Shopping Basket Survey Design

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1. Shopping Basket Survey Design

Report of Shopping Basket Survey Design for Food Standards Scotland
Fera Science Ltd.

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Note: Whilst care has been taken to ensure that the web links contained in this report are correct at the time of issue, changes may occur.

2. Contents

Contents

3. Glossary

AFB1	Aflatoxin B1
AMR	Antimicrobial Resistance
ANSES	French Agency for Food, Environmental and Occupational Health & Safety
BfR	German Federal Institute for Risk Assessment
BFR	Brominated Flame Retardants
BN	Bayesian Network
CFIA	Canadian Food Inspection Agency
DALY	Disability adjusted life years
DD	Duplicate Diet
EFSA	European Food Safety Authority
EKE	expert knowledge elicitation
EPA	Environmental Protection Agency's
EPoS	Electronic Point of Sale
EU	European Union
FAO/UN	Food and Agriculture Organization of the United Nations
FBO	Food Business Operator
FCID	EPA's Food Commodity Intake Database
FDA	United Stated Food and Drug Administration
FSA	Food Standards Agency
FSANZ	Food Standards Australia New Zealand
FSS	Food Standards Scotland
FSIS	(United States) Food Safety and Inspection Service
GC-MS	Gas chromatography-Mass spectrometry
ICMSF	International Commission on Microbiological Specifications for Foods
IFST	Institute of Food Science and Technology
IP	Integer Programming
LCF	Living Costs and Food
LOD	Limit of Detection
MB	Market Basket
MCDA	Multi-criteria decision analysis
ML	Machine Learning
MOAH	Mineral oil hydrocarbons (aromatic fraction)
MOE	Margin of Exposure
NDNS	National Diet and Nutrition Survey
NHANES	(US) National Health and Nutrition Examination Survey
NZ	New Zealand
ONS	Office for National Statistics
PBDE	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid

POPs	Persistent organic pollutants
QALY	Quality adjusted life years
QMRA	Quantitative microbiological risk assessment
RPI	Retail Prices Index
RTE	Ready to Eat
SASR	Strategic Assessment of Sampling Resources
SDGs	Scottish Dietary Goals
SHeS	Scottish Health Survey
TDS	Total Diet Study
TTB	Tax and Trade Bureau
UKFSS	United Kingdom Food Surveillance System
USFDA	United States Food and Drug Administration
WHO	World Health Organisation
WWEIA	What We Eat in America

Abstract

The overall aim of this project was to design a large-scale, non-targeted, sampling programme for food surveillance, that would complement existing monitoring activities carried out by FSS and its partners. For a general purpose design across multiple food types, or where samples are collected for multiple purposes, a pragmatic general approach is necessary for the proposed Scottish surveillance program.

In summary:

- A literature review was conducted to review existing international monitoring programmes and risk ranking methods to identify a range of suitable options and to understand their benefits, data requirements and limitations.
- A general strategy was developed to produce a priority list specifying relative sampling effort, by food type, for use within a non-targeted surveillance program. This used elements from existing international food surveillance programs and guidance, but due to the general-purpose requirements we have not assumed any particular hazard or other measured property is more important than another.
- Purchase data for the population of Scotland, (provided by the market research company Kantar) was used in combination with the top 10 hazards reported for each of these food types, where available, from the HorizonScan system. Purchase data was used as these data are readily available, frequently updated, and cover a wide range of products.
- A consequence score 1-5 was assigned to each hazard and food type combination, to indicate insignificant, minor, moderate, major, or severe. A purchase score 1-5 was assigned based on the purchase volume of each food type. Based on the collection of all risk ratings, and the need for a flexible, general purpose approach, a dashboard was generated showing the main priority food group/hazard group combinations for the Scottish market.
- The process can be refined and repeated, to take account of practical constraints until a satisfactory balance between representative coverage and inclusion of important food types is achieved. This solution meets the need for a general purpose surveillance program, while also allowing flexibility and transparency in the criteria for food selection and hazard classification.
- It is recognised that the classification of Kantar market categories and the HorizonScan food categories were designed for different purposes and are not always directly comparable. Assumptions were made and some simplifications introduced. Overall, the impact on the prioritisation is not believed to be significant, but some manual checks on individual items that are included or excluded should be carried out.
- Flexibility is built into the solution to allow for expert input, changing priorities and other considerations such as total budget versus individual measurement costs for individual hazards of most relevance.

- To calculate an optimal sample size for each given hazard type, prior information would also be required about the variation in existing levels, as well as the required accuracy. These data were not available within this project.

A final sampling plan will include detailed instructions for the type of foods to purchase for sampling, using our priority list as the starting point. This should be based on market share with respect to brands, retail outlets and spatial/temporal population purchasing habits for each food type.

4. Executive Summary

4.1 Introduction

Surveillance sampling forms a key part of an effective food safety strategy by providing assurance over the standards of the food supply chain. Alongside enforcement and verification sampling, it generates valuable intelligence, provides proactive assessment of food risks, and links with horizon scanning activities to give an overall indication of safety and authenticity of food on the Scottish market.

The overall aim of this project was to design a large-scale, non-targeted, sampling program for food surveillance, that would complement existing monitoring activities carried out by FSS and its partners. A non-targeted, unbiased, sampling plan is one in which the complete diet is assessed within the whole population focussing on representative foods rather than specific ‘high-risk’ hazards. It will provide a consistent record of overall intakes within the population, and can identify trends over time, including any emerging risks.

Existing international monitoring programs and risk ranking methods were reviewed to identify a range of suitable options and to understand their benefits, data requirements and limitations. The most suitable methods were applied to design a high-level prioritisation and a risk visualisation, incorporating the most relevant data available for the Scottish market and the need for a flexible, general purpose approach.

4.2 General findings from literature review

Surveys designed to cover the total diet for the general population are mainly included as part of total diet studies (TDS). TDS as proposed in the general guidance of EFSA/FAO/WHO (2011) are designed to calculate average population intakes, for each contaminant or nutrient of interest, by collecting the full range of foods consumed and estimating the average daily intake levels. By averaging across multiple individuals, they do not capture the effect of extreme consumption or variations in concentrations. The levels are calculated as consumed, including any processing and cooking effects. A wide range of contaminants or nutrients can be measured. Most of the international TDS have deviated from the general guidance, by adding extra food types and measurements, or specific sub-populations, associated with a high-risk scenario or a particular assessment goal. This is a form of targeted sampling that is often necessary in practice for efficiency when there are many substances to investigate with a limited budget, or to focus on particular sub-populations.

Other market basket studies associated with food are carried out to assess economic effects such as the changing costs of a typical food shop.

In general, the number of food types and samples to collect should be larger where the source of variation is greater. The sample plan should also ensure that regional and temporal variation accurately reflects market conditions. The availability of data to determine the true level of variation within food types is a key limiting constraint. The fact that this variation also differs between target substances further complicates the design process.

Some studies described more detailed bespoke designs or mathematical optimisation routines. These included those which specify sample numbers required, but they are only available for specific risk types and food types. In addition, they are only valid when the optimisation criteria can be clearly stated. Details have been presented for each of the methods reviewed, as these may be useful for related studies. Each solution was designed for a specific purpose, according to the budget and data availability, protection goals or regulatory requirements. However, for a general purpose design across multiple food types, or where samples are collected for multiple purposes, a more pragmatic general approach is necessary for the proposed Scottish surveillance program.

Risk ranking can be applied to diverse hazard types, but methods rely on the specification of the relative levels of severity. These can range from very detailed information about the human health impacts per unit of intake, for example measured in terms of disability adjusted life years (DALYs) through to expert judgments assigned as relative scores to represent severity. DALYs are rarely available across multiple health effects, so the more pragmatic scoring system is more feasible in the case where multiple substance types are involved. A general approach developed by ANSES allows multiple risks to be assessed and visualised after combining hazards and foods into more general groups.

4.3 Proposed strategy for shopping basket survey

The proposed solution combines those aspects of international TDS guidance associated with food selections to achieve a representative coverage of the whole population diet, with aspects from the literature on risk ranking strategies that incorporate multiple hazard types. This solution meets the need for a general purpose surveillance program, while also allowing flexibility and transparency in the criteria for food selection and hazard classification. The key steps are:

- Use purchase data for the whole population of Scotland, as provided by the market research company Kantar. This includes all food and drink purchases at a national level and is designed to be representative. Each food will be sampled in proportion to the corresponding purchased volume, optionally with an adjustment to account for the prevalence of hazards (described below).
- Select all food groups to cover a large proportion of the total purchased volume, check for any important missing groups and add these if required.
- From the HorizonScan system, extract the top 10 hazards reported for each of these food types, where available.

- Assign ‘consequence’ scores 1-5 to each of the hazard and food type combination, to indicate insignificant, minor, moderate, major, or severe. Assign a purchase score 1-5 based on the purchase volume. Using a non-linear scale, we allow those items purchased relatively rarely to be included in the calculation more than they would if we used relative total percentage directly. This prevents the few highly purchased food types from dominating the calculation.
- Assign a risk rating to each combination of food type and hazard according to its position in a risk matrix, quantifying the likelihood of occurrence and its consequence for human health. The likelihood is calculated using a product of the purchase volume score and the hazard occurrence score (from HorizonScan) and mapped onto the categories: almost certain, likely, possible, unlikely, or rare.
- Based on the collection of all risk ratings, generate a dashboard showing the main priority food group/hazard group combinations. The dashboard is a useful tool to identify and check the main assessments to carry out on each of the sampled food types.
- The sampling prioritisation (from step 1) can be adjusted based on the average hazard incidence level per food type, weighted by their individual consequence scores.

The process should be refined and repeated, as required, to take account of practical constraints (see also below) until there is a satisfactory balance between representative coverage and inclusion of important food types.

