FOOD STANDARDS Australia New Zealand

Te Mana Kounga Kai – Ahitereiria me Aotearoa

SURVEY OF CHEMICAL CONTAMINANTS AND RESIDUES IN ESPRESSO, INSTANT AND GROUND COFFEE

Summary

The consumption of coffee, particularly espresso coffee, has increased in Australia over time. To update and enhance the evidence base for coffee, Food Standards Australia New Zealand (FSANZ) commissioned an analytical survey to determine the level of chemical contaminants and residues in coffee.

This survey considered a range of chemical contaminants thought to be present in coffee. The range of chemicals analysed in this survey included metals, acrylamide, furan, polycyclic aromatic hydrocarbons (PAHs), ochratoxin A, and a range of pesticide residues.

The survey analysed 41 composite samples of a variety of coffee types available from food service and retail outlets in Melbourne and Sydney. Coffee types considered in this survey included a range of espresso coffee (cappuccino, latte, flat white, mocha, short black) as well as instant and plunger coffee. The composite samples were all analysed on an 'as consumed' basis for the range of chemical contaminants identified.

The key findings from this survey are:

- **For the majority of analytes assessed, there were no detectable levels in any of the coffee types sampled. This included all 98 pesticide residues, 18 PAHs, beryllium, mercury and ochratoxin A.**
- **A small number of metals, furan and acrylamide were detected in some of the coffee types analysed, but at very low levels.**
- **The contribution of a number of metal contaminants to dietary exposure through the consumption of instant and espresso coffee in comparison to the relevant reference health standard will be assessed as part of the 23rd Australian Total Diet Study (ATDS). However, it is anticipated that instant and espresso coffee are likely to be very small contributors to dietary exposure.**
- **For the metal contaminants analysed in this study, there are no established maximum levels (MLs) under Standard 1.4.1 – *Contaminants and Natural Toxicants* of the Code for coffee or coffee beans. This is generally reflective of low levels of contaminants in these products, and of coffee not being a significant contributor to exposure of these contaminants in the total diet.**
- **The overall levels of chemical contaminants identified in this survey are generally considered to be low and are consistent with those reported in other comparable surveys both in Australia and overseas.**

This survey was undertaken as part of the surveillance program in 2008 with the intent to gather analytical data only for this commodity. Given this survey only investigated coffee for the presence of contaminants and residues, a dietary exposure assessment and comparison to the relevant reference health standard was not conducted. In addition, data collected in this survey was submitted to the 72nd meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) to inform international health risk evaluations of these contaminants.

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- The staff at Leeder Consulting for sample collection, sample analyses and technical advice.
- The staff at Symbio Alliance for the analysis of ochratoxin A in coffee samples.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations

ABS	Australian Bureau of Statistics
ATDS	Australian Total Diet Study
CCCF	Codex Committee on Contaminants in Food
FAO	Food and Agricultural Organization
FSANZ	Food Standards Australia New Zealand
GC/MC/ECD	Gas Chromatography Mass Spectrometry with Electron Capture Detector
GC/MS	Gas Chromatography Mass Spectrometry
HRGC	High Resolution Gas Chromatograph
HRMS	High Resolution Mass Spectrometer
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LC/MS/MS	Liquid Chromatography Tandem Mass Spectrometry
LOD	Limit of Detection
LOR	Limit of Reporting
LOQ	Limit of Quantification
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre
NZ TDS	New Zealand Total Diet Study
PAHs	Polycyclic Aromatic Hydrocarbons
PQL	Practical Quantitation Limit
µg/kg	Micrograms per kilogram
µg/L	Micrograms per litre
WHO	World Health Organization

Note: A glossary of terms can be found in Appendix 1

Introduction

Chemical contaminants and residues can enter the food supply through environmental factors such as air, soil and water or through food processing factors. The levels of these chemicals in food can vary. Some could have potential adverse health effects if consumed at levels considered to be unsafe. In coffee, for example, a number of chemicals have been identified such as metals (e.g. aluminium and zinc) and contaminants such as pesticide residues and mycotoxins (e.g. ochratoxin A). Chemical contaminants such as acrylamide, furan and PAHs have also been identified in coffee and are a result of food processing.

FSANZ has previously analysed instant coffee for pesticide residues, metal contaminants and ochratoxin A as part of the 20th Australian Total Diet Study (ATDS) (FSANZ, 2003). This study reported detections for copper and zinc. Conversely, aflatoxin, ochratoxin A and a range of pesticide residues were not detected. The Australia New Zealand Food Standards Code (the Code), includes a number of Maximum Residue Limits (MRLs) for agricultural residues permitted in coffee beans in Australia under Standard 1.4.2 - *Maximum Residue Limits (Australia Only)*. For the metal contaminants analysed in this study, there are no established maximum levels (MLs) under Standard 1.4.1 – *Contaminants and Natural Toxicants* of the Code for coffee or coffee beans. This is consistent with international best practice established by the Codex Committee on Food Additives and Contaminants (CCFAC), where MLs are only set for contaminants in food where consumption of the specific food significantly contributes to the total dietary exposure to the contaminant (WHO, 1995).

Given the wider range of coffee types available and the increased consumption of coffee, the current survey seeks to determine the levels of the aforementioned chemicals in a broader range of coffee including espresso, instant and ground (plunger) coffee.

Background

In Australia, coffee consumption has increased from 2.4 kg per person in 1998-99 to 3 kg per person per year in 2007 (ABS, 2000, EarthTrends, 2007). It has also been documented that between the years 2000 to 2006, coffee consumption in Australia grew at an annual rate of 3% (ICO, 2009). BIS Shrapnel published the report *Coffee in Australia 2006-2008*, which noted that in 2006, instant coffee represented 80% of coffee sales in Australia (ACTA, 2006). The report also revealed that the food service industry (cafés and restaurants) had experienced a 65% increase in the number of cups of coffee consumed over a 10 year period, with cappuccino being the most popular beverage sold in cafés (ACTA, 2006).

Coffee is prepared from coffee beans harvested from two main plant species, the *Coffea arabica* and *Coffea canephora* (Coffeeresearch.org, 2006). The former, commonly known as Arabica coffee, is the predominant source of the world's coffee, accounting for approximately 75-80% of worldwide production. Brazil is the major coffee producer (Leoni *et al.,* 2000). The majority of the world's coffee is grown and harvested between March and October each year (Coffeesearch.org, 2006). Given the extensive root system of this plant, at times reaching up to 20-25km in length, it is conceivable that contaminants in the soil could be transferred to the coffee beans during maturation or alternatively during processing procedures (Coffeeresearch.org, 2006). Subsequently, the resulting coffee that is consumed may contain some chemical contaminants which could be of concern if consumed at high levels.

International research on the types of chemical contaminants in coffee indicate that acrylamide (FDA, 2006), PAHs (EC, 2002b) and furan (FDA, 2009) might be present. This is considered to be attributed to high temperature processing, such as roasting (Bagdonaite *et al*., 2008; Orecchio *et al.,* 2009; Crews & Castle, 2007). In addition, metals (Suseela *et al.,* 2001) and pesticide residues (Jacobs & Yess, 1993) in coffee have also been reported in India and the United States (US). The fungal mycotoxin, ochratoxin A, has also been detected in green coffee beans, and in roasted and instant coffee in several countries, including Germany, Japan and Spain (WHO, 2007). Acrylamide and furan were recently reviewed at the 72nd meeting of the JECFA in February 2010 where the Committee considered both compounds to be potential genotoxic carcinogens (WHO, 2010).

While some of the chemical contaminants identified in coffee are likely to be generated from the environment, others are produced during processing. For example, acrylamide is typically formed via a process termed the Maillard reaction, which is common to foods high in carbohydrates (Lingnert *et al.,* 2002). This reaction occurs when a reducing sugar such as glucose is combined with an amino acid, namely asparagine, during heating at high temperature >100 °C (Lingnert *et al.,* 2002). Acrylamide has been found to cause cancer in experimental rodents, however, there is currently a lack of evidence to suggest that dietary exposure to acrylamide will result in an increase in the incidence of cancer in humans (WHO, 2010).

Similarly, furan, a volatile chemical, can be formed when foods are heat processed (EFSA, 2009). Based on animal studies, furan has been identified as potentially carcinogenic to humans (FDA, 2004). Reports have also suggested that PAHs in coffee can be formed in the roasting process or can result from environmental contamination of the green coffee beans (Houessou *et al.,* 2006). PAHs are a group of chemical compounds which present a potential safety concern for human health, as some such as Benzo[a]pyrene are known to be highly carcinogenic (Houessou *et al.,* 2006). Furthermore, ochratoxin A contamination of coffee has been associated with the mould species *Aspergillus ochraceus* and has been predominantly identified in coffee beans post-harvest (FAO, 2010). Ochratoxin A is known for its highly toxic properties and is considered to be a potential human carcinogen (WHO, 2007).

