New Zealand Food Safety
Haumaru Kai Aotearoa

The New Zealand Mycotoxin Surveillance Programme

Dietary exposure to fumonisins: Risk estimates and proportionality of exposure sources

New Zealand Food Safety Report No: 2020/15

Prepared for New Zealand Food Safety
By Peter Cressey (ESR) and Andrew Pearson (NZFS)

ISBN No: 978-1-99-002532-7 (online)
ISSN No: 2624-022X (online)

March 2020

New Zealand Government

Ministry for Primary Industries
Manatū Ahu Matua

New Zealand Food Safety
Haumaru Kai Aotearoa

Disclaimer

This publication is available on the Ministry for Primary Industries website at http://www.mpi.govt.nz/news-and-resources/publications/

Scientific Interpretative Summary

This SIS is prepared by New Zealand Food Safety (NZFS) risk assessors to provide context to the following report for NZFS risk managers and external readers

The New Zealand Mycotoxin Surveillance Programme

Dietary exposure to fumonisins: Risk estimates and proportionality of exposure sources

Following the completion of a survey for the occurrence of fumonisin mycotoxins in maize-based foods and wine, the results were assessed for exposure through the New Zealand diet.

For all of the New Zealand age and gender groups the estimated exposures were within the ranges reported in Europe, and well below the ranges in countries where maize is a staple food. The predominant source of exposure was estimated to result from consumption of maize-based Mexican style foods, in particular corn chips. All exposures were characterised against a health based guidance value, with the highest exposure being 11% of this value.

This report confirms that dietary exposure to fumonisins in New Zealand is a negligible health concern. NZFS will monitor any developments with fumonisins internationally, however at this stage the level of risk does not require any mitigation.

DIETARY EXPOSURE TO FUMONISINS: RISK ESTIMATES AND PROPORTIONALITY OF EXPOSURE SOURCE

APRIL 2018

Prepared by:

Peter Cressey, Risk and Response Group

PREPARED FOR:	**Ministry for Primary Industries, project code CFS/16/04, Fumonisins in New Zealand foods: Prevalence and Risk Assessment, as part of the overall contract for scientific services**
CLIENT REPORT No:	**FW17078**
REVIEWED BY:	**Andrew Chappell, Food Chemistry and NCRS Group** **Dr Rob Lake, Risk and Response Group**

Peer reviewer

Andrew Chappell

Scientist, Food Chemistry and NCRS Group

Management Reviewer

Dr Rob Lake

Manager, Risk and Response Group

Project Manager

Peter Cressey

Senior Scientist, Risk and Response Group

DISCLAIMER

CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Mycotoxin Surveillance Programme (MSP) involves investigation of food safety issues associated with mycotoxins in the New Zealand food supply. The current risk assessment relates to fumonisins. Fumonisins are mycotoxins produced predominantly by *Fusarium verticillioides* (*F. moniliforme*), *F. proliferatum* and *F. fujikuroi.* These fungal species are endemic in maize worldwide, but are rarely found in other crops.

Dietary exposure to fumonisin B_1 (FB_1) and total fumonisins (FB_T; sum of fumonisins B_1, B_2 and B_3) was estimated for a range of New Zealand age-gender groups. Mean dietary FB_1 exposure was in the range 2.1-30 ng/kg bw/day, with the lowest dietary exposure estimates for young adult males (19-24 years) and the highest for children (5-6 years). High (95th percentile) estimates of dietary FB_1 exposure were in the range 4.8-164 ng/kg bw/day. As FB_1 accounts for approximately 70% of FB_T, FB_T dietary exposures were in the expected range with mean and 95th percentile ranges of 2.6-40 and 5.9-220 ng/kg bw/day, respectively.

Dietary fumonisin exposures for New Zealanders were within the range reported for European countries and well below estimates of dietary exposure in countries where maize is a dietary staple. All mean and high percentile dietary exposures estimated for New Zealand age-gender groups were at or below 11% of the provisional maximum tolerable daily intake (PMTDI) of 2000 ng/kg bw/day.

Dietary exposure to fumonisins in New Zealand is predominantly (>60% of all age-gender groups and for FB_1 and FB_T) due to consumption of maize-based Mexican style foods. Examination of dietary records suggests that the predominance of this food group, as a contributor to dietary fumonisin exposure, is due to consumption of corn chips. Dietary exposure to fumonisins from this group of foods is likely to be over-estimated to some extent, as it was assumed that Mexican style products, such as tortillas, would be exclusively made from maize flour. In reality, these products are sometimes made from wheat flour.

The estimates of chronic high percentile dietary exposure to fumonisins will also be overestimates, as they are based on only a single day of dietary recall and will include variability that becomes 'averaged out' over a longer survey time frame.

Based on the current estimates, dietary exposure to fumonisins in New Zealand is highly unlikely to be a risk to public health.

1. INTRODUCTION

1.1 MYCOTOXIN SURVEILLANCE PROGRAMME (MSP)

The Mycotoxin Surveillance Programme (MSP) involves investigation of food safety issues associated with mycotoxins in the New Zealand food supply.

As with other activities of the Ministry for Primary Industries (MPI), activities in this area are directed on the basis of risk. A risk profile of mycotoxins in the New Zealand food supply (Cressey and Thomson, 2006; Cressey, 2014a) is viewed as a starting point for this process. The risk profile identified a number of issues to be investigated or clarified. Based on the earlier of these risk profiles, priority mycotoxin issues for New Zealand were identified, relating to aflatoxins (AF), ochratoxin A (OTA) and trichothecene mycotoxins. The work programme for these mycotoxins was completed with risk assessments (Cressey, 2011; 2014b), using results from earlier survey projects (Cressey and Jones, 2008; 2009; 2010; 2011; Cressey *et al.*, 2014).

The current risk assessment for fumonisins represents completion of work for the first priority issue identified in the latest mycotoxin risk profile (Cressey, 2014a) and draws on data from a recently completed survey (Cressey *et al.*, 2017).

1.2 FUMONISINS

1.2.1 Hazard Identification

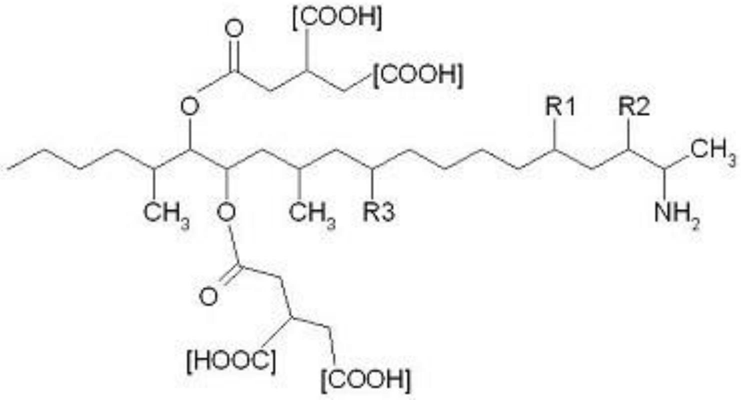
Fumonisins are mycotoxins produced predominantly by *Fusarium verticillioides* (*F. moniliforme*), *F. proliferatum* and *F. fujikuroi.* These fungal species are endemic in maize worldwide, but are rarely found in other crops (Pitt and Tomaska, 2001). The fungi grow optimally at about 25ºC and will grow at temperatures up to 32-37ºC (Pitt and Tomaska, 2001). While at least six fumonisins are known, fumonisin B_1 and B_2 (FB_1, FB_2) are the most important.