FSS has been involved in the development of this process, leading to a preliminary prioritisation of food types and hazard combinations, and outcomes have been refined in a workshop. Herbs and spices, honey and infant foods were added after calculating the prioritisation, since these are important for surveillance even though they have low volumes purchased. The main food categories by purchased volume are milk (14%), vegetables (8%), soft drinks (14%), bakery products (7%) and fruit (6%). After risk-based adjustment the respective percentages are 20%, 7%, 8%, 8%, 5%, but also with frozen prepared foods increasing from 4% to 7%. General hazard category groups were chosen as Pesticides, Microbiological, Undeclared allergens, Colours, Food additives, Veterinary drugs, Chemical contaminants, Processing contaminants, Inorganic contaminants, Mycotoxins, Natural or plant toxins, Other contaminants, and Other. Microbiological and other category groups were further subdivided to differentiate between safety and hygiene (microbiological), and other issues that would not require sampling, e.g. notifications based on incorrect paperwork or foreign bodies detected in products. The dashboard highlighted the main hazards overall were microbiological and undeclared allergens. It also shows where the most extreme risks occur for a particular hazard type, such as undeclared allergens in ready-to-eat and snacks, alcoholic drinks, bakery and breakfast goods. For some food types, the alerts are limited to a particular hazard type, e.g. drinks and colours. Others have a wide range of hazards, notably ready-to-eat and snacks.

4.4 Limitations and practical implications

It is recognised that the classification of Kantar market categories and the HorizonScan food categories were designed for different purposes and are not always directly comparable. Assumptions need to be made about the linking of foods, and some simplifications have been introduced. Overall, the impact on the prioritisation is not believed to be significant, but it is important to carry out manual checks on individual items that are included or excluded as a result.

Kantar is based on purchases, rather than consumed amounts, and does not include takeaway items or food consumed out of the home. For surveillance of food in the Scottish marketplace this is not a practical problem, but it is recognised that more accurate risk assessment methods are available and should be applied separately if required.

Grouping of food types and hazard types is based on expert judgement. Assignment of scores associated with food/hazard combinations is also based on expert judgment. It can be difficult to assign a single score to a large group of hazards (e.g. pesticides, allergens) because in reality these vary in their potential effects. Similarly, the scores assigned to purchased amounts influences the calculated adjustment factors and can change the items included in the sample list for rarely purchased items.

The number of reports in HorizonScan includes cases in which duplicated reports are associated with the same incident, rather than being independent occurrences, which may introduce bias. Prevalence for a given hazard type is expressed as the relative percentage of top 10 hazards and is calculated independently within each food type, meaning that those foods with highest total number of reports are considered just as risky as those with fewest reports.

The main determinant of the relative sampling prioritisation remains purchase volumes. These issues linked to hazard severity scores food/hazard grouping should have limited practical effects provided that sensible assumptions are made, including conservative choices where appropriate. However, the inclusion of individual items and their prioritisations should be checked.

The plan gives relative volumes of food and drink categories to sample. This is valid for obtaining information about the general diet. Further refinement of the sampling process should take account of representative purchasing within each food category. Additional data (e.g. on market share) is required to ensure a fully representative survey at the more refined level of individual product type. The detailed sampling approach per food type should use established market survey methodology. Kantar categories include lists of items that may be provided in the instructions to shoppers. In addition, the costs of sampling and testing for individual hazards varies substantially. Budget constraints will need to be considered to determine the relative sample sizes that can be collected per food type. Further statistical assessments should be carried out to quantify uncertainty of estimates. Methodology will depend on the particular type of estimate and on the true distribution of the measured data values.

By using the Kantar purchasing data consistency is maintained between food types. Sampling over time will therefore provide a measure of any changes in the safety and authenticity of products covering a high percentage of those purchased in Scotland.

4.5 Conclusions

A general strategy has been developed to produce a priority list specifying relative sampling effort, by food type, for use within a non-targeted surveillance program. This has taken elements from existing international food surveillance programs and guidance, but due to the general-purpose requirements we have not assumed any particular hazard or other measured property is more important than another.

Flexibility is built into the solution to allow for expert input and changing priorities. Purchasing data is based on Kantar summaries, as these data are readily available, frequently updated, and cover a wide range of products. For each food type, the total purchased volume is linked to the hazard reports in HorizonScan to identify the most prevalent hazards. It is important to check that important items are included in the generated priority list, covering each of the different properties to be assessed, and that the hazard scores are appropriate. Some experimentation with the generated designs and fine-tuning of the scoring system and grouping is recommended before the final survey designs are generated. However, the derived priority lists are primarily based on total purchases within the population. Adjustments based on expert assigned scores for hazard severity resulted in some relatively minor changes, which can lead to efficiency gains. For example, it reduced the number of soft drinks samples, where the expectation of positive tests is lower than some other product types. Overall, the prioritisation will still lead to a high percentage coverage of the total diet and be able to identify emerging risks. The expert scores may be more useful for their impact when visualising, and prioritising, the main types of hazards to test for within each food group, via the dashboard.

Decisions about absolute sample numbers will factor in information about total budget versus individual measurement costs for individual hazards of most relevance. To calculate an optimal sample size for each given hazard type, prior information would also be required about the variation in existing levels, as well as the required accuracy. These data were not available within this project.

A final sampling plan will include detailed instructions for the type of foods to purchase for sampling, using our priority list as the starting point. This should be based on market share with respect to brands, retail outlets and spatial/temporal population purchasing habits for each food type.

5. Introduction

5.1 Background to the study

The purpose of this project is to develop options for designing a large scale, non-targeted food surveillance sampling programme which will subsequently be commissioned by Food Standards Scotland (FSS). This programme will be referred to as a ‘shopping basket’ within this report.

Surveillance sampling forms a key part of an effective food safety strategy by providing assurance over the standards of our food supply chain. Surveillance sampling typically is not used for enforcement, but alongside enforcement and verification sampling, it generates valuable intelligence, provides proactive assessment of food risks, links with horizon scanning activities and gives an overall indication of safety and authenticity of food on the Scottish market.

A paper was presented at the FSS Board meeting in March 2022, that outlined the background and the need for a new food surveillance sampling strategy for Scotland. This set out the proposal for a rigorous, well-structured scientifically based programme that would generate comprehensive good quality data on food safety and standards and help provide oversight of emerging or new risks to consumers of the Scottish food chain (FSS, 2022).

The shopping basket survey is a new approach for FSS that will form part of the overall surveillance programme and is intended to contribute to the FSS goals set out in the five-year strategy of ensuring safe and authentic food, healthier diets and making FSS trusted and influential (FSS, 2021).

5.2 Aims and Objectives of the Study

The specific aims of the shopping basket, are to:

a) Provide assurance to the consumer that the food they purchase is safe and authentic.

b) Gather data on a range of commodities that will form a link with risk assessments, horizon scanning and the other surveillance sampling, that can inform policy and regulation.

To achieve these aims, the shopping basket survey should sample a broad range of foods to maximise the percentage coverage of the diet of the general population and analyse them for a wide variety of hazards and for nutritional content. This will provide FSS with good oversight of food safety and standards in Scotland and will create opportunities to detect previously unknown or emerging issues in a pro-active manner.

Designing a sampling plan that will be able to meet these needs is a complex process with a number of factors to consider in deciding where, when, why and what food commodities should be sampled, and which hazards they should be tested for. The purpose of this project is to explore these questions and deliver a sampling and testing framework for FSS that will ensure the subsequent shopping basket survey is as robust and informative as possible. It should be borne in mind that a single scheme is not appropriate for all needs, and any general plan should have the capacity to be tailored for specific requirements. The output of the project is expected to comprise three components:

1. A review of possible approaches with international examples.

2. The design of a framework for selecting commodities and analyses suitable for the shopping basket survey.

3. A collaboration with FSS to develop an implementation plan that would address FSS requirements with the resources available.

This report summarises the findings of the review of possible approaches.

5.3 Definitions of Terms

Sampling: A term used to describe the activities involved in the selection and collection of food items defined in terms of number, weight and nature of the material to be analysed.

Sample: A portion of material selected from a larger quantity of material.

Monitoring: A general term that refers to the systematic, continual, and active or passive observation of persons, places, things, or processes - one type of control of any programme, it is to observe / note the day-to-day activities. Monitoring of the food supply is useful for making dietary intake calculations / population exposure estimates.

Surveillance: Targeted monitoring of activities by officials for specific evidence of wrongdoing. Collection of data for action - mostly to detect a problem. When there is a breakdown in control, action can be taken. Risk based surveillance targets areas where problems are more likely and can be cost effective.

Targeted sampling: Samples taken in response to a particular risk scenario, such as a specific product type from a specific location e.g. when a ‘hot spot’ or breakdown of control has been identified. This is used in response to incidents but has the disadvantage that results from targeted sampling may not be suitable for population exposure estimates.

Risk based sampling: This is a cost-effective method where weighting is given based on risk e.g. to food business operators (FBOs) with poor quality systems, where climate / weather may increase risk of certain contaminants such as mycotoxins, or may increase prevalence of certain pests resulting in increased application of pesticides etc. This method may result in a ‘skewed’ average picture but is more likely to identify problems.

Further definitions can be found in Greenfield and Southgate (2003).

5.4 General Description of sampling requirements

Sampling is a key part of any food control system but can be carried out in a number of ways depending on the questions that the process is trying to address. A different scheme is needed to obtain samples in order to estimate dietary exposure compared to a scheme that is designed to identify new and emerging risks, or one that is designed to monitor regulatory compliance of food business operators. Some of these schemes, together with their benefits and disadvantages are outlined in Annex A.

The primary objectives in sampling, are to collect food samples that are representative, and then to ensure that changes in composition do not take place between collection and analysis. A sample should always be taken to represent the composition of the wider lot of commodity that it is taken from. Combined protocols for sampling and analysis should ensure that the representative attributes are maintained in the portions taken for analysis.

Samples are usually collected with the intention of conducting some kind of laboratory analysis. How that sample informs the larger food supply depends on both the quality and the intent of the sampling scheme. For use in estimation of human intake, sampling should be designed to take account of many factors such as the proportion of each food that is imported, and variation in the food quality among different countries of origin.