The existing data on the presence of these chemicals in coffee available in Australia is currently limited. Therefore, developing and enhancing the evidence base on the levels of chemical contaminants and residues in instant, ground and espresso coffee types in Australia will provide valuable input into future assessments of dietary exposure and the evaluation of any potential risks to human health for the Australian population. Furthermore, the data collected in this survey can also be used as a source of information to inform international health risk evaluations of these contaminants.

Objective

The objective of the survey of chemical contaminants and residues in coffee is:

- To determine the analytical concentration of a range of chemical contaminants and residues in espresso, instant and ground (plunger) coffee types.

Survey design and methodology

Market share data from the Australian Coffee Traders Association and the AustralAsian Specialty Coffee Association were used to determine the various types of coffee available from both food service and retail outlets to develop a sampling plan. The Australian Bureau of Statistics (ABS) apparent consumption of foodstuffs in Australia for data was also considered.

The chemical contaminants and residues investigated in this survey were selected based on the following criteria:

- there is a lack of available Australian data;
- the contaminant/residue is suspected to be present in coffee;
- a review of the international literature identified the occurrence of the contaminant/residue in coffee; and
- the contaminant/residue has previously been identified as a potential cause for concern for public health and safety, either in Australia or elsewhere.

FSANZ developed and provided comprehensive sampling instructions to Leeder Consulting, the analytical laboratory selected to purchase, prepare and analyse coffee samples for the majority of analyses for this survey.

A total of 164 samples of espresso, instant and ground (plunger) coffee were purchased in June 2008, from various retail outlets (café's and major supermarkets) across metropolitan locations in both Melbourne and Sydney (Table 1).

In order to maximise the range of espresso coffee types sampled, only one purchase of each of the six ready-to-drink coffee types was made at any individual retail outlet. Multiple purchases of the same coffee type were collected to ensure that the volume was enough for the purposes of analysis, although the final volume was not recorded. The types of coffee selected for sampling were nationally available and, accordingly, were not expected to show regional variation. No samples of decaffeinated coffee were purchased as part of this survey.

In relation to sample preparation of instant and plunger coffee, 2 cups were prepared by the laboratory for each purchase. For each cup, one level teaspoon of instant coffee was added to 220ml of boiling tap water, stirred and allowed to cool prior to analysis. Similarly, for plunger coffee, 2 cups were prepared by the laboratory. To do this, a 2 cup plunger was preheated with hot water and then emptied. Two level dessert spoons of ground coffee were placed in the bottom of the plunger and 440ml of near boiling water was added. The mix was stirred with a spoon and the plunger lid replaced. The brew was left standing for 3 minutes, after which the plunger knob was lowered until fully depressed. The coffee was then divided into 2 cups for analysis. For samples of instant and plunger coffee containing milk (white coffee), 20 ml (1 Australian metric tablespoon) was added prior to cooling and analysis. Unfortified full fat milk was used in both instant and plunger coffee. No sugar was added to any of the espresso, instant and plunger coffee samples.

Samples were then composited prior to analysis. Four primary purchases of the same coffee type (e.g. cappuccino) from the same city were composited together. A total of 133 contaminants which included metals (n=14), acrylamide, furan, PAHs (n=18), ochratoxin A and pesticide residues (n=98) were analysed in 41 composite samples of coffee (Appendix 2). The number of composite samples for each coffee type analysed is provided in Table 1.

Given this survey analysed coffee from retail outlets as purchased and consumed, the water used to prepare the coffee was not tested for chemical contaminants and residues. This is a limitation of the survey, as the actual contribution of chemical contaminants, particularly metals, from the coffee and the water, could not be delineated. In addition, of the three composite samples of instant coffee analysed, one composite sample containing milk was made up of four different brands compared to the other two composites which were identical, except for the presence or absence of milk. This is also a limitation of the survey, and care should be exercised when comparing the first composite to the other two composites due to the potential effects of brand variation and the presence of milk in the sample.

While this study examined a variety of coffee types, the different preparation methods for espresso, instant and ground coffee and their potential contribution to contaminant levels in the analysed samples, was outside of the scope of this survey.

Table 1: Number of samples analysed by coffee type

Coffee type	Total number of samples	No. of composites analysed	General ingredients*
Cappuccino	40	10	Single espresso shot and steamed milk
Latte	40	10	Single espresso shot and steamed milk
Flat white	32	8	Single espresso shot and steamed milk
Long black	16	4	Double espresso shot
Short black	8	2	Single espresso shot
Mocha	8	2	Single espresso shot, steamed milk and cocoa powder
Instant	12	3	Coffee powder, hot water, with and without milk
Ground (plunger)	8	2	Ground coffee, hot water, with and without milk.
Total	**164**	**41**	

* The volume of each coffee type sampled was not recorded, however sufficient amounts were purchased for the purposes of the analysis.

The method of analysis used for the pesticide residue screen was Gas Chromatography Mass Spectrometry with Electron Capture Detector (GC/MC/ECD). The Practical Quantitation Limit (PQL) was set at 0.001 mg/L. The PQL is equivalent to the Limit of Quantification (LOQ) and is reported by some laboratories instead of the LOQ.

For the analysis of metals, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used with a PQL ranging between 0.0005 – 0.001 mg/L, dependant on the analyte. Acrylamide was determined using Liquid Chromatography Mass Spectrometry (LC/MS) with a PQL of 0.0001 mg/L. The method of analysis employed for both PAHs and furan was Gas Chromatography Mass Spectrometry (GC/MS) with a PQL of 0.001 mg/L.

Symbio Alliance conducted the analysis of ochratoxin A using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) with a Limit of Reporting (LOR) of 0.005 mg/kg.

Results

A total of 41 composite samples were analysed for 133 different contaminants. Of the 5453 data points, 92% were identified as non-detects, and a remaining 8% had quantified values or "detection" above the PQL. There were no detections above the respective PQLs for all pesticide residues analysed in each coffee type. Similarly, there were no detections above the LOR for ochratoxin A (<0.005 mg/kg) and no detections above the PQL for PAHs (0.001 mg/L), beryllium (<0.001 mg/L) and mercury (<0.0005 mg/L). The remaining chemicals for which there were detections above the PQL are considered further in this report. The results for coffee samples collected in Sydney and Melbourne have been combined for the purposes of reporting. In order to calculate mean concentrations for each contaminant by coffee type, the PQL was assigned for all results reported as nd (not detected).

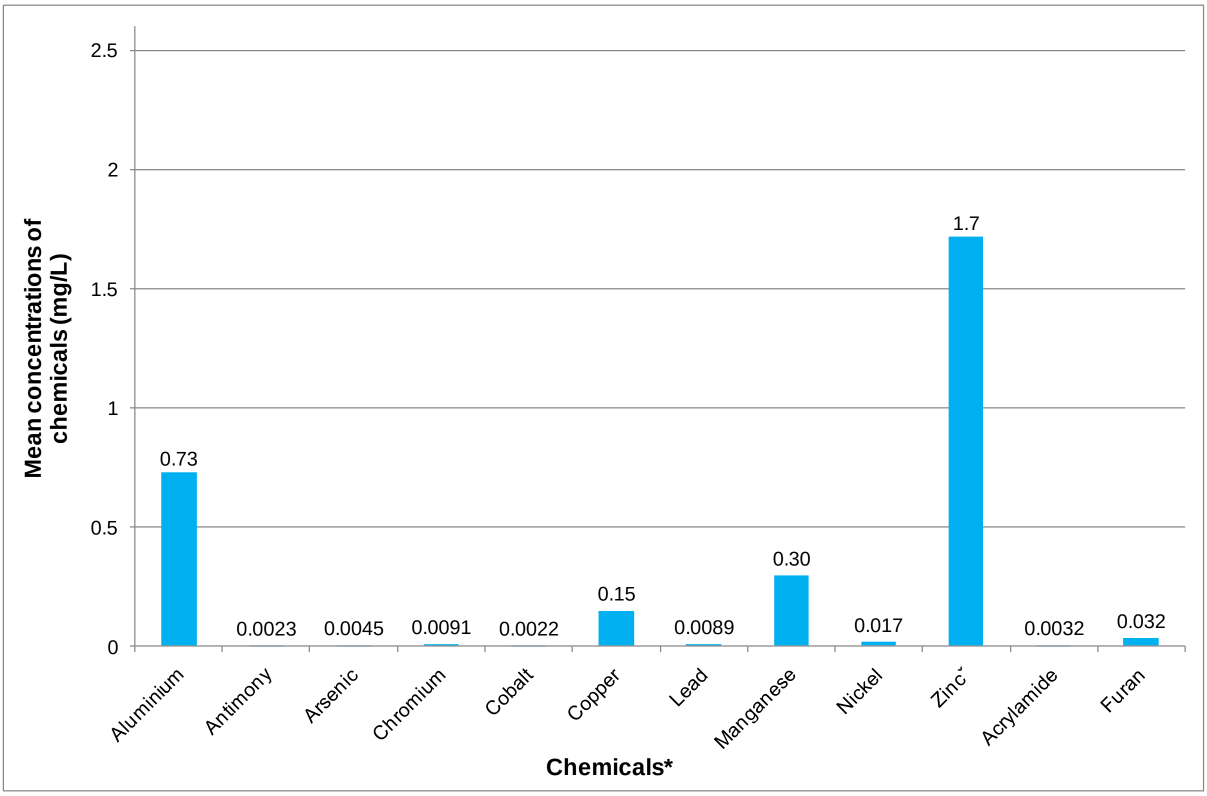
The mean concentrations of chemical contaminants for each coffee type are shown in Figures 1 - 8. A summary of results for all chemical contaminants and residues is provided in Appendix 2.

