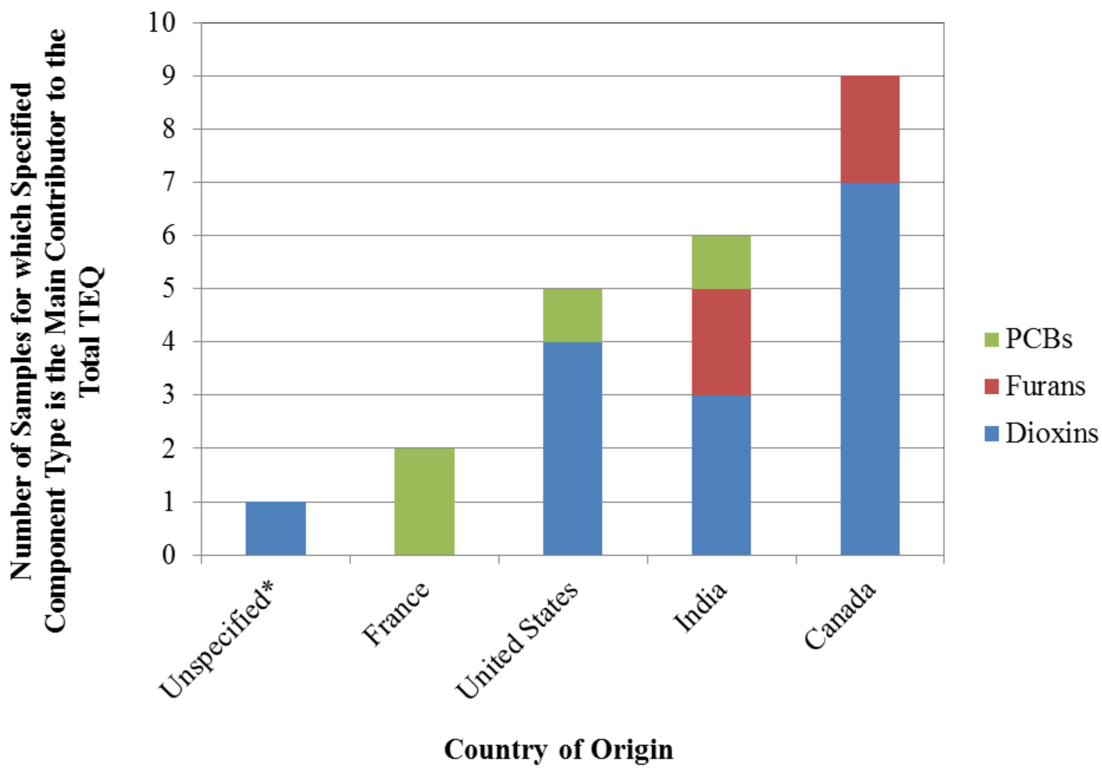
Figure 13. LB total TEQ values in guar gum by country of origin

The three highest LB total TEQ values were found in two domestic guar gum samples (0.17434 pg TEQ/g and 0.07242 pg TEQ/g) and one imported sample from India

(0.15496 pg TEQ/g). The average LB total TEQ value in guar gums was 0.02763 pg TEQ/g.

Guar gum is a permitted food additive in Canada as per the *List of Permitted Emulsifying, Gelling, Stabilizing or Thickening* Agents[25]. Previously, Health Canada has provided guidance to the CFIA that a total LB TEQ for dioxins above 1 pg TEQ/g in guar gum may lead to higher than normal TEQs in foods containing that gum, which could result in unnecessary exposure to dioxins. None of the guar gum samples tested herein were above 1 pg TEQ/g.

The relative contribution of each compound type (dioxin, furan, and PCB) to the LB total TEQ was considered (refer to Section 3.1). Dioxins were the main contributor to the overall total TEQ for guar gum samples tested in this survey (65% of the samples; see Figure 14 below).



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

Figure 14. Main contributor (dioxins, furans, or PCBs) to the LB total TEQ by country of origin and increasing number of samples

Guar gums are not monitored under the CFIA's NCRMP, nor are they included in the Canadian Total Diet Study (TDS) results[26] produced by Health Canada. The guar gum results in this survey were compared to those reported in the previous 2008-2009 FSAP Dioxin survey[3]. In that survey, all 20 samples of guar gum originated in India. The maximum LB total TEQ value seen in that survey was approximately 2.709 pg TEQ/g with an average value of 0.238 pg TEQ/g, both of which are significantly higher (by approximately 10 times) than the maximum and average values observed in the current survey. In the current and previous FSAP surveys, the concentrations of dioxins in guar gum originating from India were similar and very low.