Sampling to assess compliance with limits, whether statutory or “guidelines”, may not be appropriate for estimating average human intakes. For example, compliance monitoring may focus on domestic food production and exclude imports or aim for broad geographical coverage without weighting by food production statistics to focus more on those regions where most of the food of a given type is produced. Any indication of localised contamination usually leads to more intensive sampling; small but significantly contaminated locations may make a disproportionately large contribution to “average” concentrations. For most foodstuffs, achievement of a representative result inescapably necessitates coverage of a large number of samples.

Seasonal variation, for example, may occur when supplies available to the consumer vary at different times of year, or when favoured food imports are prevalent at only certain times, or if food has been stored for longer periods to supply markets during out of season times. Regional variation, on the other hand, refers to local food production affected by differences in climate or by local pollution sources or urbanisation.

Food prepared (“take-away” meals) or eaten outside the home (in restaurants, for example) also needs to be considered to give a complete picture (however, this is outside the scope of this study).

6. Methodology

6.1 Literature review

A peer-reviewed literature search was undertaken using the online database Web of Science to identify key scientific literature. A second search of the online database Google Scholar search was also undertaken to help identify further grey literature. All searches were limited to the English language.

All references from both Web of Science and Google Scholar were collated in a reference manager program (EndNote) and filtered to ensure relevance to the project goals. Finally, Google searches were also carried out to identify target government-funded work and sampling programmes as well as publications by relevant networks in this area.

Criteria for including/excluding papers were established and recorded, together with all search terms, Boolean operators etc. in order to create a transparent record of the findings. The title of each manuscript was considered and if relevant the abstract was read. The papers were then ranked 1-5 according to their relevance and the most relevant papers were read in their entirety. There is a lot of existing Total Diet Study (TDS) guidance, National Diet and Nutrition Survey (NDNS) descriptions available already on-line and these were also reviewed to assess if there truly is consensus on best practice.

6.2 Literature review search terms

The search spanned 01.01.1990 – 10.11.22 and was limited to the English language and Web of Science. The following search terms (and variations thereof) were used:

Sampling study design;

Chemical contaminant risk; emerging contaminant*; food safety;

Food survey; Shopping basket survey;

Sampling Food* hazard*;

Food authentic*

Market basket food sampl*

Market basket design AND food

6.3 Grey literature and internet search

A second search of the online database Google Scholar search was carried out to separately identify scientific review articles and also grey literature. All references from both Web of Science and Google Scholar were collated in a reference manager program (EndNote20). These were sorted to remove duplicates and then filtered to remove items that were not relevant to the project goals.

Finally, Google searches were also carried out to target government-funded work, international standards work by global organisations e.g. the FAO/UN and publications or website published by relevant networks in this area. These searches were informed following intelligence and information generated by the initial literature searches described above.

6.4 Other information sources

In addition to the information retrieved from searches relevant information and data were provided by FSS. This included information on a consumer recall study, Pilot of Intake24 in the Scottish Health Survey carried out recently by Newcastle University (ScotCen, 2022), and data on consumer purchase patterns from Kantar (Kantar, 2021), as well as a Review of National Food Control plans in Australia, Canada, New Zealand and United States (Food Standards Agency, 2021a).

6.5 Treatment and collation of information retrieved from searches

Once collated the evidence was reviewed by scientists with experience in sampling and analysis and a statistician with experience in risk analysis and exposure assessment (Akhandaf et al, 2014; Akhandaf et al, 2015). The information from the evidence found was summarised in a spreadsheet, the benefits and drawbacks and predicted information from each study design was tabulated. This allowed the information to be distilled down into a manageable format and the evidence and findings to be summarised.

The description of the various approaches included the following details where possible, along with any other relevant information deemed:

a) What aspects were taken into account in designing the approach, whether it is a theoretical proposal or an international example.

b) An overview of the samples collected, i.e. number of samples, what foods, where from (e.g. from retailer or manufacturers) and with what geographic and seasonal spread.

c) What analyses were performed on the samples and for what purpose.

d) What time scales the overall projects operate with respect to sampling, analysis, reporting and time intervals before a new programme cycle.

e) Comments on the quality of the datasets produced and how they are utilised.

When evaluating the approaches and discussing the benefits and drawbacks, the following aspects were considered:

i) The dietary coverage achieved by the surveyed foods and any notable gaps (i.e., what percentage of the food commodities consumed in a ‘typical’ diet are included, what percentage of the foods that make up the population’s intake are included, or a similar metric if available).

ii) The range of hazards that the analyses are capable of detecting, to what extent the chosen analyses are based on risk or other factors, and any notable gaps.

iii) The quality of the dataset, including how meaningful the interpretation of results is and how the data could be used to inform other regulatory activities.

iv) How applicable the approach is to the stated aims of the FSS shopping basket approach.

This comprehensive evidence review and evaluation of the information was used to gain an understanding of the range of approaches that could be implemented by FSS in the shopping basket survey. This analysis including an assessment of the benefits and drawbacks of each, was crucial in determining the next steps in Part 2 ‘Designing the sampling and analysis framework’.

The main output from Part 1 of the project is this report. This also introduces how this evidence was used to inform Part 2 of the project. The evidence and benefits and drawbacks contained within this report were discussed prior to moving on to Part 2 (Sections 9 and 10).

7. Results and Discussion

7.1 Results of literature searches

Initial searches using the key words listed returned large numbers of hits, and the search terms were modified in an iterative process to refine the items that were found. An initial search using the term "basket'' returned huge numbers of hits. However initial review of these found a high proportion were irrelevant and mostly related to cost of living or economic analysis and were therefore not relevant to this study.

For example, using the search strings "market basket" OR "design" AND "safety" OR "sampl*" returned 353,096 results.

The search string "market basket" AND "design" AND "safety" OR "sampl*" returned 346,882 results.

Conversely the search string "market basket" AND "design" AND "safety" AND "sampl*" returned 0 results.

Similarly searches using the terms "market basket design" AND "safety", "Market basket study design" AND "safety", and "market basket design" AND "food" all returned 0 results.

After refining the terms, the searches returned 510 items. These were screened first to remove duplicates and then each item was further screened to assess relevance to the project goals. After screening 207 items remained and these were further reviewed by accessing the abstract and full copies of the documents. Key documents were summarised in a spreadsheet. A Google search was also carried out to screen for government-funded work and publications by relevant networks in this area and these were recorded. After review of the results there were 59 documents or references listed that had relevance to this study. These are included in Annex C.

7.2 Evaluation of literature search results

7.2.1 Overall summary of relevant results and sampling schemes

A spreadsheet (Excel) was used to summarise the information from the relevant information sources. The main items of interest were summarised, examples of TDS studies from different countries were listed and references to papers reporting results of survey data obtained from TDS surveys were also recorded. The main items of interest were a mixture of reports of national or regional sampling programmes, or publications reviewing or reporting results from these, as well as information about how to define food group classifications (Annex C).

As a general first step several different approaches to sampling food were summarised in a comparison table (Annex A). A brief description of each type of sampling scheme and a summary of the pros and cons of each are listed.

7.3 Total Diet Studies

The most common approach used to calculate dietary estimates was some form of TDS. A TDS can be used for screening purposes or as a more refined exposure assessment tool. It provides background concentration and exposure levels of chemical substances in a range of representative foods prepared for consumption, while monitoring and surveillance programs can better capture highly contaminated individual food items.
There are two distinct approaches: TDS for screening or TDS for refined dietary exposure assessment. More detailed description and discussion about TDS is given in Section 8 below.

There is a lot of existing TDS guidance available already on-line, including guidance to attempt to standardise protocols (EFSA/WHO 2011, Akhandaf, 2014). In most cases the approach to decide which foods to include was similar and was taken from consumption data, either from interviews / recall, or from purchasing statistics or a combination of both. However, there were broad differences between the number of food items included, the number of food categories defined and the % coverage of food they represented.

Guidance from EFSA/FAO/WHO (2011) concluded that “a TDS can be an excellent complement to existing food monitoring and surveillance activities, or it can also be a stand-alone screening tool as a starting point for further analyses. Harmonising the TDS methodology will enhance the value of these programs by improving the comparability at international level”. EU project TDS Exposure (FP7 Grant agreement ID: 289108) standardised methods for food sampling, analysis, exposure assessment calculations and modelling, priority foods, and selection of chemical contaminants (Cordis, 2016). In the process, a variety of approaches and methods for sampling and analysis were assessed and best practice defined. Contaminants and foods that contribute most to total exposure in Europe were also established.
However, despite this there seems to be a large disparity between published TDS studies. Examples of these studies showing the variation between the amount of diet covered are given in Annex B. The amount of diet covered ranged from 24-100%. The 24% was for a study targeted specifically at one class of contaminant known to occur in animal products and fatty foods (PBDEs), so all other foods were specifically excluded. The study with 100% coverage was for young infants from birth who were exclusively fed infant formula and then weaned on retail infant foods. These extremes of dietary coverage occur under very specific circumstances, e.g., targeting of particular foods or sub-populations. When aiming for a more general sample that is representative of the whole diet of a population the target percentage should be around 90%.
EFSA/FAO/WHO (2011) also recommended that future work included a harmonised approach for classifying foods and a common format for data interchange (meta-data). This does not seem to have occurred to any great extent given the varying number of foods and descriptions observed in the studies included in Annex B.

The majority of publications were reports of analytical monitoring of TDS samples for mainly environmental contaminants, e.g., dioxins, heavy metals and radioactivity. Many TDS studies are used for calculating population nutritional information.

Many publications and documents referred to a ‘market basket’ or ‘shopping basket’ in the reporting of monitoring data, but in most cases this term was a substitute for some form of TDS study, as the description of how the market basket was designed was similar to that of a TDS. These ‘shopping basket’ studies can either be targeted, meaning they are based on knowledge relating to potential risks and non-conformances that may be associated with particular products, or unbiased, with sampling designed to cover the full range of foods that most commonly feature in the diet of the population. Some examples found from the literature search are given below.

