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

FOOD SAFETY ACTION PLAN

REPORT

2013-2014
TARGETED SURVEYS - CHEMISTRY

Perchlorate in Selected Foods

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Executive Summary

Targeted surveys are used by the Canadian Food Inspection Agency (CFIA) to focus its surveillance activities on areas of highest risk. The information gained from these surveys provides both support for the prioritization of the Agency's activities to areas of greater concern and scientific evidence to address areas of lesser concern. Originally started under the Food Safety Action Plan (FSAP), targeted surveys have been incorporated into the CFIA's regular surveillance activities as a valuable tool for generating essential information on certain hazards in foods, identifying/characterizing new and emerging hazards, informing trend analysis, prompting/refining human health risk assessments, assessing compliance with Canadian regulations, highlighting potential contamination issues, and promoting compliance.

The main objectives of this survey were to:

- generate baseline surveillance data on the levels of perchlorate in fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods available on the Canadian retail market; and
- compare the perchlorate levels in these results to other Canadian and international data on perchlorate, where possible.

Perchlorate is a chemical that occurs naturally in the environment (e.g., in some nitrate and potash deposits or formed in the atmosphere). It is also an environmental contaminant resulting from industrial processing of rocket propellants, explosives, road flares, fireworks, and automotive airbags. Since perchlorate readily dissolves in water, it can be taken up and accumulated by plants and may also be transferred to animals through the consumption of perchlorate-contaminated feed or water.

Human exposure to perchlorate occurs primarily through ingestion of food and water. At sufficiently high doses, perchlorate can interfere with the uptake of iodide by the thyroid gland which is required to produce hormones essential for metabolism and growth.

In the current survey, a total of 477 samples of fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods were collected from Canadian retail stores between April 2013 and March 2014 and analyzed for perchlorate. Two hundred and five of the 477 samples (43%) did not contain a detectable level of perchlorate. Overall, 71% of fresh vegetables, 40% of processed fruit/vegetable products, 80% of dairy products, 54% of infant formula, 30% of grain products, and 61% of assorted foods contained detectable levels of perchlorate ranging from 2 parts per billion (ppb) to 3300 ppb (detected in an arugula sample). The highest average perchlorate levels were found in fresh vegetables (130 ppb) and processed fruit/vegetable products (23 ppb), while the lowest average levels were found in grain products (5 ppb) and dairy products (6 ppb).

The occurrence and levels of perchlorate found in this survey were generally comparable with those reported in previous CFIA surveys as well data from the U.S. Food and Drug

Administration (U.S. FDA), the European Food safety Authority (EFSA), and the scientific literature.

All data were shared with Health Canada`s Bureau of Chemical Safety (BCS), including the arugula samples with the highest perchlorate levels (3300 ppb). The BCS determined that none of the perchlorate levels observed in this survey posed a human health concern, so no product recalls were warranted.

The CFIA will continue its surveillance activities and inform the Canadian public and stakeholders of its findings.

1. Introduction

1.1 Targeted Surveys

The Canadian Food Inspection Agency (CFIA) monitors both domestic and imported foods for the presence of allergenic, microbiological, chemical, and physical hazards. One of the tools used to maintain this oversight are targeted surveys, which are a means to establish baseline information on specific hazards and to investigate emerging risks. Targeted surveys are part of the Agency's core activities along with other surveillance strategies, which include the National Chemical Residue Monitoring Program (NCRMP), the National Microbiological Monitoring Program (NMMP), and the Children's Food Project (CFP). The surveys are complementary to other CFIA surveillance activities in that they examine hazards and/or foods that are not routinely included in those monitoring programs.

Targeted surveys are used to gather information regarding the possible occurrence or prevalence of hazards in defined food commodities. These surveys generate essential information on certain hazards in foods, identify or characterize new and emerging hazards, inform trend analysis, prompt or refine human health risk assessments, assess compliance with Canadian regulations, highlight potential contamination issues, and/or influence the development of risk management strategies as appropriate.

Due to the vast number of hazard and food commodity combinations, it is not possible, nor should it be necessary, to use targeted surveys to identify and quantify all hazards in foods. To identify food-hazard combinations of greatest potential health risk, the CFIA uses a combination of scientific literature, the media, 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 main objectives of this survey were to generate baseline surveillance data on the levels of perchlorate in fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods available on the Canadian retail market. The results of this survey were compared with previous FSAP results[1,2], with U.S. Food and Drug Administration (U.S. FDA) survey data[3,4], a report by the European Food Safety Authority (EFSA)[5], and to the scientific literature[6,7], where feasible.

1.2 Acts and Regulations

The specific acts and regulations applicable to this survey are described below.

The *Food and Drugs Act (U.S. FDA)* is the legal authority that governs the sale of food in Canada. 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 *Food and Drug Regulations* (U.S. FDA and FDR).

Currently, no maximum level, tolerance, or standard has been established by Health Canada for perchlorate in food and therefore, compliance with Canadian regulations was not evaluated in this survey. Similarly, regulations for perchlorate in food have not been established internationally.

2. Survey Details

2.1 Perchlorate

Perchlorate is a chemical that occurs naturally in the environment (e.g., in some nitrate fertilizers and potash deposits, and in the atmosphere)[8]. It is also considered an environmental contaminant that is industrially produced, originating from the inappropriate storage or disposal of perchlorate used in the production of rocket propellants, explosives, road flares, fireworks, automotive airbags and some fertilizers[9,10,11,12].

Since perchlorate readily dissolves in water, it can accumulate in groundwater and surface waters in areas where products containing perchlorate are manufactured or used on land previously treated with perchlorate-containing fertilizers. For example, Chilean nitrate (sodium nitrate), a naturally occurring fertilizer, has been shown to contain elevated levels of perchlorate[13]. Leached perchlorate from soil and groundwater can be taken up and accumulated by plants, particularly the leafy portions of several food crops. As such, through the consumption of perchlorate-contaminated feed or water, perchlorate may also accumulate in animal meat and milk[14].

Perchlorate has also been detected more frequently, and at higher concentrations, in organically grown leafy vegetables[15]. Although synthetic pesticides are prohibited for use in the production of organic vegetables, natural fertilizers such as sodium nitrate are permitted for use in restricted levels in the United States[16]. Note that sodium nitrate is prohibited for use in the production of organic products in Canada[17].

Human exposure to perchlorate occurs primarily through ingestion of food and water[18]. At sufficiently high doses, perchlorate can interfere with the uptake of iodide by the thyroid gland[18]. This can affect the production of thyroid hormones, which have a role in regulating many metabolic and developmental functions in humans[18]. The most sensitive subpopulations are pregnant women and their unborn children, newborns and individuals with thyroid conditions or iodine deficiencies[10].

2.2 Rationale

Studies have indicated that plants can absorb perchlorate from the soil and water, and elevated perchlorate levels have been found in leafy greens as well as various other fruits and vegetables[15,19,20].

Aside from fresh fruits and vegetables, perchlorate has been detected in dairy products resulting from the ingestion of perchlorate-contaminated water or feed by dairy cattle[12,20]. Dairy products are highly consumed by young children in particular, and results of the U.S. Food and Drug Administration's Total Diet Survey found that infants and children had the highest estimated intakes of perchlorate due to higher food and water consumption relative to body weight[10].

Low levels of perchlorate have also been found in milk-based and soy-based infant formulas; included in previous FSAP[1,2], U.S. FDA[3,4], and scientific literature reports[6,7]. The U.S. U.S. FDA exploratory and total diet studies also detected perchlorate in grain products and assorted foods, such as soups, pizza products, and salsa[3,4].

Given that many of these food products are regularly consumed by Canadian consumers, this targeted survey was designed to establish baseline data on perchlorate levels in these products available at the Canadian retail level. All data were shared with Health Canada for use in conducting human health risk assessments of perchlorate.