It has recently been discovered that *Aspergillus niger* strains are also capable of producing fumonisin mycotoxins (Frisvad *et al.*, 2007; Scott, 2012). This discovery has led to the detection of fumonisins in foods not previously considered as vehicles for these toxins, such as wine and dried fruits. *A. niger* produces predominantly FB_2 and FB_4 (Mogensen *et al.*, 2010).

1.2.2 Structure and nomenclature

Fumonisins consist of a 20 carbon aliphatic chain with 2 ester-linked hydrophilic polyol side chains. Structural details for FB_1 – FB_4 are shown in Figure 1.

Figure 1: Structure of major fumonisins



Fumonisin B_1: R1= OH; R2= OH; R3= OH; Fumonisin B_2: R1= H; R2= OH; R3= OH; Fumonisin B_3: R1= OH; R2= OH; R3= H; Fumonisin B_4: R1= H; R2= OH; R3= H

Fumonisins C_1-C_4 are identical to the corresponding B fumonisin, except the aliphatic carbon chain does not have the terminal methyl group on the right hand end (Soriano and Dragacci, 2004). Concentrations of B and C series fumonisins in maize have been shown to be correlated, but with the C series fumonisin present at concentrations 5% or less of the corresponding B series fumonisin (Shephard *et al.*, 2011).

1.2.3 Occurrence

F. verticillioides and *F. proliferatum* are amongst the most common fungi associated with maize worldwide and can be recovered from most maize kernels, even when the kernels appear healthy (WHO, 2000). *F. verticillioides* is considered to be the major cause of *Fusarium* kernel rot in maize, a significant plant disease occurring in warm, dry weather (JECFA, 2001). *Fusarium* kernel rot, and associated fumonisin synthesis, is also strongly associated with insect damage of kernels, as this provides an entry point for the fungus (WHO, 2000). Thin kernel pericarp (greater susceptibility to insect injury), propensity to kernel splitting, and previous infection with other *Fusarium* species, such as *F. graminearum*, all increase the risk of *F. verticillioides* infection and fumonisin formation (WHO, 2000).

F. verticillioides is widespread in the tropics and humid temperate zones, but is uncommon in cooler temperate zones (Pitt and Hocking, 1997). Surveys of *Fusarium* species in New Zealand maize are supportive of this observation, as the fungus is only rarely isolated (Hussein *et al.*, 2002; Sayer, 1991; Sayer and Lauren, 1991). *F. proliferatum* has not been reported in New Zealand maize.

Although fumonisin-producing fungi appear to be relatively rare in New Zealand, FB_1 was reported in New Zealand pasture grasses, at concentration in the range 1-9 mg/kg (Mirocha *et al.*, 1992). The pastures analysed were associated with an idiopathic disease of wapiti (elk) and wapiti hybrids grazed on the pastures.

1.2.4 Current Project

While information on the prevalence and concentrations of mycotoxin contamination in foods is useful, estimation of the risks associated with mycotoxin contamination in different foods requires combination of this information with food consumption information to provide estimates of dietary exposure. The current project has three objectives:

- To estimate dietary mycotoxin (fumonisins) exposure in New Zealand, including estimates of the distribution of exposure;
- To compare estimates of exposure to existing health-based exposure limits; and
- To determine the proportionality of different dietary sources of mycotoxin (fumonisins) to the overall risk.

2. METHODS, RATIONALES AND ASSUMPTIONS

For dietary exposure to chemicals, exposure can be defined as:

$$E_i = \frac{\Sigma Q_{i,k} \times C_{i,k}}{bw_i}$$

Where E_i is the exposure of individual *i* to some chemical at some specified point in time, $Q_{i,k}$ is the amount of food *k* consumed by individual *i*, $C_{i,k}$ is the concentration of the chemical of interest in food *k* consumed by individual *i* and bw_i is the body weight of individual *i*. For deterministic (point) estimates of exposure these parameters (concentration, food consumption and body weight) are represented by population averages or selected percentiles. For dietary modelling, food consumption and body weight will be represented by actual reported values for an individual on one particular day or on several days, depending on the structure of the dietary survey.

2.1 CONCENTRATION DATA - FUMONISINS

2.1.1 Sources of concentration data

Recent data are available on the concentration of fumonisins (FB_1, FB_2, FB_3) in foods consumed in New Zealand (Cressey *et al.*, 2017). The survey considered maize-based foods and red wine. Fumonisins were only detected in maize-based foods and it has been assumed that results in red wine represent true evidence of fumonisin absence.

2.1.2 Reporting of fumonisin concentrations. Chemical entity reported

Most toxicological data for fumonisins relates to FB_1. However, the three main fumonisins (FB_1, FB_2 and FB_3) are assumed to be equally toxic. Consequently, the health-based guidance value for fumonisins is defined in terms of FB_1, FB_2 and FB_3, alone or in combination (JECFA, 2017). In line with the approach taken by the Joint FAO/WHO Expert Committee on Food Additives (JECFA), the current assessment considered dietary exposure to FB_1 and dietary exposure to the sum of FB_1, FB_2 and FB_3, termed total fumonisins (FB_T).

2.1.3 Use of fumonisin concentration data in exposure assessment

Exposure to fumonisins is of concern due to effects on the liver and kidneys (JECFA, 2017). While fumonisins have not been demonstrated to be acutely toxic, the adverse effects seen in lifetime studies are the same as those seen in sub-chronic (less than lifetime) studies. In this context, the parameter of interest is the chronic, habitual/usual level of exposure. In the absence of more detailed information, it must be assumed that individuals within the population will be exposed to the complete distribution of fumonisin concentrations in a particular food over time. Therefore, the most appropriate parameter of the distribution of fumonisin concentrations for calculation of chronic exposure is the mean or expected value. This is consistent with the conclusions of JECFA (JECFA, 2011; 2017).

2.1.4 Treatment of 'not detected' (left censored) data

Left censorship refers to the situation where the distribution of observed results is truncated at the left hand end due to the limited sensitivity of measurement technologies. The data set for fumonisins in New Zealand foods contains a moderate proportion of left-censored (non-detected) data (35%). This may include both true zero and true very low concentration data.