7.4 Examples of TDS

Total Diet Studies (TDS) are undertaken in a number of countries, and different approaches are applied to the design of sampling methods. Recent examples of these sampling programmes are the BfRMeal project in Germany (BfRMeal, 2019) and studies conducted in France (ANSES, 2019a) and the Netherlands (Sprong et al 2015; Pustjens et al, 2021). These studies are conducted in different ways, the French and Netherlands examples also targeted studies directly at food for children and infants as well as the general population (Sprong et al, 2015; Pustjens et al, 2021; ANSES, 2018).

We refer to targeted and non-targeted TDS studies to highlight these differences and introduce these in sections 7.4.1 and 7.4.2 respectively. International examples from individual countries are then summarised in 7.4.3-7.4.9.

7.4.1 Targeted TDS

The targeted TDS approach provides information on the occurrence of established or suspected issues and can be designed to target specific contaminant groups or to target specific sub-populations.

Examples of these are the mycotoxin studies carried out in the Netherlands (Sprong et al, 2015; Lopez et al, 2016 and Sprong et al, 2016), or the study in Hong Kong that analysed a subset of collected TDS samples for polybrominated diphenyl ethers (PBDEs) (Chen et al, 2013). The studies from the Netherlands were further targeted by focussing on specific subpopulations, in this case infants and young children (Pustjens et al, 2021).

Some studies, e.g., iTDS in France (ANSES, 2018) were designed from the outset to calculate exposure intake assessments for specific target subpopulations, and samples collected were foods for this target population, infants and young children.

In other cases, samples are collected based on overall consumption. Depending on the detail of the food intake estimates, intakes can be calculated for different groups that may be important, e.g., specific age groups (infants, elderly), lactating women, vegetarians, those on restricted diets for religious or medical purposes by using the same set of analytical data and food consumption figures specific to each age/sex group (Dabeka and Cao, 2013).

7.4.2 Non-targeted TDS

The second (non-targeted) TDS approach has greater potential to pick up previously unknown risks and would provide more realistic data on foods associated with the typical diet. This approach has the potential to detect previously unknown or emerging issues pro-actively and provide an overall picture of the safety and standards of foods in the form they are presented to the consumer.

There was very little evidence of TDS or market basket studies being used in this non-targeted way, they all seemed to have some kind of targeted approach. Some focussed on a particular compound or class of compounds (e.g., metals, Avegliano et al, 2008) while others, such as the programme in Sweden carried out a broader range of analyses including both nutritional composition and chemical analysis (Livsmedelsverkets, 2017).

The standard TDS approach was designed to be non-targeted and to represent the average diet of the whole population. However, adaptations have been made to tailor the studies to individual cases. In the subsections below we list examples of TDS from individual countries. These include a mix of targeted and non-targeted TDS studies.

7.4.3 Australian TDS

Consumption data from the Australian National Nutrition Survey is used to design the food lists of the Australian TDS (FSANZ, 2022), carried out every two years, to reflect current consumption habits. It includes around 100 different food types. As with TDS from other countries, the selection was based on a combination of representative items and items believed to contain the contaminants of interest. Regional variation was accounted for, for those foods in which regional variation was expected.

7.4.4 Canadian TDS

The Canadian TDS (Health Canada, 2022) is conducted annually or to some other pre-determined cycle and follows the WHO guidance on TDS (ESFA/FAO/WHO, 2011). Food lists are designed to reflect the most commonly consumed foods in Canada.

7.4.5 New Zealand TDS

The New Zealand TDS looks at a range of foods consumed in a typical diet, with around 130 foods that make up 90% of the population’s intake (NZ MPI, 2022). Foods are selected based on information from the New Zealand National Nutrition Surveys, plus a small number of foods that are known to contain contaminants. Regional foods are given special treatment as in the Australian TDS.

7.4.6 USA TDS

The US FDA changed its TDS sampling plan to be more representative and to capture regional variations more accurately for foods with nutrients or contaminants likely to vary by region or time of year (US FDA, 2022). This indicates that the survey design is not totally representative, because it suggests particular focus on specific foods, i.e., those believed to be associated with the nutrient(s)/contaminant(s) of interest.

USA TDS sampling cycle lasts 2 years. The food list is periodically updated to ensure it includes highly consumed foods. 6 US regions represent all 50 states. For national foods, the aim is to include products covering 50% market share (per product). It is not clear whether a particular percentage of the total diet was targeted in designing the food lists. Data sources mentioned are: What We Eat in America (WWEIA), the dietary interview portion of the U.S. Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey (NHANES) and the consumption of food ingredients from the Environmental Protection Agency's (EPA's) Food Commodity Intake Database (FCID).

7.4.7 BfRMeal study – Germany

The BfRMeal press release in 2019 claimed the TDS for Germany was "the most comprehensive TDS worldwide". It aimed to analyse 60,000 food items for just under 300 substances over 7 years, at a cost of around €13 million (BfRMeal, 2019).

The value of BfRMeal study as a complement to national monitoring for dietary exposure is presented by Kolbaum et al, (2022). The paper sets out the characteristics of both programmes and explains how they have complementary features. First, substances analysed are partly different, although there is some overlap. However, some analytes are included in one programme but not the other. The comparison shows that the BfRMeal study can provide comprehensive additional data for substances and foods not analysed in the National Monitoring programme. For example, data on calcium, potassium phosphorous have been published (Schwerbel et al, 2022). This analysis would not be included in the National Monitoring Plan. The different study designs of the programmes regarding variability, representativeness, food processing (preparing TDS samples as consumed) and in certain cases analytical sensitivity, mean the data from both programmes are appropriate for different questions for exposure assessment. Appropriate selection or combination of the data sets will best inform future risk assessments and contribute to improved consumer safety.

7.4.8 French TDS - ANSES

Another example of a broader non-targeted scheme is the French national TDS run by ANSES. This has increased the number of substances tested for over the years of the study to cover 445 substances of interest in its TDS2 (ANSES, 2019a).

A further development was to target the infant food market, in which 670 substances were analysed allowing dietary exposure to be assessed for over 500 substances and risk assessment for 400 substances (ANSES, 2018). It should be noted that the iTDS is a targeted TDS as it focussed on a particular population.

The programme of work took more than 6 years to complete, and 200,000 analytical results were produced, so was a huge undertaking in terms of time and resource. Four reports are available, (ANSES report - Infant TDS Volume 2 Parts 1-4, iTDS). Part one describes the overall methods, limitations etc., then Parts 2-4 cover inorganic compounds, organic compounds and pesticide residues (ANSES, 2018).

7.4.9 Swedish Market basket

The Swedish Market basket study calculates exposure per capita and so considers the whole population (Livsmedelsverkets, 2017), so was initially non-targeted in design. However more recently they have also considered subpopulations such as adolescents and designed a national dietary survey that collected an array of data on dietary intake, physical activity, body measurements and biological samples from a subset of participants (Moraeus et al, 2018).

7.5 Microbiological Sampling

Microbiological sampling requires different considerations to sampling for chemical testing. Codex and FAO have published many guides that provide guidance, support and frameworks to allow risk-based food inspection and sampling, e.g., FAO (2008).

A summary of sampling plans is given in the IFST Handbook of Microbiological Criteria for Foods (IFST, 2020). The section on sampling describes sampling terms and the choice of sampling plan. The choice of sampling for microorganisms, should consider:

- The risk to public health associated with the hazard
- The susceptibility of the target consumer groups(s)
- The heterogeneity of distribution of microorganisms, including the physical state of the food
- The randomness of the sampling
- The acceptable quality level
- The likely prevalence of the hazard in materials and the desired statistical probability of accepting or rejecting a non-conforming lot
- Cost benefit of the plan and its purpose

The sampling plan structures for two-class and three-class sample plans are described IFST (2020) and in the Microorganisms in Foods 7 Microbiological Testing in Food Safety Management (ICMSF, 2018). The most commonly used sampling plans in industry are two-class and three- class attribute plans.

7.5.1 Two-class attribute sampling plan

A 2-class sampling plan provides a simple means of inspection where results are either satisfactory or unsatisfactory. The sampling plan is defined by the three values, n, m and c:

- n - The value of n defines the sample size in terms of the number of items analysed;
- m - is the maximum acceptable level of the target organism (or toxin);
- c - denotes the maximum number of items allowed to exceed m.

For a given value of c, the probability of rejection using the plan will increase as n increases as there is a greater chance of detecting the target organism when larger samples are examined (e.g. 50g or 100g rather than 25g). The probability of detecting non-conformance also increases as the number of items or sample units increases.

Generally, 2-class plans are applied to presence/absence determinations. An example of this type of plan can be found in Commission Regulation (EC) 2073/2005 on microbiological criteria for foodstuffs (Figure 1). In this sampling plan Salmonella must be absent (not detected) in 30 x 25g samples tested; i.e. n=30, m=0 and c=0.

Figure 1. Example of a 2-class sampling plan (Commission Regulation (EC) 2073/2005)

Food category	Micro-organisms/their toxins, metabolites	Sampling plan (1)		Limits (2)	
		n	c	Vm	M
1.22 Dried infant formulae and dried dietary foods for special medical purposes intended for infants below six months of age	*Salmonella*	30	0	Absence in 25 g	

The IFST Handbook presents the probability of accepting a batch containing specific % levels of defective product, reproduced here as
Table 1.

Table 1. Probability (expressed as percentages) of accepting a batch with a given % of true defective samples in the batch, depending on the number of samples tested. Taken from the IFST handbook (IFST, 2020).

Number of sample units examined	**Probability of Acceptance of a Defective Batch**			
	Actual % of defective samples			
	10%	**20%**	**30%**	**40%**
3	73	51	34	22
5	59	33	17	8
10	35	11	3	1
20	12	1	<0.5	<0.5

The values in the table are % probability of accepting a batch containing 10-40% positives (defective product). This information is often calculated and presented in ‘Operating Characteristic’ (OC) curves which visualise the probability of accepting or rejecting batches in relation to the amount of defective product in the batch. An example is given below (from Dahms, 2004). These OC curves are used in chemical sampling (e.g., mycotoxins) as well as for microbiological sampling. Figure 2 shows how increasing the number of items tested (n) changes the curve, leading to better assurance that lots with a high proportion of defective items will be rejected.