2.3 Sample Distribution

In the current survey, a total of 477 samples of fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods were collected from Canadian retail stores between April 2013 and March 2014 and analyzed for perchlorate. The general distribution of samples by product type is presented in Table 1.

Table 1. Distribution of samples by product type

Category	Sub-Category	Number of Samples
Infant Formula	Soy Based	9
	Dairy Based	30
Grain Products	Rice Products	25
	Wheat Products	35
Dairy Products	Frozen Desserts	10
	Cheese	20
	Yogurt	30
Assorted Foods	Salsa	9
	Soup	15
	Pizza Products	20
	Soy Products	20
Processed Fruit/Vegetables	Dried Vegetables	17
	Dried Fruit	45
	Beverages	50
Fresh Vegetables	Leafy Greens	40
	Potatoes	48
	Herbs	54
Grand Total		**477**

The 477 samples included 104 domestic products, 214 imported products, and 159 samples of unspecified origin. Here, "unspecified" refers to those samples for which the country of origin could not be determined from the sample label or product information. It is important to note that the products sampled often contained the statement "imported for Company A in Country Y" or "manufactured for Company B in Country Z". Although 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 24 countries, with the United States accounting for 62% of imported products.

2.4 Method Details

Samples were analyzed for perchlorate by an ISO 17025 accredited laboratory under contract with the Government of Canada. The laboratory used ion chromatography-tandem mass spectrometry to analyze perchlorate levels in the samples. The method employed had a limit of detection (LOD) of 2 ppb.

2.5 Limitations

The current targeted survey was designed to provide a snapshot of the levels of perchlorate in fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods available for sale in Canada, and had the potential to highlight commodities that warrant further investigation. The limited sample size analyzed represents a small fraction of the products available to Canadian consumers. Therefore, care must be taken when interpreting and extrapolating these results. Regional differences, impact of product shelf-life, packaging and storage conditions, or cost of the commodity on the open market were not examined in this survey.

All samples, including infant formulas, were tested as sold, meaning that the product was not prepared as per the package instructions (if applicable).

3. Results and Discussion

3.1 Overview of Perchlorate Survey Results

In the current survey, a total of 477 samples of fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods were collected from the Canadian retail market and analyzed for perchlorate. Figure 1 summarizes the occurrence of perchlorate by product type for the current survey. Dairy products had the highest occurrence, with 80% of samples having a detectable level of perchlorate, followed by fresh vegetables (71%), assorted foods (61%), infant formula (54%), processed fruit/vegetable products (40%), and grain products (30%).

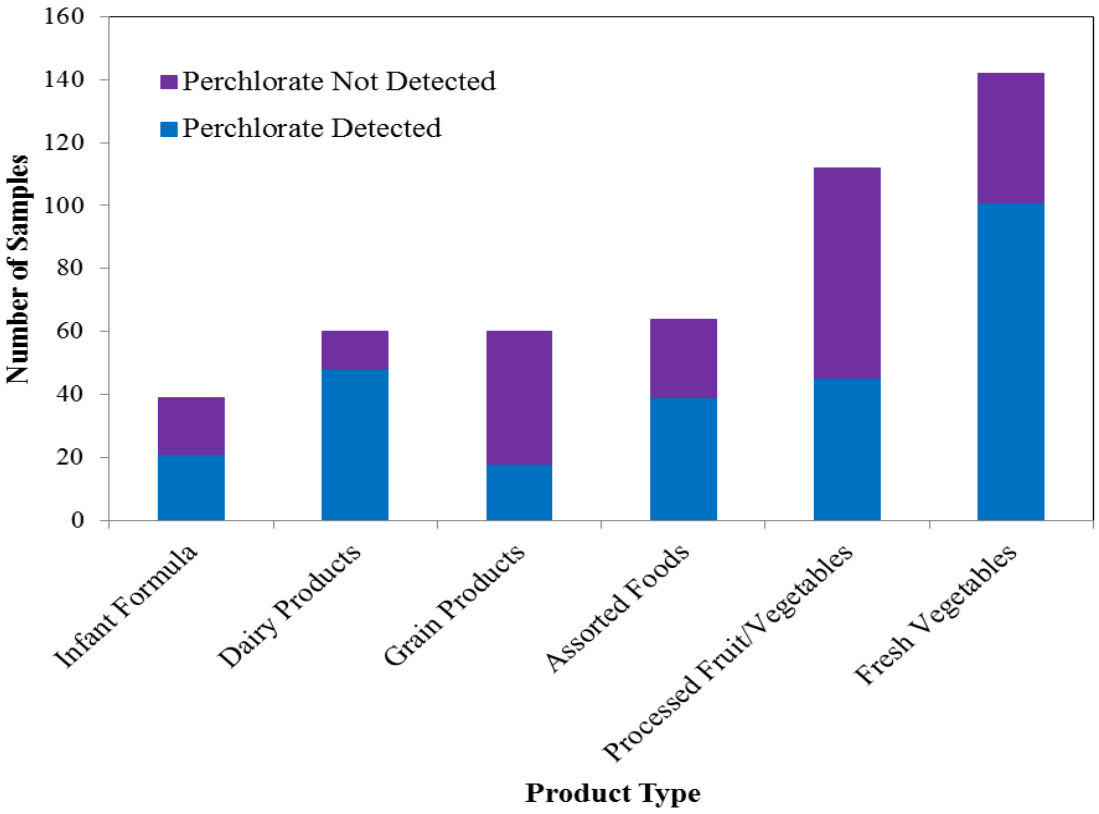


Figure 1. Summary of perchlorate occurrence by product type.

Table 2 summarizes the number of samples, minimum/maximum, and average perchlorate results by product type for the current survey. Overall, fresh vegetables had the highest average (130 ppb) and maximum (3300 ppb) perchlorate levels detected. Grain products had the lowest occurrence, maximum and average perchlorate levels of all product types sampled.

Table 2. Number of samples, minimum/maximum, and average perchlorate results by product type

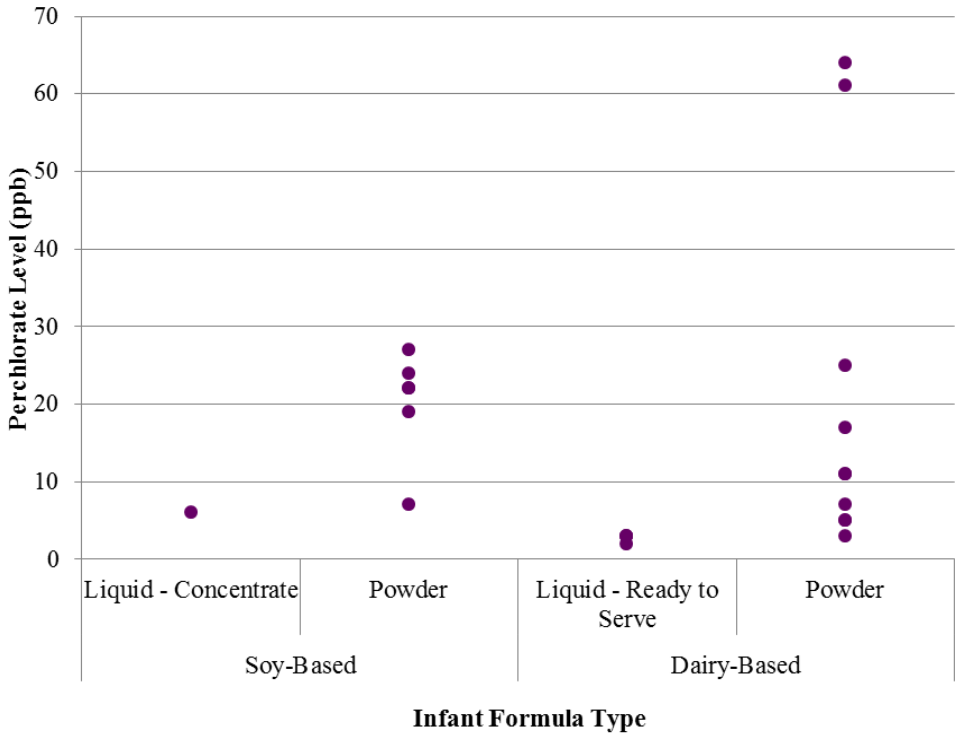
Category	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Infant Formula	39	21 (54)	2	64	17
Grain Products	60	18 (30)	2	9	5
Dairy Products	60	48 (80)	2	42	6
Assorted Foods	64	39 (61)	2	86	8
Processed Fruit/Vegetables	112	45 (40)	2	190	23
Fresh Vegetables	142	101 (71)	2	3300	130
Total	**477**	**272 (57)**	**2**	**3300**	**56**

