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

FOOD SAFETY ACTION PLAN

REPORT

2008-2009
TARGETED SURVEYS - CHEMISTRY
TS-CHEM-08/09-03

PESTICIDE RESIDUES AND METALS
IN
PROCESSED TOMATO PRODUCTS

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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 test various foods for specific hazards.

The main objectives of the processed tomato product survey were:

- To provide baseline surveillance data for pesticide residues in processed tomato products not surveyed under the National Chemical Residue Monitoring Program (NCRMP)
- To obtain a snapshot of the imported processed tomato products where pest control measures are not under the authority of the Canadian Government

There were 297 (290 imported, 7 domestic) processed tomato products collected and analyzed in the targeted survey. The samples included 10 different types of processed tomatoes from 13 different countries. The top import countries of processed tomato products were targeted which include the United States and Italy.

The pesticide multi-residue method can detect approximately 300 individual carbamate, organochlorine and organophosphate compounds. The multi-metal method can detect 18 metal elements, including aluminum, arsenic, antimony, beryllium, boron, cadmium, chromium, copper, iron, manganese, mercury, molybdenum, nickel, lead, selenium, tin, titanium and zinc.

Of the 297 samples tested, the majority of samples analyzed (250 or 84.18%) contained no measurable pesticide residues, and all samples were in compliance with Canadian MRLs. Thirty nine samples contained one detectable pesticide residue, seven samples contained two detectable residues and one sample contained three detectable residues.

All of the 297 survey samples contained one or more of the 18 metals analyzed for. All of the samples were in compliance with existing Canadian metal tolerances. All other metals (with no existing tolerances) were at concentrations low enough not to pose a risk to human health.

1 Introduction

1.1 Food Safety Action Plan

Objective
The Food Safety Action Plan (FSAP) aims to modernize and enhance Canada's food safety system. The FSAP includes multiple partners and processes that work collectively towards providing safe foods for Canadians.

The Canadian Food Inspection Agency (CFIA) has been given the lead in the area of enhanced surveillance, an important initiative of the FSAP. The CFIA works on this initiative with input from 1) Federal partners, including Agriculture Agri-Food Canada and Health Canada, 2) Provincial and Territorial (P/T) representatives and 3) industry and other non-government organizations (NGOs).

As part of the FSAP enhanced surveillance initiative, targeted surveys are used to test various foods for specific hazards. Targeted surveys are a complementary approach to the CFIA's regular monitoring activities and will allow the CFIA to ask specific questions regarding the level and presence of various chemical and microbiological hazards in targeted foods.

1.2 Targeted Surveys

Targeted surveys can be considered special or pilot surveys that are used to gather preliminary information about the occurrence of chemical residues and metals in food. They are designed to answer a specific question. Therefore the testing activity is targeted to a sample population (such as commodity types and/or geographical areas). Due to the large number of chemicals and food types that exist in the world today, it is not possible to use targeted surveys to identify and quantify all chemical hazards in foods. The CFIA uses a prioritization approach to identify food-hazard combinations of greatest potential health risk. Risk prioritization is performed by 1) consulting the results of a risk-based model, 2) consulting the scientific opinion of Federal, Provincial and Territorial (F/P/T) partners and non-government organizations (NGOs), and 3) using existing survey/monitoring data.

The risk-based model was developed by a multi-disciplinary Food Safety Science Committee (FSSC). Publicly available hazard and food exposure information is entered into a model that generates a relative risk score. The hazards are further evaluated by FSSC members and a consensus is reached on their overall priorities.

The current targeted survey reports on the level of pesticides and heavy metals in processed tomato products. Processed tomatoes are widely consumed in Canada in many forms, from whole canned tomatoes to pizza sauce and ketchup.

1.3 Processed Tomato Products

1.3.1 Definition of Processed Tomato Products

Tomato fruits are berries of varying shapes, sizes and colours, with upwards of 10 000 varieties in existence. They have a limited shelf life when fresh, and so processing tomatoes, such as making canned sauces, creates a product desirable for its increased shelf life. Tomatoes are processed most commonly to tomato paste, and also into peeled tomatoes, canned tomatoes, chopped tomatoes, strained tomatoes, tomato sauce, pizza sauce and tomato marinara.

1.3.2 Canadian Market for Processed Tomatoes

The highest overall per capita consumption of tomato products are found in the USA with 30 kg per year, while consumption in Canada and Europe is 23 kg per capita per year and 19 kg per capita per year, respectively[1].

Canada is a member of the World Tomato Processing Council (WTPC), an international organization representing the tomato processing industry. According to the WTPC, the top eight countries, representing 84% of world production, are: United States (California), 9.33 million; Italy, 4.97 million; China, 1.74 million; Spain, 1.52 million; Turkey, 1.5 million; Brazil, 1.17 million; Greece, 1.01 million; and Portugal, 950 000; Canada reports production of 590 000 (measured in average metric tonnes from 1998 to 2003).

1.3.3 Tomato Processing

The majority of tomatoes grown for processing are used to make tomato paste (84% worldwide), followed by whole peeled tomatoes. Tomato paste is created by a concentration of tomato pulp after the removal of skin and seeds. Tomato pulp can be created by mortar and pestle, by mills or by small pulping machines[2]. The resulting solids are then suspended in an aqueous medium. Tomato paste manufacturing is an industrial process that includes heat-treatment and pulping–finishing, as well as other more minor processes. Heat-treatment and pulping-finishing have different objectives; inactivation of the pectinolytic enzymes by heat-treatment, and the softening of tissues and removal of skin and seeds by pulping-finishing. The final physical properties of tomato paste are dependent on these processing variables, which will differ between brands and products[3].

Tomato paste may also be an ingredient in other products, such as tomato ketchup and tomato soup. Alternately, tomatoes may be canned in other forms (chopped, peeled, puréed), all involving mechanical cutting.

1.4 Potential hazards in processed tomatoes

There are several types of hazards that can exist in processed tomato products. These include physical, microbiological and chemical hazards.

Many of the tomatoes used for the tomato processing industry are grown in fields. Therefore, extraneous matter, such as sand, grit and debris can be present on the tomatoes. Physical hazards from extraneous matter are minimized in the production process by multiple levels of washing.

Microbiological hazards can also exist in tomatoes. Blemishes and cuts that occur on the surface of fruits as a result of a physical injury is an ideal location for bacterial growth, insects, mould and mildew. Mould and mildew can also form during transportation and storage. There are multiple processing steps that can aid in reducing microbiological hazards from tomatoes when producing processed tomato products. Washing will physically remove surface hazards whereas heating (or high pressure) steps can destroy moulds and bacteria that may have contaminated the tomato flesh.

Chemical hazards that can originate from fresh tomatoes in processed tomato products include pesticides, mycotoxins and environmental contaminants that may include toxic metal species. Others can be introduced during processing and canning and include chemical preservatives and metal species from food additives and processing aids.

Pesticides are an important tool in crop management practices and are widely used all over the world. Although pesticides are deliberately added to enhance growth conditions for the tomatoes used in tomato processing, inappropriate uses of these chemical compounds may pose a health hazard. Pesticides are to be applied according to label instructions as the pesticide 1) may only be effective when applied at the appropriate time and 2) may require sufficient time to degrade and be removed from the surface of the fruit before it is harvested and consumed.

Metals can be used as tools in agricultural practices. Metals can also originate from the environment, food additives, processing aids, storage in cans and packaging. Unlike synthetic pesticides, many metals are ubiquitous in nature at low levels and can be essential components of living organisms. High levels of certain metals can represent a health hazard.

This report will focus on pesticide residues and metals in processed tomato products.

1.5 Pesticides

Tomato crops grown for processing are susceptible to pests, including moulds, insects and worms. There are many widely known pest management programs used to control pests in tomato crops in a variety of different countries.

Many of the processed tomato products consumed by Canadians and tested in this survey are imported from other countries. As these crops were not grown in Canada, the pest management tools and techniques used in foreign countries are not regulated by the Canadian Government. However, the resulting residues from these pesticide practices must meet established Canadian Maximum Residue Limits (MRLs) in final products[4].

It is important to note that much of the tomato crop utilized in the production of processed tomato products is grown specifically for processing and pesticides used for aesthetic purposes are normally not necessary. Therefore, it is expected that, relative to fresh tomato farming, there are less pesticide products used in the growing of tomatoes for processing, which would result in far fewer pesticide residues.

The CFIA is responsible for enforcing the MRLs set by Health Canada's Pesticide Management Regulatory Agency (PMRA) on food commodities in Canada[4]. All Canadian MRLs for pesticides are established under the Pest Control Products Act (PCPA). Although many pesticides used in foreign countries have no applicable uses in Canada, the PMRA has established specific import MRLs for these pesticide residues. A default MRL level of 0.1 part per million (ppm) applies for pesticides with no specific MRL.

1.6 Metals

Metals are essential components for plant life. Unlike organic chemicals, metals are neither created nor destroyed by biological or chemical processes. Metals such as chromium, copper, iron, manganese, selenium and zinc are essential minerals required for good health in humans. While inadequate amounts of an essential mineral in the diet can be detrimental to health, high levels of certain metals may result in toxic effects. Metals of particular concern to human health include arsenic, cadmium, lead and mercury.

Ongoing lead exposure can lead to anaemia, kidney toxicity and may result in damage to the central nervous system and brain. Young children and the developing foetus are most susceptible to lead toxicity. Health effects of mercury exposure will vary depending on the chemical form. Elemental mercury, when inhaled, can cause damage to the respiratory tract, mouth and lungs. Inorganic mercury may cause gastrointestinal and kidney damage. Ongoing exposures to organic mercury compounds, such as methyl mercury, can be detrimental to a child's developing brain and sensory changes are observed in both children and adults. Arsenic is considered a human cancer-causing agent. Ongoing exposure can lead to cardiovascular and circulatory effects[5]. Cadmium exposure can produce health effects on the kidney, stomach and bones. Cadmium may also play a role in human carcinogenesis[6].