A previous New Zealand mycotoxin (aflatoxin) exposure study applied statistical techniques to the determination of mean values for left-censored data sets (Cressey, 2011). However, these techniques (maximum likelihood, regression on order statistic, Kaplan-Meier) proved to be unsatisfactory for small data sets (less than 50 data points), with a high proportion of non-detects. These characteristics apply equally to the fumonisin concentration data set.

WHO GEMS/Food have developed conventions for left-censored data sets (WHO GEMS/Food-Euro, 1995), specifically:

- When 60% or less of data are censored, the mean was calculated using a value of half the limit of detection for values below the limit of detection; and
- When more than 60% of data are censored, two estimates of the mean are calculated; one assuming that all values less than the limit of detection are true zero values (lower bound; LB) and one assuming that all values less than the limit of detection are true non-detects with values equal to the limit of detection (upper bound; UB)

However, it was noted that both the European Food Safety Authority (EFSA) and JECFA have moved away from the calculation of 'middle bound' (values below LOD = LOD/2) estimates of mean concentrations and dietary exposure. It was decided to follow the current approach of these bodies and calculate LB-UB estimates of mean concentrations and dietary exposure. The LB and UB mean concentration values for FB_1 and FB_T used in the current project are summarised in Appendix 1.

2.2 FOOD CONSUMPTION INFORMATION

2.2.1 National Nutrition Survey (NNS) records

Periodic national nutrition surveys (NNSs) are carried out in New Zealand. The most recent are the 2008-2009 Adult Nutrition Survey (2009ANS) covering adult New Zealanders, aged 15 years and over (University of Otago and Ministry of Health, 2011) and the 2002 National Children's Nutrition Survey (2002CNS) covering New Zealand children aged 5-14 years (Ministry of Health, 2003).

These two surveys include 24-hour dietary recall records (24HDR). These include a complete listing of all foods consumed by an individual during one 24-hour period. Days of the week and time of year are randomised across the survey to avoid bias due to these factors. The 2009ANS contains 24HDR records for 4,721 respondents and the 2002CNS contains 24HDR records for 3,275 respondents.

2.2.2 Mapping of NNS foods to mycotoxin-containing foods

The NNSs contain almost 11,000 unique food descriptors. In order to estimate the fumonisin concentration of each of these foods it is necessary to map the foods for which fumonisin concentrations are available to the list of unique NNS food descriptors. Three situations arise:

- The food for which fumonisin concentration information is available is sufficiently similar to the NNS food descriptor to allow direct application of the determined fumonisin concentration;
- The NNS food is unrelated to any food for which fumonisin concentration information is available and is unlikely to contain fumonisins. Such foods are assumed to have a fumonisin concentration of zero; or
- The NNS food is similar to or contains (as part of a recipe) one of the foods for which fumonisin concentration information is available.

The bulk of the effort in mapping relates to the third situation. Appendix 2 outlines the methodology used to determine the amount of fumonisin-containing food in a recipe, while Appendix 3 identifies the range of foods and recipes that were identified as needing to be mapped to the list of fumonisin-containing foods.

It should be noted that maize starch is used as an ingredient in a wide range of foods. However, due to the highly refined nature of this product and the small amount used in many cases, no attempt has been made to map survey foods to the small amounts of maize starch present in some highly-processed foods.

2.3 CHRONIC DIETARY EXPOSURE ASSESSMENT

The food mapping was used to assign a mean fumonisin concentration to all instances of consumption of relevant foods reported in the 24HDR components of the 2002CNS and 2009ANS. Concentration values were multiplied by the food consumption amount and summed for each NNS respondent to give 3275 (2002CNS) and 4721 (2009ANS) individual estimates of daily dietary fumonisin (FB_1 or total fumonisins) exposure. Body weight information was not collected for all NNS respondents and the resulting set of dietary exposure estimates had to be 'cleaned' to remove estimates for respondents for whom no body weight information was available. The remaining exposure estimates were divided by the respondent's body weight. All calculations were carried out using Microsoft Excel.

For fumonisins, it should be noted that the toxicological effects of concern following chronic exposure are also apparent in a subchronic timeframe. Consequently, estimates of dietary exposure were derived for children as well as adults. Estimates of dietary exposure were also determined for 'high consumers'. High consumers are individuals who, either through their high consumption of key foods or their high consumption of foods in general, are consistently exposed to greater amounts of food contaminants. For the current study, a high consumer was defined as an individual with dietary exposure to fumonisins at the 95^{th} percentile, based on 24-hour dietary recall food consumption information.

2.3.1 Estimation of usual dietary exposure to mycotoxins

While the 24HDR records provide a very good record of the food intake and resultant dietary exposure to fumonisins by an individual on a particular day, this is not the same as the individual's habitual long-term (usual) food intake and may include consumption of foods rarely eaten by the individual or exclude foods commonly eaten by the individual. This will mean that any dietary exposure estimate based on 24HDR records may not be a true representation of habitual exposure for an individual. While the mean of dietary exposures derived from single day 24HDR are likely to be good estimates of the true mean, it is expected that the variability in dietary exposure derived from 24HDR records will be greater than the true population habitual dietary exposure variability, as it will include both between person variability (inter-person) and within person variability (intra-person) (Dodd *et al.*, 2006; Hoffmann *et al.*, 2002; Nusser *et al.*, 1996). Between-person variability is the parameter of interest for risk assessment associated with chronic exposure, as is the case for fumonisins.

For the 2009ANS and 2002CNS, 24HDR dietary information was collected on a second day for approximately 15% of respondents. These duplicate days can be used to estimate intra-person variability and correct the overall estimate of exposure variability to only represent inter-person variability (Dodd *et al.*, 2006; Hoffmann *et al.*, 2002; Nusser *et al.*, 1996).

However, the correction process does not work well when the dataset contains a high proportion of zero dietary exposure days. This was the case for fumonisins and percentiles of the dietary exposure distribution were unable to be corrected for intra-person variability using PC-SIDE software.[1]

2.4 RISK ASSESSMENT

Fumonisins are considered to be threshold contaminants. That is, there is a level of dietary exposure below which there is considered to be a negligible risk of adverse health effects. For chemicals with a threshold to toxicological effects, risks can be assessed by comparison of estimates of dietary exposure with health-based exposure limits. Risk is usually expressed in terms of the percentage of the health-based exposure limits, with lower percentages representing lower levels of risk.

2.4.1 Tolerable intake

JECFA reassessed fumonisins at their 83rd meeting (JECFA, 2017). After considering new toxicological studies, the Committee confirmed their previous dose-response analysis, deriving a $BMDL_{10}$ of 165 μg/kg bw/day for induction of megalocytic hepatocytes in mice (JECFA, 2011). The $BMDL_{10}$ is the lower one-sided 95% confidence limit of the benchmark dose (BMD), associated with a 10% increase in the incidence of megalocytic hepatocytes compared to controls. JECFA applied an uncertainty factor of 100 to account for inter- and intra-species variability to derive a provisional maximum tolerable daily intake (PMTDI) of 2 μg/kg body weight/day.