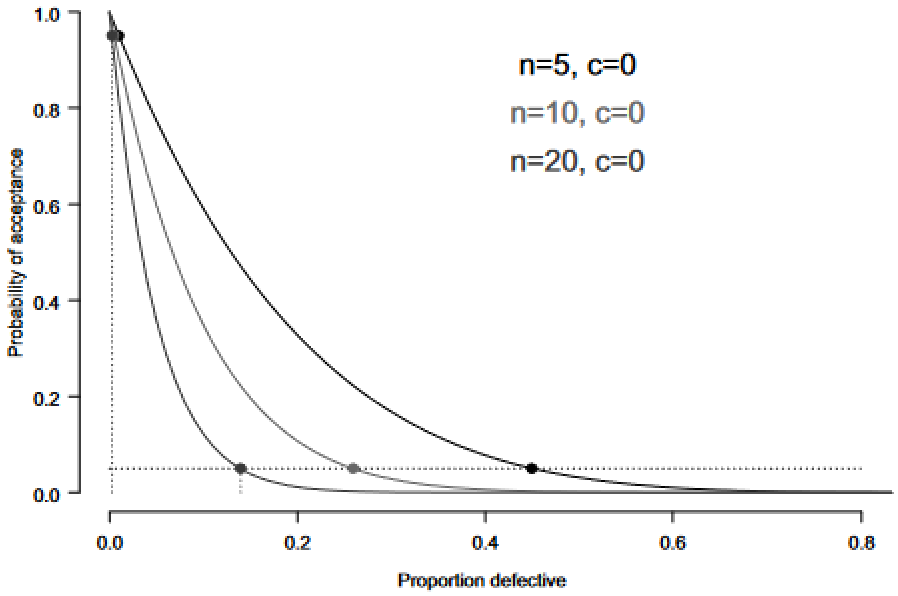


Figure 2. OC-curves for two-class sampling plans, showing the effect of varying the number of sample units (Dahms, 2004).

7.5.2 Three-class attribute sampling plan

In a 3-class attribute sampling plan results can be satisfactory, acceptable or unsatisfactory. The sampling plan is defined by the values, n, m, M and c:

- n - number of items analysed;
- m – maximum level of target organism acceptable under conditions of good manufacturing practice;
- M - is the level of the target organism (or toxin), which if exceeded, is considered unacceptable (defective);
- c - the maximum number of items that can fall between m and M without the batch being considered unacceptable.

Levels between m and M are sometimes referred to as marginally acceptable. In industry 3-class sampling plans are applied when using enumeration tests.
To decide if a 2-class or 3-clas sampling plan should be used, consideration must be made whether any positives can be allowed in the sample items. If the answer is no, then a 2-class plan should be used, with c = 0. If the answer is yes, then a 2-class or 3-class plan can be applied, and if the number of microorganisms in an item or mass can be measured, a three-class plan is recommended. Three-class plans may be more suitable to accept several sample items or units with results in the marginally acceptable range, and they are more useful for trend analysis.

The ICMSF website provides software tools to support design of sampling plans (ICMSF, 2023). There is a standard program Version 10. This calculates probabilities of acceptance for materials with different microbial loads and population standard deviations. The microbes are assumed to be lognormally distributed. This new version 10 (November 2020) includes several tabs and includes 2-class and 3 class sampling plans. An application of its use on Listeria approaches is given in Farber et al (2021). There is also a spreadsheet to explore the ICMSF Food Safety Objective (FSO) equation to determine the per cent compliance of products from processes that are affected by variability. This is described in detail in the publication by Zwietering et al (2010).

7.6 Key relevant findings from selected articles – Sampling design

7.6.1 Review of national food control plans in Australia, Canada, New Zealand and United States.' Issue 10: FS430629 (December 2021)

Campden BRI was commissioned by the Food Standards Agency (2021a) (FSA) to complete a desk study reviewing and comparing the sampling systems of four countries of interest – Australia, Canada, New Zealand, and the United States. Whilst the FSA distinguishes three main types of sampling: (i) for official controls; (ii) as a means of testing hypotheses; and (iii) as a source of intelligence data gathering, it was found that the other authorities do not necessarily do the same. These differences result in a challenge when comparing sampling systems in the four regimes.

It was reported that planning of various sampling activities was easier where the oversight of the entire food chain from farm to fork, including animal feed and biosecurity, as in Canada and New Zealand is predominantly in the hands of a single regulatory authority.

A number of programmes were identified where regulated businesses are required to share sampling and testing data with the authorities. In Canada, such information feeds into Establishment-based Risk Assessment models, which then use the cumulative data to calculate the level of risk associated with a specific establishment and determine the level of oversight that it will receive.

As all four countries are major exporters of agri-food products, exporting establishments are subject to additional oversight, including mandatory participation in dedicated sampling and testing programmes, including for microbiological hazards and chemical residues. The research revealed that in terms of imports, Australia and New Zealand classify imported foods based on risk to consumers and public health associated with the food, and foods with higher associated risks are subjected to a significantly higher level of scrutiny. For instance, “risk food” imported into Australia is initially inspected and tested at a rate of 100% of consignments. The rate later drops to 25% or even 5%, meanwhile “surveillance food” is inspected and potentially tested at a rate of 5% at random. In New Zealand, imported foods presenting a greater risk to consumers and public health known as “High Regulatory Interest Food” and “Increased Regulatory Interest Food” require a food safety clearance, are monitored for specific hazards, and may need to be sampled and tested.

The CFIA in Canada is gradually adopting a risk-based approach, where product inspection and sampling is conducted primarily through the ongoing compliance verification of the importer’s Preventive Control Plan. Also, the CFIA aims to develop a dedicated Establishment-based Risk Assessment model for importers to automatically determine the frequency of inspection and sampling needed.

In the United States, all shipments of FDA- and Tax and Trade Bureau (TTB)-regulated products must be notified to the FDA and therefore are electronically screened. Risky products or entries that are incomplete or contain inaccurate data are flagged. Properly notified shipments of lower-risk product are most likely to be allowed to enter without further FDA review. At the same time, all imported Food Safety and Inspection Service (FSIS)-regulated products are subject to reinspection to verify the equivalence of inspection systems in exporting countries. One or more types of inspection are conducted on every lot of product before it enters the United States.

Considering inherent differences in the regulatory systems as well as other aspects such as market size, products on the market, or share of imports/exports, a comparison of the numbers of samples taken by authorities for various purposes was considered subjective. Where specific sample sizes are expressed, it relates to targeted sampling in which one or more commodities and contaminants have been identified as priorities. Using statistical arguments, it is then possible to set a minimum threshold, e.g. 1600 samples/commodity to have high probability of detecting a 1% prevalence, or 300 samples to provide 95% confidence of detecting a 1% incidence in raw milk (NZ). There were challenges in having a comprehensive view of sampling activities due to the fact that not all documents are in the public domain.

The enforcement agencies may also publish reports on some past activities with a significant delay. The level of information on sampling activities was particularly inconsistent in the United States. Authorities in all four countries reviewed periodically conduct nationwide total diet surveys to assess consumers' exposure to certain food safety risks but certain differences in the organisation of such studies were highlighted. These include whether it is an ongoing programme or taking place every 2 or even 5 years, how many kinds of foods and beverages are collected, and which parameters are being tested.

Although any industry intelligence sampling systems in use that would be similar to Food Industry Intelligence Network (a UK industry members network for sharing data relating to raw material or ingredient testing, including both analytical and/ or supply chain traceability) were not identified in the four countries, several examples were found of how authorities leverage the industry sampling and testing data. In certain cases, such sampling, testing and data sharing with the relevant authorities is mandated, in certain others, sharing of own sampling and testing data is only encouraged.

Ongoing efforts by FSIS and the CFIA to review their sampling activities were noted. A strategic review of sampling resources at FSIS has been published, it reported nine main findings and made recommendations to address them. The underlying premise guiding the Strategic Assessment of Sampling Resources (SASR) workgroup through the evaluation was that FSIS sampling only fulfils its purpose when the data it generates is used by the Agency. Relying on that guiding principle, the SASR workgroup developed a framework to assess whether data generated under each of the Agency's sampling projects are analysed, and if the results of those analyses are factored into the Agency's decision-making. It developed a multiphase approach, and the report details results from Phases 1-5. It is expected to yield a semi-quantitative method to rank current and future sampling projects (Phase 6).

Overall, this publication demonstrated the extreme complexity of planning and operating food control plans, and that there is no 'one size fits all'. Lots of information was presented in the report demonstrating the diverse nature of sampling plans and what they are used for. It was noted that there was different organisation of sampling programmes between Responsible Authorities and where one authority has oversight of entire food chain (Canada & NZ) this seemed to facilitate planning of sampling activities. Other interesting take home messages were the lack of common terminology and approaches, even between organisations within one country. There was also significant variation of operational activities within and between countries, for some all activities were undertaken by government while some used third parties for some activities. Finally, in some cases FBOs are required to take samples and submit data to authorities.

7.6.2 Methods for designing risk-based monitoring programs, including mathematical approaches

Official food safety monitoring has been moving towards risk-based approaches to improve efficiency and minimise the burden on businesses, partly in response to the Official Controls Regulation (EU) 2017/625 (EU Commission, 2017). However, there are still currently predefined statutory sampling regimes in place in some instances such as veterinary medicines and pesticides residue testing. Products imported, particularly those of animal origin are deemed to be higher risk and undergo higher levels of checks (EU, 2023). In addition, high risk foods of non-animal origin are also subject to checks, the products included for testing and the frequency of these checks is updated every six months within the EU. The Retained EU Regulation Commission Implementing Regulation (EU) 2019/1793 of 22 October 2019 contains Annex II ‘Food and feed from certain third countries subject to special conditions for the entry into Great Britain due to contamination risk by mycotoxins, including aflatoxins, pesticide residues, pentachlorophenol and dioxins and microbiological contamination’ (EU, 2019).