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 existing Canadian regulation for the complete absence of chlorinated dibenzo-*p*-dioxins in foods, with the exception of fish, was established many years ago and is considered to be outdated by Health Canada. The absence of dioxins from certain animal-based and high-fat foods is not realistically achievable, and does not reflect the large improvements that have been made to analytical methods of detection for these substances. 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, a "zero tolerance" approach is not practical and is not applied by Canada or any of its' major trading partners.

The CFIA considered it appropriate to examine levels of dioxins and dioxin-like compounds in retail products, specifically vegetable oils/fats, dairy-containing foods, nut/seed butters, nutritional supplements/meal replacements, and guar gums, as these products are commonly consumed by Canadians on a daily basis and are not routinely monitored under the CFIA National Chemical Residue Monitoring Program.

One or more dioxins and/or dioxin-like compounds were detected in all samples tested in the 2011-2012 FSAP targeted survey. This is expected given the presence and persistence of these compounds in the environment. Relative to other samples in this survey, vegetable oils/fats and guar gums had the lowest levels of dioxins and dioxin-like compounds, while dairy-containing foods had the highest. These findings are consistent with plant fats bioaccumulating fewer dioxins and dioxin-like compounds than animal fats. There did not appear to be a dominant contributor to the LB total TEQ for most of the food categories sampled in this survey. This was in contrast to the case for guar gums, where dioxins appeared to be the dominant contributor to the total TEQ.

The levels of dioxins and dioxin-like compounds observed in this survey were evaluated by Health Canada's Bureau of Chemical Safety and none of the samples were expected to pose a safety concern to human health. Appropriate follow-up actions were initiated that reflected the magnitude of the human health concern. No product recalls were warranted.

5 Appendix

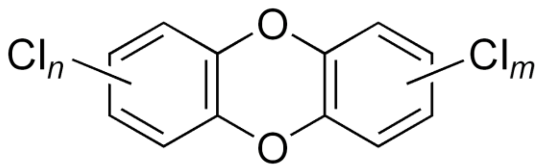
Table A. Various regulatory tolerances and maximum levels for dioxins and dioxin-like compounds in selected commodities

Country/Organization	Commodity	Sum of Dioxins only (WHO-PCDD/F-TEQ)	Sum of Dioxins and Dioxin-like PCBs (WHO-PCDD/F-PCB-TEQ)
European Union[28]	Raw milk and dairy products, including butterfat, containing > 2 % fat	2.5 pg TEQ/g fat[†]	5.5 pg TEQ/g fat[†]
	Vegetable oils and fats	0.75 pg TEQ/g fat[†]	1.25 pg TEQ/g fat[†]
Australia/FSANZ[29]	Milk and milk products	N/A	0.2 mg/kg (Total PCBs only)
Canada[7]	All foods	Elevated levels identified in foods are 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 Canadian *Food and Drugs Act*	
United States*	Milk, milk products, or vegetable fats/oils	N/A	N/A

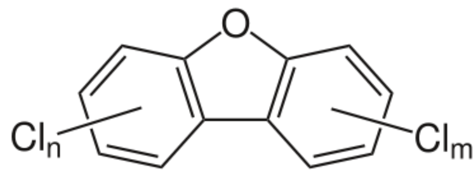
[†]The level is an upper bound level conservatively based on a worst-case exposure scenario
*Note: Action levels do exist in the US for PCBs in red meat[30] and for 2,3,7,8-TCDD in drinking water[31]

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

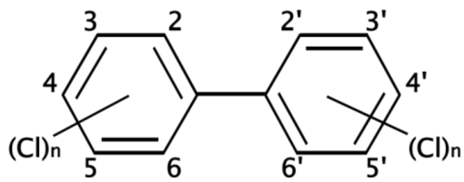
a)



b)



c)