EFSA have not reviewed fumonisins, however, a predecessor organisation, the Scientific Committee on Food (SCF) reviewed FB_1 in 2000 and derived a tolerable daily intake (TDI), also of 2 μg/kg bw/day (Scientific Committee on Food, 2000).

[1] http://www.side.stat.iastate.edu/pc-side.php PC-SIDE software for intake distribution estimation. Iowa State University. Accessed 7 November 2013

3. RESULTS AND DISCUSSION

3.1 ESTIMATED DIETARY EXPOSURE

3.1.1 Fumonisin B_1 (FB1)

Table 1 summarises estimates of dietary exposure to FB_1. If should be noted that, while LB and UB estimates of mean and 95th percentile dietary exposure were determined, the proportion of quantified analytical concentrations in the data set meant that there was little difference between the LB and UB estimates of dietary exposure. To simplify the presentation of data, only the more conservative UB estimates of dietary exposure are included in Table 1.

Table 1: Estimated FB_1 dietary exposure for various New Zealand population subgroups

Age-gender group	Estimated dietary FB_1 exposure, upper bound, ng/kg body weight/day (percentage of PMTDI)	
	Mean	95th percentile
PMTDI/TDI (JECFA, SCF) = 2000 ng/kg body weight/day		
Child (5-6 years)	30 (1.5)	164 (8.2)
Female (11-14 years)	13 (0.7)	93 (4.7)
Male (11-14 years)	15 (0.7)	81 (4.1)
Male (19-24 years)	2.1 (0.1)	7.0 (0.4)
Female (25+ years)	4.4 (0.2)	11 (0.6)
Male (25+ years)	2.8 (0.1)	4.8 (0.2)

PMTDI = provisional maximum tolerable daily intake, TDI = tolerable daily intake, JECFA = Joint FAO/WHO Expert Committee on Food Additives, SCF = (European) Scientific Committee on Food

No previous New Zealand estimates of dietary exposure to FB_1 are available for comparison.

Estimates of dietary exposure to FB_1 for the New Zealand population are generally very low, with no estimate exceeding 10% of the PMTDI, even at the 95th percentile level of dietary exposure.

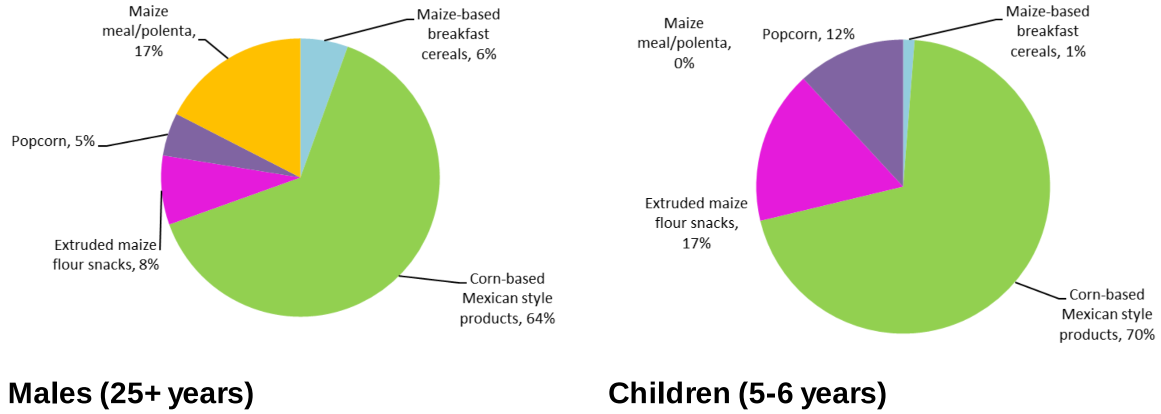
Other national estimates of dietary exposure to FB_1 have recently been reviewed and will not be presented here (Cressey, 2014a; JECFA, 2017). Few estimates were determined for FB_1 alone, with most estimates of dietary exposure for FB_T or $FB_1 + FB_2$. Dietary exposure to FB_1 in France was similar to New Zealand, with LB-UB mean estimates for children of 15-45 ng/kg bw/day (95th percentile 50-106 ng/kg bw/day) and for adults of 7.5-29 ng/kg bw/day (95th percentile 23-66 ng/kg bw/day) (Sirot *et al.*, 2013). In contrast, dietary exposure to FB_1 in three provinces of the People's Republic of China was in the range 2300-7700 ng/kg bw/day (Sun *et al.*, 2011), while FB_1 dietary exposure in Zimbabwe was estimated to be in the range 2200-5400 ng/kg bw/day, depending on the age group considered (Hove *et al.*, 2016).

The 2017 JECFA reassessment of fumonisins also derived international estimates of dietary FB_1 exposure (JECFA, 2017), based on the GEMS/Food cluster diets (WHO, 2017). Across the 17 cluster diets, FB_1 dietary exposures were in the range 2-560 ng/kg bw/day (LB) or 300-1200 ng/kg bw/day (UB). It should be noted that, for the JECFA analysis, few data were available from regions other than Europe.

3.1.2 Contributing foods (FB_1)

Figure 2 shows the proportional contribution of different food groups to estimated dietary FB_1 exposure for an adult male and a 5-6 years old child (the group with the highest exposure on a per kilogram body weight basis). Figures are based on UB estimates of dietary exposure. The contribution of food groups to FB_1 exposure for all age-gender groups are included in Appendix 4.

Figure 2: Contribution of food groups to mean upper bound estimates of FB_1 dietary exposure for adult males (25+ years) and children (5-6 years)



Dietary exposure estimates for FB_1 for both age-gender groups are dominated by the contribution from corn-based Mexican style food, including corn chips. As might be expected, extruded maize flour snacks and popcorn contribute a greater proportion of dietary exposure for children than for adults. Maize meal or polenta products contribute 17% of the UB dietary exposure for adult males, but do not contribute at all to children's UB dietary exposure to FB_1.

The predominance of the corn-based Mexican style food for dietary FB_1 exposure is due to consumption of corn/maize chips or crisps. Of a mean consumption of 4.6 g/day of this food group by children, 3.4 g/day is from consumption of corn chips. Similarly, of a mean of 1.6 g/day of this food group consumed by adults, 1.1 g/day is from consumption of corn chips.

3.1.3 Total fumonisins (FB_T)

Table 1 summarises estimates of dietary exposure to FB_T. If should be noted that, while LB and UB estimates of mean and 95th percentile dietary exposure were determined, the proportion of quantified analytical concentrations in the data set meant that there was little difference between the LB and UB estimates. To simplify the presentation of data, only the UB estimates of dietary exposure are included in Table 2.