In biological systems, metals can be transformed from one ionic species to another; however, harsh conditions are usually required to convert metals between inorganic and organic forms. As discussed, toxic metals, such as mercury, cadmium and arsenic, exist in a number of physico-chemical forms, some of which are highly toxic to human health

while others are less toxic to biological processes. The toxicity, bioavailability, bioactivity, transport and impact of the element in the body are determined by the particular element species present in food[7]. Currently, the CFIA has analytical capabilities limited to the determination of total metal species. However, as new research begins to unveil the effects from toxic species of metal elements, more robust and sensitive methods are needed to determine (both qualitatively and quantitatively) metal speciation in food samples.

Processed tomato products may contain metals originating from a variety of sources. Metals can be deliberately added to tomato crops as components of pesticide formulations or as a pesticide itself (i.e., copper). These agricultural chemicals are regulated and monitored in the same way as pesticides. Metals can also be present in processed tomato products as a result of processing or from the addition of food additives. For example, food colours can contain metal species such as aluminum, arsenic, iron, lead, silver and titanium. Processing equipment can also be a source of metals. Tin may leach into processed tomato products that are stored in plated cans.

Metals in processed tomato products can result from environmental contamination. The tomatoes can become contaminated with toxic metals from fertilizers (i.e., cadmium) or from water and soil sources (such as arsenic, cadmium, lead, mercury, etc). Many of these toxic metal species can result from industrial waste and persist in the environment. As a result of these possible metal sources, the presence of metal analytes in processed tomato products is not unexpected.

1.7 Targeted Survey Objective

CFIA's regular monitoring program for chemical residues in foods is the National Chemical Residue Monitoring Program (NCRMP). This program tests for multiple hazards in various commodities including a limited scope of processed tomato products.

Since many processed tomato products are not regularly monitored under the NCRMP, there was a need to collect baseline surveillance data for both pesticide residues and metal levels in the non-monitored processed tomato products. Furthermore, many of Canada's processed tomato products are imported, and Statistics Canada consumption data indicate that more Canadians are consuming imported tomato products than ever before[8]. It should also be noted that the country of origin on a processed tomato product is not necessarily indicative of the origin of the raw materials; the country of origin on a product is based on the location where the majority of economic value is added.

Therefore, there is a need to survey both domestic and imported processed tomato products. The choice of processed tomato products in planning the survey was derived from import statistics from the Canada Border Services Agency (CBSA), also taking into account consumption statistics (Statistics Canada), Canadian population distribution, and through collaboration with the Processed Products Section of the CFIA's Agri-food Division.

2 Survey Samples & Analytical Methods

2.1 Targeted Survey Sample Overview

A full description of all processed tomato products, including product type, and country of origin can be found in Appendix A

The 2008-2009 Processed Tomato project collected samples at the consumer retail level of the production chain. Samples were purchased in Ontario, Quebec, Alberta and British Columbia. There were a total of 297 samples (290 imported and 7 domestic) collected from 13 countries. The number of samples collected was related to the variety of products and/or brands available and it is not meant to reflect the relative composition of, nor the relative amounts of, the various tomato products consumed by Canadians.

Items for this survey include tomato products commonly available in national grocery stores: tomato soup; pizza sauce; salsa; tomato ketchup; tomato marinara; tomato paste; canned tomatoes (whole); chopped tomatoes (canned); strained tomatoes (canned). Meat-containing foods (such as spaghetti sauce) and fresh tomatoes were excluded from the study as these commodities are well-monitored by other sampling programs; the focus was to be placed on processed tomato products. Foods were neither selected nor excluded based on their nutritional value.

The distribution of samples with respect to country of origin is depicted in Figure 2-1. The survey design with regards to types of tomato products and country of origin was based on information available from Industry Canada (import statistics) and Statistics Canada (consumption statistics). The countries chosen for sampling represent 98.5% of Canada's imported tomato products, with the United States accounting for 87.5% of the total. As the United States is the most important exporter of processed tomato products to Canada, most of the survey samples were products from the United States, as indicated by the label. It is not possible to determine if in fact all of the ingredients were grown in the United States. This uncertainty is true for all samples collected in the survey.

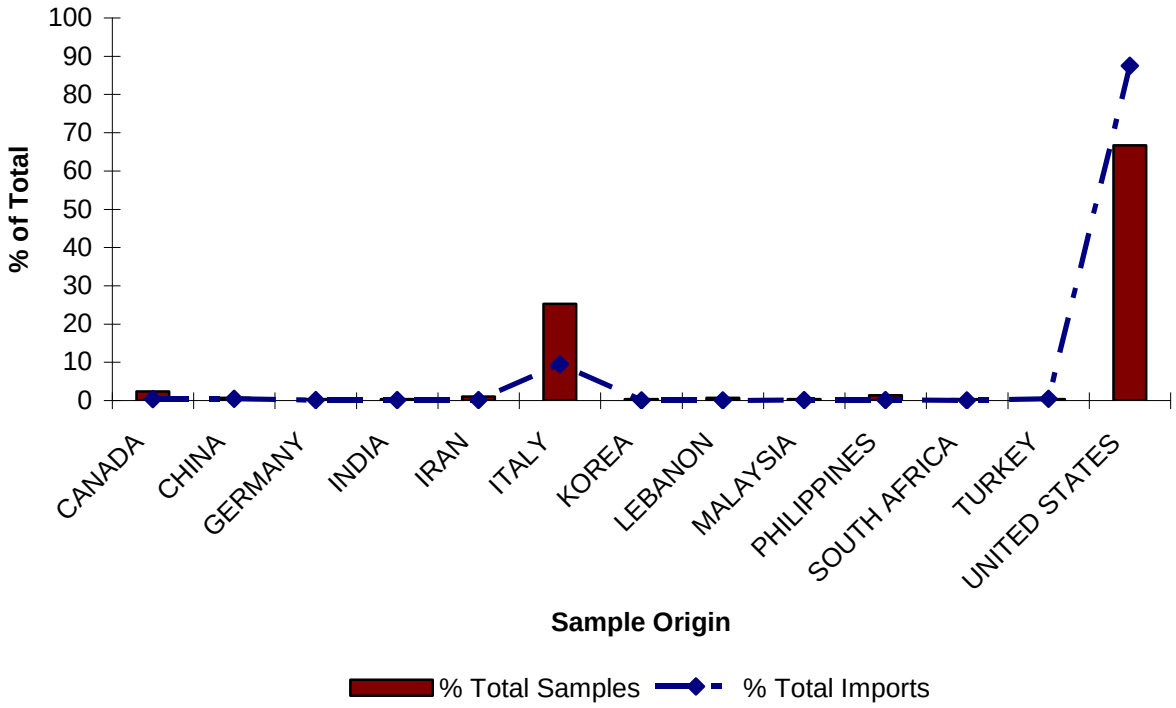

Figure 2-1 Distribution of Samples by Country of Origin

There were a total of 10 different types of processed tomato products sampled. More emphasis was put on canned tomatoes and tomato sauce as they are most available at the retail level in Canada. Similarly to the designed breakdown of sample origin, the number of samples for each product type was determined based on import statistics from the CBSA and input from the Processed Products section of the CFIA. **Figure 2-2** is a graphical depiction of sample distribution by product type.

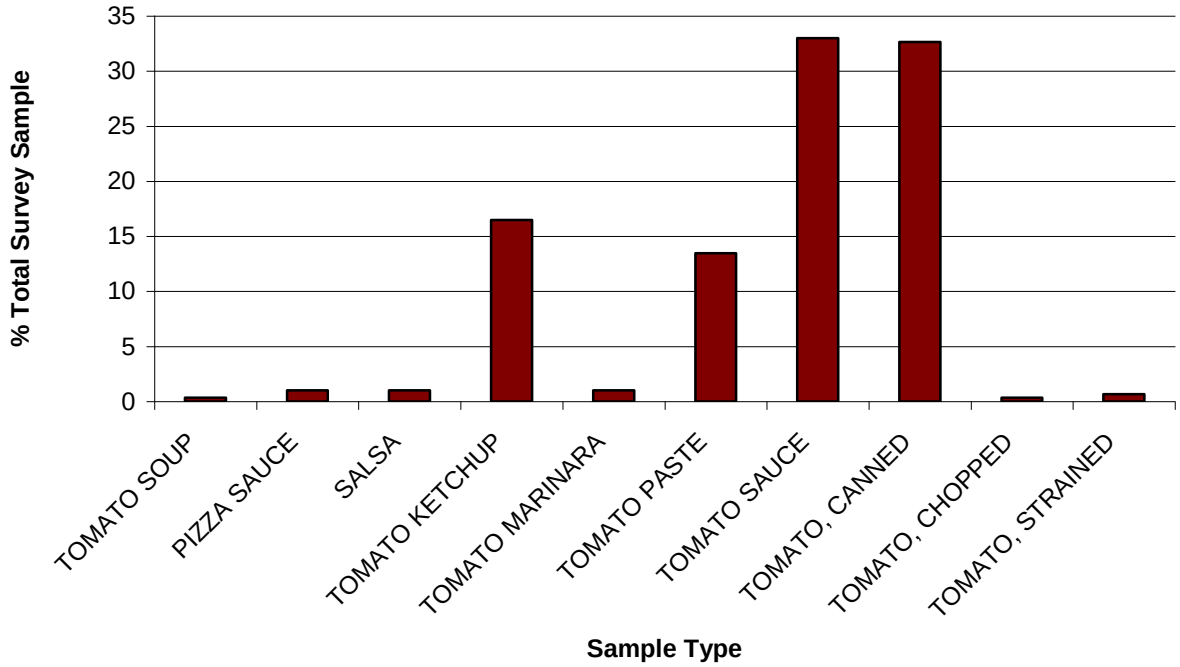

Figure 2-2 Distribution of Samples by Type of Processed Tomato Product.