*Average of positive results only

The following sections present the perchlorate results organized by individual product type. Where possible, the results of this survey were compared with previous FSAP results [1,2], with U.S. FDA survey data [3,4], a report by the EFSA[5], and to the scientific literature[6,7]. It should be noted that the average perchlorate values discussed in the current and previous CFIA FSAP surveys were calculated using only those results above the LOD of 2 ppb (i.e., average of the positive results only).

3.2 Infant Formula

A total of 39 of infant formula products were analyzed for perchlorate, including 30 dairy- and 9 soy-based formula samples. The infant formula products were in the form of liquid and powder concentrates (requiring water dilution prior to consumption), as well as in the form of ready-to-serve liquids. Of the 39 samples collected, 21 (54%) had a detectable level of perchlorate, ranging from 2 ppb to 64 ppb. Figure 2 illustrates the distribution of detected perchlorate levels by formula type and product form (liquid ready-to-serve, liquid concentrate, and powder). Concentrated powder products (which require the addition of water before consumption) contained higher concentrations of perchlorate in comparison to liquid products (which may or may not require the addition of water). Dairy-based infant formula products had higher maximum (64 ppb) perchlorate levels in comparison to soy-based formula.



*Only values at or above the limit of detection are shown

Figure 2. Distribution of perchlorate levels detected in infant formula samples by product type and form

Table 3 presents a comparison of the perchlorate levels in infant formulas in the current survey with the previous FSAP surveys, as well as to reports from the scientific literature. Overall, the occurrence (percentage of samples testing positive) is very consistent between CFIA FSAP survey years for both dairy- and soy-based infant formulas. In all years, the levels of perchlorates are generally quite low in infant formulas.

Table 3. Number of samples, minimum/maximum, and average perchlorate levels in infant formulas

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Dairy-Based						
CFIA[1,2]	2013-2014	30	14 (47)	2	64	16
	2011-2012	68	36 (53)	2	33	9
	2010-2011	74	43 (58)	2	22	4
Pearce[7]	2007	14	14 (100)	0.2	4.1	1.7
Schier[6]	2010	15	15 (100)	0.68	5.05	1.72
Soy-Based						
CFIA[1,2]	2013-2014	9	7 (78)	6	27	18
	2011-2012	18	13 (72)	2	35	19
	2010-2011	15	13 (87)	2	50	17
Pearce[7]	2007	3	3 (100)	0.3	0.6	0.4
Schier[6]	2010	15	15 (100)	0.1	0.44	0.21

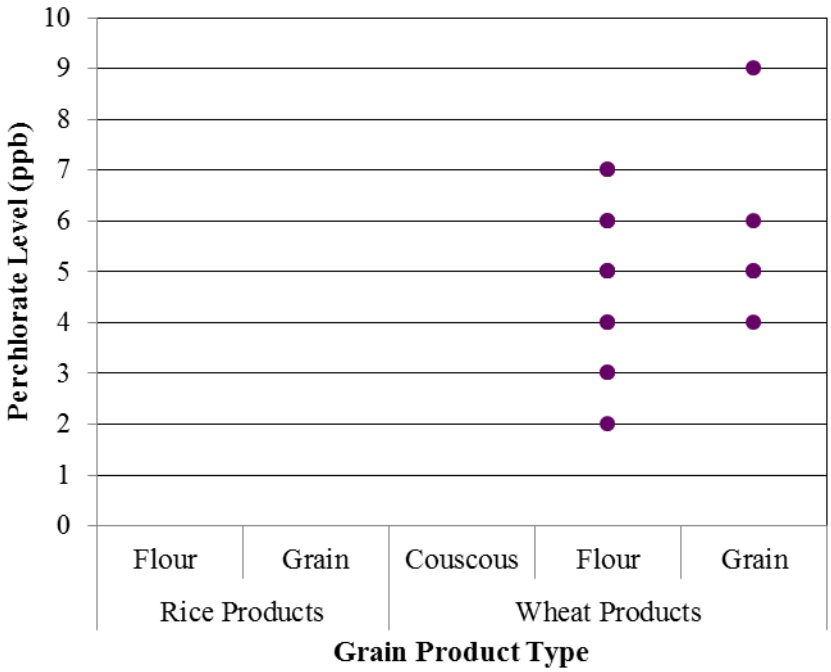
*Average of positive results only

Scientific literature results regarding perchlorate levels in infant formula are summarized in Table 3 [6, 7]. Note that these reports analyzed samples as-consumed, in contrast to the as-sold testing performed by the CFIA. For liquid concentrate formulas, the product is typically mixed with an equal amount of water (dilution factor of 0.5). For powdered formulas, the specific manufacturer's instructions vary but in general, one part infant powdered formula is mixed with 7 parts of water (dilution factor of 0.125). When the manufacturer's recommended preparation instructions are taken into consideration, the results from the current survey are in good agreement with those reported in the literature[6,7].

3.3 Grain Products

A total of 60 grain products were analyzed for perchlorate, including 25 rice products (grain, flour) and 35 wheat products (couscous, grain, flour). Of the 60 samples, 18 (28%) were found to contain a detectable level of perchlorate. The 18 positive samples were all wheat products; no samples of rice products contained detectable levels of perchlorate. Specifically, 6 samples of wheat grain and 12 samples of wheat flour were found to contain perchlorate. The distribution of perchlorate levels in these products is shown in

Figure 3. The detected levels of perchlorate ranged from 2 ppb to 9 ppb with an average of 5 ppb.



*Only values at or above the limit of detection are shown

Figure 3. Distribution of perchlorate levels detected in grain products by product type

Table 4 summarizes the number of samples, minimum/maximum, and average perchlorate levels in grain products for the current survey, as well as the results of a 2004 U.S. FDA survey on perchlorate that included rice grain and wheat flour[3]. The U.S. FDA data on perchlorate in grain products agree with the current FSAP survey results.

Table 4. Number of samples, minimum/maximum, and average perchlorate levels in grain products

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Rice Products						
CFIA	2013-2014	25	0 (0)	-	-	-
U.S. FDA[3]	2004-2005	19	0 (0)	-	-	-
Wheat Products						
CFIA	2013-2014	35	18 (51)	2	9	5
U.S. FDA[3]	2004-2005	19	12 (63)	3.78	9.39	6.47

*Average of positive results only

3.4 Dairy Products

A total of 60 dairy products were analyzed for perchlorate, including frozen desserts (cheesecake, ice cream/bars, other dessert), yogurt products (yogurt, beverages, frozen yogurt) and cheese. Of the 60 samples, 48 (80%) were found to contain a detectable level of perchlorate. Figure 4 presents the distribution of detected perchlorate values in dairy products. The concentrations of perchlorate ranged from 2 ppb to 42 ppb with an overall average of 6 ppb. Cheese products had the highest maximum and average perchlorate levels of the dairy products surveyed.