Table 2: Estimated FB_T dietary exposure for various New Zealand population subgroups

Age-gender group	Estimated dietary FB_T exposure, upper bound, ng/kg body weight/day (percentage of PMTDI)	
	Mean	95th percentile
PMTDI/TDI (JECFA, SCF) = 2000 ng/kg body weight/day		
Child (5-6 years)	40 (2.0)	220 (11)
Female (11-14 years)	18 (0.9)	124 (6.2)
Male (11-14 years)	20 (1.0)	107 (5.4)
Male (19-24 years)	2.6 (0.1)	8.3 (0.4)
Female (25+ years)	6.0 (0.3)	15 (0.8)
Male (25+ years)	3.8 (0.2)	5.9 (0.3)

PMTDI = provisional maximum tolerable daily intake, TDI = tolerable daily intake, JECFA = Joint FAO/WHO Expert Committee on Food Additives, SCF = (European) Scientific Committee on Food

No previous New Zealand estimates of dietary exposure to FB_T are available for comparison.

Estimates of dietary exposure to FB_T for the New Zealand population are generally very low, with no estimate exceeding 11% of the PMTDI, even at the 95th percentile level of dietary exposure. Given that there is a fairly consistent ratio between the three fumonisins included in the descriptor total fumonisins (Cressey *et al.*, 2017; JECFA, 2012), the estimates of FB_T are consistently about one-third higher than the equivalent FB_1 dietary exposures.

Other national and international estimates of dietary exposure to FB_T have recently been reviewed and will not be presented here (Cressey, 2014a; JECFA, 2017). Most estimates were determined for FB_T or FB_1 + FB_2. As FB_3 is a minor contributor to dietary fumonisin exposure, assessments based on FB_1 + FB_2 have been considered to report dietary FB_T exposure. In European countries, adult mean dietary exposure to FB_T is generally estimated to be in the range 2-60 ng/kg bw/day, while mean dietary exposure to FB_T for children is estimated to be in the range 5-720 ng/kg bw/day (Cressey, 2014a; JECFA, 2017). The results of the current study are within the range of these European estimates.

Dietary exposure to fumonisins can be much higher in developing countries, particularly those where maize is a dietary staple. Estimates of FB_T exposure greater than 5000 ng/kg bw/day have been reported for Guatemala (Torres *et al.*, 2007), South Africa (Burger *et al.*, 2010), the Transkei (Shephard *et al.*, 2007), Tanzania (Kimanya *et al.*, 2009) and Malawi (Matumba *et al.*, 2015).

3.1.4 Contributing foods (FB_T)

As FB_1 is the main component of FB_T, the pattern of foods contributing to dietary FB_T exposure is not noticeably different to the pattern for FB_1 exposure. Details of the contribution of different maize-based food types to estimated mean dietary exposure for all age-gender groups are summarised in Appendix 4.

4. CONCLUSIONS

Dietary exposure to fumonisins (FB_1 and FB_T) was estimated for a range of New Zealand age-gender groups. Mean dietary FB_1 exposure was in the range 2.1-30 ng/kg bw/day, with the lowest dietary exposure estimates for young adult males (19-24 years) and the highest for children (5-6 years). High (95th percentile) estimates of dietary FB_1 exposure were in the range 4.8-164 ng/kg bw/day. As FB_1 accounts for approximately 70% of FB_T (JECFA, 2017), FB_T dietary exposures were in the expected range with mean and 95th percentile ranges of 2.6-40 and 5.9-220 ng/kg bw/day, respectively.

Dietary fumonisin exposures for New Zealanders were within the range reported for European countries and well below estimates of dietary exposure in countries where maize is a dietary staple. All mean and high percentile dietary exposures estimated for New Zealand age-gender groups were at or below 11% of the PMTDI.

Dietary exposure to fumonisins in New Zealand is predominantly (>60% of all age-gender groups and for FB_1 and FB_T) due to consumption of maize-based Mexican style foods. Examination of dietary records suggests that the predominance of this food group, as a contributor to dietary fumonisin exposure, is due to consumption of corn chips. Dietary exposure to fumonisins from this group of foods is likely to be over-estimated to some extent, as it was assumed that Mexican style products, such as tortillas, would be exclusively made from maize flour. In reality, these products are sometimes made from wheat flour.

The estimates of chronic high percentile dietary exposure to fumonisins will also be overestimates, as they are based on only a single day of dietary recall. Unfortunately, the nature of the data set (high proportion of zero dietary exposure days) means that statistical methods for adjusting the variability of the dietary exposure distribution could not be applied.

Based on the current estimates, dietary exposure to fumonisins in New Zealand is highly unlikely to be a risk to public health.

REFERENCES

Bergstrom L. (1999) Nutrient losses and gains in the preparation of foods. NLG- Project Rapport 32/94 revised. Uppsala, Sweden: National Food Administration.

Burger HM, Lombard MJ, Shephard GS, Rheeder JR, van der Westhuizen L, Gelderblom WCA. (2010) Dietary fumonisin exposure in a rural population of South Africa. Food and Chemical Toxicology; 48(8–9): 2103-2108.

Cressey P, Thomson B. (2006) Risk Profile: Mycotoxins in the New Zealand food supply. ESR Client Report FW0617. Christchurch: ESR.

Cressey P, Jones S. (2008) Mycotoxin surveillance programme 2007-08. Aflatoxins in maize products. ESR Client Report FW08027. Christchurch: ESR.

Cressey P, Jones S. (2009) Mycotoxin surveillance programme 2008-09. Aflatoxins and ochratoxin A in dried fruits and spices. ESR Client Report FW09042. Christchurch: ESR.

Cressey P, Jones S. (2010) Mycotoxin surveillance programme 2009-2010. Aflatoxins in nuts and nut products. ESR Client Report FW10036. Christchurch: ESR.

Cressey P. (2011) Dietary exposure to aflatoxins: Risk estimates and proportionality of exposure source. ESR Client Report FW11032. Christchurch: ESR.

Cressey P, Jones S. (2011) Mycotoxin Surveillance Programme 2011. Ochratoxin A in cereal products, wine, beer and coffee. ESR Client Report FW11075. Christchurch: ESR.

Cressey P. (2014a) Risk profile: Mycotoxins in the New Zealand food supply. ESR Client Report FW14005. Christchurch: ESR.

Cressey P. (2014b) Dietary exposure to ochratoxin A and trichothecene mycotoxins: Risk estimates and proportionality of exposure source. ESR Client Report FW14019. Christchurch: ESR.

Cressey P, Chappell A, Grounds P. (2014) Mycotoxin Surveillance Programme 2012-2013. Trichothecene mycotoxins in cereal products. ESR Client Report FW14007. Christchurch: ESR.