Cappuccino

From the ten composite samples analysed, the mean concentrations of each detected contaminant in cappuccino are reported in Figure 1. A total of twelve chemical contaminants were detected above the respective PQLs in cappuccino.

No detections above the PQL were reported for cadmium (PQL <0.0005 mg/L) and tin (PQL <0.001 mg/L).

Figure 1: Mean concentrations of chemicals in cappuccino



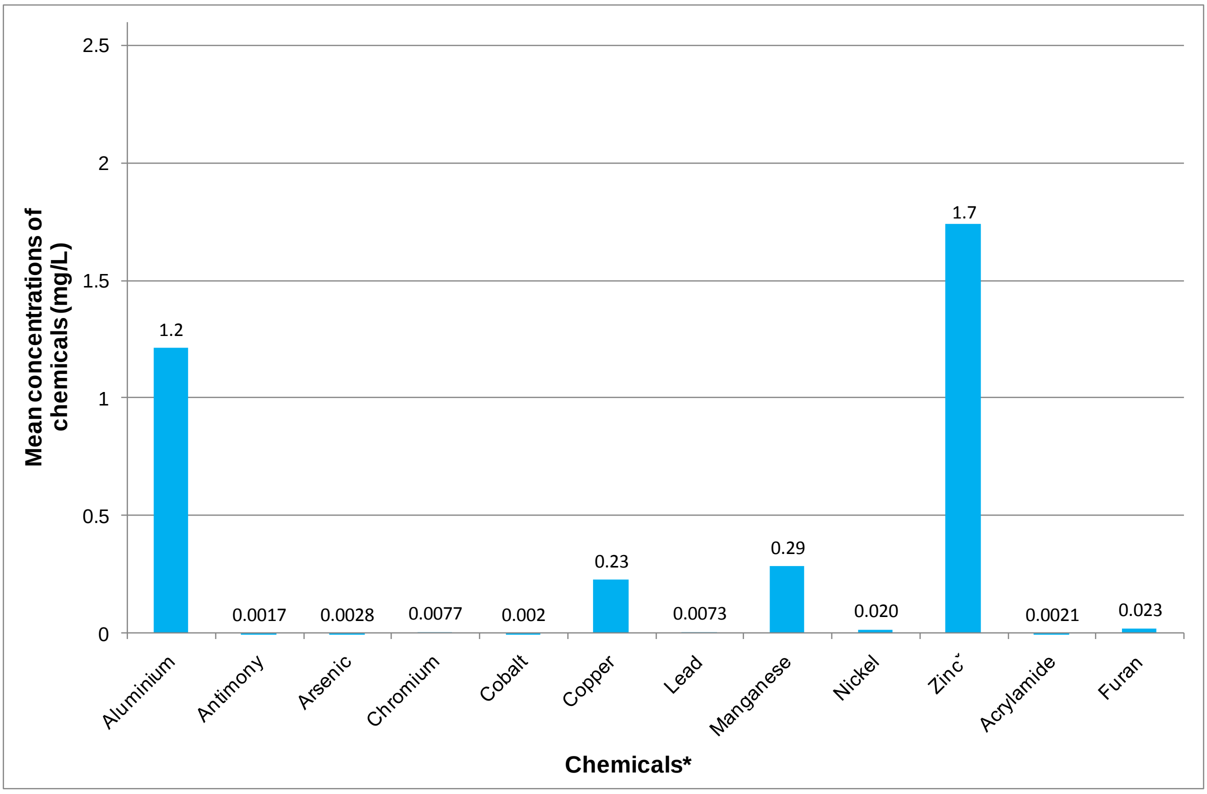
* Only contaminants with detections reported above the respective PQLs have been graphed; nd=PQL.
˘ Zinc is considered to be a nutrient and can be found in milk.
All results have been reported to two significant figures.

Latte

From the ten composite samples analysed, the mean concentrations of each detected contaminant in latte are reported in Figure 2. A total of twelve chemical contaminants were also detected above the respective PQLs.

As reported for cappuccino, no detections above the PQL were reported for cadmium (PQL <0.0005 mg/L) and tin (PQL <0.001 mg/L).

Figure 2: Mean concentrations of chemicals in latte



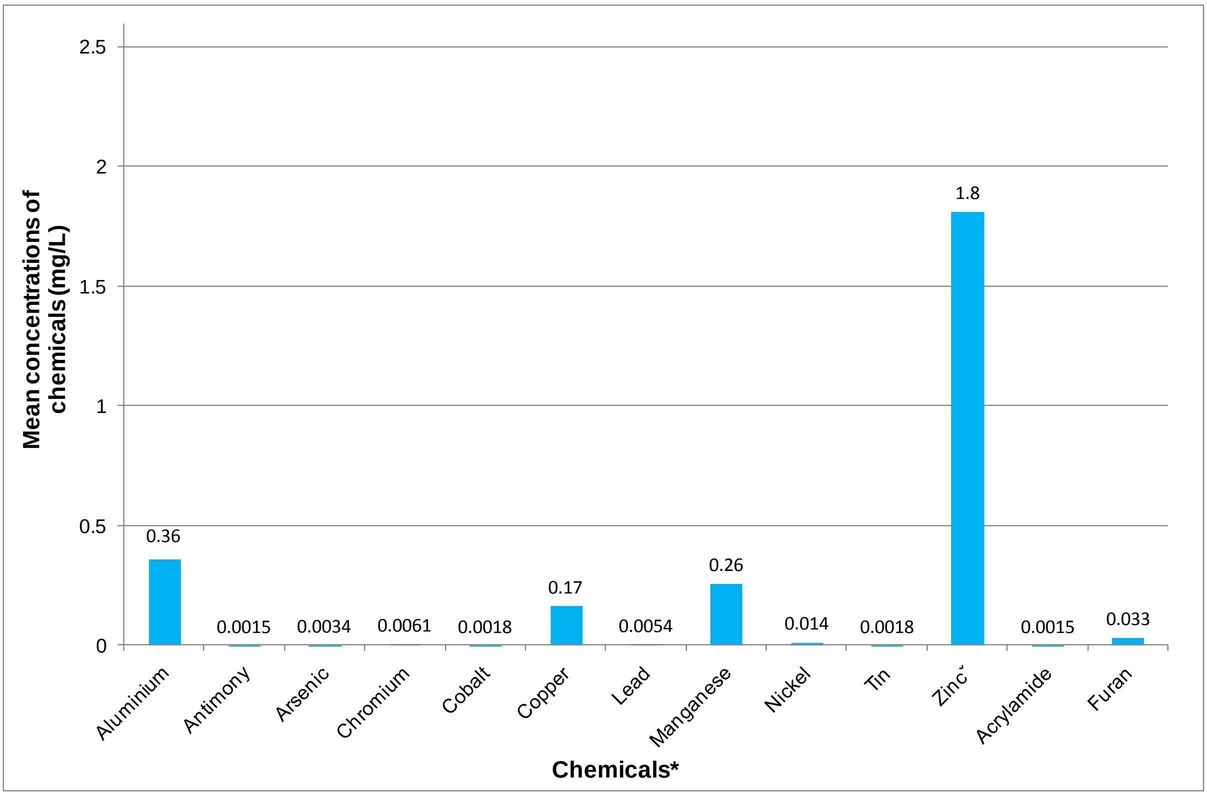
* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
ˇ Zinc is considered to be a nutrient and can be found in milk.
All results have been reported to two significant figures.

Flat white coffee

From the eight composite samples analysed, the mean concentrations of each detected contaminant in flat white coffee are reported in Figure 3. A total of thirteen chemical contaminants were detected above the respective PQLs.

No detections above the PQL were reported in flat white coffee for cadmium (PQL <0.0005 mg/L).