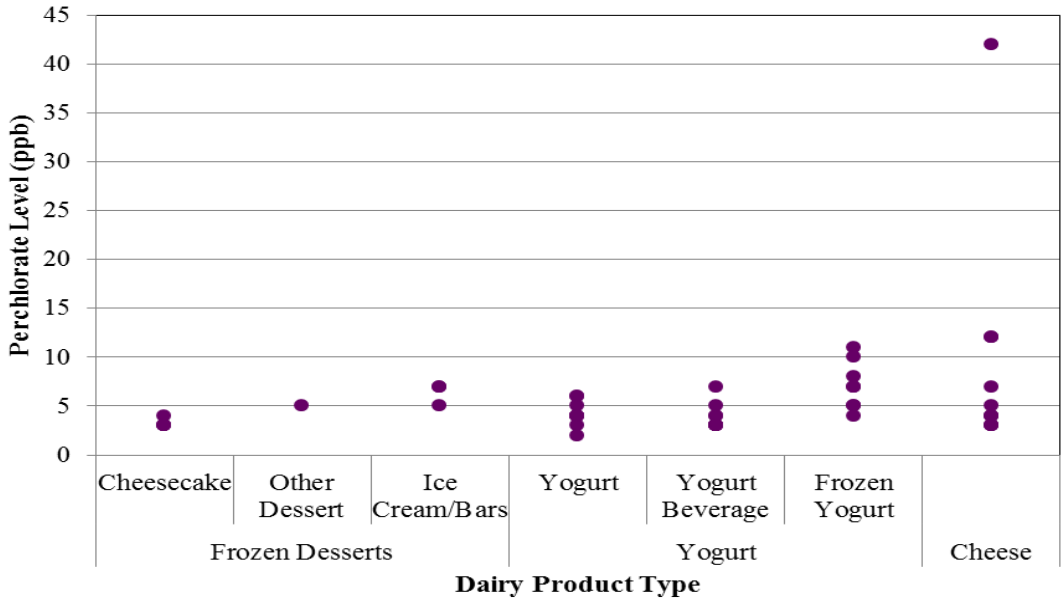


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Figure 4. Distribution of perchlorate levels detected in dairy products by product type

Frozen Desserts

Ten frozen dessert samples were analyzed for perchlorate, including four cheesecakes, four ice cream and two other dessert products (pie, cake). Eight samples (80%) from the current survey were found to contain perchlorate, with levels ranging from 3 ppb to 7 ppb. Table 5 shows a comparison of the current survey data to previous FSAP survey results, as well as to an U.S. FDA total diet study on perchlorate. Overall, the FSAP results are highly consistent between survey years, with very similar positive rates, maximum and average perchlorate levels. As well, these results are consistent with the U.S. FDA survey of perchlorate levels in ice cream products. Note that the U.S. FDA study sampled only ice cream products. For a more direct comparison, the four ice cream products from the current survey had an average perchlorate concentration of 6 ppb; slightly lower than the U.S. FDA average.

Table 5. Summary of FSAP and U.S. FDA survey data on perchlorate in frozen desserts

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Frozen Desserts						
CFIA[2]	2013-2014	10	8 (80)	3	7	5
	2012-2013	35	30 (86)	2	10	4
	2011-2012	17	15 (88)	2	9	4
U.S. FDA[4]	2005-2006**	8	8 (100)	5.6	10.3	7.5

*Average of positive results only
**U.S. FDA frozen desserts sampled only ice cream

Cheese

Twenty cheese samples were analyzed for perchlorate, including varieties of cheddar, gouda, feta, camembert, swiss, edam, montamore, jarlsberg, reggiano, red leichester, grana padano, and brillat-savarin. Eleven of the 20 samples (55%) were found to contain perchlorate, with levels ranging from 3 ppb to 42 ppb and an average of 9 ppb. Table 6 shows a comparison of the current survey data to previous FSAP survey results, as well as to an U.S. FDA total diet study on perchlorate. The current year has a higher maximum perchlorate level than the previous FSAP survey, but a lower occurrence and a comparable average. The 2005-2006 U.S. FDA study included cheese products such as American processed, swiss, cheddar, and cottage cheeses. In comparison to the U.S. FDA survey, the FSAP surveys have higher maximum perchlorate levels but lower occurrence.

Table 6. Summary of FSAP and U.S. FDA survey data on perchlorate in cheese

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Cheese						
CFIA[1]	2013-2014	20	11 (55)	3	42	9
	2010-2011	23	16 (70)	2	24	7
U.S. FDA[4]	2005-2006	20	20 (100)	3.3	11.9	6.5

*Average of positive results only

Yogurt Products

Thirty yogurt products were analyzed for perchlorate, including yogurt cups, beverages, and frozen yogurt desserts. Twenty-nine of the 30 samples (97%) were found to contain perchlorate, with concentrations ranging from 2 ppb to 11 ppb. As shown in Table 7, the

occurrence, maximum and average values from the current survey are very consistent with previous FSAP and U.S. FDA survey results.

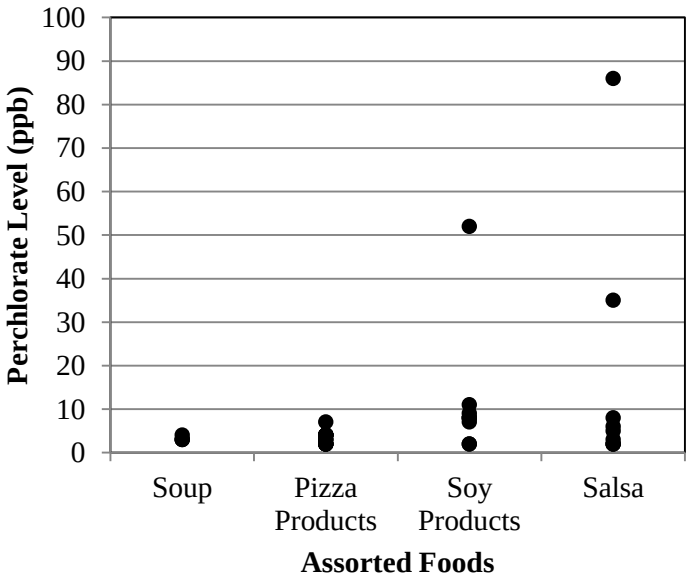
Table 7. Summary of FSAP and U.S. FDA survey data on perchlorate in yogurt products

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Yogurt Products						
CFIA[1]	2013-2014	30	29 (97)	2	11	5
	2010-2011	24	23 (96)	2	12	5
U.S. FDA[4]	2005-2006	4	4 (100)	4.1	10.5	6.8

*Average of positive results only

3.5 Assorted Foods

The assorted foods category consisted of soup, pizza products (frozen pizzas), soy products (tofu and other meat alternatives) and salsa. Of the 64 samples, 39 (61%) were found to contain perchlorate, with concentrations ranging from 2 ppb to 86 ppb and an average level of 8 ppb. Figure 5 presents the distribution of detected perchlorate values in assorted food products. The levels of perchlorate in assorted food products are generally consistent aside from one soy product and 2 salsa samples.



*Only values at or above the limit of detection are shown

Figure 5. Distribution of perchlorate levels detected in assorted foods by product type

Soup

Fifteen soup products (vegetable, tomato, and bean soups) were included in the current survey, with 4 samples (27%) having detectable levels of perchlorate. The detected perchlorate levels in soup products were very low, with maximum and average concentrations of 4 ppb and 3 ppb, respectively (Table 8). In comparison to the 2005-2006 U.S. FDA study on soup (tomato, vegetable, bean, soups), the current survey has lower maximum and average perchlorate concentrations.

Table 8. Summary of FSAP and U.S. FDA survey data on perchlorate in soup

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Soup						
CFIA	2013-2014	15	4 (27)	3	4	3
U.S. FDA[4]	2005-2006	20	4 (20)	3.5	14.1	7.8

*Average of positive results only

Pizza Products

Twenty pizza products (frozen mini pizzas, pizza pockets, and rising crust pizzas) were surveyed, with 17 samples (85%) having a detectable level of perchlorate. The detected perchlorate levels in pizza products were very low, with maximum and average

concentrations of 7 ppb and 3 ppb respectively. In comparison to the U.S. FDA survey, the FSAP survey has a higher maximum perchlorate level but lower occurrence. The average perchlorate levels are comparable between surveys (Table 9).