The review of Focker et al (2023) summarises the factors considered in general risk-based monitoring programs for food safety, and in particular addresses the specific design requirements when considering microbiological hazards.

The hazard is considered first, ranking pathogen-product combinations, based on the probability of contamination. Selection of food business operators (FBO) can also be risk-based or can be influenced by other factors. Finally, the numbers of samples, distribution of samples and sampling methods are considered. Previous reviews focussed on the individual steps, whereas the review of Focker et al (2023) proposes a more integrated solution for microbiological hazards in food and feed that takes into account the various practical factors. Some mathematical formulations are reviewed for use in the optimisation process, which can also incorporate relative costs of sampling and other factors. A measure of effectiveness within a mathematical formulation can be defined as the probability of detection per sample collected. This can then be estimated with various calculation methods in which parameters are selected according to the specific scenario.

The 3 steps and the information used to inform decisions are summarised in Figure 1 of Focker et al (2023) (copied below in Figure 3). Further information on each step is described below along with general conclusions from the review.

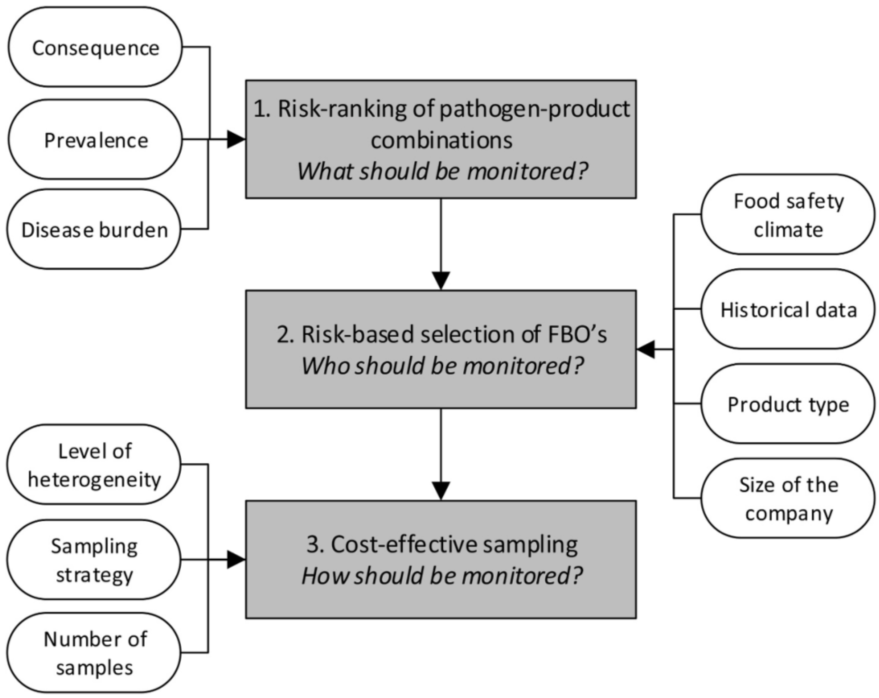


Figure 3. The 3 steps of risk-based monitoring and the factors influencing the optimal budget allocation at each step. Diagram reproduced from Focker et al (2023).

7.6.2a. Risk assessment: The What?

Quantitative microbiological risk assessment (QMRA) methods use information on hazards and intakes to estimate the overall burden of a particular hazard within a population of interest. The prevalence of the microbiological hazard and consumption of relevant foods are key inputs to these models. For transparency, full details should be provided on assumptions, data, uncertainties and limitations. This should allow for future updates when new data become available.

Measures of disease burden, e.g. disability adjusted life years (DALY) or quality adjusted life years (QALY) are used more often in association with microbiological hazards than with chemical hazards, because exposure to pathogens via food consumption can be more directly linked to resulting health impacts. It is discussed how these ranking methods are often limited because of the need for detailed data on health incidences and prevalence in food products that is unavailable in practice. Qualitative or semi-quantitative risk assessment methods are less desirable but may be a compromise solution allowing for transparency. Multi-criteria decision analysis (MCDA) is given as an example in which expert knowledge elicitation (EKE) was used to rank pathogens using a scoring system that weighted individual factors (number of illnesses, severity, etc.). International examples of risk prioritisation using this technique are given from Norway (Skjerdal et al, 2021) and France (ANSES, 2020). The weights given to the different criteria is influential, so it is important to be transparent about the values assigned. The factors used in MCDA can include socio-economic factors.

Available user-friendly tools for risk ranking of pathogens are listed in Table 1 of Focker et al (2023).

7.6.2b. *Selection of Food Business Operators: The Who?*

FBOs might be prioritised based on company size, results from historical monitoring, their use and compliance with quality systems such as HACCP, GMP, ISO etc. and socio-economic factors. Smaller companies may have a higher probability of non-compliance due to limited resources or experience.

Van Asselt et al (2021) has proposed a ranking process. Socio-economic factors including education, food safety culture, risk awareness are all relevant factors in addition to previous monitoring data.

7.6.2c. *Sampling and analysis: The How?*

To properly reflect the population, an optimal sampling strategy should consider the number and frequency of samples required, and the distribution of sample points. For each FBO, the volume of products, prevalence of the pathogen, and cost of the analysis are taken into account to maximise the probability of detection for the given budget. There is no simple equation for all cases, but example studies are presented that estimate sample sizes needed and analyse cost-effectiveness of a sampling plan when resources are limited.

The homogeneity of the pathogen within a food lot determines the contamination fraction (small for heterogeneously distributed pathogen). Samples can be collected randomly or systematically within a lot. If prior information is available to estimate this fraction, then a systematic approach can be developed to maximise the probability of detection, but simulation studies are required to understand the impact. The sample size required depends on the probability of detection per sample and the desired precision of the plan. With standard assumptions, mathematical formulas are available to estimate the number of samples required to give a defined probability, e.g. 95%, of finding contamination within a lot/FBO with a given hypothetical true contaminated fraction. Similar formulas are referred to in the discussion of national food control plans. Previous historical data for specific FBOs or importers can be used within these formulas.

The sensitivity and specificity of the analytical test used to detect the pathogen also affects the probability of detection and therefore the number of samples required. Incorporating the cost of different methods and their accuracies leads to more complex algorithms to derive optimal sampling plans but may generate more cost-effective strategies. Due to the added complexity, these methods tend to require simulation models to generate optimal solutions or to assess their performance.

7.6.2d. *General conclusions from Focker et al (2023)*

The review of Focker et al (2023) provides useful practical suggestions and references for prioritising hazards and designing monitoring for microbiological risks. It highlights the limited number of tools available for integrated monitoring design and assessment of the effectiveness of monitoring programmes but refers to the more common approaches for the single steps that may be applied independently. If disease burden studies are available for individual pathogens, the integrated approaches that use the 3 steps can be used to optimise the sampling strategy according to the overall health burden. Other than this, the description of methods for selecting foods and FBOs uses ideas similar to those already in place when risk-based approaches have been followed. For example, the use of relative volumes of food produced by FBOs, imported, or consumed as a basis for sampling is widely used. Detailed optimisation or analysis of sampling plans relies heavily on different types of data, that are often missing. Therefore, in practice one or more of the steps has to be replaced with simpler assumptions.

The aim of the monitoring (e.g., to detect rare events with high impact, or common events with lower impact on a population) will also influence the risk-based approach that is followed. The cost of sampling and analysis will also have to be considered because the theoretical optimal solutions suggested by these mathematical modelling or simulation approaches will often require extremely large sample numbers which are unachievable.

7.6.3 Using historical monitoring data and machine learning to target monitoring towards high-risk cases

Wang et al (2022a) compared several machine learning algorithms to design a risk-based monitoring program for aflatoxin B_1 (AFB1) in feed. The aim was to design a system to maximise predicted accuracy (for the probability of detection), but amongst the methods with similar accuracy also to select one with lowest total costs. It was shown that in the test example the cost could be dramatically reduced compared with the official monitoring program. The study is similar to the methods reviewed in Focker et al (2023), in that the aim was to integrate cost considerations when searching for an optimal sampling plan. A simplified economic model was assumed to estimate the costs of monitoring including the sampling and analysis itself but also the follow-up actions and cost of potential disease burden from a missed non-compliant sample (false negative case).

This approach could be adapted to design a monitoring program for any other contaminant provided the historical data are available and an economic cost model could be developed for the particular contaminant, food sources and health impacts of concern. The results are only as good as the data used to train the machine learning algorithm, so it is important to gather as much data as possible and to ensure the training data are representative of future conditions. Another related problem arises because the aim of the optimised plan is to reduce the number of samples required by targeting those most likely to be positive. If the resulting monitoring plans were implemented, fewer data points would be generated, with a larger proportion of positive/non-compliant values. Because these are targeted and not totally representative, this would lead to reductions in predictive performance over time if the algorithm was later re-tuned to reflect up-to-date conditions. The optimal targeted designs would then need to be augmented with randomly sampled points to achieve a more balanced dataset. The methods are not designed to be used in situations where major changes occur, e.g., caused by new regulations. Algorithms would also need to be compared independently on a case-by-case basis. Each monitoring and control scenario involves different occurrence patterns and costs, so it will not necessarily be the same type of ML algorithm that is optimal for all contaminants and food types.

7.6.4 Designing optimal food safety monitoring schemes using Bayesian network and integer programming: The case of monitoring dioxins and DL-PCBs

In Wang et al (2022b) the aim was to optimise resources to identify non-compliant samples and also estimate background levels of dioxin-like PCBs in animal derived food products. A Bayesian network (BN) model to predict the probability of detecting contamination was combined with a cost optimisation model. The model was tuned using 10 years of monitoring data. As in Wang et al (2022a) the results suggested that resources could be switched from low-risk products and conditions to higher risk conditions as part of a more cost-effective, risk-based approach. The same potential practical problems, including the need for up-to-date data and inaccuracies due to simplified assumptions involved in the cost model, would apply.