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

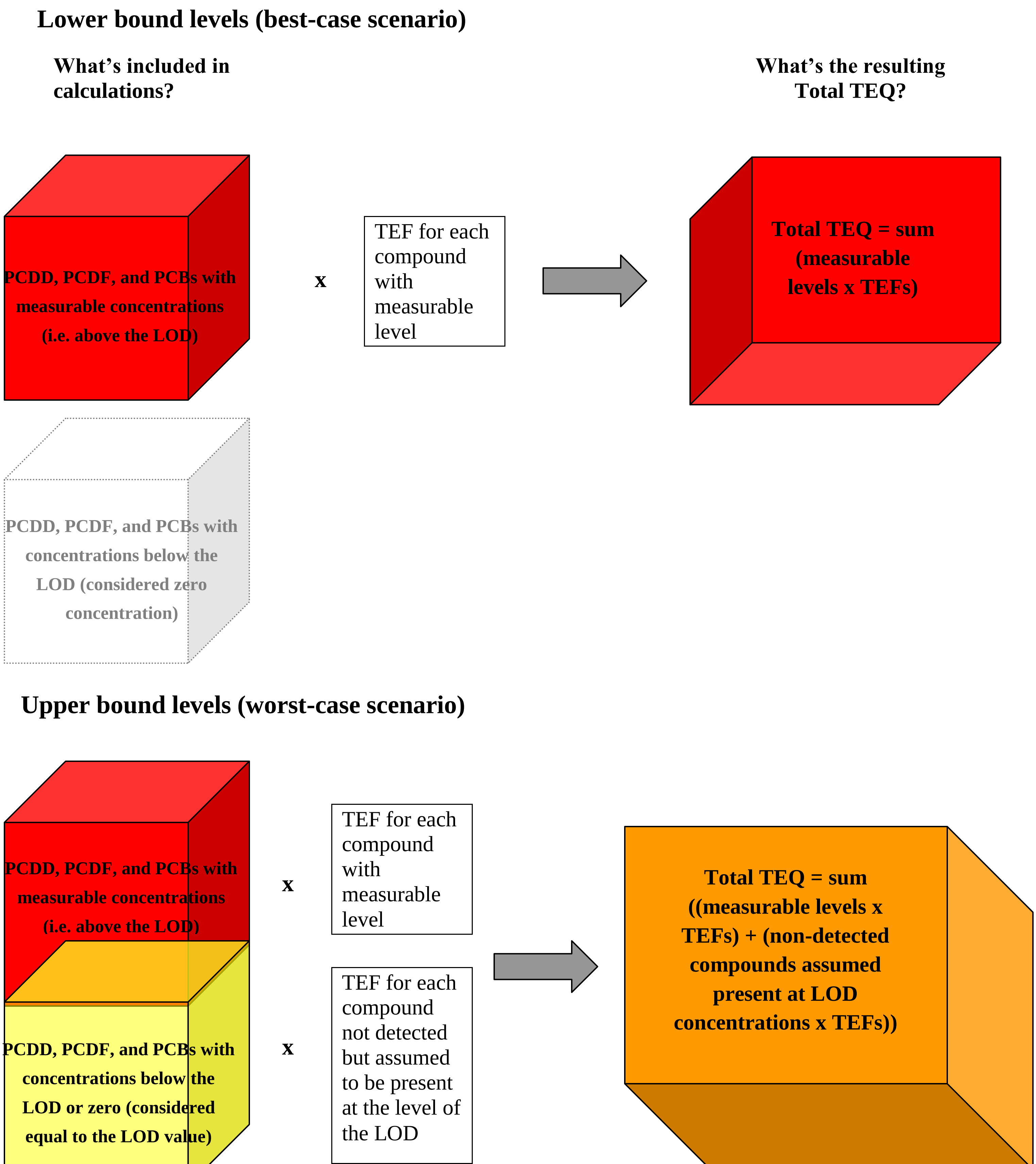
c) Polychlorinated biphenyls (referred to as dioxin-like PCBs) - there are 209 PCB congeners consisting of different arrangements and number of chlorine atoms around two joined benzene rings (lacking any oxygen atoms)

Table B. Limits of detection and WHO 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)[8]

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



6 References

[1] World Health Organization. *Exposure to Dioxins and Dioxin-like Substances: A Major Public Health Concern.* [online]. Published 2010. Consulted April 17, 2014, http://www.who.int/ipcs/features/dioxins.pdf

