Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

FOOD SAFETY ACTION PLAN

REPORT

2013-2015
TARGETED SURVEYS - CHEMISTRY

Multi-Mycotoxin Analysis in Selected Foods

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Executive Summary

Targeted surveys (TS) 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 targeted survey were to:

- Expand baseline data on the presence and levels of mycotoxins in corn products, oat products, other grain products, processed grain products and wheat products; and
- Compare these results to other data, where feasible.

Mycotoxins are natural toxins released by moulds. Their human health effects are varied; the health effects depend on the type and level of mycotoxin in the food. Canada does not have maximum levels for most of the mycotoxins in finished grain-based products targeted in this survey, with the exception of ochratoxin A, for which Canada has proposed maximum levels in certain foods. According to the Food and Drug regulations, nut and nut products that contain more than 15 parts per billion of aflatoxin are considered adulterated (FDR (B.01.046(n)).

A total of 2235 samples were analyzed for the presence of mycotoxins. These samples included 1174 processed grain products, 360 wheat products, 348 other grain products, 186 corn products and 167 oat products. Mycotoxins where detected in 1327 samples (59.4%). A total of 21 different mycotoxins were detected in the product types sampled by this survey. Aflatoxins G_2, diacetoxyscirpenol and fusarenone-X were not detected in any of the samples. The mycotoxin detected most frequently was deoxynivalenol in a total of 1044 samples (46.7%).

Some of the mycotoxins in this survey are being examined for the first time, such as 3-acetyldeoxynivalenol, 15-acetyldeoxynivalenol, diacetoxyscirpenol, fusarnone-X, neosolaniol, nivalenol, ergot alkaloids, HT-2/T2 toxins, cyclopiazonic acid, sterigmatocystin, α-zearalenol, β-zearalenol and zearalenone.

All mycotoxin results were assessed by Health Canada's Bureau of Chemical Safety (BCS). Health Canada's BCS concluded that the levels detected in this survey were not expected to pose a human health concern. No product recalls were warranted given the lack of a human health concern.

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 (TS), 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 (FSSC), a group of federal, provincial and territorial subject matter experts in the area of food safety.

1.2 Acts, Regulations, and the Codes of Practice

The *Food and Drugs Act* (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* (FDR).

Health Canada establishes 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* (FDR), where they are referred to as tolerances. There are also a number of maximum levels that do not appear in the regulations and are referred to as standards, which are available on Health Canada's website[1].

Health Canada has not established tolerances or standards for the majority of the mycotoxins in finished grain products targeted in this survey. In 2009, Health Canada proposed maximum levels (ML) for the mycotoxin ochratoxin A (OTA) in a variety of foods. An ML of 3 ppb has been proposed for grains for direct consumption and derived cereal products (e.g. flour, bread, breakfast cereal), an ML of 7 ppb has been proposed for wheat bran and an ML of 0.5 ppb has been proposed for infant formulas and cereal-based foods[2]. These MLs as well as an industry guidance value for OTA in unprocessed cereal grains are still under consideration and remain in "proposed" status[2].

In the absence of applicable tolerances or standards, elevated levels of mycotoxins may be assessed by Health Canada's Bureau of Chemical Safety (BSC) on a case-by-case basis using the most current scientific data available. If the BCS identifies a potential safety concern, the CFIA can exercise follow-up actions. Follow-up actions are initiated in a manner that reflects the magnitude of the health concern. Actions may include notification of the producer or importer, follow-up inspections, additional directed sampling, and/or recall of products.

2. Survey Details

2.1 Mycotoxins

Mycotoxins are a group of natural toxins. Mycotoxins are toxic chemical products formed by fungi that can grow on crops in the field or after harvest[3]. These toxins are released by moulds which can grow on agricultural products, such as on cereals (e.g. wheat, oats, and corn), legumes, nuts and fruit. The type of agricultural product, insect damage, and the climatic conditions (temperature, humidity) during growth, processing, and storage are some factors that can influence the types and levels of mycotoxins present in the foods available at the retail level[4].

Research has shown that of the hundreds of mycotoxins associated with food, a small fraction has the potential to adversely affect human health and pose a global health concern. The Codex Alimentarius Commission[*] has published a Code of Practice to reduce and prevent mycotoxin contamination in cereals (e.g., wheat, corn, oats, and barley)[4]. This Code of Practice acknowledges that the complete elimination of mycotoxins from foods is not possible but it provides guidance on ways to control and manage the mycotoxin levels at the farm level and after harvest (e.g. during processing, storage, and transport).

There are now more than 300 known mycotoxins of widely different chemical structures and differing modes of action - some target the kidney, liver, or immune system and some are carcinogenic. Common mycotoxins include aflatoxins, ochratoxin A, ergot alkaloids, fumonisins, trichothecenes (such as deoxynivalenol which is also known as vomitoxin) and zearalenone[3].

Please see Appendix A for a listing of all the mycotoxins monitored in this study.

[*] The Codex Alimentarius Commission is an international body established by the United Nations' Food and Agriculture Organization and the World Health Organization to develop harmonized international food standards, guidelines, and codes of practice to protect the health of the consumers and to ensure fair practices in the food trade.

2.1.1 *Aflatoxins*

Aflatoxins are a family of naturally-occurring, toxic secondary metabolites produced by *Aspergillus flavus* and *A. parasiticus* fungi[5]. Aflatoxin-producing fungi may contaminate agricultural products (such as corn, nuts, spices, dried fruit) if grown, transported, stored, or processed under hot, humid conditions for prolonged periods of time, or with pest pressures resulting in bruising or cuts on the commodity[5,6]. Drought pressure on corn is also a major risk factor for the occurrence of aflatoxins in the field[5,6,7]. Due to the cooler Canadian climate, domestically-grown agricultural commodities (and products thereof) are less likely to contain aflatoxins than those imported from warmer climates. Aflatoxins are not destroyed by heating, cooking or most other processing methods[8].

One aflatoxin form, aflatoxin $B_{1,}$ is among the most potent naturally-occurring liver carcinogens known[9]. The International Agency for Research on Cancer (IARC) classified aflatoxins to be carcinogenic to humans (Group 1 carcinogen)[10]. Chronic exposure to aflatoxins has also been associated with growth impairment in children living in developing countries where exposure to aflatoxins is relatively high. Aflatoxins have been shown to cause immune suppression in experimental animals[11,12,.13,14] Short-term exposure to high levels of aflatoxins can cause illness in human which is characterized by vomiting, abdominal pain, convulsions, coma, and death. The illness is very rare in the developed world[15].