In addition, a Bayesian network requires the specification of conditional probability tables to represent beliefs about dependencies between each variable (i.e., risk factor) and its parent variable. In this way the Bayesian network model allows for dependence between input variables and their joint uncertainty distributions to be accounted for. Subjective expert knowledge can also be incorporated.

Historical data were first used to estimate the conditional probability tables of the BN. An integer programming (IP) model was used to optimise the monitoring costs. This involved specification of an objective function (cost model) that is to be minimised. This was a multi-input function with integer valued decision variables that are subject to pre-defined constraints. The constraints define the required properties of the monitoring e.g., what percent of true non-compliant sampled must be detected. The inferred values from the BN were then used as the decision variables within the optimisation algorithm. The BN included nine variables: animal species, food product type, control point, year, quarter of year, screening results, confirmation (GC/MS) results, number of samples analysed for estimating background levels and total sample size. This also included the minimum number of samples required to estimate the background level of contamination in each of the different food products. By including this variable, it is possible for the optimisation process not only to optimise the cost but also to maintain the extra requirement to estimate background levels within each food type.

Costs arising from losses due to false negatives were not accounted for in this model. It included only the actual monitoring costs. Wider socio-economic factors were also excluded.

7.7 Key relevant findings – predicting chemical contaminant risks

7.7.1 Review of Priority Chemical Contaminant Risks, Food Production and Consumer Diets in Scotland' FSS 217028

In 2018, a review conducted by Fera Science Ltd. for Food Standards Scotland was published summarising evidence relating to chemical contaminant risks from the food chain, specifically in a Scottish context (FSS, 2018). Data from a number of sources including scientific literature, grey literature, HorizonScan, and Scottish Food Sampling Database (SFSD, formerly UK Food Surveillance System - UKFSS) surveillance reports were reviewed for chemical contaminant classes and major food types. Further refined searches focussing on Scotland and Scottish produce were also conducted. Data from the UK National Diet and Nutrition Survey (NDNS) were examined for any differences in consumption of key food categories for Scottish participants.

No specific significant acute or chronic chemical contaminant risks which are particular to food in Scotland, or the Scottish diet, were identified in the review. Scottish consumption patterns were not significantly different to the rest of the UK and were very similar for most food groups and consumer age groups.

Some classes of contaminant may be of particular relevance to economically important food industries in Scotland, such as those related to fish production (e.g. environmental contaminants such as dioxins and PCBs, pollutants from oil or fuel or heavy metals), and some cereal crops (e.g. mycotoxins). However, no evidence was found of any contaminant issues specifically associated with Scottish products.

There was no evidence of any significant issues that may affect the major industries in the Scottish food and drink sector. Some industries of high importance to the Scottish economy e.g. shellfish, fish and aquaculture are associated with certain classes of contaminant such as arsenic, mercury, dioxins and PCBs. There was no evidence of any specific issues with these contaminants in Scottish produce from SFSD results, literature or HorizonScan reports.

It was reported that there was virtually no food surveillance data for 'emerging' contaminants, such as PFOS/PFAS, MCPD esters, furan, or pyrrolizidine alkaloids because methodology and targeted monitoring plans were not yet in place.

The review recommended that:

- The sampling carried out by Scottish Local Authorities (LAs) should be maintained to ensure the data held on the SFSD is up to date and relevant, and where possible to check Scottish Food and Feed business operators' compliance with current regulations.
- Monitoring should increase for many of the classes of contaminants, particularly those contaminants classed as 'emerging'. There are also other contaminants that are not currently regulated but where there is evidence of exposure and toxicity, and data are limited such or specific key products (e.g. seaweed) where monitoring should be reviewed or considered.
- Continue with horizon scanning and intelligence gathering activities, particularly in relation to issues that may be important to Scotland to inform future decision making.

7.8 Other sources of information for sampling

The Food and Agriculture Organisation (FAO) of the United Nations have published a Global strategy that outlines an overview of how to achieve safe and healthy food for all so that all countries are capable of promoting, supporting and protecting their population's health by applying food safety best practice to reduce the burden of foodborne diseases (FAO/WHO,2019). The Tool is based on Codex principles and Guidelines for National Food Control Systems as well as other relevant Codex guidance for food control systems, which are referenced throughout the document. Its scope is given by the dual objectives quoted in Codex guidance for these systems: protect health of consumers and ensure fair practices in the food trade.

Codex has published many methods for sampling over a long period of time, e.g. recommended methods of sampling for pesticides in compliance with MRLs (FAO, 1999). Codex have also published many sets of guidelines on sampling. The 39th Session of the Committee on Methods of Analysis and Sampling (CCMAS39) agreed to start new work on the revision of the General Guidelines on Sampling (CXG 50-2004) (the Guidelines, CXG 50) (Codex, 2021). The revised guidelines have a focus on acceptance sampling plans to control the risks of accepting poor quality product (Consumer's Risk) and of rejecting product of good quality (Producer's Risk). It also provides a wider range of sampling plan options. This enables different types of sampling plans to be designed and evaluated, providing wider consideration of cost and fairness as well as sampling, testing and a decision on acceptance or rejection of the lot.

The work is ongoing, an Electronic Working Group chaired by New Zealand and co-chaired by the USA, continue the work on revising the CXG 50, and on developing the supplementary document (e-book with sampling plan apps), taking into account written comments submitted. The e-book with embedded apps for a variety of sampling plans including the ICMSF plan mentioned above is available (Codex Sampling, 2019). Various parameters can be entered and their effect within the different sampling plans can be observed. For example, this can be used to design sampling plans providing different levels of consumer or producer risk depending on a given scenario. An example is given in Table 2 below, reproduced from Codex (1999).

Incidence of non-compliant residues in the lot	Minimum number of samples (n_O) required to detect a non-compliant residue with a probability of:		
%	*90%*	*95%*	*99%*
90	*1*	-	*2*
80	-	*2*	*3*
70	*2*	*3*	*4*
60	*3*	*4*	*5*
50	*4*	*5*	*7*
40	*5*	*6*	*9*
35	*6*	*7*	*11*
30	*7*	*9*	*13*
25	*9*	*11*	*17*
20	*11*	*14*	*21*
15	*15*	*19*	*29*
10	*22*	*29*	*44*
5	*45*	*59*	*90*
1	*231*	*299*	*459*
0.5	*460*	*598*	*919*
0.1	*2302*	*2995*	*4603*

Table 2. Example of Minimum number of samples required for a given probability of finding at least one non-compliant sample (taken from Codex, 1999, Table 2).

8. Literature on food shopping basket surveys to capture representative diets

In this section, we begin by outlining the main strategies that have been used to design sampling plans when the objective is to learn about the overall dietary consumption (or intake of a substance linked to diet) for the whole population. Targeted approaches are not considered here, as these are outside the scope of this report, and suitable plans are already in place in FSS. Some details of targeted approaches are included in Annex A. The representative sampling approaches have been designed for different purposes, and each has its own individual features to fit the purpose of the study. Examples are presented for each type, illustrating how the 'standard' approaches have been modified to meet different objectives or data/resources, and the potential benefits or practical difficulties that can arise.

We also present below sources of information that can be used to select (i) food and drink categories that represent a target level (e.g., for total % consumption) within the population and (ii) lists of items making up a representative shopping basket.

Finally, a general algorithm is suggested that can be used to develop a preliminary plan that uses the methods and data outlined. Further refinement of the list and detailed shopping will depend on the resources available, the relative cost of sampling different food types, and additional information including market share for each item.

8.1 Shopping lists design as recommended for Total diet surveys

For assessing intakes in the overall diet of a population, TDS (introduced above in 7.3) are used to gather overall estimates of exposure and to identify trends. Although as explained in 7.4.1, there have been variations of TDS that design targeted studies, our interest here is to capture the representative non-targeted diet. Food lists are designed to cover a high percentage of consumption as measured in dietary consumption surveys (rather than sales). Some information on country-specific examples is summarised in sections 7.4.3-7.4.9. A TDS is designed to capture average levels of contaminants or nutrients in the total population diet. Much of this is concerned with food preparation and analysis of pooled samples, leading to efficient estimates of the average population levels 'as consumed'. The preparation and pooling will not be considered here, but there are also aspects that are specifically relevant for designing surveys for a representative snapshot of the whole diet. EFSA/FAO/WHO (2011) includes guidance on the establishment of the TDS food list (Section 7 of the guidance) and sampling plan (Section 8 of the guidance). It also recommends the use of existing formats for data exchange. This international cooperation can be seen in part as an attempt to harmonise the TDS process, which is useful in terms of data sharing (common data formats and protocols) and international comparisons of dietary trends. However, individual countries and assessments have unique requirements and data collection, so the application of the guidance varies in practice.

Coverage of 80-95% of foods in the diet is often targeted for inclusion in the TDS food list, where 'food in the diet' is defined by different criteria e.g., food consumed at >1 g/day per person, >10g/day per person or consumed by more than a specified target percent of the population (5%, 10%, etc.). The guidance also allows for further flexibility by suggesting that the selection of foods should be determined by multiple stakeholders and should take into account the chemical substances of interest. The TDS food list should use food consumption data to select the most consumed foods covering the main contributors to exposure *to the substances under consideration*. In practice this could mean that for a substance that occurs in a rarely consumed food, that food might be given higher priority than it would using the consumption/purchase data alone, leading to supplementary items in the shopping list. The guidance recommends ranking foods by the total weight consumed, taking all foods covering 90% of this weight (more if feasible) then adding any missing foods that are believed to be of special concern due to their consumption by at-risk groups or high levels of substances of concern. If the survey is to be used to assess exposure for special population groups, then the level of dietary coverage can be estimated using their specific consumption data (Akhandaf et al, 2014). If household budget, or purchase, data are used these need to be transformed to ‘as consumed’ as far as possible, or the resulting data will be less representative of the true population consumption.

In a TDS used for screening it is recommended to generate samples from a minimum of 20-30 food groups, whereas for more refined assessments (e.g., detailed sub-types of foods, regions, or sub-populations) there might be 200-300 group samples.