[2] Codex Alimentarius. *Code of Practice for the Prevention and Reduction of Dioxin and Dioxin-like PCB Contamination in Food and Feeds.* [online]. CAC/RCP 62-2006, Published 2006. Consulted April 17, 2014, http://www.codexalimentarius.org/standards/list-of-standards/en/

[3] Canadian Food Inspection Agency. Chemical Residues in Food. Chemical Residue Reports. *2008/2009 Dioxins in Guar Gum from India* and *2010/2011 Dioxins* and *Dioxin-like Compounds in Vegetable Oils and Cheese.* [online]. Last modified March 27, 2014. Consulted April 17, 2014, http://www.inspection.gc.ca/food/chemical-residues-microbiology/chemical-residues/eng/1324258929171/1324264923941

[4] Canadian Food Inspection Agency. Chemical Residues in Food. Chemical Residue Reports. *2009/2010 Annual Report – National Chemical Residue Monitoring Program.* [online]. Last modified March 27, 2014. Consulted April 17, 2014, http://www.inspection.gc.ca/food/chemical-residues-microbiology/chemical-residues/eng/1324258929171/1324264923941

[5] Health Canada. Food Safety. Chemical Contaminants. *Canadian Standards (Maximum Levels) for Various Chemical Contaminants in Foods.* [online]. Last modified June 28, 2012. Consulted June 3, 2014, http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives-eng.php

[6] Department of Justice. *Food and Drugs Act (R.S.C., 1985, c. F-27). Part I. Food. 4 (1) (d).* [online]. Last modified April 16, 2014. Consulted April 17, 2014, http://laws-lois.justice.gc.ca/eng/acts/f-27/index.html

[7] Department of Justice. *Food and Drug Regulations (C.R.C., c. 870). Division 1. B.01.046. (1) (p) and B.01.047. (f).* [online]. Last modified April 16, 2014. Consulted April 17, 2014, http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._870/index.html

[8] World Health Organization. *2005 Re-evaluation of human and mammalian toxic equivalency factors (TEFs).* [online]. Updated 16 November 2011. Consulted April 17, 2014, http://www.who.int/foodsafety/chem/tef_update/en/

[9] The Stockholm Convention. *The 12 initial POPs under the Stockholm Convention.* [online]. Entered into force 17 May 2004. Consulted April 17, 2014, http://chm.pops.int/Convention/ThePOPs/The12initialPOPs/tabid/296/Default.aspx

[10] Ogura, Isamu. Half-life of each dioxin and PCB congener in the human body. *Organohalogen Compounds*. Volume 66 (2004): 3329-3337.

[11] Health Canada. It's Your Health. Environment. *Dioxins and Furans.* [online]. September 2006. Consulted April 17, 2014, http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/dioxin-eng.php

[12] World Health Organization. *Dioxins and their effects on human health.* [online]. Fact sheet No. 225 May 2010. Consulted April 17, 2014, http://www.who.int/mediacentre/factsheets/fs225/en/

[13] The Stockholm Convention. *Listing of POPs in the Stockholm Convention - Annexes A and C.* [online]. Entered into force 17 May 2004. Consulted April 17, 2014, http://chm.pops.int/Convention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx

[14] United States Environmental Protection Agency. *Dioxins and Furans.* [online]. Undated. Consulted June 3, 2014, http://www.epa.gov/osw/hazard/wastemin/minimize/factshts/dioxfura.pdf

[15] European Commission. *Assessment of dietary intake of dioxins and related PCBs by the population of EU Member States.* [online]. 7 June 2000. Consulted April 17, 2014, http://ec.europa.eu/dgs/health_consumer/library/pub/pub08_en.pdf

[16] Malavia, J., Abalos, M., Santos, F.J., Abad, E., Rivera, J., Galceran, M.T. Analysis of polychlorinated dibenzo-p-dioxins, dibenzofurans and dioxin-like polychlorinated biphenyls in vegetable oil samples by gas chromatography-ion trap tandem mass spectrometry. *Journal of Chromatography A.* Volume 1149, Issue 2 (2007): 321-332.