2.1.2 *Cyclopiazonic Acid*

Cyclopiazonic acid is produced by *Penicillium cyclopium*, *Penicillium* species (e.g. *P. commune* and *P. camembertii*), *Aspergillus flavus and A. versicolor*. Cyclopiazonic acid has been detected in corn, millet, peanuts, pulses, cheese, ham, sausage, hot dogs, tomato, and milk[16].

There is little information available regarding potential human health effects associated with cyclopiazonic acid. However, it has been linked to ‘Kodua’ poisoning in India resulting from ingestion of contaminated millet seeds. The symptoms included sleepiness, tremors and giddiness which lasted 1-3 days, followed by complete recovery[17]. Experimental animal studies indicate that cyclopiazonic acid is toxic only when ingested in high concentrations. Repeat exposure to high doses of cyclopiazonic acid show a range of effects such as neurotoxicity, liver and kidney damage, weight loss, diarrhea, dehydration, convulsions and death in several different species[18].

2.1.3 *Ergot Alkaloids*

Ergot alkaloids are formed by fungi of the *Claviceps* species, particularly *C. purpurea*. These fungi parasitize the seed heads of cereals, replacing individual grain kernels with discoloured fungal structures (dark purple or black) known as sclerotia or ergot bodies. The predominant ergot alkaloids present in ergot bodies are ergometrine, ergotamine, ergosine, ergocristine, ergocryptine and ergocornine (only ergosine, ergocristine and ergocryptine were successfully included in the current multi-mycotoxin method). The type and levels of these alkaloids in ergot bodies vary considerably depending on the fungal strain, the host species, the weather conditions and geographic region. Wet weather and soil favour the growth of ergot bodies. These bodies are harvested with the cereals and can thus lead to contamination of cereal based food and feed products with ergot alkaloids. The cleaning methods used during grain processing usually remove the ergot bodies from the grain[19].

Long-term exposure to ergot alkaloids causes ergotism, also known as ergotoxicosis, ergot poisoning and Saint Anthony's Fire[20,21]. The symptoms can include fevers, hallucinations, swollen or rigid limbs, severe inflammation sometimes followed by loss of affected tissues and death[22]. Experimental animal studies indicate the ergot alkaloids act on a number of neurotransmitter receptors which with repeat dosing results in restricted blood flow, particularly of the limbs, weight loss and changes in the levels of some hormones in rats[23].

2.1.4 *Fumonisins*

Fusarium moniliforme and *Fusarium proliferatum* are plant pathogens common in grain-growing regions throughout the world. These pathogens can infect grain crops either in the field (pre-harvest) or during storage (post-harvest). The moulds proliferate if grains are grown in hot, dry weather followed by very humid conditions. Mould growth is also favoured by storage under wet conditions. The plant pathogens produce mycotoxins known as fumonisins. Corn is the grain most vulnerable to fumonisin contamination[24]. The levels of fumonisins can be quite high, even in the absence of visible signs of mould proliferation[25]. There are several forms of fumonisin: fumonisins B1, B2 and B3 are the most prevalent. While studies have focused on fumonisin B1, available data suggests that fumonisins B2 and B3 have a similar toxicological profile[26,27,28,29]. Fumonisins are heat-stable up to 150°C and are unaffected by mechanical forces (such as grinding), but can be reduced by alkaline treatment (a traditional means of preparing corn masa and other corn-based products such as tacos)[30].

Although fumonisin contamination is mainly observed in corn, some scientific studies have shown the presence of fumonisins in red wine[31], sorghum[32], white beans, wheat[29], barley[29], soybeans[29], figs[29], rice[33], black tea[29], and medicinal herbs[29].

The ingestion of foods containing fumonisins may be harmful to human health. Health effects which have been observed in specific populations where corn is a major component of the diet and where the climate may favor fumonisin proliferation include esophageal cancer in South Africa and China[28,34], neural tube defects in Central America and the southwestern US[35]). The precise biological effects of fumonisins are complex and relate to their interference with cell metabolism[27]. Experimental animal studies have revealed that fumonisins induce liver and kidney damage in many species[36]. Fumonisin B1 has been classified by IARC as possibly carcinogenic to humans based on evidence in experimental animal studies[37].

2.1.5 *Ochratoxin A*

OTA is a naturally occurring metabolite of *Aspergillus* and *Penicillium* moulds. Under favourable moisture and temperature conditions, the fungi can grow on stored material and produce OTA[38]. OTA has been widely detected in cereal grains (wheat, corn, oat, and barley), green coffee, grape juice, beer, wines, cocoa, dried fruits, and nuts[39]. OTA is heat-stable and is only partially destroyed under normal cooking or processing conditions[40].

The International Agency for Research on Cancer (IARC) has classified OTA as a possible human carcinogen based largely on data from animal studies[41]. The mechanism by which OTA causes kidney tumours in rodents has yet to be fully explained. In animal studies, OTA has also been shown to have effects on the kidneys, the developing fetus, and the immune system. Health Canada completed a risk assessment for OTA, and as a result, has proposed maximum levels for OTA in various food commodities[2] as well as an industry guidance value for OTA in unprocessed cereal grains.

2.1.6 *Sterigmatocystin*

Sterigmatocystin is a mycotoxin produced mainly by various *Aspergillus* species. It can also be produced by species such *as Bipolaris, Chaetomium*, and *Emiricella*. It has been detected in grains, corn, bread, cheese, spices, coffee beans, soybeans, and pistachio nuts. Wet, warm, conditions favour sterigmatocystin production[42].

The IARC has classified sterigmatocystin as a possible human carcinogen[43]. It also has properties capable of causing DNA mutations. It is acutely toxic to animals, with the liver and kidneys as its principle targets. This toxin is structurally similar to aflatoxin, however, tests in rats have shown that it is ten times less lethal following acute exposure to high doses and ten to a hundred times less effective at inducing liver cancer[42]. Its human health effects have not been well-studied.