Figure 3: Mean concentrations of chemicals in flat white



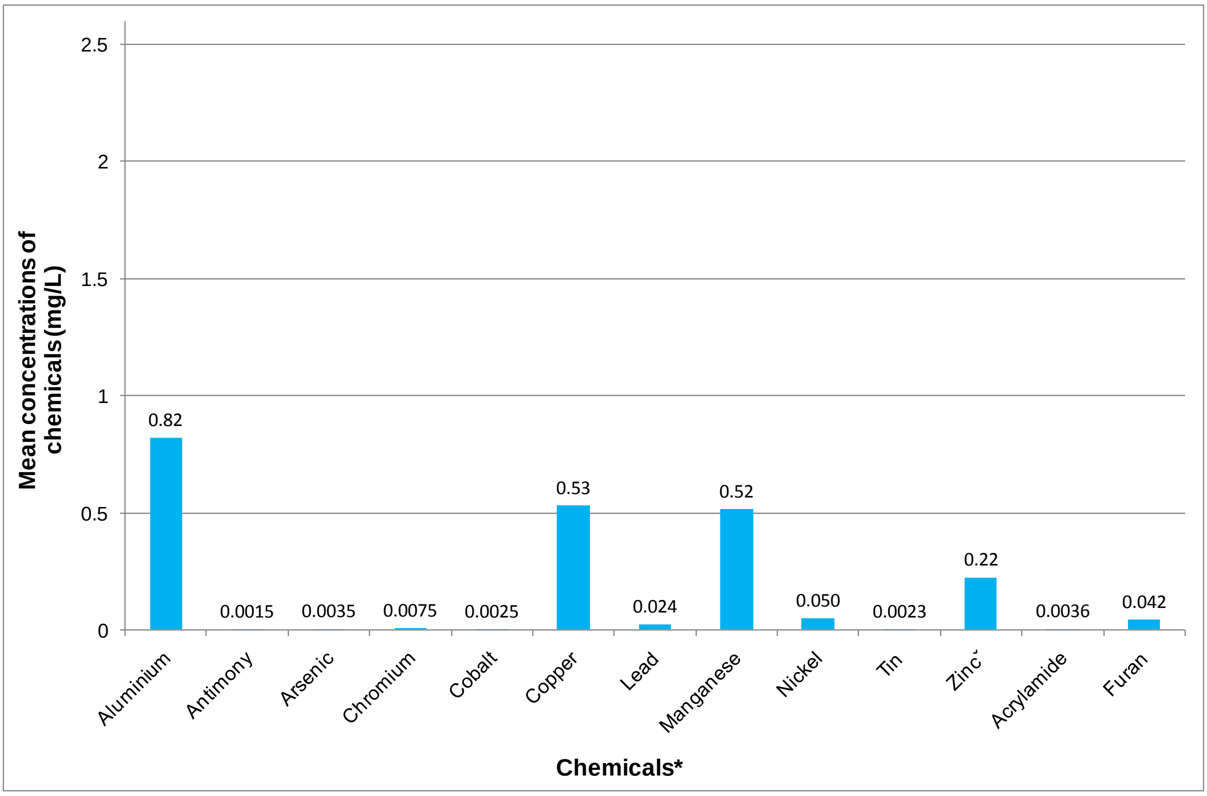
* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
˘ Zinc is considered to be a nutrient and can be found in milk.
All results have been reported to two significant figures.

Long black coffee

From the four composite samples analysed, the mean concentrations of each contaminant in long black coffee are reported in Figure 4. A total of thirteen chemical contaminants were detected above the respective PQLs.

No detections above the PQL were reported in long black coffee for cadmium (PQL <0.0005 mg/L)

Figure 4: Mean concentrations of chemicals in long black coffee



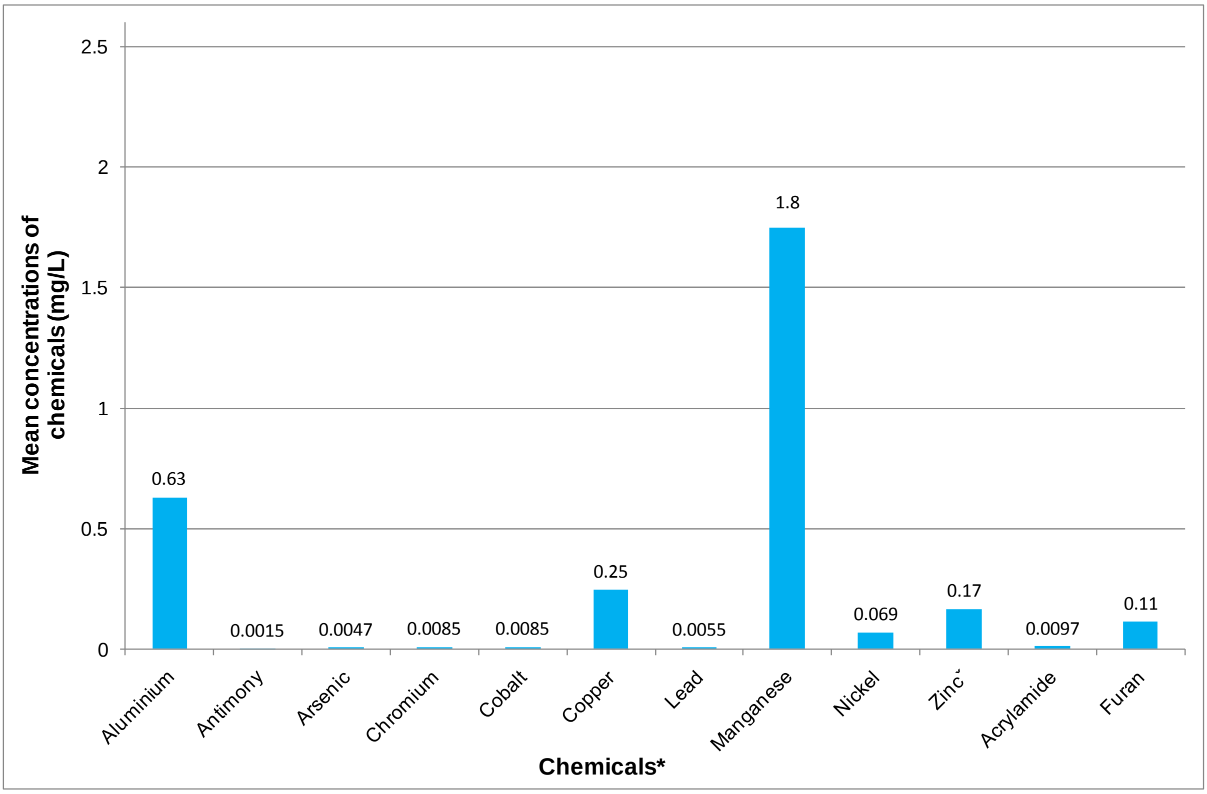
* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
˘ Zinc is considered to be a nutrient and can be found in milk.
\# All results have been reported to two significant figures.

Short black coffee

From the two composite samples analysed, the mean concentrations of each contaminant in short black coffee are reported in Figure 5. A total of twelve chemical contaminants were detected above the respective PQLs.

As reported for cappuccino and latte, no detections above the PQL were reported in short black coffee for cadmium (PQL <0.0005 mg/L) and tin (0.001 mg/L)

Figure 5: Mean concentrations of chemicals in short black coffee

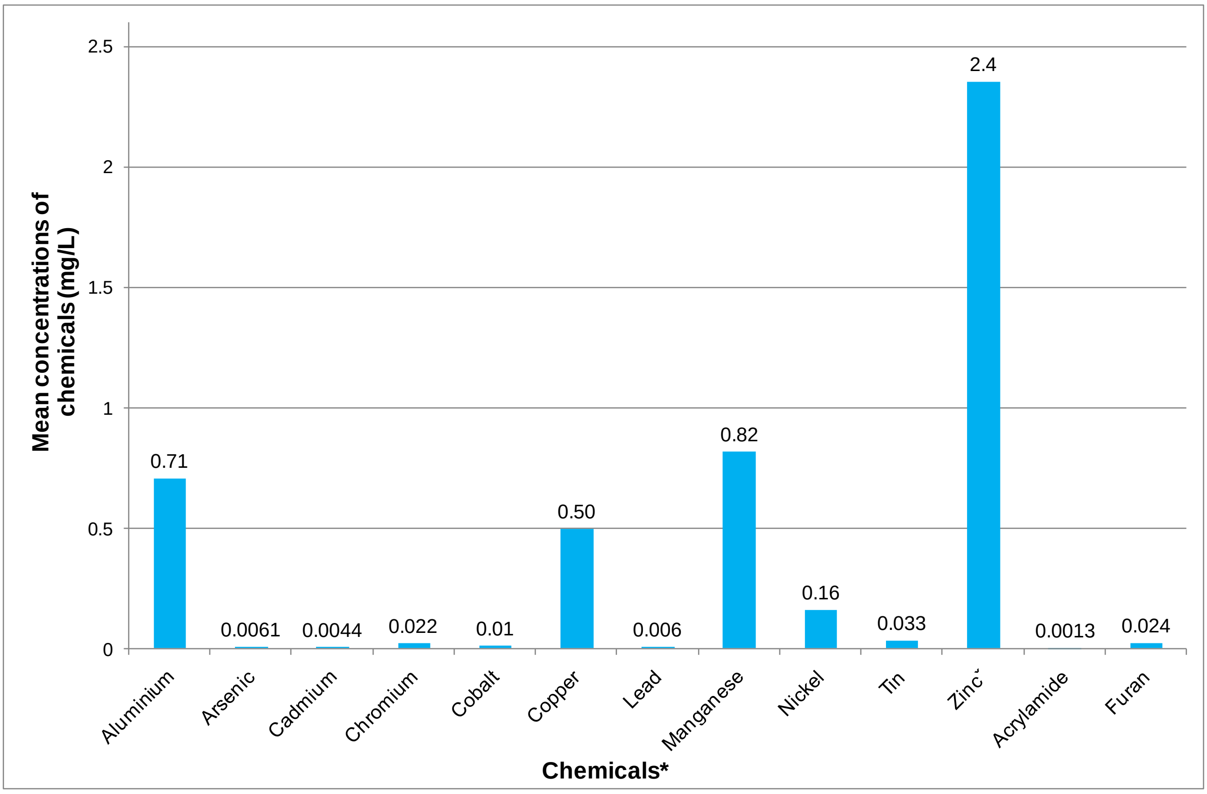


* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
˘ Zinc is considered to be a nutrient and can be found in milk.
\# All results have been reported to two significant figures.