2.2 Survey Limitations

The processed tomato product survey was designed to give a snapshot of the industry. There were a limited number of samples (297 in total) that are used to collect information on processed tomatoes as a class of foods. Conclusions regarding sample country of origin cannot be made as it is impossible to establish where the ingredients used to manufacture the product were grown. The term 'sample origin' refers to the country of manufacture, as indicated on the product label. The survey does not examine seasonality, year-to-year trends or impact of product shelf-life. The survey also does not consider the cost of the commodity on the open market.

2.3 Analytical Methods

To analyze the survey samples whose pesticide treatment history is generally unknown, a contracted third party laboratory employed an analytical method capable of simultaneously determining a large number of pesticide residues. The CFIA has established requirements for the acceptance of analytical results from third party laboratories. Such laboratories must be accredited to ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories* or its replacement by the Standards Council of Canada (SCC). Acceptance of results is

contingent on those routine tests and analytical matrices being included in the laboratory's current scope of accreditation[9].

To become accredited, an analytical method must be relevant for its intended purpose and meet certain validation parameters. Typical validation characteristics considered include:

- recovery
- selectivity
- specificity
- accuracy
- linearity/range
- precision
- repeatability/reproducibility
- limit of quantification (LOQ)
- limit of detection (LOD)

There were two analytical tests conducted on all samples in the targeted survey; a method for the determination of pesticides in processed foods by gas chromatography-mass spectroscopy (GC-MS/MS) and a method for the analysis of metals in processed foods by inductively-coupled plasma-mass spectroscopy (ICP-MS).

2.3.1 Pesticide Residue Analysis

The pesticide method must meet the majority of the requirements of the CFIA reference method PMR-002-V1.1 entitled 'Determination of Pesticides in Honey, Fruit Juice and Wine (With Solid Phase Extraction Clean-Up and GC-MSD and HPLC Fluorescence Detection)'. The pesticide method can detect 300 pesticides (consult Appendix B for full list of pesticides included in method). The multi-residue method includes banned pesticides (in Canada), pesticides that have established Canadian MRLs and pesticides that lack MRLs.

2.3.2 Metal Analysis

All samples were analyzed for metals using a third party method that analyzes for the following 18 metals: aluminum, arsenic, boron, cadmium, chromium, copper, iron, mercury, manganese, nickel, lead, selenium, tin, titanium, zinc, molybdenum, antimony and beryllium.

3 Results

3.1 General Results

The results from this targeted survey are presented below. The supporting information is presented in tabular form in the appendices.

When discussing the results of this study, it is important to remember the origin of the chemical compounds that are being evaluated. The application of pesticides to a food crop is a deliberate action whereas the presence of metals in a food product can be the result of multiple processes such as the direct addition to the food as a food additive or pesticide, from the soil or from other natural sources.

The results of analysis were compared to the applicable standards established by Health Canada at the time of sampling. For the different types of compounds tested, the following documents were used:

- For pesticides, MRLs were established and regulated under the Pest Control Products Act (PCPA) and can be found on Health Canada's *Consumer Product Safety* website

http://www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/food-nourriture/mrl-lmr-eng.php

- For metals, any applicable entry in the various divisions of the Food and Drug Regulations (FDR)

http://laws.justice.gc.ca/PDF/Regulation/C/C.R.C.,_c._870.pdf

Unless otherwise stated, the results in this report are presented in mg/kg (ppm). No distinction was made in the discussion regarding the origin of the chemical tested (i.e., if the food was fortified with minerals and vitamins) as this information was not available for this survey.

3.2 Results of Pesticide Residues Analysis

3.2.1 Samples for Pesticide Analysis

The 2008-2009 Processed Tomato Sampling Program tested samples at the retail level from 13 countries (including Canada). The 297 samples (7 domestic and 290 imported) collected in this study were analysed for pesticide residues according to the protocols described above. There were no Canadian pesticide MRL violations found in any sample. A non-violative residue is defined as a measurable residue that is less than, or equal to, the established MRL but is above the limit of quantification (LOQ) of the method used (i.e. the minimum concentration that can be accurately quantified).

Two hundred fifty of the 297 samples (84.18 %) contained no detectable residues. Of the 47 samples containing detectable residues, 39 samples contained one detectable residue, seven samples contained two detectable residues, and one sample contained three detectable residues (Figure 3-1). There were no instances in which residue concentrations exceeded Canadian MRLs.

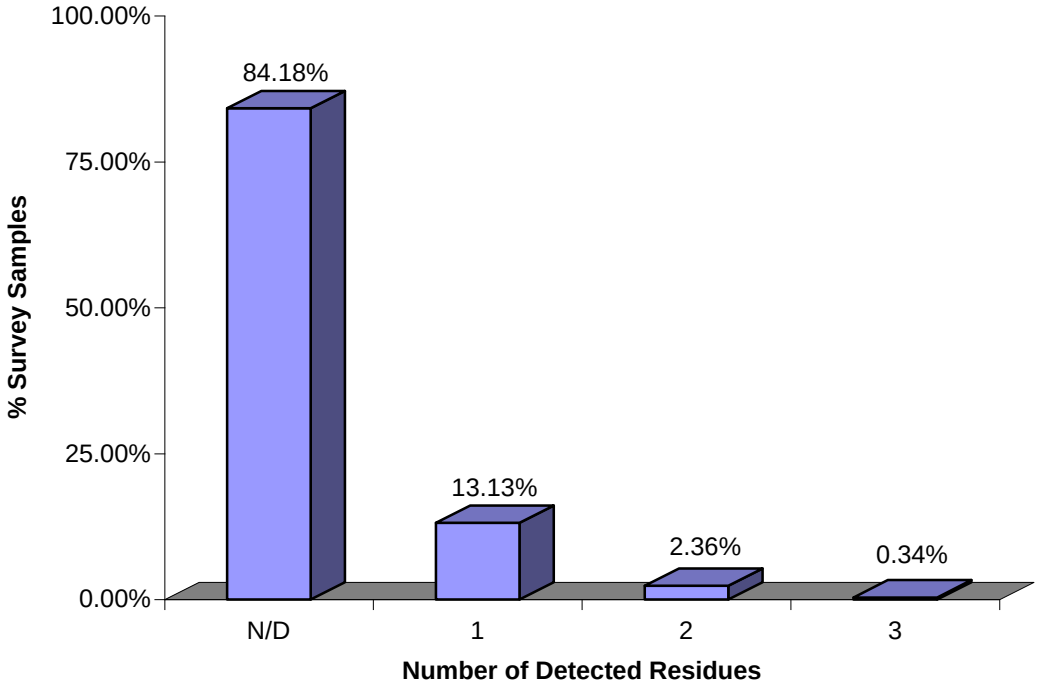

Figure 3-1 Distribution of Samples According to Number of Detectable Residues.

3.2.2 Residue Distribution by Country of Origin

The processed tomato products targeted survey included samples from 13 countries. Two countries were identified in the planning of the targeted survey as being Canada's top importing countries of processed tomato products: United States and Italy. Therefore, a large number of samples (91.8%) originate from these countries. A complete list of the detected chemical residues by sample origin is represented in Table 3-1. The United States, with 198 samples, had 39 (19.7%) samples with detectable residues. There were 13 different pesticide residues found in these samples. Italy, with 75 samples, had a total of 16 (21.3%) samples with detectable residues, with seven different pesticide residues in these 16 samples. The extremely small number of samples collected from other countries is insufficient to determine whether the rate of incidence of pesticide residues would deviate significantly from the overall detection rate (18.9 % of samples with detectable residues). However, as there were no pesticide violations from any country, the results of

the processed tomato product targeted survey indicate no difference in product safety based on the country of origin.

Table 3-1 Distribution of Pesticide Residues in Processed Tomato Products According to Country of Origin.

PRODUCT ORIGIN	Number of Samples	Number of Negative (N/D)	% N/D	ANALYTE	COUNT
CANADA	7	6	**85.7%**	Chlorpyrifos	1
CHINA	2	2	**100.0%**	None	N/A
GERMANY	1	1	**100.0%**	None	N/A
INDIA	1	1	**100.0%**	None	N/A
IRAN	3	3	**100.0%**	None	N/A
ITALY	75	61	**81.3%**	2-phenylphenol	4
				Azoxystrobin	1
				Benalaxyl	1
				Chlorpyrifos	2
				Endosulfan Total	1
				Metalaxyl	3
				Procymidone	3
SOUTH KOREA	1	1	**100.0%**	None	N/A
LEBANON	2	2	**100.0%**	None	N/A
MALAYSIA	1	1	**100.0%**	None	N/A
PHILIPPINES	4	4	**100.0%**	None	N/A
SOUTH AFRICA	1	1	**100.0%**	None	N/A
TURKEY	1	1	**100.0%**	None	N/A
UNITED STATES	198	166	**83.8%**	2-phenylphenol	11
				Azoxystrobin	7
				Bifenthrin	5
				Chlorpyrifos	1
				Cyprodinil	1
				Endosulfan Total	1
				Fenpropathrin	1
				Fludioxonil	1
				Metalaxyl	1
				Myclobutanil	1
				p,p'-DDE	3
				Permethrin (Total)	5
				Trifluralin	1

3.2.3 Residue Distribution by Product Type

There were 10 types of processed tomato products sampled in this survey. Of the 10 different products in the survey, six contained at least one detectable pesticide residue (pizza sauce, salsa, ketchup, tomato paste, tomato sauce, canned tomatoes), while there were no residues detected in any sample of four products (tomato soup, tomato marinara, chopped tomatoes, and strained tomatoes). Fifteen different residues were detected; three

of those (bifenthrin, 2-phenylphenol and azoxystrobin) accounted for 59% of the positive results. The product types with the greatest number of samples contained the highest number of different analytes detected: tomato sauce and canned tomatoes. Table 3-2 lists the residues found in the various types of processed tomato products. It should be noted that many of these results are based on a very small number of samples for each product type and should not be considered indicative of those products. It should also be noted that none of these samples represented a violation of Canadian MRLs.