Table 9. Summary of FSAP and U.S. FDA survey data on perchlorate in pizza products

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Pizza Products						
CFIA	2013-2014	20	17 (85)	2	7	3
U.S. FDA[4]	2005-2006	4	4 (100)	3	4.2	3.6

*Average of positive results only

Soy Products

Twenty soy products (tofu and meat alternatives) were included in the current survey, with 9 samples (45%) having detectable levels of perchlorate. The detected concentrations of perchlorate ranged from 2 ppb to 52 ppb, with an average of 12 ppb. As evident in Figure 5, one soy product sample (a tofu roast) was found to contain perchlorate at 52 ppb, considerably higher than the other soy product samples. There is a lack of data in the literature regarding perchlorate levels in soy products; therefore, a direct comparison of the current results could not be made.

Salsa

Nine salsa samples (mild, medium, and hot) were analyzed, with all 9 samples (100%) having detectable levels of perchlorate. The detected concentrations of perchlorate ranged from 2 ppb to 86 ppb with an average of 17 ppb (Table 10). The U.S. FDA has also included salsa in a previous total diet study, with a single sample found to contain 15.4 ppb perchlorate. The FSAP data has a higher occurrence and maximum level of perchlorate; however, the U.S. FDA sample size was smaller.

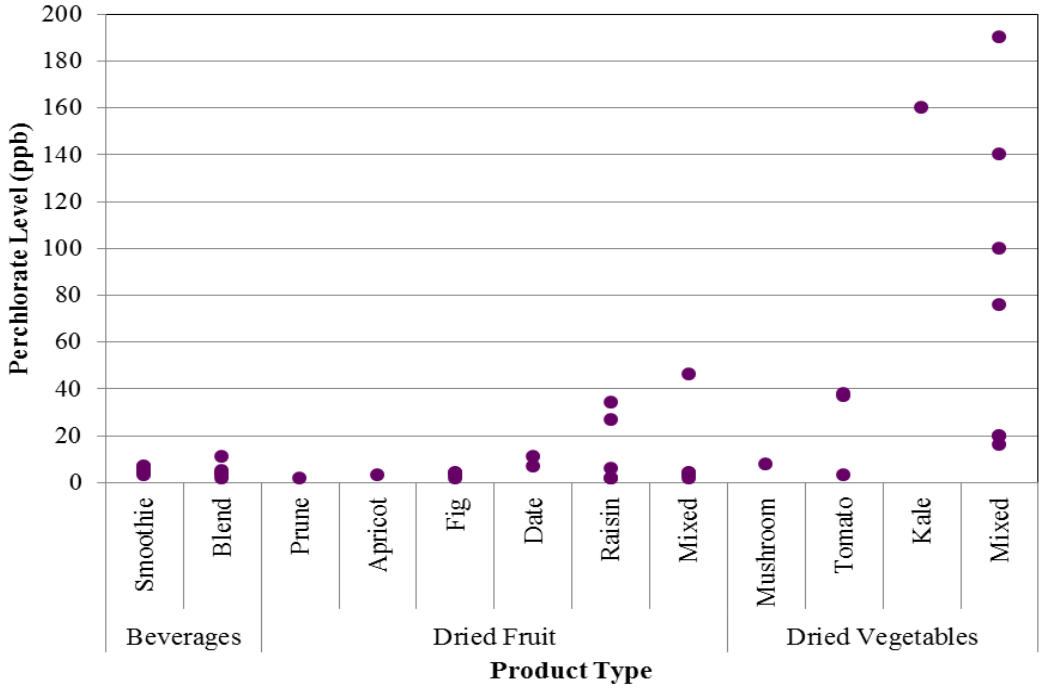
Table 10. Summary of FSAP and U.S. FDA survey data on perchlorate in salsa

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Salsa						
CFIA	2013-2014	9	9 (100)	2	86	17
U.S. FDA[4]	2005-2006	4	1 (25)	-	15.4	NA

*Average of positive results only

3.6 Processed Fruit and Vegetables

The processed fruit and vegetable category consisted of beverages (fruit juice blends and smoothies), dried fruit (prunes, apricots, figs, dates, raisins, and mixed) and dried vegetables (mushrooms, tomatoes, kale, and mixed vegetables). Of the 112 samples, 45 (40%) were found to contain detectable levels of perchlorate, with concentrations ranging from 2 ppb to 190 ppb and an average of 23 ppb. Figure 6 presents the distribution of perchlorate levels detected in processed fruit and vegetables by product type. Dried vegetables had the highest maximum and average perchlorate concentrations in comparison to beverages and dried fruit.



*Only values at or above the limit of detection are shown

Figure 6. Distribution of perchlorate levels detected in processed fruit and vegetables by product type

Fruit/Vegetable Beverages

Fifty fruit/vegetable beverages were surveyed, with 14 samples (28%) having detectable levels of perchlorate. The detected concentrations ranged from 2 ppb to 11 ppb, with an average level of 5 ppb. The levels of perchlorate detected were very similar for smoothies and juice blends. Table 11 presents a comparison of the current survey data to previous FSAP and U.S. FDA surveys on perchlorate in fruit/vegetable juices. The occurrence and average levels of perchlorate are highly consistent between FSAP survey years. As well, the current FSAP results fall within the range of results reported in the two U.S. FDA surveys.

Table 11. Summary of FSAP and U.S. FDA survey data on perchlorate in fruit/vegetable beverages

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Fruit/Vegetable Beverages						
CFIA[2]	2013-2014	50	14 (28)	2	11	5
	2012-2013	147	34 (23)	2	20	5
	2011-2012	78	17 (22)	2	11	5
U.S. FDA[3,4]	2005-2006	36	7 (19)	3.3	12.8	5.9
	2004-2005	14	14 (100)	1.28	3.45	2.31

*Average of positive results only

Dried Fruit

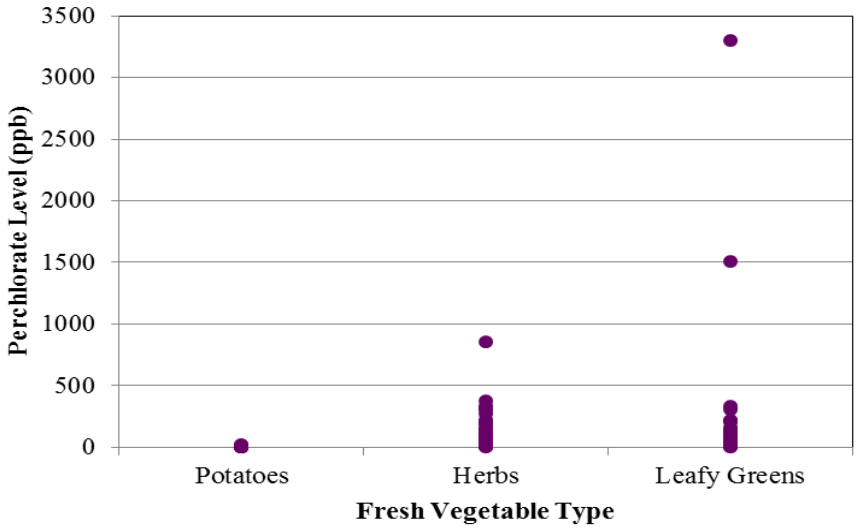
Forty-five dried fruit products were analyzed, including prunes, apricots, figs, dates, raisins, and mixed fruit. Of the 45 samples, 19 (42%) were found to contain a detectable level of perchlorate ranging from 2 ppb to 46 ppb, with an average of 9 ppb. Apricots and figs had low levels of perchlorate whereas raisins and mixed fruit samples had the highest levels (Figure 6). Dried fruit products have not been included in previous FSAP surveys or, to the best of our knowledge, any reports in the scientific literature. Therefore, no comparisons could be made.