Mocha

From the two composite samples of mocha analysed, the mean concentrations of each contaminant are reported in Figure 6. A total of thirteen chemical contaminants were detected above the respective PQLs. Cadmium was detected in mocha coffee with a result of 0.0044 mg/kg.

Figure 6: Mean concentrations of chemicals in mocha



* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
ˇ Zinc is considered to be a nutrient and can be found in milk.
All results have been reported to two significant figures.

Instant coffee

Three instant coffee samples were analysed for a range of chemical contaminants and pesticide residues. Of the three composites, one was instant coffee (black) without milk, whereas the remaining two composites contained milk (white).

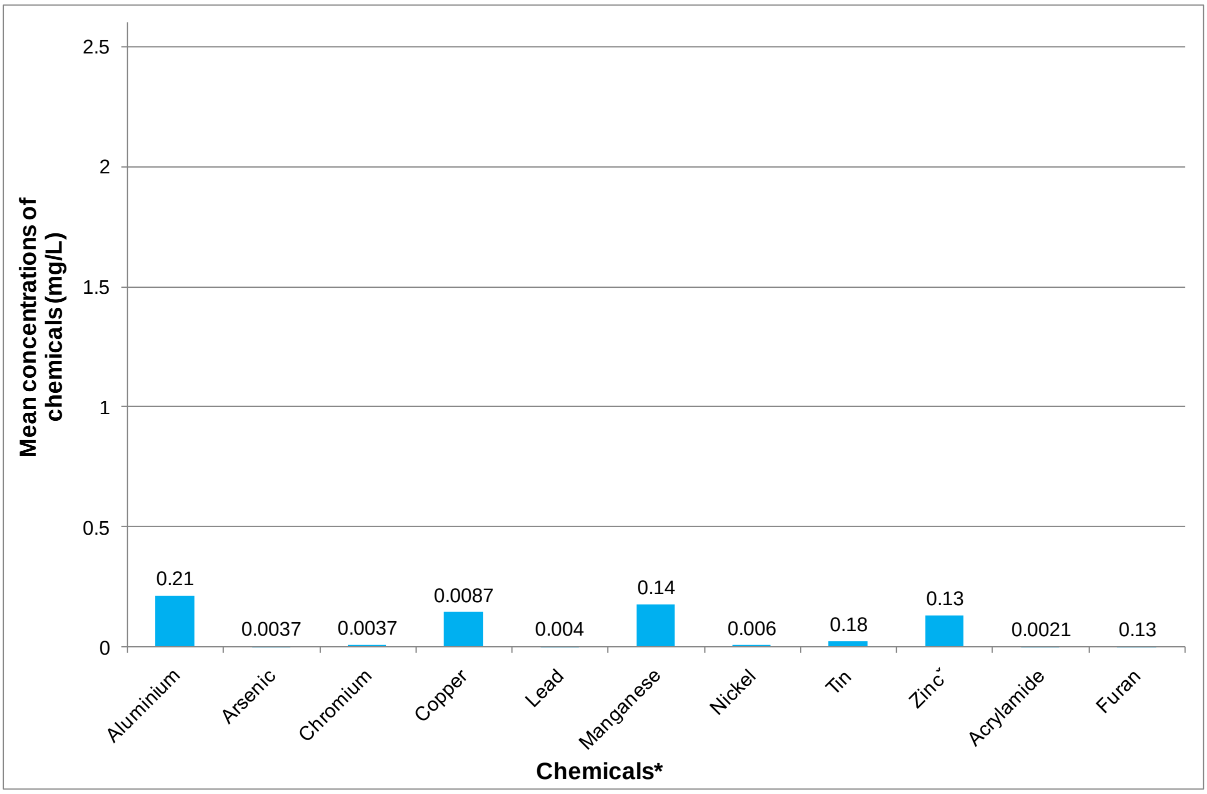
The mean concentrations of each contaminant detected in instant coffee (mean derived from combined values for both black and white) are reported in Figure 7. A total of eleven chemical contaminants were detected above the respective PQLs.

As reported for flat white coffee and long black coffee, no detections above the PQL were reported in instant coffee for cadmium (PQL <0.0005 mg/L).

In general, a comparison of instant coffee (white) and instant coffee (black) indicates that similar levels of contaminants were present, which is to be expected as the proportion of milk in these samples comprised less than 10% of the prepared beverage . However, there was some variation in the level of chromium (0.016 mg/L in black; 0.005 mg/L in white), lead (0.01 mg/L in black; 0.001mg/L in white), tin (0.07 mg/L in black; 0.001 mg/L in white) and zinc (0.042 mg/L in black; 0.18 mg/L in white).

While a comparison of these samples has been made, care should be exercised as one composite of instant coffee (white) was made up of four different brands compared to the other two composites which were identical except for the presence or absence of milk. This is also a limitation of the survey due to the potential effects of brand variation and the presence of milk in the sample.

Figure 7: Mean concentrations of chemicals in instant coffee



* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
ˇ Zinc is considered to be a nutrient and can be found in milk.
All results have been reported to two significant figures.
^ Combined results for instant white and instant black coffee have been graphed.

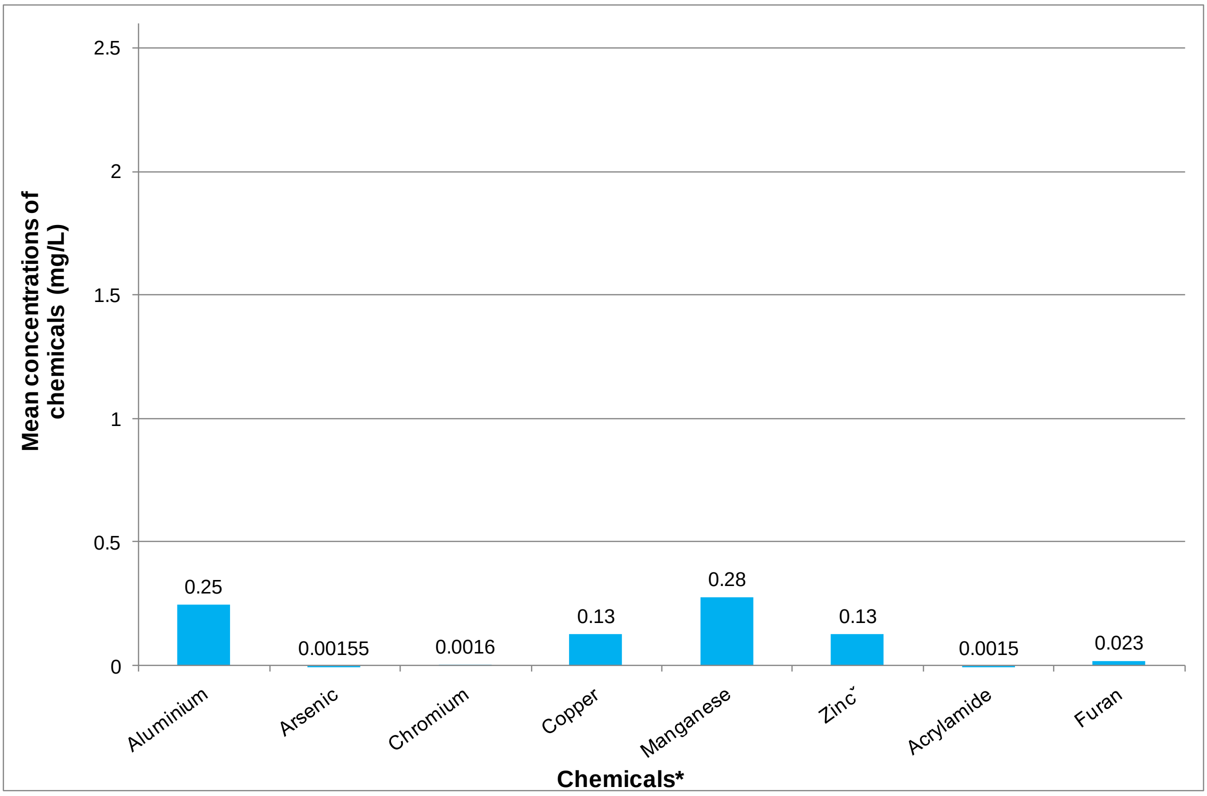
__Ground (plunger) coffee__

Two composite samples of ground coffee were analysed, one sample contained milk (white) and the other was without milk (black). The mean concentrations of each contaminant detected in ground (plunger) coffee (mean derived from combined values for both black and white) are reported in Figure 8. A total of eight chemical contaminants were detected above the respective PQLs.