Table 3-2. The number and Type of Pesticide Residue According to Processed Tomato Product Type.

PRODUCT TYPE	Number of +ve Samples	Number of -ve Samples (N/D)	% Negatives	ANALYTE	COUNT
TOMATO SOUP	1	1	100.0%	None	N/D
PIZZA SAUCE	3	2	66.7%	Fenpropathrin	1
				Myclobutanil	1
SALSA	3	2	66.7%	Bifenthrin	1
TOMATO KETCHUP	49	48	98.0%	Permethrin (Total)	1
TOMATO MARINARA	3	3	100.0%	None	N/D
TOMATO PASTE	40	34	85.0%	2-phenylphenol	1
				Azoxystrobin	2
				Bifenthrin	1
				Endosulfan Total	1
				Metalaxyl	1
TOMATO SAUCE	98	74	75.5%	2-phenylphenol	7
				Azoxystrobin	5
				Bifenthrin	3
				Chlorpyrifos	3
				Cyprodinil	1
				Endosulfan Total	1
				Fludioxonil	1
				Metalaxyl	1
				p,p'-DDE	3
				Permethrin (Total)	3
				Trifluralin	1
TOMATO, CANNED	97	83	85.6%	2-phenylphenol	7
				Azoxystrobin	1
				Benalaxyl	1
				Chlorpyrifos	2
				Metalaxyl	2
				Permethrin (Total)	1
				Procymidone	3
TOMATO, CHOPPED	1	1	100.0%	None	N/D
TOMATO, STRAINED	2	2	100.0%	None	N/D

3.2.4 Discussion of Specific Results from Pesticide Survey

The samples analysed in this targeted survey illustrated a 100% compliance rate with Canadian pesticide MRLs in processed tomato products. This is similar to the compliance rates seen in most fresh and processed tomato products sampled under the regular monitoring program.

The products that contained detectable pesticide residues with established MRLs were all compliant with the established regulations. Of the products that contained pesticide residues with no established MRLs, residue levels were below the default 0.1 ppm MRL.

Several processed tomato products had no detectable pesticide residues; these included tomato soup, tomato marinara, chopped tomatoes and strained tomatoes. This is not to say that these processed tomato products are pesticide-free, but rather that pesticide residues were not detected with the method used at the time of analysis.

3.3 Results of Metal Analysis

3.3.1 Samples for Metal Analysis

The 297 samples (7 domestic and 290 imported) collected in the 2008-2009 Processed Tomato Product Targeted Survey were analysed for metals according to the protocols described above (Section 2.3.2). This method analyzes for 18 metals, including aluminum (Al), antimony (Sb), arsenic (As), beryllium (Be), boron (B), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), tin (Sn), titanium (Ti) and zinc (Zn).

The results presented below are a measure of the total metal concentration present in the food and do not distinguish between organic and inorganic forms, or ionic species. As such, these results do not provide direct information about the bioavailability or the toxicity of the metal. The metal results do not reveal the potential source (i.e. endogenous versus deliberate addition from pesticide use or food additive, etc). Nevertheless, the results obtained in this case study may be used to estimate the nature of metal levels in processed tomato products and to identify any existing patterns.

All the survey samples had detectable levels of metal elements. The following section provides a discussion of the metal results by sample origin and processed tomato product type.

3.3.2 Discussion of Metals by Country and Product Type

There were samples from 13 countries in the processed tomato product targeted survey (see Figure 2-1). A list of detected metals by sample origin is presented in Appendix C. There were 10 different processed tomato product types in the survey. A list of detected

metals by commodity is available in Appendix D. A brief discussion of the results follows.

Aluminum

Aluminum is a ubiquitous element that can be present naturally in the foods consumed by Canadians. It can be used for multiple food preparation purposes, such as a processing aid, firming agent, anti-caking agent, stabilizer, etc. The *Food and Drug Regulations* (FDR) specify the levels of aluminum that are permitted in food. This survey does not explore the source of the aluminum present (i.e. whether the source is natural, from pesticide use or as a processing aid). Out of 297 samples tested, 296 samples had detectable levels of aluminum. The level of aluminum observed in this survey ranged from 0.109 ppm to 30.35 ppm. None of the products had levels of aluminum that exceeded levels acceptable in Canada. There were no specific patterns observed for aluminum with respect to country of origin or product type.

Antimony

Antimony is a rare and non-essential metal. There are no Canadian tolerances or guidelines established for antimony in foods. However, antimony can be present in titanium dioxide, and the FDR has established a 50 ppm tolerance for antimony in titanium dioxide when used in food colours. Of the 297 survey samples, none had detectable levels of antimony.

Arsenic

Arsenic is a natural element present in certain foods like fruit. It can also be a component of arsenic-containing fungicides. The levels of arsenic allowed in foods are specified in Table I of Division 15 of the FDR. In addition, a 3 ppm arsenic tolerance exists for food colours. There are no Canadian tolerances or guidelines established specifically for arsenic in processed tomato products. Out of 297 samples analysed, 117 samples contained detectable levels of arsenic. Most detectable concentrations ranged between 0.005 and 0.048 ppm, with a single sample outside of this range that contained 0.248 ppm (tomato paste originating in Turkey).

Beryllium

Beryllium is a relatively rare element and is not known to be necessary for either plant or animal life. There are no Canadian tolerances or guidelines established for beryllium in food. None of the 297 survey samples contained detectable levels of beryllium.

Boron

Boron is a natural element and ubiquitous in nature. It is found in most commodities and is reportedly being used (as boric acid) on whole fruit as a fungicide[10]. Boric acid is naturally present in crop plants and deposits resulting from its use as an agricultural

compound may also degrade to provide the essential element boron. Given the natural levels of boric acid and boron occurring in the plant, the result of agricultural compound use would be indistinguishable from background levels. It is present in significant levels in crops such as pome fruit, stone fruit and grapes[x]. Boron and boric acid are of low toxicity and levels reported would not pose a human health risk. There are no established Canadian tolerances or guidelines for boron in food. All 297 samples had detectable amounts of boron, ranging between 0.549 ppm and 8.292 ppm.

Cadmium

Cadmium is a minor component of a variety of ores and is found in small quantities in zinc and phosphate ore. As a result cadmium is produced mainly as a by-product of mining and smelting, and is a common contaminant of fertilizer. There are no Canadian tolerances or guidelines established for cadmium levels in food. All 297 samples contained detectable amounts of cadmium ranging from 0.0029 ppm to 0.2006 ppm. The levels observed are very low and do not represent a health risk to humans. There were no specific patterns observed for cadmium with respect to country of origin or product type.

Chromium

Chromium is an essential mineral in the human diet. There are no Canadian tolerances or guideline levels for chromium in food. There were 285 samples that had detectable levels of chromium, ranging between 0.011 ppm and 0.454 ppm. There were no specific patterns observed for chromium with respect to country of origin or product type.

Copper

Copper can be used as a fungicide. An MRL of 50 ppm has been established for copper compounds in all fresh fruits and vegetables. This MRL also applies to processed foods derived from treated crops, such as processed tomato products. All of the 297 samples contained detectable amounts of copper, ranging between 0.312 ppm and 8.422 ppm. All of the products were in compliance with the Canadian MRL.

Iron

Iron is a natural component of most living organisms and is an essential nutrient for the human body. There are no Canadian tolerances or guidelines for iron in food. All 297 samples had detectable amounts of iron, ranging between 0.671 ppm and 108.00 ppm. There were no specific patterns observed for iron with respect to country of origin or product type.

Lead

Lead exposure may result from a number of environmental and food sources. There are several tolerances and guidelines for lead in food that can be found in *Division 15* of the FDR. A tolerance of 1.5 ppm exists for tomato paste and tomato puree. In addition, a 10 ppm tolerance for lead exists for food colours. Of the 297 survey samples, 243 had detectable levels of lead, ranging between 0.002 ppm and 0.125 ppm. There were no samples that exceeded Canadian tolerances for lead, and no specific patterns were observed for lead with respect to country of origin or product type.

Manganese

Manganese is an essential trace mineral in human diet. At present, there are no Canadian tolerances or guideline values for manganese in foods. All 297 samples had detectable levels of manganese. The levels ranged between 0.326 ppm and 7.288 ppm with no specific patterns observed for manganese with respect to country of origin or product type.

Mercury

Mercury is a rare element used primarily in the manufacture of industrial chemicals and electronics applications. None of the samples tested as part of this targeted survey had detectable levels of mercury.

Molybdenum

Molybdenum is an essential trace element in the human diet. There are no Canadian MRLs or guidelines established for molybdenum in foods. Of the 297 survey samples, 283 contained detectable levels of molybdenum. The levels ranged between 0.020 ppm and 0.856 ppm. There were no specific patterns observed for molybdenum with respect to country of origin or product type.

Nickel

Concentrations of nickel in processed tomato products can result from food processing equipment or from environmental contamination. There are presently no Canadian tolerances or guidelines for nickel in food. All of the 297 survey samples contained detectable levels of nickel, ranging between 0.014 ppm and 1.722 ppm. There were no specific patterns observed for nickel with respect to country of origin or product type.

Selenium

Selenium is an essential trace element in the human diet. There are presently no Canadian tolerances or guidelines for selenium in foods. Of the 297 samples, 94 contained detectable levels of selenium. The detectable concentrations ranged between 0.020 ppm and 0.131 ppm. There were no specific patterns observed for selenium with respect to country of origin or product type.