[17] Europa. European Commission. Food and Feed Safety. *Final Report of a Mission Carried out in India… To Gather Information on the source of Contamination of Guar Gum with Pentachlorophenol and Dioxins and to Assess the Control Measures put in Place by the Indian Authorities to Avoid a Reoccurrence of this Contamination.* [online]. 2007. Consulted April 17, 2014, http://ec.europa.eu/food/fvo/rep_details_en.cfm?rep_id=1886#

[18] United States Environmental Protection Agency. *Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8 – Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds.* [online]. December 2010. Consulted April 17, 2014, http://www.epa.gov/raf/files/tefs-for-dioxin-epa-00-r-10-005-final.pdf

[19] Europa. European Commission. Food and Feed Safety. *Feed contamination – Dioxin in Germany.* [online]. Updated January 2011. Consulted April 17, 2014, http://ec.europa.eu/food/food/chemicalsafety/contaminants/dioxin_germany_en.htm

[20] Europa. European Commission. Food and Feed Safety. *Food Contaminants – Dioxins and PCBs.* [online]. Updated January 2011. Consulted April 17, 2014, http://ec.europa.eu/food/food/chemicalsafety/contaminants/dioxins_en.htm

[21] United States Department of Agriculture. Animal and Plant Health Inspection Service. Animal Health. Emerging Issues. *Dioxins in the Food Chain: Background.* [online]. Published 2000. Consulted April 17, 2014, http://www.aphis.usda.gov/animal_health/emergingissues/downloads/dioxins.pdf

[22] Food Standards Australia New Zealand. *Dioxins in food: Dietary Exposure Assessment and Risk Characterisation.* [online]. Findings released 28 May 2004. Consulted April 17, 2014, http://www.foodstandards.gov.au/publications/pages/dioxinsinfood/Default.aspx

[23] Statistics Canada. Summary tables. *Food available, by major food groups (Animal products) - 2009 data*. [online]. Updated April 2, 2012. Consulted April 17, 2014, http://www40.statcan.gc.ca/l01/cst01/famil102d-eng.htm

[24] Statistics Canada. Summary table. *Food available, by major food groups (Other) - 2009 data*. [online]. Updated March 31, 2011. Consulted April 17, 2014, http://www40.statcan.gc.ca/l01/cst01/famil102e-eng.htm

[25] Health Canada. Food Safety. Food Additives. Lists of Permitted Food Additives. *List of Permitted Emulsifying, Gelling, Stabilizing or Thickening Agents (Lists of Permitted Food Additives)*. [online]. Last modified August 19, 2013. Consulted June 3, 2014, http://www.hc-sc.gc.ca/fn-an/securit/addit/list/4-emulsif-eng.php

[26] Health Canada. Food and Nutrition Surveillance. Canadian Total Diet Study. *Concentration of Contaminants and Other Chemicals in Food Composites.* [online]. Publications April 2002 – Vancouver (Total PCBs) and January 1999 – Calgary (Dioxins, furans, and PCBs - Total TEQ). Consulted April 17, 2014, http://www.hc-sc.gc.ca/fn-an/surveill/total-diet/concentration/index-eng.php

[27] United States Food and Drug Administration. *Dioxin Analysis Results/Exposure Estimates.* [online]. Updated November 2007. Consulted April 17, 2014, http://www.fda.gov/Food/FoodborneIllnessContaminants/ChemicalContaminants/ucm077444.htm

[28] Europa. EUR-Lex. Access to European Union law. *Commission Regulation (EU) No 1259/2011 of 2 December 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non dioxin-like PCBs in foodstuffs.* [online]. Official Journal of the European Union, L320/18 – L 320/23, published 2 December 2011. Consulted April 17, 2014, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:320:0018:0023:EN:PDF

[29] Australian Government ComLaw. *Australian New Zealand Food Standards Code – Standard 1.4.1 – Contaminants and Natural Toxicants.* [online]. Updated 21 Feb 2013. Consulted April 17, 2014, http://www.comlaw.gov.au/Details/F2013C00140

[30] United States Food and Drug Administration. *Guidance for Industry: Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed.* [online]. CPG 565.200 published August 2000. Consulted April 17, 2014, http://www.fda.gov/food/guidanceregulation/guidancedocumentsregulatoryinformation/chemicalcontaminantsmetalsnaturaltoxinspesticides/ucm077969.htm

[31] United States Environmental Protection Agency. National Primary Drinking Water Regulations. *Organic Chemicals.* [online]. Last updated 3 June 2013. Consulted April 17, 2014, http://water.epa.gov/drink/contaminants/index.cfm#Organic