No detections above the PQL were reported in ground (plunger) coffee for cadmium (PQL <0.0005 mg/L), cobalt (<0.001 mg/L), lead (<0.001 mg/L), nickel (<0.001 mg/L) and tin (<0.001 mg/L).

A comparison of ground coffee (white) and ground coffee (black) indicates some differences. There were variations in the level of aluminium (0.31 mg/L in black; 0.18 mg/L in white), arsenic (0.0013 mg/L in black; 0.0018 mg/L in white), zinc (0.047 mg/L in black; 0.22 mg/L in white) and acrylamide (0.0001 mg/L in black; 0.0029 mg/L in white).

Figure 8: Mean concentrations of chemicals in ground (plunger) coffee



* Only contaminants with reported detections above the respective PQLs have been graphed; nd=PQL.
# All results have been reported to two significant figures.
ˇ Zinc is considered to be a nutrient and can be found in milk.
^ Combined results for ground (plunger) coffee white and ground (plunger) coffee black have been graphed.

Comparison of contaminants in various coffee types sampled

A comparison of the number of contaminants detected for the 8 different coffee types analysed indicates that flat white, long black and mocha contained the largest number of chemical contaminants above the PQL (Table 2). In contrast, instant coffee (white and black combined) and ground (plunger) coffee (white and black combined) reported the lowest number of chemical contaminants, followed by cappuccino, latte and short black coffee. Cadmium was only detected in mocha.

Table 2: Comparison of the chemicals detected in various types of coffee

Contaminant (with detects >PQL)	Detection in the eight (8) coffee types							
	Cappuccino	Latte	Flat white	Long black	Short black	Mocha	Instant*	Ground (plunger)#
Aluminium	✓	✓	✓	✓	✓	✓	✓	✓
Antimony	✓	✓	✓	✓	✓	✗	✗	✗
Arsenic	✓	✓	✓	✓	✓	✓	✓	✓
Cadmium	✗	✗	✗	✗	✗	✓	✗	✗
Chromium	✓	✓	✓	✓	✓	✓	✓	✓
Cobalt	✓	✓	✓	✓	✓	✓	✗	✗
Copper	✓	✓	✓	✓	✓	✓	✓	✓
Lead	✓	✓	✓	✓	✓	✓	✓	✗
Manganese	✓	✓	✓	✓	✓	✓	✓	✓
Nickel	✓	✓	✓	✓	✓	✓	✓	✗
Tin	✗	✗	✓	✓	✗	✓	✓	✗
Zinc˘	✓	✓	✓	✓	✓	✓	✓	✓
Acrylamide	✓	✓	✓	✓	✓	✓	✓	✓
Furan	✓	✓	✓	✓	✓	✓	✓	✓

* Includes both instant coffee with milk (white) and instant coffee without milk (black).
\# Includes both ground coffee (plunger) with milk (white) and ground coffee (plunger) without milk (black).
˘Zinc is considered to be a nutrient and can be found in milk.

The highest mean concentrations of aluminium were found in latte (1.2 mg/L), long black coffee (0.82 mg/L) and cappuccino (0.73 mg/L). The highest mean concentrations for manganese were in short black coffee (1.8 mg/L), mocha (0.82 mg/L) and ground (plunger) coffee (white and black) (0.28 mg/L). The highest mean concentrations of zinc were found in mocha (2.4 mg/L), flat white (1.8 mg/L), cappuccino and latte (1.7 mg/L).

Interestingly, this survey shows that the levels of zinc were found to be highest in espresso coffee types where milk was added. This suggests that the presence of milk contributed to reported zinc levels. The presence of zinc has previously been analysed in milk and reported in the FSANZ food composition database for full fat (0.4 mg / 100g), reduced fat (0.4 mg / 100g) and skim milk varieties (0.3 mg / 100g) (FSANZ, 2006). Given the low levels of zinc reported in this database, it is likely that the zinc present in these coffee types is due a combination of the presence of zinc in milk and water. It should be noted that the milk used in coffee types sampled was not analysed separately in this survey, therefore no clear conclusions can be made.

Comparison of contaminant levels in coffee sampled in Sydney vs. Melbourne

A comparison of the contaminants detected in coffee types sampled in Sydney and Melbourne revealed some small differences. For example, there were no detections for antimony in all coffee types sampled in Sydney. This is consistent with Sydney Water findings for 2008-2009 which reported a mean concentration value of <0.001 mg/L from 104 water samples tested (Sydney Water, 2010). However, in this survey, antimony was detected in all coffee types sampled in Melbourne. A report from South East Water (Victoria) indicates that for 13 samples tested in 2008, the mean level of antimony was <0.001 mg/L (South East Water, 2008). This inconsistency between the FSANZ survey and South East Water data could be due to the larger number of samples analysed in the FSANZ survey (n=23), or an alternative source of antimony, which may not be a constituent of the coffee, but is in contact with the coffee during preparation.

Conversely, there were no detections for tin in all coffee types sampled in Melbourne. This is consistent with the data provided by Melbourne Water for 2008 where 8 sites were sampled, all reporting a concentration level of <0.001 mg/L (Melbourne Water, 2010).

There were detections of tin in some samples of coffee purchased in Sydney. Tin is not routinely analysed by Sydney Water as there is no guideline value in the 2004 Australian Drinking Water Guidelines and tin is considered to be a low risk (Sydney Water, 2010).

Discussion

The results of this survey indicate that only a small number of contaminants were detected in the various coffee types analysed. While no pesticide residues, beryllium, total mercury, ochratoxin A or PAHs were detected above the PQL, most metals and chemical contaminants from processing such as acrylamide and furan were found.

A comparison of the concentration levels of metals and processing contaminants in this survey with those reported in a number of studies overseas is outlined in Table 3. The levels of these chemicals in coffee available in Australia are generally considered to be low and are consistent with levels reported overseas. However caution needs to be exercised in making direct comparisons due to variation in coffee preparation, analytical methodology, treatment of non-detect values and the reporting of the data (mean versus median) between the studies.

Table 3: Comparison of the concentration levels of metal and processing contaminants found in this survey with levels reported overseas

Contaminants	FSANZ Study† (mg/L)	Overseas Comparison	Comments
Pesticide residues	nd	nd-0.0141 mg/kg (Triadimefon only)	2009 New Zealand Total Diet Study (NZ TDS) 3rd quarter results - ground coffee beans.
Aluminium	0.18-1.2	19 mg/L	Germany; ground coffee (Mueller *et al.*, 1997).

Contaminants	FSANZ Study† (mg/L)	Overseas Comparison	Comments
Antimony	nd-0.0023	0.0007 mg/L*	Hong Kong; Median concentration (CFS, 2007).
Arsenic	0.0013-0.0061	nd-0.0016 mg/kg	2009 NZ TDS - values are for ground coffee only, nd for instant coffee.
Beryllium	nd	n/a	
Cadmium	nd-0.0044	nd (ground) nd-0.0005 mg/kg (instant).	2009 NZ TDS
Chromium	0.005-0.022	nd	India; 100% instant coffee powder (Suseela *et al.*, 2001).
Cobalt	nd-0.0085	BDL^	Turkey; (Citak *et al.*, 2009).
Copper	0.12-0.53	0.4 mg/L	India; 100% instant coffee powder (Suseela *et al.*, 2001).
Lead	nd-0.024	nd-0.0043 mg/kg (ground) 0.0015-0.0024 mg/kg (instant).	2009 NZ TDS
Manganese	0.16-0.82	6.6 mg/L	India; 100% instant coffee powder (Suseela *et al.*, 2001).
Mercury, total	nd	nd	2009 NZ TDS
Nickel	nd-0.16	0.6 mg/L	India; 100% instant coffee powder (Suseela *et al.*, 2001).
Tin	nd-0.07	n/a	
Zinc˘	0.042-2.4	2.4 mg/L	India; 100% instant coffee powder (Suseela *et al.*, 2001).

Contaminants	FSANZ Study[†] (mg/L)	Overseas Comparison	Comments
Acrylamide	0.0001-0.0097	<0.005- 0.023 mg/L nd-0.028 mg/L (ground). 0.499-0.502 mg/kg (instant) and 0.204-0.208 mg/kg (roasted)	Excludes decaffeinated (Eckert, 2006). US FDA 2004-2006 TDS Mean values (EFSA, 2010).
Furan	0.002-0.11	0.037 – 0.084 mg/L (brewed) <0.002 mg/L (instant). 0.177-0.181 mg/L (instant coffee), 0.089-0.090 mg/L (roasted bean coffee), 0.026-0.030 mg/L (roasted ground coffee) and 0.244-0.246 mg/L (coffee type not specified).	Excludes decaffeinated coffee (FDA, 2004). Mean concentrations from coffee samples analysed as consumed (EFSA, 2010).
Ochratoxin A	nd	0.00064 mg/kg to 0.008 mg/kg	Vietnam; green coffee beans, (De Obanos *et al.,* 2005).
Polycyclic Aromatic Hydrocarbons (PAHs)	nd	0.0006 mg/L to 0.0018 mg/L (5 mins); 0.00063 mg/L to 0.0017 mg/L 20mins.	France; Mean concentrations for ground coffee roasted for either 5 mins or 20 mins. PAHs level increased with high temperatures (260°C). Data represents PAHs levels at 240°C & 260°C, respectively (Houessou *et al.,* 2007).