Tin

Tin is a major component in canning materials. The tolerance for tin in canned foods is 250 ppm. Most of the survey samples were sold in consumer-sized tin cans. 266 of the 297 samples contained detectable concentrations of tin. The level of tin ranged between 0.02 ppm and 82.49 ppm. None of the samples exceeded the Canadian tolerance for tin, and no specific patterns were observed for tin with respect to country of origin or product type.

Titanium

Titanium is a fairly abundant non essential element that is present in most sediment. Titanium, in the form of titanium dioxide is also used as a food additive. There are presently no Canadian tolerances or guidelines for titanium in foods. There were 296 of 297 samples that contained detectable levels of titanium. The levels ranged between 0.148 ppm and 2.785 ppm. There were no specific patterns observed for titanium with respect to country of origin or product type.

Zinc

Zinc is an essential trace element in the human diet. There are no Canadian tolerances or guidelines established for zinc in foods. All of the 297 survey samples contained detectable concentrations of zinc. The levels ranged between 0.588 ppm and 10.31 ppm. There were no specific patterns observed for zinc with respect to country of origin or product type.

4 Conclusions

The 2008-2009 processed tomato product targeted survey indicates that the majority of samples analyzed (84.18% of 297 samples) contained no measurable pesticide residues, and all samples were in compliance with Canadian MRLs. These results are expected for processed tomato products, as it is anticipated that fewer pesticides are used on tomatoes intended for processing. Furthermore, processing (washing, heating, etc) may also remove or deplete pesticide residues.

All 297 survey samples contained one or more metals. Metals can be natural components of biological processes, can result from environmental contamination, nutritional fortification or arise from food processing and food packaging. It is therefore not unexpected to find low levels of metals in processed tomato products. All of the 297 samples were in compliance with existing Canadian metal MRLs and tolerances. Mercury was not detected in any of the samples. All other metals were present at low concentrations that do not pose a human health risk.

5 Future Considerations

All 297 processed tomato product samples were 100% compliant with Canadian standards for pesticide residues and metals. As the number of samples (297) was small, this does not represent a statistically relevant data set, but rather provides a snapshot of the industry.

A future pesticide and metal survey on processed tomato products will help address the following concerns:

- Increase the number of samples to obtain a statistically-relevant data set
- Identify trends based on seasonality, etc.;
- Increase the scope of analysis by incorporating a second pesticide multi-residue screen and new metal speciation methods (new metal speciation methods were developed by the CFIA laboratories in 2009 and are fully validated and available for future surveys);
- Focus on processed tomato product types and countries with increased incidence of pesticide residues to ensure continued compliance**.**

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7 Appendix A

Table A-1 Number of each type of processed tomato sample analysed, by country.

PRODUCT	COUNTRY OF ORIGIN	# OF SAMPLES
TOMATO SOUP	UNITED STATES	1
PIZZA SAUCE	UNITED STATES	3
SALSA	UNITED STATES	3
TOMATO KETCHUP	CANADA	2
	GERMANY	1
	ITALY	3
	KOREA, REPUBLIC OF	1
	LEBANON	1
	MALAYSIA	1
	PHILIPPINES	1
	SOUTH AFRICA	1
	UNITED STATES	38
TOMATO MARINARA	UNITED STATES	3
TOMATO PASTE	CHINA, PEOPLE'S REPUBLIC	2
	IRAN	3
	ITALY	6
	LEBANON	1
	TURKEY	1
	UNITED STATES	27
TOMATO SAUCE	CANADA	3
	INDIA	1
	ITALY	8
	PHILIPPINES	3
	UNITED STATES	83
TOMATO, CANNED	CANADA	2
	ITALY	57
	UNITED STATES	38
TOMATO, CHOPPED	UNITED STATES	1
TOMATO, STRAINED	ITALY	1
	UNITED STATES	1
Grand Total		297

8 Appendix B

Table B-1: List of pesticides (300) included in third party method (Method for the Determination of Pesticides in Processed Foods and Animal Derived Foods)

Analyte	Cycloate	Fluchloralin	Parathion
2-phenylphenol	Cyfluthrin (I,II,III,IV)	Flucythrinate	Parathion-methyl
3-OH Carbofuran	Cyhalothrin-lambda	Fludioxonil	Pebulate
Acephate	Cypermethrin	Flumetralin	Penconazole
Acibenzolar-s-methyl	Cyprazine	Fluorochloridone	Pendimethalin
Alachlor	Cyproconazole	Fluorodifen	Pentachloroaniline
Aldicarb	Cyprodinil	Flusilazole	Permethrin cis
Aldicarb Sulfone	Cyromazine	Fluvalinate	Permethrin trans
Aldicarb sulfoxide	Dacthal (chlorthal-dimethyl)	Folpet	Phenthoate
Aldrin	delta-HCH (delta-lindane)	Fonofos	Phorate
Allidochlor	Deltamethrin	Heptachlor	Phorate sulfone
Ametryn	delta-trans-allethrin	Heptachlor epoxide endo	Phosalone
Aminocarb	Demeton-O	Heptanophos	Phosmet
Aramite	Demeton-S	Hexachlorobenzene	Phosphamidon
Aspon	Demeton-S-methyl	Hexaconazole	Piperonyl butoxide
Atrazine	Des-ethyl Atrazine	Hexazinone	Pirimicarb
Azinphos-ethyl	Desmetryn	Imazalil	Pirimiphos-ethyl
Azinphos-methyl	Di-allate	Iodofenphos	Pirimiphos-methyl
Azoxystrobin	Dialofos	Iprobenfos	Prochloraz
Benalaxyl	Diazinon	Iprodione	Procymidone
Bendiocarb	Diazinon o analogue	Iprodione metabolite	Prodiamine
Benfluralin	Dichlobenil	Isazophos	Profenofos
Benodanil	Dichlofluanid	Isofenphos	Profluralin
Benzoylprop-ethyl	Dichloran	Isopropalin	Prometon
BHC Alpha	Dichlormid	Isoprothiolane	Prometryne
BHC beta	Dichlorvos	Kresoxim-methyl	Pronamide
Bifenox	Diclobutrazole	Leptophos	Propachlor
Bifenthrin	Diclofenthion	Lindane (gamma-BHC)	Propanil
Biphenyl	Diclofop-methyl	Linuron	Propargite
Bromacil	Dicofol	Malaoxon	Propazine
Bromophos	Dicrotophos	Malathion	Propetamphos
Bromophos-ethyl	Dieldrin	Mecarbam	Propham
Bromopropylate	Diethatyl-ethyl	Metalaxyl	Propiconazole
Bufencarb	Dimethachlor	Metazachlor	Propoxur
Bupirimate	Dimethoate	Methamidophos	Prothiophos
Buprofezin	Dinitramine	Methidathion	Pyracarbolid
Butachlor	Dioxacarb	Methiocarb	Pyrazophos
Butralin	Dioxathion	Methiocarb Sulfoxide	Pyridaben
Butylate	Diphenamid	Methomyl	Quinalphos

Captafol	**Diphenylamine**	**Methoprotryne**	**Quinomethionate**
Captan	**Disulfoton**	**Methoxychlor**	**Quintozene**
Captan metabolite	**Disulfoton sulfone**	**Methyl - trithion**	**Schradan**
Carbaryl	**Edifenphos**	**Methyl Pentachlorophenyl sulphide**	**Secbumeton**
Carbetamide	**Endosulfan alpha**	**Metobromuron**	**Simazine**
Carbofenthion	**Endosulfan beta**	**Metolachlor**	**Simetryn**
Carbofuran	**Endosulfan sulfate**	**Metribuzin**	**Sulfallate**
Carboxin	**Endrin**	**Mevinphos-cis**	**Sulfotep**
Chlorbenside	**EPN**	**Mevinphos-trans**	**Sulprophos**
Chlorbenzilate	**EPTC**	**Mexacarbate**	**TCMTB**
Chlorbromuron	**Erbon**	**Mirex**	**Tebuconazole**
Chlorbufam	**Esfenvalerate**	**Monocrotophos**	**Tecnazene**
Chlordane cis	**Etaconazole**	**Monolinuron**	**Terbacil**
Chlordane trans	**Ethalfluralin**	**Myclobutanil**	**Terbufos**
Chlordimeform	**Ethion**	**Naled**	**Terbumeton**
Chlorfenson	**Ethofumsate**	**Nitralin**	**Terbutryne**
Chlorfenvinphos (e+z)	**Ethoprophos**	**Nitrapyrin**	**Terbutylazine**
Chlorflurenol-methyl	**Ethylan**	**Nitrofen**	**Tetrachlorvinphos**
Chloridazon	**Etridiazole**	**Nitrothal-isopropyl**	**Tetradifon**
Chlormephos	**Etrimfos**	**Norflurazon**	**Tetraiodoethylene**
Chloroneb	**Fenamiphos**	**Nuarimol**	**Tetramethrin**
Chloropropylate	**Fenamiphos sulfone**	**o,p'-DDD (o,p'-TDE)**	**Tetrasul**
Chlorothalonil	**Fenamiphos sulfoxide**	**o,p'-DDE**	**Thiobencarb**
Chlorpropham	**Fenarimol**	**o,p'-DDT**	**Tolclofos-methyl**
Chlorpyrifos	**Fenbuconazole**	**Octhilinone**	**Tolyfluanid**
Chlorpyriphos-methyl	**Fenchlorophos (Ronnel)**	**Omethoate**	**Triadimefon**
Chlorthiamid	**Fenfuram**	**Oxadiazon**	**Triadimenol**
Chlorthion	**Fenitrothion**	**Oxadixyl**	**Tri-allate**
Chlorthiophos	**Fenpropathrin**	**Oxamyl**	**Triazophos**
Chlozolinate	**Fenpropimorph**	**Oxycarboxin**	**Tribufos**
Clomazone	**Fenson**	**Oxychlordane**	**Tricyclazole**
Coumaphos	**Fensulfothion**	**Oxyflurofen**	**Trifloxystrobin**
Crotoxyphos	**Fenthion**	**p,p'-DDD (p,p'-TDE)**	**Triflumizole**
Crufomate	**Fenvalerate**	**p,p'-DDE**	**Trifluralin**
Cyanazine	**Flamprop-isopropyl**	**p,p'-DDT**	**Vernolate**
Cyanophos	**Flamprop-methyl**	**Paraoxon**	**Vinclozolin**

9 Appendix C

Table C-1 Metal analysis results in processed tomato products, by country of origin. MIN, MAX and MEAN are expressed in ppm.