Dried Vegetables

Seventeen dried vegetable products were analyzed, including mushrooms, tomatoes, kale, and mixed vegetables. Of the 17 samples, 12 (71%) were found to contain a detectable level of perchlorate ranging from 3 ppb to 190 ppb, with an average of 67 ppb. Mixed vegetables contained the highest levels of perchlorate whereas mushrooms contained the lowest (Figure 6). Dried vegetables had the highest average and maximum levels of perchlorate for processed fruit and vegetables. Dried vegetables have not been included in previous FSAP surveys or, to the best of our knowledge, any reports in the scientific literature. Therefore, no comparison could be made.

3.7 Fresh Vegetables

The fresh vegetable category included potatoes, herbs, and leafy greens. Of the 142 samples, 101 (71%) contained detectable levels of perchlorate with concentrations ranging from 2 ppb to 3300 ppb and an average of 130 ppb. Figure 7 shows the distribution of detected perchlorate levels in fresh vegetable products. Potatoes had the lowest overall levels of perchlorate whereas fresh leafy greens had the highest.



*Only values at or above the limit of quantification are shown

Figure 7. Distribution of perchlorate levels detected in fresh vegetables by product type

Potatoes

Forty-eight potato samples were analyzed, including fingerling, red, russet, white, and yellow potatoes. Of the 48 samples, 10 (21%) contained detectable levels of perchlorate ranging from 2 ppb to 19 ppb with an average of 6 ppb. Baking potatoes had the highest levels of perchlorate of the potato types surveyed. Overall, the levels of perchlorate in potatoes were very low.

Table 12 presents a summary of the current FSAP and previous U.S. FDA survey data on perchlorate in potatoes. Potatoes have been tested under two U.S. FDA surveys; the 2004-2005 survey sampled fresh, uncooked potatoes, whereas the 2005-2006 survey tested cooked potatoes (baked, fried, boiled). The current FSAP results fall within the range of reported results from the two U.S. FDA surveys.

Table 12. Summary of FSAP and U.S. FDA survey data on perchlorate in fresh potatoes

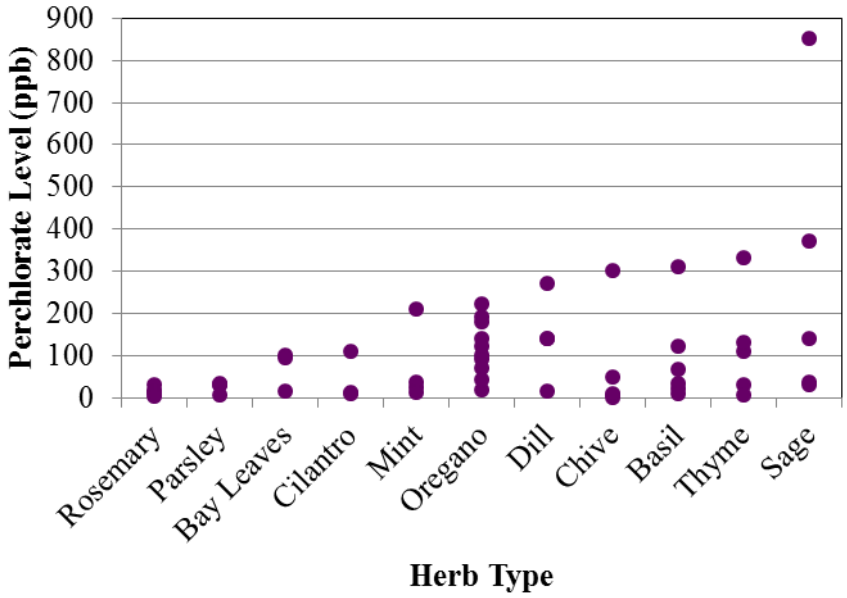
Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Potatoes						
CFIA	2013-2014	48	10 (21)	2	19	6
U.S. FDA[3,4]	2005-2006**	20	4 (20)	5.7	26.4	14
	2004-2005	12	6 (50)	1.00	2.07	1.40

*Average of positive results only

**U.S. FDA Total Diet Study analyzed cooked potatoes/potato products

Herbs

A variety of fresh herbs were analyzed, including basil, chives, bay leaves, cilantro, dill, mint, oregano, parsley, rosemary, sage, thyme. Fifty-three samples (98%) were found to contain perchlorate, with levels ranging from 3 ppb to 850 ppb and an average of 103 ppb. Figure 8 illustrates the distribution of detected perchlorate levels in herbs, organized by herb type. Rosemary samples had the lowest maximum and average perchlorate levels whereas sage samples had the highest. A recent EFSA publication included 92 herb samples with a middle bound mean perchlorate level of 74.1 ppb[5]. This value is slightly lower than the average perchlorate level found in the current FSAP survey (105 ppb).

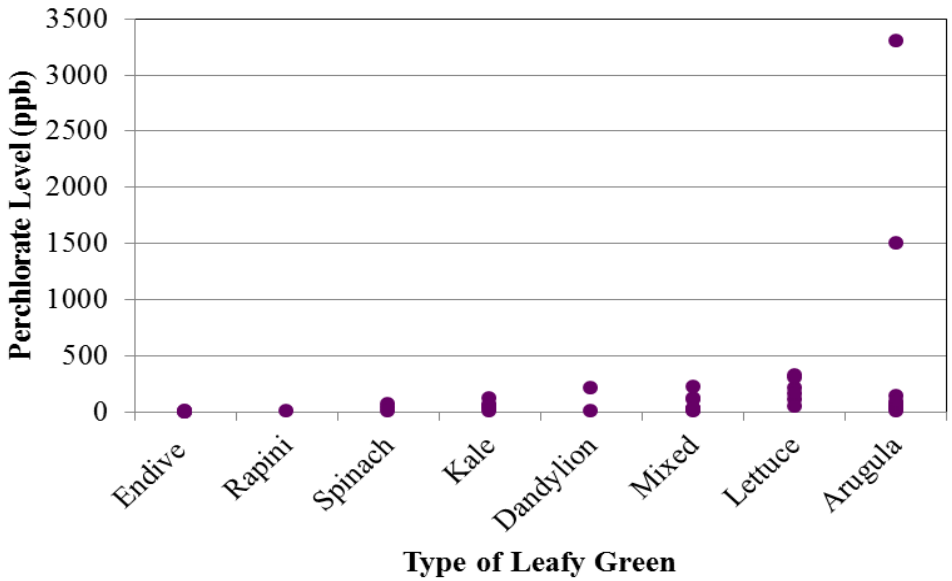


*Only values at or above the limit of detection are shown

Figure 8. Distribution of perchlorate levels detected by herb type

Leafy Greens

Fresh leafy greens included arugula, rapini, kale, lettuce, spinach, broadleaf endive, dandelion greens, and mixed greens. Thirty-eight of the 40 samples (95%) were found to contain perchlorate, with concentrations ranging from 5 ppb to 3300 ppb and an average of 200 ppb. Figure 9 shows the distribution of detected perchlorate levels by leafy green type. Overall, the perchlorate concentrations are fairly consistent between leafy green types; aside from two samples of arugula with elevated levels (1500 and 3300 ppb). Leafy green samples contained the highest maximum and average perchlorate levels of the product types sampled in the current survey.



*Only values at or above the limit of detection are shown

Figure 9. Distribution of perchlorate levels in fresh leafy greens

Table 13 presents a summary of the current and previous FSAP and U.S. FDA survey data on perchlorate levels in leafy greens. The current survey year has the highest occurrence, maximum and average perchlorate levels in comparison to previous FSAP and U.S. FDA surveys of leafy greens. Note that exclusion of the two elevated arugula samples from the current survey leads to an average perchlorate concentration of 78 ppb, which is much more consistent with previous results.