[†] The mean concentration range in mg/L is presented for the FSANZ data to represent the different coffee types analysed.
nd; not detected above the PQL.
[*] The median concentration in bottled coffee.
[^] BDL means below detection limit.
[ˇ] Zinc is considered to be a nutrient.
n/a data not available.

As outlined in Table 3, the level of metal and chemical contaminants was generally lower in this survey in comparison to data collected in overseas studies, with the exception of cadmium and antimony. For cadmium, detectable values were only reported in samples of mocha (Table 2). Mocha coffee differs from the other types of coffees analysed due to the addition of cocoa powder to the beverage (Table 1). Suseela *et al.* (2001) investigated the daily intake of trace metals through coffee consumption in India and the lowest concentration of cadmium was detected in pure instant coffee powder, as opposed to blended coffee which reported a higher cadmium concentration. In addition, Mounicou *et al.* (2003) investigated the concentrations and bioavailability of cadmium and lead in cocoa powder and related products. This study found that during the processing of cocoa beans into cocoa liquor, a greater proportion of cadmium remained in the cocoa powder rather than in the cocoa butter fraction. These findings suggest that the cocoa powder component of mocha may be a contributing source of cadmium in mocha coffee.

In relation to the antimony levels compared to those overseas (Table 3), it appears that the levels identified in this survey are higher. It is noteworthy that the Hong Kong study reported the median concentration from 1 composite of bottled coffee (comprising 3 individual samples) whereas this survey reports the range in 41 composite samples of coffee (a total of 164 individual samples). These differences in sample type and size may account for some of the variation in the results.

Furan was also detected in all coffee types analysed as part of this survey. Mean concentrations ranged from 0.0023 mg/L in instant coffee (with and without milk) to 0.11 mg/L in short black coffee. The higher level of furan in short black could largely be attributed to the concentration of coffee present. For example, although cappuccino and latte contain the same amount of coffee as short black, the addition of milk has a dilution effect. Overall, the results for furan from this survey are consistent with those reported by the US FDA and by EFSA in 2010.

Furan is a chemical of international interest. At the 72nd meeting of JECFA in February 2010, the Committee expressed concern for furan in a variety of foods given it is a known carcinogenic compound (WHO, 2010). It was suggested that furan levels can be reduced in foods via a process of volatilisation (e.g. the combined heating and stirring of canned foods in an open vessel). Following the JECFA meeting, it was agreed at the 4th session of the Codex Committee on Contaminants in Foods (CCCF) held in April 2010 that a working group is established to investigate the occurrence, distribution and risk management of furan (WHO, 2010a).

In this survey, ochratoxin A was not detected in any of the coffee types analysed. This is consistent with the findings of the 20th ATDS conducted in 2000, where ochratoxin A was not detected in instant coffee (FSANZ, 2003). The current survey, however, has delineated further to investigate ochratoxin A in a number of espresso coffee types. The presence of ochratoxin A in coffee has previously been reported by De Obanos *et al.,* (2005) (Table 3), noting that roasting green coffee beans resulted in a mean reduction (66.5%) in levels of ochratoxin A. A reduction of the ochratoxin A levels in roasted green coffee beans, has been reported when using an espresso coffee maker which resulted in the greatest mean reduction (49.8%), compared to using a moka (percolator) brewing method (32.1%) or an auto-drip method (14.5%). At the first session of the CCCF in April 2007, a draft code of practice was presented for the prevention and reduction of ochratoxin A contamination in coffee for consideration (WHO, 2007). The code of practice was formally adopted by the 32nd session of the Codex Alimentarius Commission in June-July 2009 (WHO, 2009).

For the 18 PAHs tested in this survey, no detections were reported in any of the coffee types analysed. This is in contrast to the findings of Houessou *et al.,* (2007) outlined in Table 3. The dietary exposure to PAHs in Australia has been previously estimated and was recently published by FSANZ, where exposure levels were considered to be low. The FSANZ report analysed concentration levels of 20 PAHs in 35 foods consumed as part of a typical Australian diet. While the survey did not include coffee, it was concluded that the health risk to the Australian public from dietary exposure to PAHs is unlikely to be of public health and safety concern (FSANZ, 2010).

Next steps

Metal contaminants and pesticide residues in the food supply continue to be monitored by FSANZ on a regular basis through the ATDS. The current ATDS, the 23rd, has investigated metals, pesticide residues and ochratoxin A in instant and espresso coffee amongst other foods commonly consumed in a typical Australian diet (unpublished). The analytical results from the 23rd ATDS will be compared with the results of this survey. A dietary exposure estimate to metals, pesticide residues and ochratoxin A for the Australian population will be conducted and the contribution of these contaminants to dietary exposure through coffee will be assessed. A dietary exposure assessment and subsequent risk characterisation has not been conducted for this survey as the focus was on one food commodity and not in the context of the total diet.

FSANZ continues to remain informed of developments in relation to acrylamide levels in foods. It is anticipated that FSANZ will conduct an analytical survey of acrylamide levels in a range of common foods and beverages in the near future. FSANZ also continues to encourage industry to reduce levels of acrylamide in food. Additionally, FSANZ will be submitting relevant data to the FAO/WHO for consideration in international assessment, in particular FSANZ will be submitting furan data for assessment by CCCF.

Conclusion

The analytical data reported in this survey indicates that the chemicals present in a range of coffee types and the levels at which they are present, are consistent with those reported in other comparable surveys both in Australia and overseas.

For further information on acrylamide, please refer to the fact sheet on the FSANZ website (http://www.foodstandards.gov.au/scienceandeducation/factsheets/factsheets2010/acrylamideandfoodmar4759.cfm).

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Appendix 1 Definitions and glossary of terms

Limit of Detection (LOD)

The LOD is the lowest concentration of a chemical that can be qualitatively detected using a specified laboratory method and/or item of laboratory equipment (i.e. its presence can be detected but not quantified).

Limit of Quantification (LOQ)

The LOQ is the lowest concentration of a chemical that can be detected and quantified, with an acceptable degree of certainty, using a specified laboratory method and/or item of laboratory equipment.

Limit of Reporting (LOR)

The LOR is the lowest concentration level that the laboratory reports analytical results. For the purposes of this report, the LOD was chosen as the basis for the LOR (i.e. the LOR is equivalent to the LOD).

Practical Quantitation Limit (PQL)

The PQL is equivalent to the LOQ and is used by some laboratories instead of the limit of quantification (LOQ).

Appendix 2 Mean concentration of chemicals and residues in coffee

Table A1: Mean concentrations of aluminium in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	0.73
Latte	10	1.2
Flat white	8	0.36
Long black	4	0.82
Short black	2	0.63
Mocha	2	0.71
Instant black	1	0.26
Instant white	2	0.19
Ground coffee (plunger) white	1	0.31
Ground coffee (plunger) black	1	0.18

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. All results have been rounded to two significant figures.

Table A2: Mean concentrations of antimony in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	5	0.0018	0.0023
Latte	10	5	0.0012	0.0017
Flat white	8	4	0.001	0.0015
Long black	4	2	0.001	0.0015
Short black	2	1	0.001	0.0015
Mocha	2	1	0.0005	0.001
Instant black	1	1	0.001	0.001
Instant white	2	1	0.001	0.001
Ground coffee (plunger) white	1	1	0.001	0.001
Ground coffee (plunger) black	1	1	0.001	0.001

Notes to table:

1. Results are derived from composite samples
2. 'nd' denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.001 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A3: Mean concentrations of arsenic in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	2	0.0044	0.0045
Latte	10	3	0.0026	0.0028
Flat white	8	1	0.0033	0.0034
Long black	4	1	0.0034	0.0035
Short black	2	0	0.0047	0.0047
Mocha	2	0	0.0061	0.0061
Instant black	1	0	0.0029	0.0029
Instant white	2	0	0.0041	0.0041
Ground coffee (plunger) white	1	0	0.0018	0.0018
Ground coffee (plunger) black	1	0	0.0013	0.0013

Notes to table:

1. Results are derived from composite samples
2. 'nd' denotes a non-detect value which is less than the practical quantitation limit (PQL 0.0005 mg/L).
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.0005 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A4: Mean concentrations of beryllium in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	nd
Latte	10	nd
Flat white	8	nd
Long black	4	nd
Short black	2	nd
Mocha	2	nd
Instant black	1	nd
Instant white	2	nd
Ground coffee (plunger) white	1	nd
Ground coffee (plunger) black	1	nd

Notes to table:

1. Results are derived from composite samples

2. 'nd' denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).