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
Aluminum	CANADA	7	7	0	0.270	4.721	1.494
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.786	1.629	1.208
	GERMANY	1	1	0	3.077	3.077	3.077
	INDIA	1	1	0	1.453	1.453	1.453
	IRAN	3	3	0	1.354	3.634	2.425
	ITALY	75	75	0	0.109	12.000	2.658
	KOREA, REPUBLIC OF	1	1	0	3.930	3.930	3.930
	LEBANON	2	2	0	0.937	1.675	1.306
	MALAYSIA	1	1	0	0.317	0.317	0.317
	PHILIPPINES	4	4	0	0.400	8.412	4.060
	SOUTH AFRICA	1	1	0	1.316	1.316	1.316
	TURKEY	1	1	0	30.350	30.350	30.350
	UNITED STATES	198	197	1	0.158	9.332	2.476
Antimony	CANADA	7	0	7	N/D	N/D	N/D
	CHINA, PEOPLE'S REPUBLIC	2	0	2	N/D	N/D	N/D
	GERMANY	1	0	1	N/D	N/D	N/D
	INDIA	1	0	1	N/D	N/D	N/D
	IRAN	3	0	3	N/D	N/D	N/D
	ITALY	75	0	75	N/D	N/D	N/D
	KOREA, REPUBLIC OF	1	0	1	N/D	N/D	N/D
	LEBANON	2	0	2	N/D	N/D	N/D
	MALAYSIA	1	0	1	N/D	N/D	N/D
	PHILIPPINES	4	0	4	N/D	N/D	N/D

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	SOUTH AFRICA	1	0	1	N/D	N/D	N/D
	TURKEY	1	0	1	N/D	N/D	N/D
	UNITED STATES	198	0	198	N/D	N/D	N/D
Arsenic	CANADA	7	1	6	0.006	0.006	0.006
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.012	0.060	0.036
	GERMANY	1	0	1	N/D	N/D	N/D
	INDIA	1	1	0	0.008	0.008	0.008
	IRAN	3	2	1	0.006	0.013	0.010
	ITALY	75	17	58	0.005	0.013	0.008
	KOREA, REPUBLIC OF	1	1	0	0.048	0.048	0.048
	LEBANON	2	0	2	N/D	N/D	N/D
	MALAYSIA	1	1	0	0.008	0.008	0.008
	PHILIPPINES	4	4	0	0.009	0.011	0.010
	SOUTH AFRICA	1	1	0	0.008	0.008	0.008
	TURKEY	1	1	0	0.258	0.258	0.258
	UNITED STATES	198	86	112	0.005	0.041	0.008
Beryllium	CANADA	7	0	7	N/D	N/D	N/D
	CHINA, PEOPLE'S REPUBLIC	2	0	2	N/D	N/D	N/D
	GERMANY	1	0	1	N/D	N/D	N/D
	INDIA	1	0	1	N/D	N/D	N/D
	IRAN	3	0	3	N/D	N/D	N/D
	ITALY	75	0	75	N/D	N/D	N/D
	KOREA, REPUBLIC OF	1	0	1	N/D	N/D	N/D
	LEBANON	2	0	2	N/D	N/D	N/D
	MALAYSIA	1	0	1	N/D	N/D	N/D

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	0	4	N/D	N/D	N/D
	SOUTH AFRICA	1	0	1	N/D	N/D	N/D
	TURKEY	1	0	1	N/D	N/D	N/D
	UNITED STATES	198	0	198	N/D	N/D	N/D
Boron	CANADA	7	7	0	0.830	1.652	1.262
	CHINA, PEOPLE'S REPUBLIC	2	2	0	1.836	4.792	3.314
	GERMANY	1	1	0	0.779	0.779	0.779
	INDIA	1	1	0	0.829	0.829	0.829
	IRAN	3	3	0	2.464	3.503	2.912
	ITALY	75	75	0	0.549	5.391	1.362
	KOREA, REPUBLIC OF	1	1	0	1.836	1.836	1.836
	LEBANON	2	2	0	1.064	2.114	1.589
	MALAYSIA	1	1	0	0.927	0.927	0.927
	PHILIPPINES	4	4	0	0.888	1.430	1.181
	SOUTH AFRICA	1	1	0	1.815	1.815	1.815
	TURKEY	1	1	0	5.970	5.970	5.970
	UNITED STATES	198	198	0	0.672	8.292	2.022
Cadmium	CANADA	7	7	0	0.016	0.029	0.022
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.009	0.035	0.022
	GERMANY	1	1	0	0.010	0.010	0.010
	INDIA	1	1	0	0.003	0.003	0.003
	IRAN	3	3	0	0.013	0.015	0.014
	ITALY	75	75	0	0.004	0.079	0.018
	KOREA, REPUBLIC OF	1	1	0	0.024	0.024	0.024
	LEBANON	2	2	0	0.005	0.026	0.016
	MALAYSIA	1	1	0	0.008	0.008	0.008

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	4	0	0.005	0.022	0.009
	SOUTH AFRICA	1	1	0	0.009	0.009	0.009
	TURKEY	1	1	0	0.095	0.095	0.095
	UNITED STATES	198	198	0	0.006	0.201	0.032
Chromium	CANADA	7	7	0	0.013	0.057	0.029
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.023	0.079	0.051
	GERMANY	1	1	0	0.064	0.064	0.064
	INDIA	1	1	0	0.043	0.043	0.043
	IRAN	3	3	0	0.042	0.084	0.068
	ITALY	75	74	1	0.013	0.454	0.082
	KOREA, REPUBLIC OF	1	1	0	0.051	0.051	0.051
	LEBANON	2	2	0	0.016	0.050	0.033
	MALAYSIA	1	1	0	0.019	0.019	0.019
	PHILIPPINES	4	3	1	0.038	0.165	0.091
	SOUTH AFRICA	1	1	0	0.035	0.035	0.035
	TURKEY	1	1	0	0.382	0.382	0.382
	UNITED STATES	198	188	10	0.011	0.307	0.051
Copper	CANADA	7	7	0	0.671	1.212	0.937
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.933	4.891	2.912
	GERMANY	1	1	0	0.647	0.647	0.647
	INDIA	1	1	0	0.429	0.429	0.429
	IRAN	3	3	0	1.951	2.534	2.270
	ITALY	75	75	0	0.603	8.422	1.553
	KOREA, REPUBLIC OF	1	1	0	0.988	0.988	0.988
	LEBANON	2	2	0	0.525	1.377	0.951
	MALAYSIA	1	1	0	0.732	0.732	0.732

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	4	0	0.474	0.715	0.556
	SOUTH AFRICA	1	1	0	0.804	0.804	0.804
	TURKEY	1	1	0	2.648	2.648	2.648
	UNITED STATES	198	198	0	0.312	4.609	1.340
Iron	CANADA	7	7	0	5.733	19.190	9.488
	CHINA, PEOPLE'S REPUBLIC	2	2	0	14.820	56.200	35.510
	GERMANY	1	1	0	8.117	8.117	8.117
	INDIA	1	1	0	5.478	5.478	5.478
	IRAN	3	3	0	8.902	86.900	38.994
	ITALY	75	75	0	0.671	32.380	7.174
	KOREA, REPUBLIC OF	1	1	0	9.748	9.748	9.748
	LEBANON	2	2	0	6.559	7.498	7.029
	MALAYSIA	1	1	0	2.411	2.411	2.411
	PHILIPPINES	4	4	0	2.813	10.320	5.371
	SOUTH AFRICA	1	1	0	5.141	5.141	5.141
	TURKEY	1	1	0	56.770	56.770	56.770
	UNITED STATES	198	198	0	1.956	108.000	14.031
Lead	CANADA	7	5	2	0.003	0.009	0.005
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.003	0.006	0.004
	GERMANY	1	1	0	0.006	0.006	0.006
	INDIA	1	1	0	0.006	0.006	0.006
	IRAN	3	3	0	0.016	0.033	0.026
	ITALY	75	75	0	0.002	0.125	0.019
	KOREA, REPUBLIC OF	1	1	0	0.007	0.007	0.007
	LEBANON	2	2	0	0.005	0.005	0.005
	MALAYSIA	1	1	0	0.003	0.003	0.003

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	3	1	0.004	0.006	0.005
	SOUTH AFRICA	1	1	0	0.066	0.066	0.066
	TURKEY	1	1	0	0.051	0.051	0.051
	UNITED STATES	198	147	51	0.002	0.069	0.008
Manganese	CANADA	7	7	0	0.878	1.921	1.396
	CHINA, PEOPLE'S REPUBLIC	2	2	0	1.338	3.782	2.560
	GERMANY	1	1	0	1.961	1.961	1.961
	INDIA	1	1	0	0.880	0.880	0.880
	IRAN	3	3	0	2.204	3.041	2.551
	ITALY	75	75	0	0.603	6.245	1.412
	KOREA, REPUBLIC OF	1	1	0	1.516	1.516	1.516
	LEBANON	2	2	0	0.874	1.915	1.395
	MALAYSIA	1	1	0	0.628	0.628	0.628
	PHILIPPINES	4	4	0	0.646	0.904	0.806
	SOUTH AFRICA	1	1	0	1.744	1.744	1.744
	TURKEY	1	1	0	7.288	7.288	7.288
	UNITED STATES	198	198	0	0.326	6.607	1.728
Mercury	CANADA	7	0	7	N/D	N/D	N/D
	CHINA, PEOPLE'S REPUBLIC	2	0	2	N/D	N/D	N/D
	GERMANY	1	0	1	N/D	N/D	N/D
	INDIA	1	0	1	N/D	N/D	N/D
	IRAN	3	0	3	N/D	N/D	N/D
	ITALY	75	0	75	N/D	N/D	N/D
	KOREA, REPUBLIC OF	1	0	1	N/D	N/D	N/D
	LEBANON	2	0	2	N/D	N/D	N/D
	MALAYSIA	1	0	1	N/D	N/D	N/D