2.1.7 *Trichothecenes*

This large family of mycotoxins are typically found in cereal grains (notably wheat, barley, and corn), and have been detected in their derived products (flours, meals, bran, grits, cereals, and beer). These toxins are produced by various species of *Fusarium* mould in some crops prior to harvest. These toxins are observed in grains suffering from Fusarium head blight (FHB) in the field. Wet, warm weather conditions in the field will favour the development of FHB, and subsequently the production of trichothecenes[44]. The trichothecenes are heat-stable and are only partially destroyed under normal cooking or processing conditions[45]. The most widely commonly occurring trichothenece is deoxynivalenol (DON).

The human health effects of nivalenol[46], fusarenone[47], 3-acetyldeoxynivalenol (3-AcDON)[47], 15-acetyldeoxynivalenol (15-AcDON) [47], neosolaniol (NEO) [47] and diacetoxyscirpenol (DAS)[47] are not as well-studied as those of DON. DON is not known to be carcinogenic, but it has been associated with acute and chronic health effects. Outbreaks in Asia, attributed to the consumption of grains with high levels of DON, are associated with short-term human illness, involving nausea, vomiting, abdominal pain, headache and dizziness. In experimental animal studies, long-term exposures to low levels of DON are associated with decreased food intake, weight loss, and effects on the immune system[48].

T-2 and HT-2 toxins are are formed when grain crops remain in the field at or after harvest for extended periods, especially in cold weather, or in grain that becomes wet during storage. They have been detected in wheat, corn, oats, barley, rice, beans, and soybeans and some cereal-based products. Oats are most likely to contain these toxins but they have been detected frequently at lower concentrations in barley. Wheat is only rarely contaminated with these toxins[49].

The human health effects associated with chronic exposure to HT-2 and T-2 are not known. In animals, these toxins inhibit DNA, RNA and protein synthesis and are cytotoxic. IARC considers HT-2/T-2 toxins not classifiable as to their carcinogenicity to humans based on the lack of available human carcinogenicity data and only limited evidence in experimental animals[50],[51].

2.1.8 *Zearalenone and Related Compounds*

Zearalenone (ZEA) is a mycotoxin produced mainly by *Fusarium* species. It has been detected in wheat, barley, rice, corn, and other cereals. It is heat-resistant and can be found in finished grain-based products. ZEA is metabolised to α-zearalenol (α-ZOL) and β-zearalenol (β-ZOL)[52,53,54].

ZEA is not an acute toxin. ZEA is an estrogenic compound and its major metabolites are more potent estrogenic compounds. It causes infertility in sheep, cattle and pigs, and may lead to earlier sexual maturation in some animals. In experimental animal studies, high oral doses of ZEA have also been shown to be genotoxic, toxic to the liver, and affect blood and the immune system[54,55]. IARC concluded that there is limited evidence of the carcinogenicity of ZEA[56]. ZEA has been considered a possible contributing agent in the outbreaks of early puberty in thousands of girls in Puerto Rico and may play a role in human breast and cervical cancer in highly exposed populations[53].

2.2 Rationale

The FSSC has ranked mycotoxins as a high priority due to their potential to adversely affect human health. The Canadian Grain Commission (CGC) tests raw, domestically-grown cereal grains intended mainly for export for mycotoxins, pesticides, and certain metals, but does not have jurisdiction over finished or imported grain products. Some mycotoxins in grains and grain products have been periodically examined by Health Canada's BCS and through other CFIA activities.

The CFIA has previously performed targeted surveys on specific mycotoxins in foods, such as aflatoxins[57,58,59,60,61], fumonisins[62,63], ochratoxin A[64,65,66,67] and deoxynivalenol[64,65,68,69] in a variety of food products.

Health Canada, which has purview over foods sold in Canada, has conducted surveys to analyze the presence of certain mycotoxins in infant[25] and breakfast cereals[70]. However, the monitoring of finished grain products (whether domestically produced or imported) available at the retail level is limited. The present targeted survey was designed to build and expand on baseline datasets to assess the exposure of Canadians to natural toxins. The current survey also looks to gain insight on mycotoxins in corn products, oat products, other grain products, processed grain products and wheat products. Some of the mycotoxins in this survey are being examined for the first time, such as 3-acetyldeoxynivalenol, 15-acetyldeoxynivalenol, diacetoxyscirpenol, fusarnone-X, neosolaniol, nivalenol, ergot alkaloids, HT-2/T2 toxins, cyclopiazonic acid, sterigmatocystin, α-zearalenol, β-zearalenol and zearalenone.

2.3 Sample Distribution

A total of 2235 samples were analyzed for the 2013-2015 CFIA Multi-mycotoxins survey. Samples were collected from retail stores in 6 Canadian cities between May 2013 and February 2015. The 2235 samples collected included 729 domestic products, 958 imported products (from at least 33 countries) and 548 products of unspecified origin. Samples of unspecified origin are those for which the country of 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 "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 identify 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.

2.4 Limitations

This targeted survey was designed to provide a snapshot of the presence and levels of mycotoxins in selected grain-based products available to Canadian consumers, and to potentially highlight commodities that warrant further investigation. The limited survey sample size represents 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 and/or require preparation prior to consumption (i.e. cooking, mixing with liquid). The results should only be interpreted as finished food products available as sold and not as they would be consumed.

Country of origin was assigned for the samples collected based on information provided by the sampler or as indicated on the product label; however, no inferences or conclusions were made regarding the data with respect to country of origin. Regional differences, impact of product shelf-life, storage conditions, or cost of the commodity on the open market were not examined in this survey.

3. Results and Discussion

3.1 Overview of Multi-Mycotoxin Results

In total, 2235 samples of grain-based products were sampled. The products sampled were separated into 5 product types: corn products, oat products, other grain products, processed grain products and wheat products. Of the 2235 samples tested for mycotoxins, 1327 (59.4%) had detectable levels of mycotoxins. Figure 1 illustrates the number of samples with detectable levels of mycotoxins for all of the product types.