Table A5: Mean concentrations of cadmium in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	10	0	0.0005
Latte	10	10	0	0.0005
Flat white	8	8	0	0.0005
Long black	4	4	0	0.0005
Short black	2	2	0	0.0005
Mocha	2	0	0.0044	0.0044
Instant black	1	1	0	0.0005
Instant white	2	2	0	0.0005
Ground coffee (plunger) white	1	1	0	0.0005
Ground coffee (plunger) black	1	1	0	0.0005

Notes to table:

1. Results are derived from composite samples
2. 'nd' denotes a non- detect value which is less than the practical quantitation limit (PQL 0.0005 mg/L).
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.0005 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A6: Mean concentrations of chromium in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	0.0091
Latte	10	0.0077
Flat white	8	0.0061
Long black	4	0.0075
Short black	2	0.0085
Mocha	2	0.022
Instant black	1	0.016
Instant white	2	0.005
Ground coffee (plunger) white	1	0.007
Ground coffee (plunger) black	1	0.006

Notes to table:

1. Results are derived from composite samples
2. 'nd' denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. All results have been rounded to two significant figures

Table A7: Mean concentrations of cobalt in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	0	0.0022	0.0022
Latte	10	2	0.0018	0.002
Flat white	8	3	0.0014	0.0018
Long black	4	0	0.0025	0.0025
Short black	2	0	0.0085	0.0085
Mocha	2	0	0.01	0.01
Instant black	1	0	0.001	0.001
Instant white	2	2	0	0.001
Ground coffee (plunger) white	1	1	0	0.001
Ground coffee (plunger) black	1	1	0	0.001

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.001 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A8: Mean concentrations of copper in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	0.15
Latte	10	0.23
Flat white	8	0.17
Long black	4	0.53
Short black	2	0.25
Mocha	2	0.5
Instant black	1	0.15
Instant white	2	0.14
Ground coffee (plunger) white	1	0.13
Ground coffee (plunger) black	1	0.12

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. All results have been rounded to two significant figures

Table A9: Mean concentrations of lead in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	2	0.0087	0.0089
Latte	10	1	0.0072	0.0073
Flat white	8	3	0.005	0.0054
Long black	4	0	0.024	0.024
Short black	2	0	0.0055	0.0055
Mocha	2	0	0.006	0.006
Instant black	1	0	0.01	0.01
Instant white	2	2	0	0.001
Ground coffee (plunger) white	1	1	0	0.001
Ground coffee (plunger) black	1	1	0	0.001

Notes to table:

1. Results are derived from composite samples

2. 'nd' denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.001 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A10: Mean concentrations of manganese in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	0.3
Latte	10	0.29
Flat white	8	0.26
Long black	4	0.52
Short black	2	1.8
Mocha	2	0.82
Instant black	1	0.21
Instant white	2	0.16
Ground coffee (plunger) white	1	0.28
Ground coffee (plunger) black	1	0.28

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. All results have been rounded to two significant figures

Table A11: Mean concentrations of nickel in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	1	0.017	0.017
Latte	10	0	0.02	0.02
Flat white	8	2	0.014	0.014
Long black	4	0	0.05	0.05
Short black	2	0	0.069	0.069
Mocha	2	0	0.16	0.16
Instant black	1	0	0.004	0.004
Instant white	2	0	0.007	0.007
Ground coffee (plunger) white	1	1	0	0.001
Ground coffee (plunger) black	1	1	0	0.001

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.001 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A12: Mean concentrations of tin in coffee (mg/L)

Coffee Type	No. of analyses	No. of 'nd' samples	Mean (nd=0)	Mean (nd=PQL)
Cappuccino	10	8	0.0002	0.001
Latte	10	10	0	0.001
Flat white	8	6	0.001	0.0018
Long black	4	3	0.0015	0.0023
Short black	2	2	0	0.001
Mocha	2	1	0.033	0.033
Instant black	1	1	0.07	0.07
Instant white	2	2	0	0.001
Ground coffee (plunger) white	1	1	0	0.001
Ground coffee (plunger) black	1	1	0	0.001

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L)
3. Two means are given in this table; one derived assuming results less than the PQL are assigned a value of '0' (nd=0), and the other derived assuming results less than the PQL are assigned a value of 0.001 mg/L (i.e. the PQL) (nd=PQL).
4. All results have been rounded to two significant figures

Table A13: Mean concentrations of zinc in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	1.7
Latte	10	1.7
Flat white	8	1.8
Long black	4	0.22
Short black	2	0.17
Mocha	2	2.4
Instant black	1	0.042
Instant white	2	0.18
Ground coffee (plunger) white	1	0.22
Ground coffee (plunger) black	1	0.047

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. All results have been rounded to two significant figures

Table A14: Mean concentrations of acrylamide in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	0.0032
Latte	10	0.0021
Flat white	8	0.0015
Long black	4	0.0036
Short black	2	0.0097
Mocha	2	0.0013
Instant black	1	0.0023
Instant white	2	0.0021
Ground coffee (plunger) white	1	0.0029
Ground coffee (plunger) black	1	0.0001

Notes to table:

1. Results are derived from composite samples
2. 'nd' denotes a non-detect value which is less than the practical quantitation limit (PQL 0.0001 mg/L).
3. All results have been rounded to two significant figures

Table A15: Mean concentrations of furan in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	0.032
Latte	10	0.023
Flat white	8	0.033
Long black	4	0.042
Short black	2	0.11
Mocha	2	0.024
Instant black	1	0.002
Instant white	2	0.0025
Ground coffee (plunger) white	1	0.024
Ground coffee (plunger) black	1	0.022

Notes to table:

1. Results are derived from composite samples
2. ‘nd’ denotes a non-detect value which is less than the practical quantitation limit (PQL 0.001 mg/L).
3. All results have been rounded to two significant figures

Table A16: Mean concentrations of ochratoxin A in coffee (mg/L)

Coffee Type	No. of analyses	Mean
Cappuccino	10	nd
Latte	10	nd
Flat white	8	nd
Long black	4	nd
Short black	2	nd
Mocha	2	nd
Instant black	1	nd
Instant white	2	nd
Ground coffee (plunger) white	1	nd
Ground coffee (plunger) black	1	nd

Notes to table:

1. Results are derived from composite samples
2. 'nd' denotes a non-detect value which is less than the limit of reporting (LOR 0.005 mg/kg).
3. All results have been rounded to two significant figures

Table A17: Pesticide residue screen[#]

Aldrin	Malathion	Mevinphos	Permethrin
alpha-BHC	Mevinphos	MGK-264,mixed isomers	Phenothrin
beta-BHC	Methyl parathion	Molinate	Pyrethrin
delta-BHC	Parathion	Napropamide	Tetramethrin
gamma-BHC (lindane)	Phorate	Norflurazon	Total Dithiocarbamates as CS2 (carbon disulphide)
Chlordane	Stirofos	Pebulate	Carbaryl
4,4-DDD	Sulfotepp	Prometon	Carbofuran
4,4-DDE	Thionazin	Prometryn	Ethyl Carbamate
4,4-DDT	O,O,O-triethylphosphorothioate	Pronamide	Mexacarbate
Dieldrin	Alachlor	Propachlor	Phenobarbital
Endosulfan 1	Ametryn	Propazine	Schradan
Endosulfan 2	Atraton	Simetryn	
Endosulfan Sulphate	Atrazine	Tetrachlorvinphos	
Endrin	Bromacil	Tebuthiuron	
Endrin Aldehyde	Butachlor	Terbacil	
Heptachlor	Butylate	Terbutryn	
Heptachlor Epoxide	Chlorpropham	Triadimefon	
Hexachlorobenzene	Chlorpyrifos	Tricyclazole	
Methoxychlor	Cycloate	Trifluralin	
Chlorfenvinphos	Cyanazine	Simazine	
Chlorpyrifos	Dichlorvos	Vernolate	
Dichlorvos	Diphenamid	Bifenthrin	
Dimethoate	EPTC	Bioallethrin	
Disulfoton	Ethoprop	Bioresmethrin	
Ethion	Fenarimol	Cyfluthrin	
Famphur	Fluridone	Cyhalothrin	
Fenitrothion	Hexazinone	Cypermethrin	
Fensulfothion	Methyl Paraoxon	Deltamethrin	
Fenthion	Metolachlor	Flumethrin	

[#]No detections above the PQL 0.001 mg/L were found for all pesticide residues analysed with the exception of total Dithiocarbamates as CS2 (carbon disulphide) which has a PQL 0.02 mg/L.

Table A18: Polycyclic aromatic hydrocarbons*

Acenaphthene
Acenaphthylene
Anthracene
Benz[a]anthracene
Benzo[a]pyrene
Benzo[b]fluoranthene
Benzo[g,h,i]perylene
Benzo[k]fluoranthene
Chrysene
Dibenz[a,h]anthracene
7,12-Dimethylbenz[a]anthracene
Fluoranthene
Fluorene
Indeno[1,2,3-c,d]pyrene
3-Methylcholanthrene
Naphthalene
Phenanthrene
Pyrene

*No detections above the PQL 0.001 mg/L were found for all PAHs analysed.