Cressey P, Chappell A, Ashmore E, Watson S. (2017) Mycotoxin Surveillance Programme 2016-2017: Fumonisins in maize-based products and wine. ESR Client Report FW17044. Christchurch: ESR.

Dodd KW, Guenther PM, Freedman LS, Subar AF, Kipnis V, Midthune D, Tooze JA, Krebs-Smith SM. (2006) Statistical methods for estimating usual intake of nutrients and foods: A review of the theory. Journal of the American Dietetic Association; 106(10): 1640-1650.

Frisvad JC, Smedsgaard J, Samson RA, Larsen TO, Thrane U. (2007) Fumonisin B2 production by *Aspergillus niger*. Journal of Agricultural and Food Chemistry; 55(23): 9727-9732.

Hoffmann K, Boeing H, Dufour A, Volatier JL, Telman J, Virtanen M, Becker W, De Henauw S. (2002) Estimating the distribution of usual dietary intake by short-term measurements. European Journal of Clinical Nutrition; 56(SUPPL. 2): S53-S62.

Holland B, Welch AA, Unwin ID, Buss DH, Paul AA, Southgate DAT. (1991) McCance and Widdowson's The composition of foods. Cambridge: Royal Society of Chemistry.

Hove M, De Boevre M, Lachat C, Jacxsens L, Nyanga LK, De Saeger S. (2016) Occurrence and risk assessment of mycotoxins in subsistence farmed maize from Zimbabwe. Food Control; 69(Supplement C): 36-44.

Hussein HM, Christensen MJ, Baxter M. (2002) Occurrence and distribution of *Fusarium* species in maize fields in New Zealand. Mycopathologia; 156(1): 25-30.

JECFA. (2001) Fumonisins. Safety Evaluation of Certain Food Additives and Contaminants. WHO Food Additive Series 47. Geneva: World Health Organization.

JECFA. (2011) Safety evaluation of certain contaminants in food. Prepared by the seventy-second meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO Food Additive Series 63. Geneva: World Health Organization.

JECFA. (2012) Fumonisin (addendum). Safety evaluation of certain food additives and contaminants. Prepared by the seventy-fourth meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO Food Additive Series 65. Geneva: World Health Organization.

JECFA. (2017) Evaluation of certain contaminants in food. Eighty-third report of the Joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series 1002. Geneva: World Health Organization.

Kimanya ME, De Meulenaer B, Tiisekwa B, Ugullum C, Devlieghere F, Van Camp J, Samapundo S, Kolsteren P. (2009) Fumonisins exposure from freshly harvested and stored maize and its relationship with traditional agronomic practices in Rombo district, Tanzania. Food Additives and Contaminants: Part A; 26(8): 1199-1208.

Matumba L, Sulyok M, Monjerezi M, Biswick T, Krska R. (2015) Fungal metabolites diversity in maize and associated human dietary exposures relate to micro-climatic patterns in Malawi. World Mycotoxin Journal; 8(3): 269-282.

Ministry of Health. (2003) NZ Food NZ Children. Key results of the 2002 National Children's Nutrition Survey. Wellington: Ministry of Health.

Mirocha CJ, Mackintosh CG, Mirza UA, Xie W, Xu Y, Chen J. (1992) Occurrence of fumonisin in forage grass in New Zealand. Applied and Environmental Microbiology; 58(9): 3196-3198.

Mogensen JM, Larsen TO, Nielsen KF. (2010) Widespread occurrence of the mycotoxin fumonisin B2 in wine. Journal of Agricultural and Food Chemistry; 58(8): 4853-4857.

Nusser SM, Carriquiry AL, Dodd KW, Fuller WA. (1996) A semiparametric transformation approach to estimating usual daily intake distributions. Journal of the American Statistical Association; 91(436): 1440-1449.

Pitt JI, Hocking AD. (1997) Fungi and Food Spoilage. London: Blackie Academic and Professional.

Pitt JI, Tomaska L. (2001) Are mycotoxins a health hazard in Australia? 1. Aflatoxins and *Fusarium* toxins. Food Australia; 53(12): 535-539.

Reinivuo H, Bell S, Ovaskainen M-L. (2009) Harmonisation of recipe calculation procedures in European food composition databases. Journal of Food Composition and Analysis; 22(5): 410-413.

Russell DG, Parnell WR, Wilson NC, Faed J, Ferguson E, Herbison P, Horwath C, Nye T, Reid P, Walker R, Wilson B, Tukuitonga C. (1999) NZ Food: NZ People. Wellington: Ministry of Health.

Sayer ST. (1991) *Fusarium* infection in some Waikato maize. New Zealand Journal of Crop and Horticultural Science; 19: 149-155.

Sayer ST, Lauren DR. (1991) *Fusarium* infection in New Zealand grain. New Zealand Journal of Crop and Horticultural Science; 19: 143-148.

Scientific Committee on Food. (2000) Opinion of the scientific Committee on Food on *Fusarium* toxins. Part 1: Fumonisin B1 (FB1). Accessed at: http://ec.europa.eu/food/fs/sc/scf/out73_en.pdf. Accessed: 6 September 2011.

Scott PM. (2012) Recent research on fumonisins: a review. Food Additives and Contaminants: Part A; 29(2): 242-248.

Shephard GS, Marasas WFO, Burger HM, Somdyala NIM, Rheeder JP, Van der Westhuizen L, Gatyeni P, Van Schalkwyk DJ. (2007) Exposure assessment for fumonisins in the former Transkei region of South Africa. Food Additives and Contaminants; 24(6): 621-629.

Shephard GS, van der Westhuizen L, Sewram V, van Zyl J, Rheeder JP. (2011) Occurrence of the C-series fumonisins in maize from the former Transkei region of South Africa. Food Additives and Contaminants: Part A; 28(12): 1712-1716.

Sirot V, Fremy J-M, Leblanc J-C. (2013) Dietary exposure to mycotoxins and health risk assessment in the second French total diet study. Food and Chemical Toxicology; 52(0): 1-11.

Soriano JM, Dragacci S. (2004) Occurrence of fumonisins in foods. Food Research International; 37(10): 985-1000.

Sun G, Wang S, Hu X, Su J, Zhang Y, Xie Y, Zhang H, Tang L, Wang JS. (2011) Co-contamination of aflatoxin B1 and fumonisin B1 in food and human dietary exposure in three areas of China. Food Additives and Contaminants: Part A; 28(4): 461-470.

Torres OA, Palencia E, de Pratdesaba LL, Grajeda R, Fuentes M, Speer MC, Merrill AH, O'Donnell K, Bacon CW, Glenn AE, Riley RT. (2007) Estimated fumonisin exposure in Guatemala is greatest in consumers of lowland maize. Journal of Nutrition; 137(12): 2723-2729.