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	0	4	N/D	N/D	N/D
	SOUTH AFRICA	1	0	1	N/D	N/D	N/D
	TURKEY	1	0	1	N/D	N/D	N/D
	UNITED STATES	198	0	198	N/D	N/D	N/D
Molybdenum	CANADA	7	6	1	0.041	0.066	0.057
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.101	0.300	0.201
	GERMANY	1	1	0	0.044	0.044	0.044
	INDIA	1	1	0	0.042	0.042	0.042
	IRAN	3	3	0	0.151	0.317	0.258
	ITALY	75	64	11	0.020	0.187	0.051
	KOREA, REPUBLIC OF	1	1	0	0.080	0.080	0.080
	LEBANON	2	2	0	0.038	0.044	0.041
	MALAYSIA	1	1	0	0.049	0.049	0.049
	PHILIPPINES	4	4	0	0.045	0.085	0.062
	SOUTH AFRICA	1	1	0	0.067	0.067	0.067
	TURKEY	1	1	0	0.164	0.164	0.164
	UNITED STATES	198	196	2	0.021	0.856	0.099
Nickel	CANADA	7	7	0	0.053	0.206	0.098
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.048	0.180	0.114
	GERMANY	1	1	0	0.083	0.083	0.083
	INDIA	1	1	0	0.046	0.046	0.046
	IRAN	3	3	0	0.144	0.538	0.388
	ITALY	75	75	0	0.014	1.080	0.115
	KOREA, REPUBLIC OF	1	1	0	0.270	0.270	0.270
	LEBANON	2	2	0	0.064	0.135	0.100
	MALAYSIA	1	1	0	0.025	0.025	0.025

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	4	0	0.049	0.143	0.101
	SOUTH AFRICA	1	1	0	0.081	0.081	0.081
	TURKEY	1	1	0	1.196	1.196	1.196
	UNITED STATES	198	198	0	0.015	1.722	0.178
Selenium	CANADA	7	0	7	N/D	N/D	N/D
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.022	0.026	0.024
	GERMANY	1	0	1	N/D	N/D	N/D
	INDIA	1	1	0	0.030	0.030	0.030
	IRAN	3	3	0	0.051	0.131	0.099
	ITALY	75	10	65	0.023	0.107	0.042
	KOREA, REPUBLIC OF	1	1	0	0.087	0.087	0.087
	LEBANON	2	0	2	N/D	N/D	N/D
	MALAYSIA	1	0	1	N/D	N/D	N/D
	PHILIPPINES	4	1	3	0.021	0.021	0.021
	SOUTH AFRICA	1	1	0	0.025	0.025	0.025
	TURKEY	1	1	0	0.024	0.024	0.024
	UNITED STATES	198	74	124	0.020	0.096	0.037
Tin	CANADA	7	6	1	0.029	0.898	0.346
	CHINA, PEOPLE'S REPUBLIC	2	1	1	1.296	1.296	1.296
	GERMANY	1	0	1	N/D	N/D	N/D
	INDIA	1	0	1	N/D	N/D	N/D
	IRAN	3	3	0	0.061	40.550	13.568
	ITALY	75	75	0	0.023	69.860	11.837
	KOREA, REPUBLIC OF	1	0	1	N/D	N/D	N/D
	LEBANON	2	1	1	0.032	0.032	0.032
	MALAYSIA	1	0	1	N/D	N/D	N/D

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	4	0	0.022	0.039	0.029
	SOUTH AFRICA	1	1	0	0.023	0.023	0.023
	TURKEY	1	1	0	1.252	1.252	1.252
	UNITED STATES	198	174	24	0.020	82.490	1.137
Titanium	CANADA	7	7	0	0.306	0.639	0.454
	CHINA, PEOPLE'S REPUBLIC	2	2	0	0.630	1.460	1.045
	GERMANY	1	1	0	0.506	0.506	0.506
	INDIA	1	1	0	0.445	0.445	0.445
	IRAN	3	3	0	1.306	1.548	1.457
	ITALY	75	75	0	0.148	2.785	0.522
	KOREA, REPUBLIC OF	1	1	0	0.925	0.925	0.925
	LEBANON	2	2	0	0.215	0.651	0.433
	MALAYSIA	1	1	0	0.305	0.305	0.305
	PHILIPPINES	4	4	0	0.288	0.698	0.480
	SOUTH AFRICA	1	1	0	0.677	0.677	0.677
	TURKEY	1	1	0	2.747	2.747	2.747
	UNITED STATES	198	197	1	0.161	2.231	0.631
Zinc	CANADA	7	7	0	1.170	2.896	2.045
	CHINA, PEOPLE'S REPUBLIC	2	2	0	1.742	6.173	3.958
	GERMANY	1	1	0	1.553	1.553	1.553
	INDIA	1	1	0	0.793	0.793	0.793
	IRAN	3	3	0	3.876	4.554	4.177
	ITALY	75	75	0	0.749	10.310	1.908
	KOREA, REPUBLIC OF	1	1	0	2.000	2.000	2.000
	LEBANON	2	2	0	1.063	2.987	2.025
	MALAYSIA	1	1	0	1.222	1.222	1.222

ANALYTE	COUNTRY	Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PHILIPPINES	4	4	0	0.720	1.171	0.951
	SOUTH AFRICA	1	1	0	1.856	1.856	1.856
	TURKEY	1	1	0	6.368	6.368	6.368
	UNITED STATES	198	198	0	0.588	8.984	2.609

10 Appendix D

Table D-1 Metal analysis results in the processed tomato product, by type. MIN, MAX and MEAN are expressed in ppm.

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
Aluminum	TOMATO SOUP	1	1	0	2.485	2.485	2.485
	PIZZA SAUCE	3	3	0	3.106	4.309	3.720
	SALSA	3	3	0	0.895	1.434	1.209
	TOMATO KETCHUP	49	49	0	0.317	4.723	1.872
	TOMATO MARINARA	3	3	0	1.489	2.812	1.949
	TOMATO PASTE	40	40	0	0.786	30.350	4.347
	TOMATO SAUCE	98	98	0	0.400	9.332	3.059
	TOMATO, CANNED	97	96	1	0.109	10.290	1.692
	TOMATO, CHOPPED	1	1	0	1.840	1.840	1.840
	TOMATO, STRAINED	2	2	0	1.819	12.000	6.910
Antimony	TOMATO SOUP	1	0	1	N/D	N/D	N/D
	PIZZA SAUCE	3	0	3	N/D	N/D	N/D
	SALSA	3	0	3	N/D	N/D	N/D
	TOMATO KETCHUP	49	0	49	N/D	N/D	N/D
	TOMATO MARINARA	3	0	3	N/D	N/D	N/D
	TOMATO PASTE	40	0	40	N/D	N/D	N/D
	TOMATO SAUCE	98	0	98	N/D	N/D	N/D
	TOMATO, CANNED	97	0	97	N/D	N/D	N/D
	TOMATO, CHOPPED	1	0	1	N/D	N/D	N/D
	TOMATO, STRAINED	2	0	2	N/D	N/D	N/D
Arsenic	TOMATO SOUP	1	0	1	N/D	N/D	N/D

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PIZZA SAUCE	3	1	2	0.006	0.006	0.006
	SALSA	3	0	3	N/D	N/D	N/D
	TOMATO KETCHUP	49	23	26	0.005	0.048	0.010
	TOMATO MARINARA	3	0	3	N/D	N/D	N/D
	TOMATO PASTE	40	26	14	0.005	0.258	0.021
	TOMATO SAUCE	98	49	49	0.005	0.018	0.008
	TOMATO, CANNED	97	17	80	0.005	0.015	0.007
	TOMATO, CHOPPED	1	0	1	N/D	N/D	N/D
	TOMATO, STRAINED	2	1	1	0.007	0.007	0.007
Beryllium	TOMATO SOUP	1	0	1	N/D	N/D	N/D
	PIZZA SAUCE	3	0	3	N/D	N/D	N/D
	SALSA	3	0	3	N/D	N/D	N/D
	TOMATO KETCHUP	49	0	49	N/D	N/D	N/D
	TOMATO MARINARA	3	0	3	N/D	N/D	N/D
	TOMATO PASTE	40	0	40	N/D	N/D	N/D
	TOMATO SAUCE	98	0	98	N/D	N/D	N/D
	TOMATO, CANNED	97	0	97	N/D	N/D	N/D
	TOMATO, CHOPPED	1	0	1	N/D	N/D	N/D
	TOMATO, STRAINED	2	0	2	N/D	N/D	N/D
Boron	TOMATO SOUP	1	1	0	1.533	1.533	1.533
	PIZZA SAUCE	3	3	0	1.304	1.735	1.498
	SALSA	3	3	0	0.941	1.490	1.228
	TOMATO KETCHUP	49	49	0	0.779	4.832	1.666
	TOMATO MARINARA	3	3	0	0.976	1.056	1.025
	TOMATO PASTE	40	40	0	1.316	8.292	4.221
	TOMATO SAUCE	98	98	0	0.783	2.839	1.605