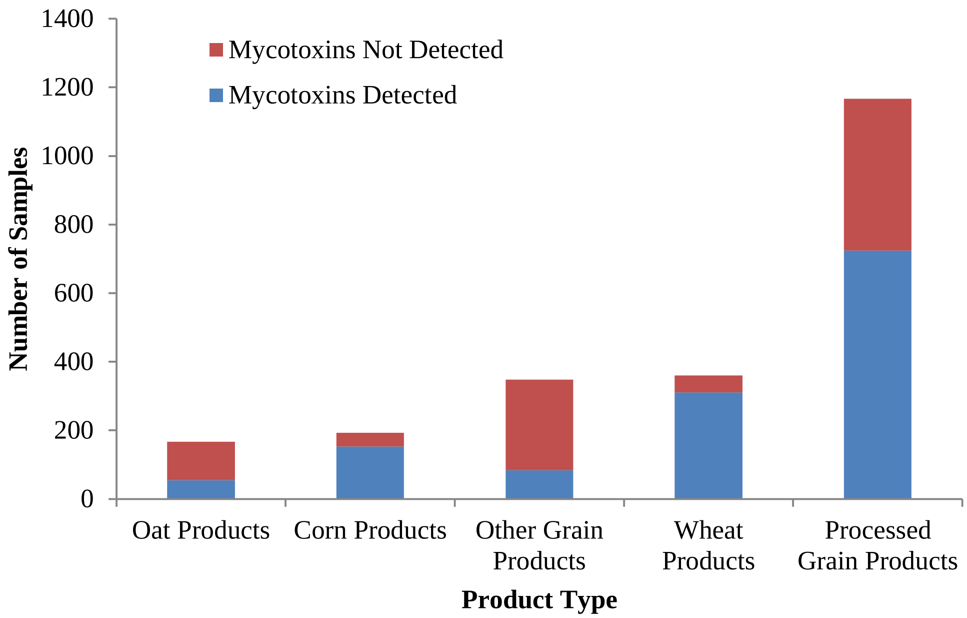

Figure 1. Number of samples with detectable levels of mycotoxins by product type (in order of increasing number of samples)

In total, 21 mycotoxins were detected. Aflatoxins G_2, diacetoxyscirpenol and fusarenone-X were not detected in any of the samples. The mycotoxin most frequently detected was deoxynivalenol in a total of 1044 samples (78.7%) with detectable mycotoxins. Figure 2 illustrates the specific detectable mycotoxins found in all the samples.

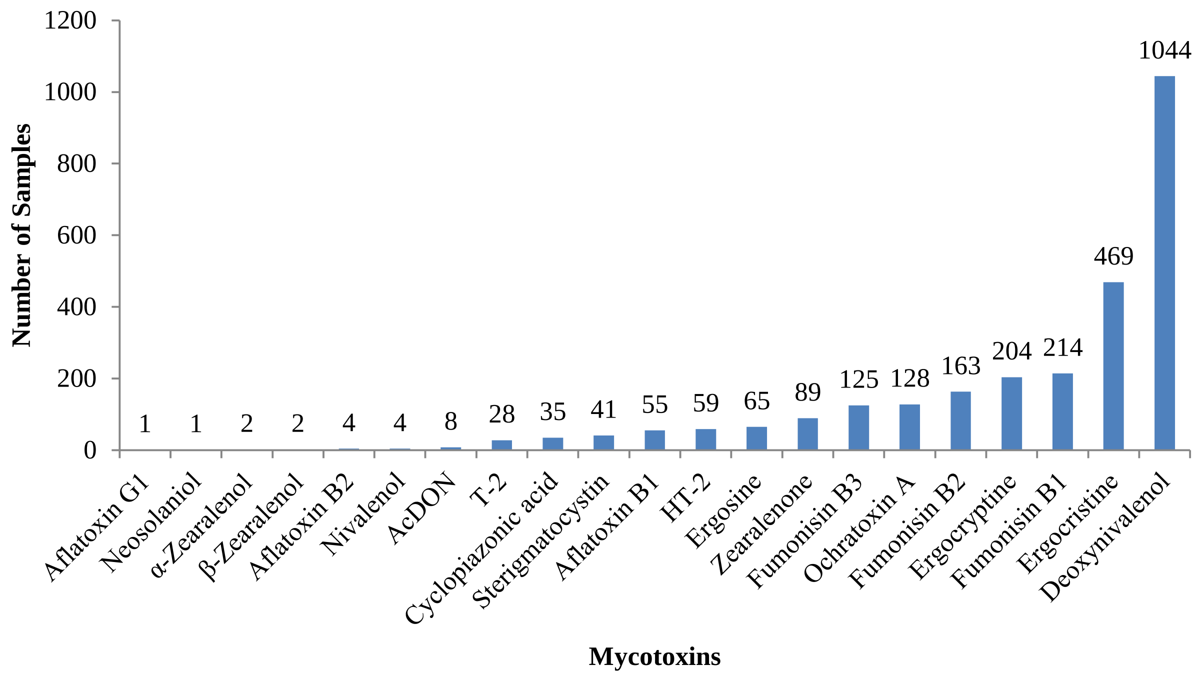

Figure 2. Frequency of detection of mycotoxins in all samples (in increasing order of the number of samples testing positive for a particular mycotoxin)

3.2 Multi-Mycotoxin Results by Product Type

The following sections present the results for mycotoxins by product type. See section 3.3 for a summary of comparison of the current survey results to the results of other studies, where feasible.

3.2.1 *Mycotoxins in Corn Products*

Corn products included 74 corn flours, 60 corn products (i.e. corn chips, tortillas and tacos), 27 cornmeal, 15 corn starch, and 10 popcorn samples. One hundred and forty-seven samples (79.0%) had detectable mycotoxins, in which 16 different mycotoxins were found. Figure 3 illustrates the specific detectable mycotoxins found in corn product samples.

Fifty-three samples (36.1%) with detected mycotoxins contained one or two mycotoxins. The remaining samples with detectable mycotoxins contained from three to a maximum of seven mycotoxins per sample. Two corn flour samples contained seven mycotoxins.

More than 50% of detected fumonisins (fumonisin B_1, fumonisin B_2 and fumonisin B_3) were detected in corn products. One corn product had detected levels of ochratoxin A above Health Canada's proposed maximum level of 3 ppb.