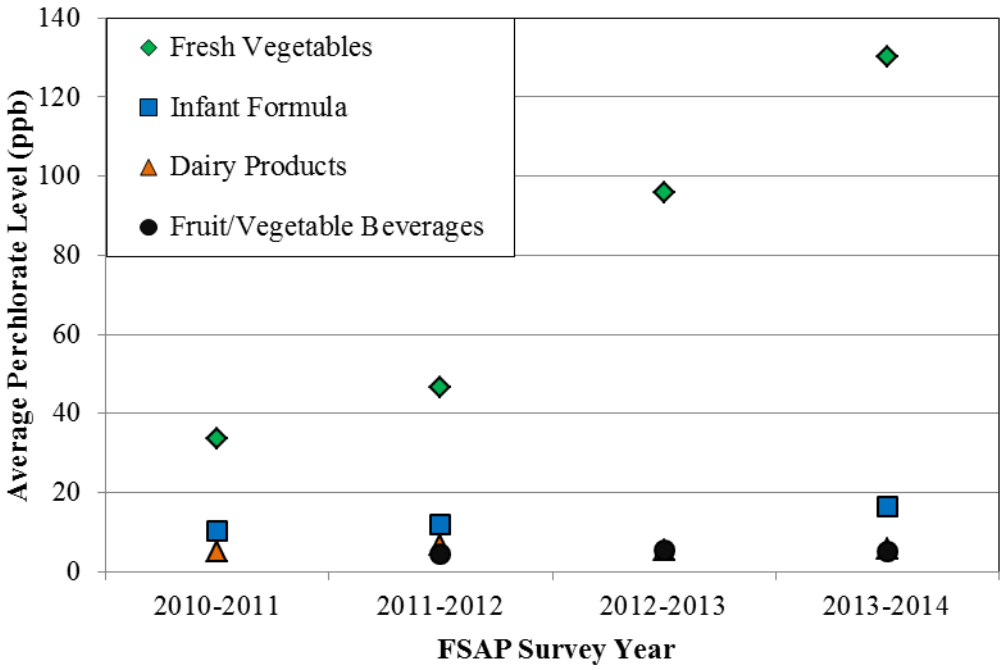
Table 13. Summary of FSAP and U.S. FDA survey data on perchlorate in leafy greens

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Leafy Greens						
CFIA[1,2]	2013-2014	40	38 (95)	3	3300	200
	2012-2013	142	105 (74)	2	2400	95
	2011-2012	200	150 (75)	2	600	35
	2010-2011	134	108 (81)	2	540	33
U.S. FDA[3,4]	2005-2006	12	7 (58)	3.1	65.9	24.8
	2004-2005	200	186 (93)	1.00	927.00	38.44

*Average of positive results only

4. Multi-Year Comparison of FSAP Perchlorate Results

One main objective of FSAP targeted surveys is the establishment and quantification of baseline levels of hazards in food products available to Canadian consumers. Therefore, perchlorate results from the four years of FSAP targeted surveys are compared and discussed below. Certain product types (fresh vegetables, infant formulas, dairy products, and fruit/vegetable beverages) have been sampled in multiple years of FSAP surveys. Figure 10 illustrates the average perchlorate concentrations in certain product types by survey year. Overall, the annual average perchlorate levels in infant formulas, dairy products, and fruit/vegetable beverages are very consistent. This is in contrast to fresh vegetables; where an increase in the average perchlorate concentration is seen in subsequent survey years.

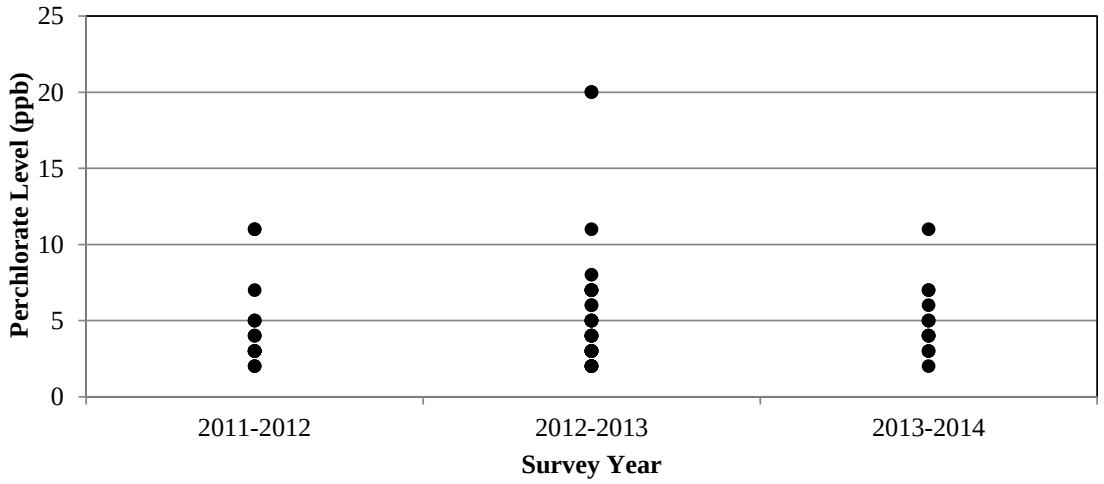


*Only values at or above the limit of detection are shown

Figure 10. Multi-year comparison of average perchlorate levels in certain product types

Fruit/Vegetable Beverages

Fruit and vegetable beverages have been included in the current and previous two FSAP survey years. This included fruit juices, fruit/vegetable blends, nectars, and smoothies. As illustrated in Figure 11, the concentrations of perchlorate are highly consistent between survey years. The average perchlorate concentration in fruit/vegetable beverages from the three years of data is 5 ppb.

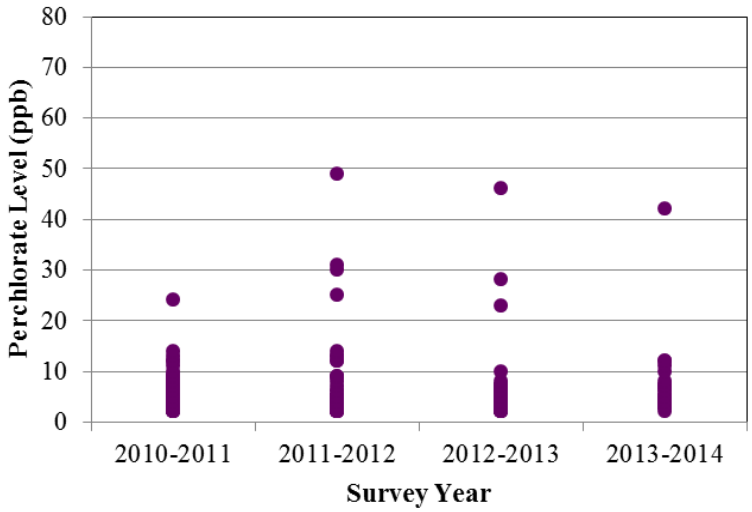


*Only values at or above the limit of detection are shown

Figure 11. Multi-year distribution of perchlorate levels fruit/vegetable beverages

Dairy Products

Dairy products have been included in all four years of FSAP perchlorate surveys. The product types included yogurt products, milk, cream, cheese, and various dairy-based desserts. Figure 12 shows the distribution of perchlorate concentrations in dairy products by FSAP survey year. The levels are generally comparable between survey years, with an overall average perchlorate concentration of 6 ppb.