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	TOMATO, CANNED	97	97	0	0.549	4.658	1.262
	TOMATO, CHOPPED	1	1	0	1.180	1.180	1.180
	TOMATO, STRAINED	2	2	0	1.257	1.310	1.284
Cadmium	TOMATO SOUP	1	1	0	0.016	0.016	0.016
	PIZZA SAUCE	3	3	0	0.017	0.021	0.018
	SALSA	3	3	0	0.011	0.019	0.015
	TOMATO KETCHUP	49	49	0	0.005	0.079	0.026
	TOMATO MARINARA	3	3	0	0.008	0.013	0.010
	TOMATO PASTE	40	40	0	0.009	0.201	0.068
	TOMATO SAUCE	98	98	0	0.003	0.071	0.022
	TOMATO, CANNED	97	97	0	0.004	0.069	0.019
	TOMATO, CHOPPED	1	1	0	0.016	0.016	0.016
	TOMATO, STRAINED	2	2	0	0.015	0.016	0.016
Chromium	TOMATO SOUP	1	1	0	0.056	0.056	0.056
	PIZZA SAUCE	3	3	0	0.051	0.068	0.060
	SALSA	3	3	0	0.015	0.033	0.023
	TOMATO KETCHUP	49	44	5	0.011	0.217	0.048
	TOMATO MARINARA	3	3	0	0.058	0.066	0.061
	TOMATO PASTE	40	40	0	0.018	0.454	0.091
	TOMATO SAUCE	98	96	2	0.011	0.234	0.058
	TOMATO, CANNED	97	92	5	0.011	0.217	0.054
	TOMATO, CHOPPED	1	1	0	0.027	0.027	0.027
	TOMATO, STRAINED	2	2	0	0.096	0.127	0.112
Copper	TOMATO SOUP	1	1	0	1.598	1.598	1.598
	PIZZA SAUCE	3	3	0	0.878	1.556	1.189
	SALSA	3	3	0	0.661	0.966	0.848

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	TOMATO KETCHUP	49	49	0	0.312	6.488	1.180
	TOMATO MARINARA	3	3	0	0.612	1.023	0.872
	TOMATO PASTE	40	40	0	0.933	8.422	2.955
	TOMATO SAUCE	98	98	0	0.429	2.590	1.055
	TOMATO, CANNED	97	97	0	0.374	3.156	1.204
	TOMATO, CHOPPED	1	1	0	1.089	1.089	1.089
	TOMATO, STRAINED	2	2	0	1.424	2.292	1.858
Iron	TOMATO SOUP	1	1	0	8.499	8.499	8.499
	PIZZA SAUCE	3	3	0	8.824	13.760	10.608
	SALSA	3	3	0	4.104	5.949	5.261
	TOMATO KETCHUP	49	49	0	1.956	19.140	6.469
	TOMATO MARINARA	3	3	0	3.689	5.554	4.852
	TOMATO PASTE	40	40	0	6.812	108.000	27.185
	TOMATO SAUCE	98	98	0	3.050	43.550	12.011
	TOMATO, CANNED	97	97	0	0.671	86.620	10.445
	TOMATO, CHOPPED	1	1	0	5.651	5.651	5.651
	TOMATO, STRAINED	2	2	0	7.931	14.880	11.406
Lead	TOMATO SOUP	1	1	0	0.017	0.017	0.017
	PIZZA SAUCE	3	3	0	0.002	0.003	0.002
	SALSA	3	2	1	0.003	0.003	0.003
	TOMATO KETCHUP	49	44	5	0.002	0.069	0.014
	TOMATO MARINARA	3	3	0	0.004	0.007	0.005
	TOMATO PASTE	40	32	8	0.002	0.052	0.012
	TOMATO SAUCE	98	73	25	0.002	0.049	0.007
	TOMATO, CANNED	97	83	14	0.002	0.125	0.015
	TOMATO, CHOPPED	1	0	1	N/D	N/D	N/D

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	TOMATO, STRAINED	2	2	0	0.005	0.022	0.014
Manganese	TOMATO SOUP	1	1	0	1.425	1.425	1.425
	PIZZA SAUCE	3	3	0	1.782	2.782	2.199
	SALSA	3	3	0	1.538	1.571	1.559
	TOMATO KETCHUP	49	49	0	0.527	4.009	1.406
	TOMATO MARINARA	3	3	0	0.752	1.554	1.272
	TOMATO PASTE	40	40	0	1.268	7.288	3.365
	TOMATO SAUCE	98	98	0	0.656	2.530	1.467
	TOMATO, CANNED	97	97	0	0.326	4.920	1.255
	TOMATO, CHOPPED	1	1	0	1.132	1.132	1.132
	TOMATO, STRAINED	2	2	0	1.846	2.166	2.006
Mercury	TOMATO SOUP	1	0	1	N/D	N/D	N/D
	PIZZA SAUCE	3	0	3	N/D	N/D	N/D
	SALSA	3	0	3	N/D	N/D	N/D
	TOMATO KETCHUP	49	0	49	N/D	N/D	N/D
	TOMATO MARINARA	3	0	3	N/D	N/D	N/D
	TOMATO PASTE	40	0	40	N/D	N/D	N/D
	TOMATO SAUCE	98	0	98	N/D	N/D	N/D
	TOMATO, CANNED	97	0	97	N/D	N/D	N/D
	TOMATO, CHOPPED	1	0	1	N/D	N/D	N/D
	TOMATO, STRAINED	2	0	2	N/D	N/D	N/D
Molybdenum	TOMATO SOUP	1	1	0	0.053	0.053	0.053
	PIZZA SAUCE	3	3	0	0.046	0.068	0.056
	SALSA	3	3	0	0.021	0.049	0.039
	TOMATO KETCHUP	49	49	0	0.031	0.174	0.086
	TOMATO MARINARA	3	3	0	0.022	0.038	0.031

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	TOMATO PASTE	40	40	0	0.040	0.856	0.222
	TOMATO SAUCE	98	97	1	0.030	0.201	0.073
	TOMATO, CANNED	97	84	13	0.020	0.242	0.052
	TOMATO, CHOPPED	1	1	0	0.036	0.036	0.036
	TOMATO, STRAINED	2	2	0	0.027	0.050	0.038
Nickel	TOMATO SOUP	1	1	0	0.280	0.280	0.280
	PIZZA SAUCE	3	3	0	0.139	0.251	0.192
	SALSA	3	3	0	0.057	0.174	0.107
	TOMATO KETCHUP	49	49	0	0.025	0.517	0.146
	TOMATO MARINARA	3	3	0	0.055	0.112	0.077
	TOMATO PASTE	40	40	0	0.048	1.722	0.364
	TOMATO SAUCE	98	98	0	0.042	0.938	0.163
	TOMATO, CANNED	97	97	0	0.014	1.080	0.091
	TOMATO, CHOPPED	1	1	0	0.069	0.069	0.069
	TOMATO, STRAINED	2	2	0	0.115	0.171	0.143
Selenium	TOMATO SOUP	1	0	1	N/D	N/D	N/D
	PIZZA SAUCE	3	1	2	0.021	0.021	0.021
	SALSA	3	0	3	N/D	N/D	N/D
	TOMATO KETCHUP	49	23	26	0.020	0.087	0.035
	TOMATO MARINARA	3	0	3	N/D	N/D	N/D
	TOMATO PASTE	40	28	12	0.021	0.131	0.050
	TOMATO SAUCE	98	28	70	0.021	0.058	0.030
	TOMATO, CANNED	97	14	83	0.022	0.107	0.041
	TOMATO, CHOPPED	1	0	1	N/D	N/D	N/D
	TOMATO, STRAINED	2	0	2	N/D	N/D	N/D
Tin	TOMATO SOUP	1	1	0	0.543	0.543	0.543

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	PIZZA SAUCE	3	3	0	0.022	0.082	0.057
	SALSA	3	2	1	0.021	0.032	0.026
	TOMATO KETCHUP	49	33	16	0.021	0.471	0.063
	TOMATO MARINARA	3	3	0	0.217	10.500	3.842
	TOMATO PASTE	40	33	7	0.029	40.550	2.768
	TOMATO SAUCE	98	94	4	0.023	82.490	1.448
	TOMATO, CANNED	97	94	3	0.025	69.860	9.459
	TOMATO, CHOPPED	1	1	0	0.020	0.020	0.020
	TOMATO, STRAINED	2	2	0	0.028	0.034	0.031
Titanium	TOMATO SOUP	1	1	0	0.458	0.458	0.458
	PIZZA SAUCE	3	3	0	0.585	0.874	0.683
	SALSA	3	3	0	0.315	0.497	0.430
	TOMATO KETCHUP	49	49	0	0.209	2.785	0.562
	TOMATO MARINARA	3	3	0	0.201	0.417	0.340
	TOMATO PASTE	40	40	0	0.373	2.747	1.284
	TOMATO SAUCE	98	98	0	0.211	1.371	0.561
	TOMATO, CANNED	97	96	1	0.148	1.590	0.433
	TOMATO, CHOPPED	1	1	0	0.302	0.302	0.302
	TOMATO, STRAINED	2	2	0	0.502	0.509	0.506
Zinc	TOMATO SOUP	1	1	0	2.383	2.383	2.383
	PIZZA SAUCE	3	3	0	2.312	3.985	2.933
	SALSA	3	3	0	0.967	2.247	1.771
	TOMATO KETCHUP	49	49	0	0.720	7.188	2.100
	TOMATO MARINARA	3	3	0	1.062	1.767	1.524
	TOMATO PASTE	40	40	0	1.742	10.310	5.391
	TOMATO SAUCE	98	98	0	0.757	3.444	2.081

ANALYTE		Total # Sampled	Total # Positive	Total # Negative	MIN Detected	MAX Detected	MEAN
	TOMATO, CANNED	97	97	0	0.588	6.591	1.718
	TOMATO, CHOPPED	1	1	0	1.624	1.624	1.624
	TOMATO, STRAINED	2	2	0	2.032	2.235	2.134