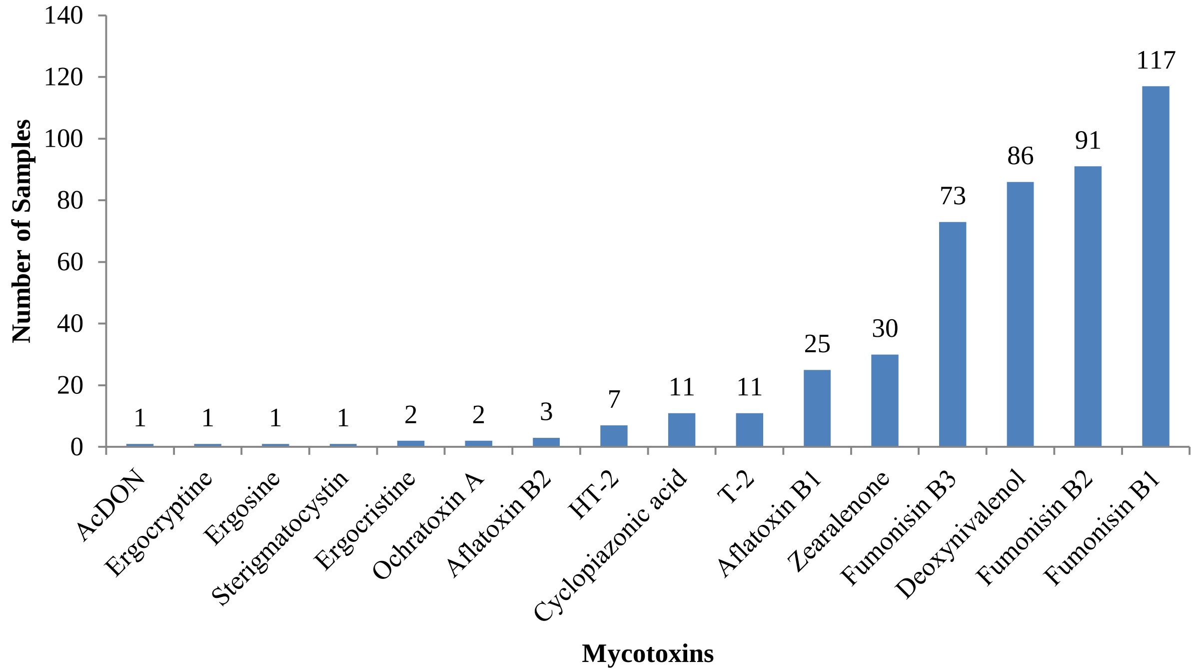

Figure 3. Frequency of detection of mycotoxins in corn product samples (in increasing order of the number of samples testing positive for a particular mycotoxin)

3.2.2 *Mycotoxins in Oat Products*

The oat products category included 65 oat grain, 51 oat flour, 35 oatmeal and 16 oat bran samples. Fifty-five samples (32.9%) had detectable mycotoxins, in which 12 different mycotoxins were found. Figure 4 illustrates the specific detectable mycotoxins found in oat product samples.

Forty-four samples (80.0%) with detected mycotoxins contained one or two mycotoxins. The remaining samples with detectable mycotoxins contained from three to a maximum of six mycotoxins per sample. One oat flour product sample contained six mycotoxins.

Aflatoxin G_1 was only detected once in a single oatmeal sample. Six oat products had detectable levels of ochratoxin A above Health Canada's proposed maximum level of 3 ppb.

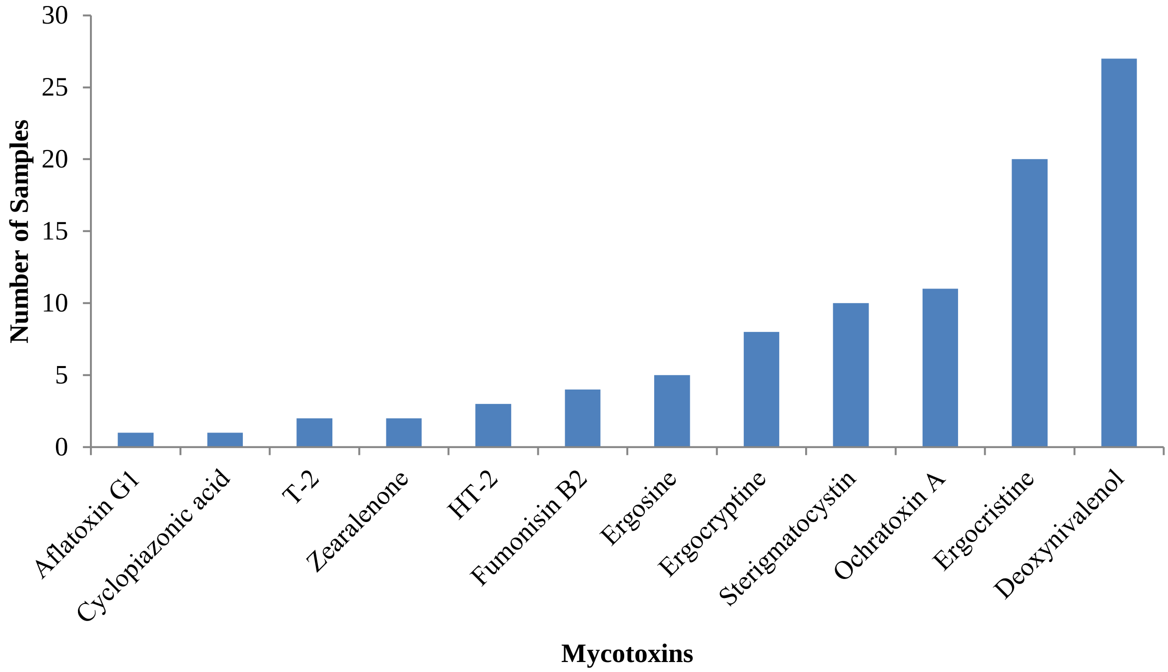

Figure 4. Frequency of detection of mycotoxins in oat product samples (in increasing order of the number of samples testing positive for a particular mycotoxin)

3.2.3 *Mycotoxins in Other Grain Products*

The other grain product category included the milled, whole grain, flakes, kernels and flours of 159 rice, 34 quinoa, 29 buckwheat, 23 barley, 21 spelt, 17 rye, 14 kamut, 13 millet, 11 amaranth, 5 mixed grains, 4 arrowroot, 3 sorghum, 1 tapioca and 1 teff samples. Other grain products had the lowest frequency of detection with eighty-four samples (24.1%) having detectable mycotoxins, in which 19 different mycotoxins were found. Arrowroot, sorghum and teff product samples did not have any detectable levels of mycotoxins. Figure 5 illustrates the specific detectable mycotoxins found in other grain product samples.

Fifty-three samples (63.1%) with detected mycotoxins contained one or two mycotoxins. The remaining samples with detectable mycotoxins contained from three to a maximum of five mycotoxins per sample. Five other grain product samples (one whole rice, one rice chip and three rye flour samples) contained five mycotoxins.