University of Otago and Ministry of Health. (2011) A focus on nutrition: Key findings of the 2008/09 New Zealand Adult Nutrition Survey. Wellington: Ministry of Health.

WHO. (2000) Fumonisin B1. Environmental Health Criteria 219. Geneva: World Health Organization.

WHO. (2017) GEMS/Food consumption database. Accessed at: http://www.who.int/nutrition/landscape_analysis/nlis_gem_food/en/. Accessed: 14 December 2017.

WHO GEMS/Food-Euro. (1995) Second workshop on Reliable Evaluation of Low-level Contamination of Food, Kulmbach, Federal Republic of Germany, 26-27 March, 1995. EUR/ICP/EHAZ.94.12/WS04. Geneva: World Health Organization.

APPENDIX 1 MEAN FUMONISIN (LOWER-UPPER BOUND) CONCENTRATION VALUES USED IN THE CURRENT STUDY

Food group	Mean FB_1 concentration, µg/kg	
	Lower bound	Upper bound
Fumonisin B_1		
Maize-based breakfast cereals	8.0	9.1
Maize-based Mexican style foods	129	129
Extruded maize flour snacks	34	35
Popcorn	33	33
Maize meal/polenta	283	283
Total Fumonisins		
Maize-based breakfast cereals	9.7	10.8
Maize-based Mexican style foods	178	178
Extruded maize flour snacks	44	44
Popcorn	37	38
Maize meal/polenta	388	388

APPENDIX 2 PROCEDURE FOR DETERMINING THE PROPORTION OF FUMONISIN-CONTAINING FOODS IN RECIPES

Sources of recipes

No single standard source for recipes exists. In the absence of such a resource, the recipes used in a database must be selected based on a pre-determined strategy. While such a strategy may be discussed and even criticised, its existence provides a methodology than can be followed for subsequent additions and can be utilised by other parties. The following sources of recipes have been identified:

- New Zealand Food Composition Database. Contains recipes for 272 foods (in the version of Food Files currently held by ESR). Not all of these are true recipes, as some describe how food descriptors have been combined to produce food composition information for other descriptors. Recipes are expressed as the percentage of the ingredient in the food.
- McCance and Widdowson's The Composition of Foods (this is essentially the British equivalent of the food composition database) contains recipes for 103 foods (Holland *et al.*, 1991). Recipes are expressed in terms of the weight of the ingredients plus an estimate of the weight loss upon cooking, where relevant.
- The National Nutrition Survey (Russell *et al.*, 1999) and National Children's Nutrition Survey (Ministry of Health, 2003) 24-hour dietary recall studies include recipes, where these were provided by respondents. These have already been integrated into our working version of the database, but could be used as a resource to define recipes for situations where recipes were not provided by respondents. Recipes are in the form of the weight of the ingredients.
- Recipes used in conjunction with the USDA Nutrient database for nationwide food surveys 2007 is available on-line[2]. Recipes are expressed as percentages of ingredients in final foods.
- Various cookbooks and internet resources. Express ingredients in terms of weights or standard measures.

Yield Factors

For many recipes, particularly cooked recipes, the final weight of the prepared recipe will be different from the sum of the weights of the (uncooked) ingredients. The ratio of these two weights is often referred to as a yield factor. Weight changes during cooking mainly relate to gains or losses in moisture (Bergstrom, 1999).

Unfortunately, the form of the calculations carried out for food composition purposes is opposite to that required for management of recipes in a food consumption database. Our interest is generally in deconvoluting from a cooked composite food to uncooked ingredients. In this case the sum of the weights of the individual ingredients would be expected to be equal

[2] http://www.nal.usda.gov/fnic/foodcomp/Data/SurveyNDB7/

to or greater than the weight of the composite food. However, different ingredients will differ in their moisture content and would be expected to lose differing amounts of their initial weights during the cooking process.

Utility of yield factor information will depend on the form of other information available. The following scenarios are envisaged:

- Consumed weight of recipe available. Yield factor available. Ingredient composition available in terms of standard measures. Calculate total weight of ingredients from recipe. Calculate total weight of ingredients from consumed weight and yield factor. Scale weight of ingredients to uncooked weight of prepared food.
- Consumed weight of recipe available. Yield factor available. Percentage figures available for recipe ingredients. If percentage refers to uncooked weight, use consumed weight and yield factor to determine uncooked weight then apply percentages. If percentage refers to cooked weight, then composition of uncooked recipe cannot be determined. However, this scenario is unlikely.

Procedure for Application of Recipes in Food Consumption Datasets

The following procedure is largely based on that of Reinivuo *et al.* (2009), although it has been modified to accommodate different formats of information. The two formats encountered are:

- Classical recipes, where the ingredients are listed in terms of weights or measures; and
- Database recipes, where the ingredients are listed in terms of percentages of the finished recipe.

The procedure is:

- Identify recipe from a source listed in the section 'Source of recipes'. Wherever possible, priority should be given to New Zealand sources. However, priority should be given to systematic sources of recipes over *ad hoc* sources (e.g. choose NZ Food Composition Database recipe before internet recipe).
- If recipe is in the form of percentages, apply directly.
- If recipe is in the form of weights and measures, convert all measures (cups, tablespoons, etc.) to weights using standard weights per measure (see 'CSM' file in the most recent version of Foodfiles held at ESR, currently Foodfiles 2006) or standard volumes of measures and density values for the ingredient. Standard volumes are listed in Attachment 1 and densities of food items can be found in the CSM file in Foodfiles.
- Convert weights to percentages.

So, to convert a weight of a final recipe to the weight of its ingredients:

- Take weight of final recipe.
- If recipe is cooked or processed otherwise in a manner that will cause a weight change, apply the inverse of the appropriate yield factor to give the total weight of ingredients. For example, if the final weight is 500 g and yield tables indicate that the recipe loses 9% of its weight through cooking, the weight of the ingredients is 500 x (100/100-9) or 500/0.91. This gives a weight of 549 g.
- Apply percentages determined above to give the weight of ingredients.

Examples

The NNS contains entries for Macaroni cheese (with or without added meat). A common serving size is 506 g. The Food files (New Zealand Food Composition Database) give a percentage recipe for Macaroni cheese:

- Milk, fluid, standard 45
- Macaroni, boiled 36
- Cheese processed 13
- Butter, salted 3
- Flour, wheat, white, standard 3
- Salt 0

European yield tables give a 9% weight loss for macaroni cheese on cooking (Bergstrom, 1999). For a serving of 506 g, the uncooked weight would be 506/0.91 = 556 g. The weight (g) of the uncooked ingredients would be:

- Milk, fluid, standard 250
- Macaroni, boiled 200
- Cheese processed 72
- Butter, salted 17
- Flour, wheat, white, standard 17
- Salt 0

McCance and Widdowson (Holland *et al.*, 1991) gives a recipe for macaroni cheese of:

- 350 ml milk
- 280 g cooked macaroni
- 100 g grated cheese
- 25 g margarine
- 25 g flour
- 0.5 tsp salt

Weight loss is 9.4%. Excluding salt and assuming a density of 1 g/ml for milk, the total weight of ingredients is 780 g, with a cooked weight equivalent of 707 g. For a 506 g serving the scale factor is 506/707 = 0.716. Applying this to the original recipe gives:

- Milk 251
- Cooked macaroni 200
- Grated cheese 72
- Margarine 18
- Flour 18

It appears probably that these two expressions of the recipe for macaroni cheese are from the same primary source.