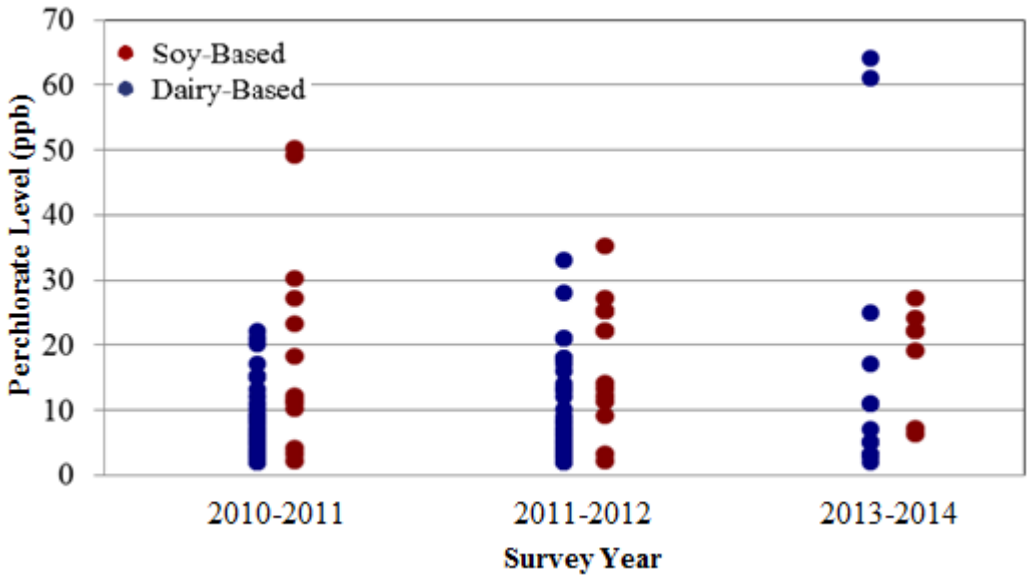


*Only values at or above the limit of detection are shown

Figure 12. Multi-year distribution of perchlorate levels in dairy products

Infant Formula

Infant formula products have been sampled in all but one FSAP surveys on perchlorate. The product types included soy- and dairy-based infant formulas, and were in the form of powders, liquid concentrates, and ready-to-serve liquids. The distribution of perchlorate concentrations in soy- and dairy-based infant formulas by survey year is shown in Figure 13. In general, the levels of perchlorate are consistent between soy- and dairy-based formulas, as well as between survey years. Note that powdered products are expected to contain higher levels of perchlorate; therefore, the relative number of powdered versus liquid samples between survey years makes direct comparison difficult. For example; the two elevated dairy-based infant formula samples from the current 2013-2014 survey were powdered products.

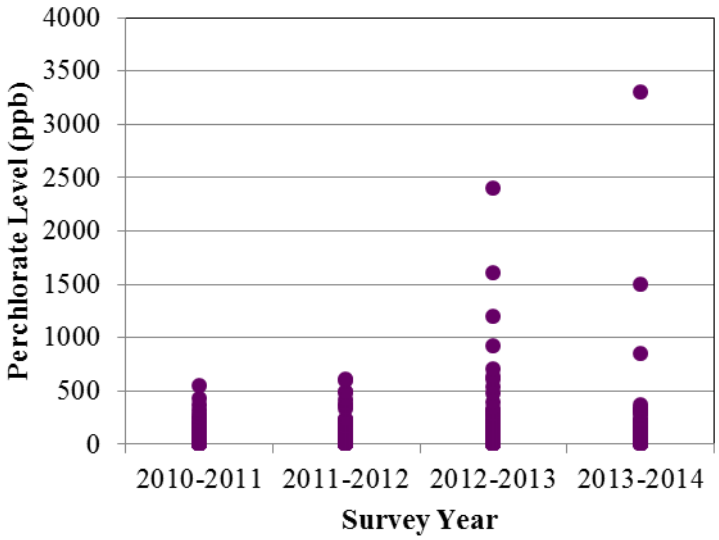


*Only values at or above the limit of detection are shown

Figure 13. Multi-year distribution of perchlorate levels in infant formula samples

Fresh Vegetables

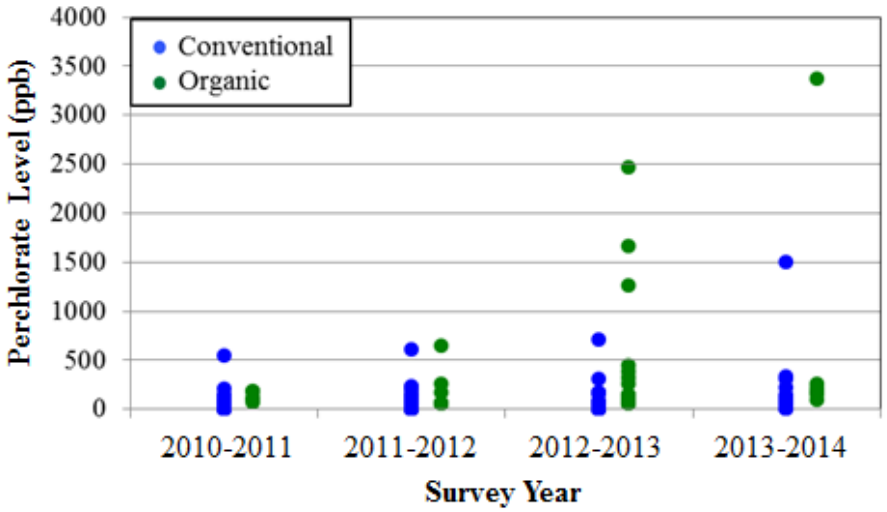
Fresh vegetables have been included in all four FSAP surveys on perchlorate. A variety of different vegetables have been sampled across the survey years, but consistent products included leafy greens, cucumber and tomato. The distribution of perchlorate levels in fresh vegetables by survey year is shown in Figure 14. The current and previous survey years (2013-2014 and 2012-2013) show some samples with elevated levels in comparison to the initial two survey years. Interestingly, these elevated samples are mostly leafy greens (spinach, arugula). The reason for the elevated perchlorate levels in these samples is unknown.



*Only values at or above the limit of detection are shown

Figure 14. Multi-year distribution of perchlorate levels in fresh vegetables

Also of interest were the relevant perchlorate concentrations between conventional vegetables and those labelled as being organically produced. A report in the scientific literature found that organically produced leafy greens contained approximately twice the concentration of perchlorate in comparison to conventionally grown products[15]. The distributions of perchlorate concentrations in organic versus conventional leafy green samples from the current and previous FSAP surveys are shown in Figure 15. Aside from several organic samples having relatively higher perchlorate concentrations (one from 2013-2014, and three from 2012-2013), the perchlorate levels between organic and conventionally grown leafy greens are fairly consistent.



*Only values at or above the limit of detection are shown

Figure 15. Distribution of perchlorate concentrations in organic versus conventionally grown leafy greens

5. Conclusions

The current 2013-2014 FSAP targeted survey expanded upon baseline surveillance data on the levels of perchlorate in fresh vegetables, processed fruit and vegetable products, dairy products, infant formula, grain products, and assorted foods. Overall, 71% of fresh vegetables, 40% of processed fruit/vegetable products, 80% of dairy products, 54% of infant formula, 30% of grain products, and 61% of assorted foods were found to contain detectable levels of perchlorate ranging from 2 ppb (detected in a russet potato sample and mixed potato sample) to 3300 ppb (detected in an arugula sample). The highest average perchlorate levels were found in fresh vegetables (130 ppb) and processed fruit/vegetable products (23 ppb), while the lowest average levels were found in grain products (5 ppb) and dairy products (6 ppb).

The prevalence and levels of perchlorate found in this survey were generally comparable with those reported in previous CFIA surveys as well as data reported by the U.S. FDA, EFSA, and in the scientific literature.

As no Canadian regulations have been established for perchlorate in food, compliance with a numerical standard was not evaluated in this survey. All data generated were shared with Health Canada's Bureau of Chemical Safety for review and use in performing human health risk assessments. Health Canada determined that the levels of perchlorate found in the current survey did not pose a health concern and therefore no product recalls were needed.

6. References

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