β-Zearalenol was only detected in two rye flour samples. Three other grain products had detectable levels of ochratoxin A above Health Canada’s proposed maximum level of 3ppb.

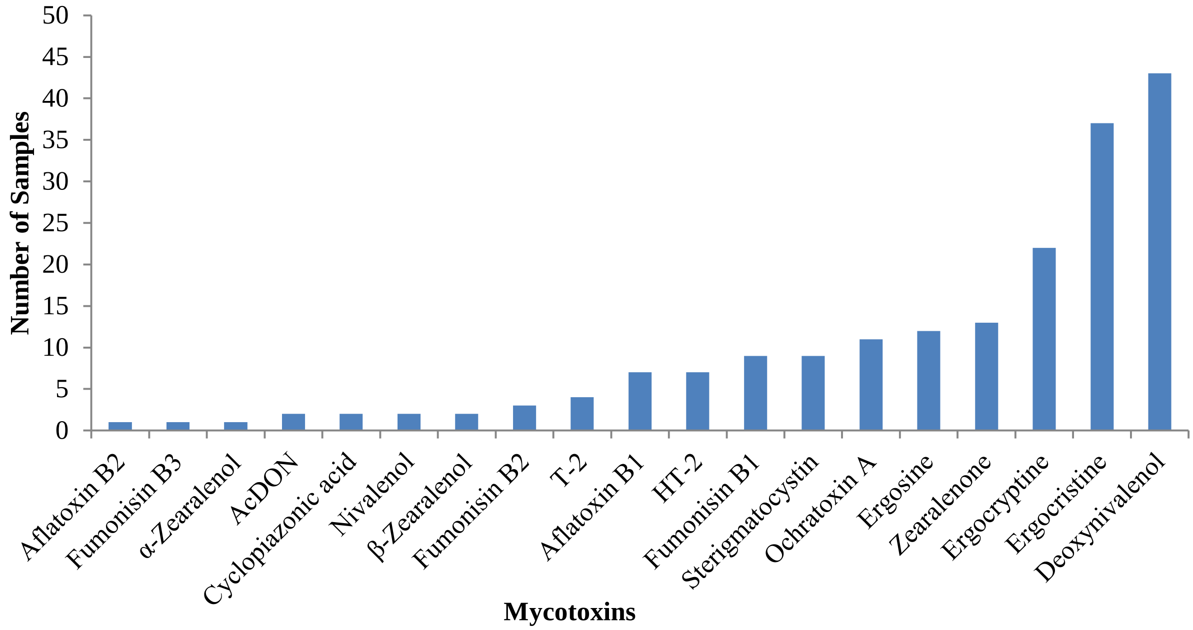

Figure 5. Frequency of detection of mycotoxins in other grain product samples (in increasing order of the number of samples testing positive for a particular mycotoxin)

3.2.4 *Mycotoxins in Processed Grain Products*

The processed grain products category included 654 cereal (including infant, children and adult), 233 bread products (i.e. loaf, English muffin and bagel), 118 baked goods (i.e. cookies, cakes and muffins), 70 baking mixes, 58 pasta and 41 cracker samples, either grain-based or gluten-free-based. Seven hundred and thirty samples (62.2%) had detectable mycotoxins, in which 15 different mycotoxins were found. Figure 6 illustrates the specific detectable mycotoxins found in processed grain product samples.

Five hundred and ninety-one samples (81.0%) with detectable mycotoxins contained one or two mycotoxins. The remaining samples with detectable mycotoxins contained from three to a maximum of nine mycotoxins per sample. Three children's cereal samples contained nine mycotoxins.

More than 50% of samples with detected levels of DON was detected in processed grain products. Neosolaniol was only detected in a single gluten-free corn pasta sample. Three processed grain products (not including infant cereals) had levels of ochratoxin A above Health Canada's proposed maximum levelof 3 ppb and 26 infant cereals had levels above the proposed maximum level of 0.5 ppb.

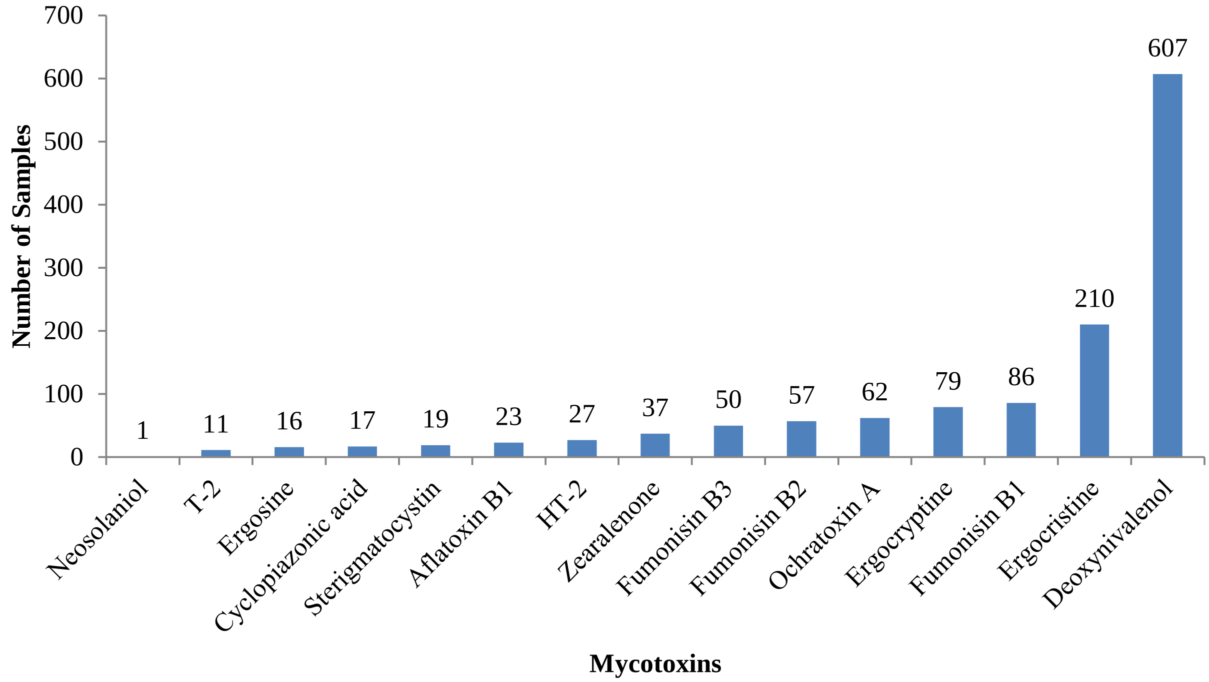

Figure 6. Frequency of detection of mycotoxins in processed grain product samples (in increasing order of the number of samples testing positive for a particular mycotoxin)

3.2.5 *Mycotoxins in Wheat Products*

The wheat products category included 283 wheat flour, 30 wheat bran, 20 couscous, 12 bulgur, 8 whole wheat and 7 wheat germ samples. Wheat products had the highest frequency of detection with three hundred and eleven samples (86.4%) having detectable mycotoxins, in which 15 different mycotoxins were found. Figure 7 illustrates the specific detectable mycotoxins found in wheat product samples.