Using a more challenging source for the recipe (an internet source) of macaroni cheese (ingredients list was truncated for simplicity):

- 2 cups milk
- 2 cups macaroni, cooked

- 2 cups grated cheese
- 2 TB butter
- 2 TB flour

The 'csm' file in Foodfiles contains weights of standard measures for foods in the database. Another useful resource is the USDA measurement conversion tables:

http://www.ars.usda.gov/Aboutus/docs.htm?docid=9617

For this exercise the following are relevant:

- Milk. CSM gives a weight of 15.5 g/tablespoon for standard, fluid milk. USDA gives a conversion of 16 tablespoons per cup. 2 cups = 500 g
- Macaroni. CSM doesn't give the weight of a cup of cooked macaroni, but does give a density 0.596 g/ml. Therefore, 2 cups (500 ml) would be expected to weigh 300 g.
- Cheese. CSM gives the weight of a cup of shredded Gruyere cheese as 119 g. This is similar to using the density of cheddar cheese (0.47 g/ml) and the volume of a standard cup (250 ml). Therefore, 2 cups of grated cheese will weigh approximately 240 g.
- Butter. CSM gives the weight of a tablespoon of salted butter as 15 g. Therefore, 2 tablespoons will weigh 30 g.
- Flour. CSM gives the density of standard white flour as 0.489 g/ml. A tablespoon is approximately 15.5 ml giving a weight for 2 tablespoons of flour of 15 g.

Total weight of this recipe is 1085 g, corresponding to a cooked weight (-9%) of 987 g and a conversion factor for a 506 g serving of 506/987 = 0.513. The recipe weights equating to a 506 g serving, based on this recipe are:

- Milk 257 g
- Macaroni 154 g
- Cheese 123 g
- Butter 15 g
- Flour 8 g

These figures differ from those above, but are generally still recognisable.

APPENDIX 3 MAPPING OF FOODS FOR WHICH FUMONISIN CONCENTRATION INFORMATION WAS AVAILABLE TO NATIONAL NUTRITION SURVEY FOODS

Food group for which fumonisin data are available	NNS foods mapped
Maize-based products	
Maize-based breakfast cereals	All corn flake breakfast cereals and appropriate proportion of breakfast cereals stating the presence of maize/corn
Maize-based Mexican style foods	All corn chips/crisps, taco shells and tortillas. Appropriate proportion of recipes, including burritos, enchiladas, nachos, quesadilla and tacos
Extruded maize flour snacks	Maize-based snacks, such as Burger rings, Cheezels and Munchos
Popcorn	All cinema, packet and homemade popcorn
Maize meal/polenta	All maize/corn flour or meal, polenta. Appropriate proportion of maize/corn crackers, bread and crispbread

APPENDIX 4 CONTRIBUTION OF FOOD GROUPS TO MEAN DIETARY FUMONISIN EXPOSURE

Fumonisin B_1

Age-gender group	Contribution of food groups to estimated dietary exposure (%), based on lower bound – upper bound concentration estimates				
	Maize-based breakfast cereals	Maize-based Mexican style foods	Extruded maize flour snacks	Popcorn	Maize meal/polenta
Child (5-6 years)	1.1 – 1.2	70.0 – 70.4	16.8 – 16.9	11.8 – 11.9	0.0 – 0.0
Female (11-14 years)	0.4 – 0.4	70.5 – 70.8	15.8 – 15.9	13.0 – 13.1	0.0 – 0.0
Male (11-14 years)	0.8 – 0.9	81.7 – 82.0	13.4 – 13.5	3.8 – 3.9	0.0 – 0.0
Male (19-24 years)	5.0 – 5.6	63.2 – 63.6	0.0 – 0.0	5.9 – 5.9	25.2 – 25.5
Female (25+ years)	3.8 – 4.3	65.8 – 66.1	4.1 – 4.1	4.5 – 4.6	21.3 – 21.5
Male (25+ years)	4.9 – 5.5	64.0 – 64.5	8.0 – 8.0	5.0 – 5.0	17.4 – 17.7

Total fumonisins

Age-gender group	Contribution of food groups to estimated dietary exposure (%), based on lower bound – upper bound concentration estimates				
	Maize-based breakfast cereals	Maize-based Mexican style foods	Extruded maize flour snacks	Popcorn	Maize meal/polenta
Child (5-6 years)	1.0 – 1.1	72.6 – 72.8	16.1 – 16.2	10.1 – 10.2	0.0 – 0.0
Female (11-14 years)	0.4 – 0.4	73.1 – 73.3	15.2 – 15.3	11.1 – 11.2	0.0 – 0.0
Male (11-14 years)	0.7 – 0.8	83.3 – 83.4	12.7 – 12.7	3.2 – 3.3	0.0 – 0.0
Male (19-24 years)	4.5 – 5.0	64.5 – 84.8	0.0 – 0.0	4.9 – 5.0	25.6 – 25.8
Female (25+ years)	3.4 – 3.7	67.0 – 67.3	3.9 – 3.9	3.8 – 3.8	21.5 – 21.7
Male (25+ years)	4.4 – 4.9	65.5 – 65.9	7.6 – 7.6	4.2 – 4.2	17.8 – 17.9

E/S/R
Science for Communities

INSTITUTE OF ENVIRONMENTAL
SCIENCE AND RESEARCH LIMITED

Kenepuru Science Centre
34 Kenepuru Drive, Kenepuru, Porirua 5022
PO Box 50348, Porirua 5240
New Zealand
T: +64 4 914 0700 **F:** +64 4 914 0770

Mt Albert Science Centre
120 Mt Albert Road, Sandringham, Auckland 1025
Private Bag 92021, Auckland 1142
New Zealand
T: +64 9 815 3670 **F:** +64 9 849 6046

NCBID – Wallaceville
66 Ward Street, Wallaceville, Upper Hutt 5018
PO Box 40158, Upper Hutt 5140
New Zealand
T: +64 4 529 0600 **F:** +64 4 529 0601

Christchurch Science Centre
27 Creyke Road, Ilam, Christchurch 8041
PO Box 29181, Christchurch 8540
New Zealand
T: +64 3 351 6019 **F:** +64 3 351 0010

www.esr.cri.nz