One hundred and ninety-five samples (62.7%) with detectable mycotoxins contained one or two mycotoxins. The remaining samples with detectable mycotoxins contained from three to a maximum of five mycotoxins per sample. Seven wheat flour samples contained five mycotoxins.

More than 50% of detected 3-acetyldeoxynivalenol and 15-acetyldeoxynivalenol (AcDON) was detected in wheat products. Almost 50% of detected ergocryptine and ergosine were also found in wheat products. Eight wheat products had detectable levels of ochratoxin A above the health Canada proposed maximum level of 3 ppb.

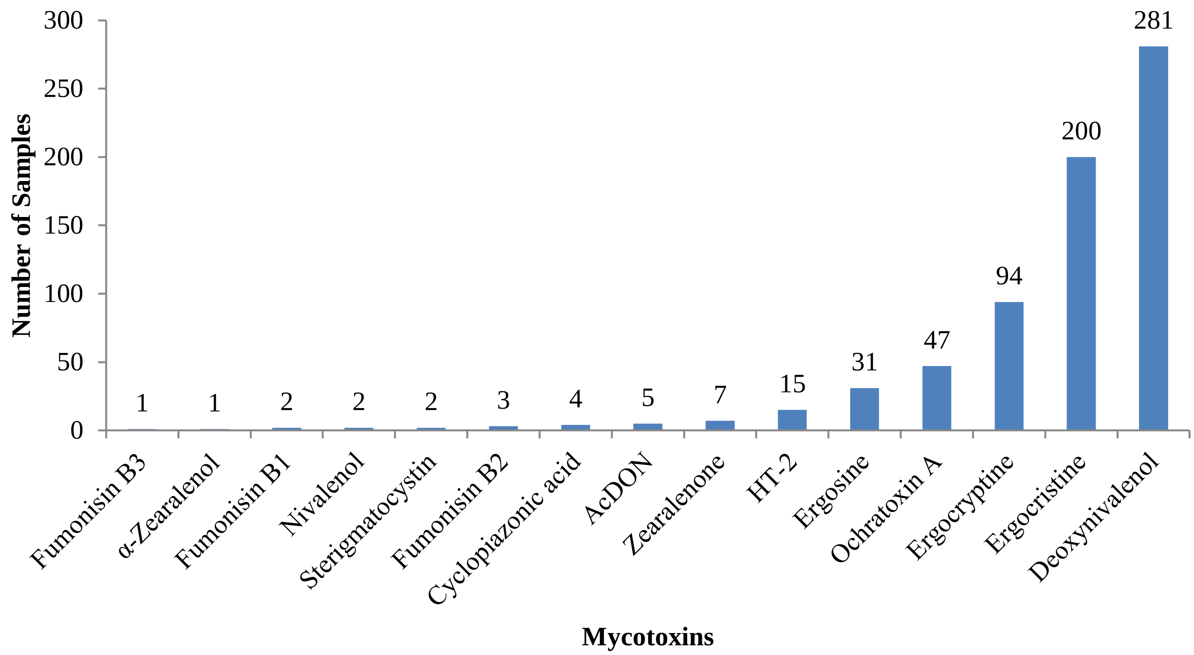

Figure 7. Frequency of detection of mycotoxins in wheat product samples (in increasing order of the number of samples testing positive for a particular mycotoxin)

3.3 Summary of Comparison of the Current Survey Results to the Results of Other Surveys

The summary of comparison of the current survey results to the results of previous CFIA surveys, two surveys conducted by Health Canada and scientific literature, where feasible, are shown in Table 2. The current survey, previous CFIA surveys and the scientific literature targeted a variety of grain-based foods (except 2011-2012 TS on fumonisins, which only targeted corn products) such as milled, whole grain, flakes, kernels and flours of corn, oat, wheat and other grain products and processed grain products (baked goods, baking mixes, breads, infant and breakfast cereals and pastas). The Health Canada (2008) survey targeted grain-based breakfast cereals only and the Heath Canada (2003) survey targeted grain-based infant cereals (including soy based cereals), biscuits and soy formulas. This may account for some of the differences observed between surveys as well as the difference in laboratory method used and the limits of detection.

In general, the percentages of samples with detectable mycotoxins in the current survey are similar to or lower than the results of the other surveys, except for HT-2 toxin. The highest observed mycotoxin level results of the current survey are similar to or higher than the results of the Health Canada surveys. The highest observed mycotoxin levels of the current survey are similar to or lower than the results of the previous CFIA surveys. In the current survey, the average mycotoxin levels are similar to or higher than the results reported in the previous targeted survey, with the exception of aflatoxins and ochratoxin A.

Table 2. Summary of Comparison of the current survey results to the results of previous CFIA studies and two surveys conducted by Health Canada

Survey Author	Year	Analyte	Number of Samples	Number of Samples with Detectable Mycotoxins (Percentage)	Maximum Mycotoxin Level (ppb)	Average* Mycotoxin Level (ppb)
Aflatoxins						
CFIA	2013-2015	Total Aflatoxins	2235	57 (2.5)	17.3	3.56
CFIA	2013-2014	Total Aflatoxins	514	44 (8.6)	16.2	2.19
DON and Related Compounds						
CFIA	2013-2015	3-acetyldeoxynivalenol and 15-acetyldeoxynivalenol (AcDON)	2235	8 (0.004)	53	35.25
CFIA	2013-2015	Deoxynivalenol	2235	1044 (46.3)	2330	175.91
CFIA[69]	2012-2014	Deoxynivalenol	3099	2735 (88.3)	4380	105.29
HC (2008)[70]	1999-2001	Deoxynivalenol	156	72 (46.0)	940	N/A
HC (2003)[25] [25]	1997-1999	Deoxynivalenol	237	150 (63.3)	980	N/A
CFIA	2013-2015	Diacetoxyscirpenol	2235	0 (0.0)	-	-
CFIA	2013-2015	Fusarenone-X	2235	0 (0.0)	-	-
CFIA	2013-2015	Neosolaniol	2235	1 (0.0004)	30	30
CFIA	2013-2015	Nivalenol	2235	4 (0.002)	98	42.5
HC (2008)[70]	1999-2001	Nivalenol	156	1 (0.6)	20	N/A
HC (2003)[25]	1997-1999	Nivalenol	237	0 (0.0)	-	N/A
Ergot Alkaloids						
CFIA	2013-2015	Ergot Alkaloids**	2235	478 (21.4)	1078	62.0
HC (2003)[25]	1997-1999	Ergot Alkaloids***	162	41 (25.3)	108	N/A
Fumonisins						
CFIA	2013-2015	Fumonisins B_1, B_2 and B_3	2235	233 (10.4)	2062	187.33
CFIA[63]	2011-2012	Fumonisins B_1 and B_2	274	161 (58.8)	4442.5	253.26
HC (2008)[70]	1999-2001	Fumonisins B_1 and B_2	136	54 (40.0)	1980	N/A
HC (2003)[25]	1997-1999	Fumonisins B_1 and B_2	142	42 (29.6)	130	N/A
HT-2/T-2 Toxins						
CFIA	2013-2015	HT-2 toxin	2235	59 (2.6)	148	21.19
HC (2008)[70]	1999-2001	HT-2 toxin	156	1 (0.6)	20	N/A
HC (2003)[25]	1997-1999	HT-2 toxin	237	0 (0.0)	-	N/A
CFIA	2013-2015	T-2 toxin	2235	28 (1.2)	123	22.29
Other Mycotoxins						
CFIA	2013-2015	Cyclopiazonic acid	2235	35 (1.5)	8.3	2.68
CFIA	2013-2015	Ochratoxin A	2235	128 (5.7)	33.6	2.58
CFIA[67]	2012-2014	Ochratoxin A	3100	1720 (55.4)	21.1	0.528
HC (2008)[70]	1999-2001	Ochratoxin A	156	53 (35.0)	1.4	N/A
HC (2003)[25]	1997-1999	Ochratoxin A	161	42 (26.1)	6.9	N/A
CFIA	2013-2015	Sterigmatocystin	2235	41 (1.8)	17.6	3.07
MoI[71]	2013-2014	Sterigmatocystin	1259	124 (9.8)	33	N/A
Zearalenone and Related Compounds						
CFIA	2013-2015	α-zearalenol	2235	2 (0.0009)	464	266.5
CFIA	2013-2015	β-zearalenol	2235	2 (0.0009)	13	12.5
CFIA	2013-2015	Zearalenone	2235	89 (4.0)	577	45.65
HC (2008)[70]	1999-2001	Zearalenone	156	34 (22.0)	100	N/A
HC (2003)[25]	1997-1999	Zearalenone	181	59 (32.6)	35	N/A

*Average of positive results only

** Total of ergosine, ergocryptine and ergocristine

*** Total of ergosine, ergotamine, ergocornine, ergocryptine and ergocristine

4. Conclusions

The 2013-2015 Multi-mycotoxins Analysis in Selected Foods targeted survey expanded on baseline data on the presence and levels of mycotoxins in grain-based foods. A total of 2235 samples were analyzed for mycotoxins. The 2235 samples included 1174 processed grain products, 360 wheat products, 348 other grain products, 186 corn product and 167 oat products.

Of these samples, 1327 (59.4%) had detectable levels of mycotoxins. Mycotoxins were detected in all product types. A total of 21 different mycotoins were detected in 2235 product types sampled in this survey. Aflatoxins G_2, diacetoxyscirpenol and fusarenone-X were not detected in any of the samples. The mycotoxin detected most frequently was deoxynivalenol in a total of 1044 samples (46.7%).

In general, when comparing the current survey to other data, when feasible, the data was consistent and comparable in terms of the compliance rates, and the maximum and average levels of mycotoxins detected.

Compliance to a numerical standard for the levels of mycotoxins found in the products sampled could not be completed as there are no Canadian regulations or maximum levels set for these commodities, with the exception of certain proposed maximum levels for ochratoxin A by Health Canada. Of the 128 samples having detectable levels of ochratoxin A, one corn product, three other grain products, 29 processed grain products (including infant cereals), six oat products and 8 wheat products had detected levels above Health Canada's proposed maximum levels applicable to the food commodities in question. Health Canada determined that the levels of mycotoxins detected in grain-based foods sampled in this survey did not pose a human health concern. No follow up actions were warranted given the lack of human health concern.

5. Appendix A

List of analytes targeted by the HPLC-MS/MS method used by the laboratory in this survey and their respective limits of detection (LOD)

Mycotoxin Class	Analyte	LOD (ppb)
Aflatoxins	Aflatoxin B_1 (AFB_1)	0.5
	Aflatoxin B_2 (AFB_2)	0.3
	Aflatoxin G_1 (AFG_1)	0.7
	Aflatoxin G_2 (AFG_2)	0.9
Cyclopiazonic Acid	Cyclopiazonic acid (CPA)	0.6
Ergot Alkaloids	Ergocristine	5
	Ergocryptine	6
	Ergosine	9
Fumonisins	Fumonisin B_1 (FB_1)	4
	Fumonisin B_2 (FB_2)	10
	Fumonisin B_3 (FB_3)	8
Ochratoxin A	Ochratoxin A (OTA)	0.8
Sterigmatocystin (STE)	Sterigmatocystin (STE)	0.4
Trichothecenes	3-acetyldeoxynivalenol and 15-acetyldeoxynivalenol (AcDON)	13
	Deoxynivalenol (DON)	10
	Diacetoxyscirpenol (DAS)	10
	Fusarenone-X (FUS-X)	17
	HT-2 toxin (HT-2)	8
	Neosolaniol (NEO)	10
	Nivalenol (NIV)	7
	T-2 toxin (T-2)	9
Zearalenone and Related Compounds	Zearalenone (ZEA)	7
	α-zearalenol (α-ZOL)	7
	β-zearalenol (β-ZOL)	7

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