The TDS guidance on food sampling emphasises the need for the collected samples to be representative of the market for the levels in foods for the chemical substances being considered. Any factor that influences these levels should be included when designing the sampling plan. In a TDS, seasonality and/or regional variations are usually considered in the plan. Depending on how the samples will be used, and the nature of the specific substances, other variations should also be considered, although if regional, seasonal and market share variations were included in the study design (if properly captured) this would result in other factors of variation being included. Regional differences in consumption patterns or of contamination (particularly for locally sourced products) may be relevant. Examples of the use of regional sampling plans are provided in the EFSA/FAO/WHO (2011) guidance. The type of premises where samples are taken from can be important, so the sampling should be done in proportion to market share. Here the purchasing data of Kantar may provide useful information (see section 8.2.7). Seasonality should be addressed if climatic or other seasonal factors are influential, e.g., import versus locally grown produce.

Generally, the representative sampling plan removes bias when estimating an average exposure level with highly pooled samples. Alternatively, if using more granular individual samples, representative sampling allows us to quantify the variability within the population and understand the impact of individual factors.

8.2 Information sources for assessing the representative diet

8.2.1 National Diet and Nutrition Survey (NDNS)

The National Diet and Nutrition Survey (NDNS) is a long-running rolling program collecting 4-7 day diaries from a representative sample of individuals within the UK population (years 1-11, 2008/9-2018/19). The NDNS sampling strategy ensures these are representative of the UK population, including children and adults. It includes a very detailed breakdown of specific food types, with thousands of individual food codes. A food recipes database is available (MRC, 2017) that can be used to calculate the individual raw commodities contained in each food item if this is required for linking those commodities to nutrients or contaminant levels.

The level of complexity provided by NDNS makes it very useful for research on nutrition or other types of dietary intakes, because a very precise estimate of food ingredient intakes can be obtained per individual. However, this requires a degree of data organisation and modelling that is not necessarily practical for all applications. The NDNS also provides aggregated consumption levels for specific food types. These aggregated summaries, or similar summaries provided by the Family Food survey or Kantar sales data include broad food categories that are much simpler to work with, but without necessarily having the same degree of accuracy or individual-level variation required for the more detailed risk assessment.

Sample weightings are provided to allow for any variation in the representativeness of the sample. These should be recalculated to account for the differences in sample sizes between years, if multiple years are combined. Alternatively, individual years can be used in isolation, although this would result in a smaller sample size.

NDNS data are published, and updated versions are made available through the UK Data Service (NatCen Social Research, 2021). The dietary intakes in Scotland and the rest of the UK are very similar overall (Food Standards Scotland, 2018), so this survey can be used to identify the priority food types for monitoring as part of the shopping basket.

Partly to reduce financial cost and burden on participants, the NDNS moved from a 7-day diary based on weighed food to a 4-day rolling survey based on estimated amounts. More recently (October 2019) NDNS started using a version of Intake24 (as described below in Section 8.2.4) with the latest food composition data.

8.2.2 Obesity Action Scotland study

In 2021, Obesity Action Scotland carried out a survey to investigate food and drink promotions (Obesity Action Scotland, 2021). The study used two shopping baskets collected via online retail from multiple supermarkets. These comprised a ‘healthy’ basket and a ‘standard’ basket. The standard basket was based on the Grocer 33 list, published in January 2020. It contained 31 food and drink items and 2 domestic products (shampoo and sponge cloths). There is no published information on the methods used to select the items, except to refer to them as popular purchased items, or typical purchases (Robertson, 2020). More recent updates are available from the Grocer (Grocer, 2023)

8.2.3 Other shopping basket studies

Commercial services like trolley.co.uk monitor the prices of products purchased by their signed-up members. This potentially allows for a large sample of shoppers habits to be continuously monitored thereby providing a representative snapshot of the most common items. However, it is a self-selecting sample and not truly representative of the whole population.

Along similar lines, the ONS has been developing new systems and analyses as part of its work on cost-of-living. In an experimental study, online grocery prices of 30 everyday food and drink items were tracked. The 30 items were chosen as a trade-off between coverage of a high proportion of expenditure – based on Family Food data – from low-income households and the complexity of adding more items to the analysis.

Furthermore, the ONS publishes its ‘shopping basket’ of items used in compiling the various measures of consumer price inflation, these are updated and are reviewed annually (ONS, 2022) to ensure that they are representative of consumer spending patterns.

8.2.4 Pilot of Intake24 in the Scottish Health Survey

ScotCen Social Research (2022) piloted the use of Intake24, an online dietary recall system designed to capture detailed food consumption information over a single 24-hour period per individual. Individuals aged 11 and over from the existing Scottish Health Survey (SHeS) were invited to participate. By collecting complete dietary information for each surveyed individual, a more complete picture of total nutrients can be derived and assessed against target levels for the whole population, compared to more targeted surveys related to specific food types, e.g., fruit/vegetables.

Respondents were asked to complete the 24-hour recall the day after consumption. Recalls have some known disadvantages compared to dietary diary methods, e.g., difficulty in remembering all foods and drinks, particularly snacks and water intakes and under-reporting is common. Statistical difficulties also arise because there is no information about within-individual variation between days. This does not affect estimates of average intake levels but does have an effect on estimates of the proportion of individuals exceeding target levels, particularly for rarely consumed items. The Intake24 system allows an optional add-on for individuals completing 2 or more recalls and one aim of the pilot was to assess the best approach to obtain more than 1 recalls. Each pair of recalls included a weekday and a weekend, to account for potential weekday/weekend effects. If both recalls per individual could be incorporated, some of these difficulties could be overcome. Recalls beyond the first 2 were discarded in the analysis to prevent any carryover bias between days for these individuals.

Individual respondents were assigned sample weights to account for non-response and to achieve the required balance of age and gender within the populations. The weights made use of the main SHeS survey weight and census data.

1053 respondents completed 2 or more recalls. Response rates varied by age, with low level participation rates in older age groups 75+ but of those participating the 65-74 group were more likely to complete 2 or more recalls. For older groups there was generally a need to provide more interviewer assistance by telephone rather than use of personal devices. The diets of younger individuals (children below 11 years) were not covered. More effort is required to ensure all age groups are represented. Males were also less likely to participate at all in the first recall.

Where there were comparable methods (fruit and vegetable intakes recorded in the SHeS) the overall mean population estimates were found to be similar, however the pilot study reported poor agreement at the individual level. Partly this is explained because the Intake24 method includes fruit and vegetable ingredients in composite dishes whereas the fruit and vegetable survey of consumption is less comprehensive (e.g., reporting 'portions'). The possibility of social desirability bias was also mentioned, where participants may over-report fruit consumption in face-to-face interviews.

The Intake24 system has the potential to provide more detailed dietary intakes per individual, including more precise food categories and capture ingredient-level intakes, but for a smaller sample and/or greater cost. If all foods are captured by the survey this could be used to derive a representative list of foods to include in a shopping list, perhaps combining with other lists such as the ONS list mentioned above. Systematic errors such as under-reporting may not be a problem in cases where the overall trend is important but may be important for health-based safety thresholds.

The focus of the analysis of the pilot data was on nutrition – for example assessment against the Scottish Dietary Goals (SDGs) – and not on contaminants or microbiological hazards. However, the food definitions are linked to the NDNS food codes and can be searched by food groups or disaggregated using recipes data. Therefore, these intakes results could also be used for the analysis of contaminants and for determining a representative diet. Some problems with classifying food items were identified, for example not being able to distinguish 'foods and milk' from 'drinks' for calculating total energy from milk as required for the SDG.

If the incentive of a £20 voucher was to be offered to the full SHeS sampled population the cost would be around £40,000. Suggestions for improvement include asking for 4 days of recall. However, these would be expected to reduce the completion rate. The ambition to obtain Local Authority level dietary information would be even more challenging.

8.2.5 Other methodologies and tools for national dietary surveys

In 2014 EFSA published guidance on the EU Menu methodology framework (EFSA, 2014). As part of the EU Menu framework project to carry out dietary surveys in the EU 15 countries have completed dietary surveys. The data on food consumption is a long term objective for EFSA to be used for the collection of harmonized and high-quality food consumption data to support EFSA's dietary exposure assessment work. As part of the planning for the EU Menu Phase 2, an inventory and literature review were carried out to document methods and tools available/used for national dietary surveys outside the EU Menu project, and to evaluate those used in the project. It is planned to use the results to update the EU Menu guidance for phase 2 (RIVM, 2022). The inventory showed the most commonly used dietary assessment methods were repeated 24-hour dietary recalls and, among the younger children, food diary records. Underreporting was indicated in 30% of the studies. The literature review was an umbrella review (review of reviews) and showed that among the conventional dietary assessments, the 24-hour dietary recall is the preferred method to collect information as it is both feasible and produces valid results.

The review also highlighted that new technology-based dietary assessment tools have been developed. Most of these were variations of the conventional dietary assessment methods. Examples were online 24-hour dietary recalls and smartphone food records. Several technology-based methods were image-based. These methods have advantages like reduced costs, flexibility (time and location), but also disadvantages such as the required e-skills, non-response bias, and investment costs (as also seen in Section 8.2.4). Although, not yet fully validated, they appear to have similar or slightly lower (relative) validity than conventional methods. Both online 24-hour recalls and smart-phone food records have potential for use in national dietary surveys. Few methodologies for quantification of food portions were validated. The review indicated a reasonable level of validity and showed that image-based portion size estimation was more accurate than food models and household utensils.

8.2.6 Purchasing data from Market Research or Retailers

There are three main suppliers of grocery market analysis services (Grocer, 2018): Kantar Worldpanel, IRI Market Measurement and Nielsen Scantrack. They provide market analysis of grocery purchases, although each use slightly different methodologies. The consequence of this is that they can lead to different results. Kantar Worldpanel Take Home Grocery uses a demographically representative panel of 30,000 consumers, with a sample of 2,000-3,000 households in Scotland. The others buy retailers Electronic Point of Sale (EPoS) data. No methodology is perfect (Grocer, 2018), some will include more or less data for certain categories, e.g., the extent to which own label goods sales are included, or how products are categorised. Table 3 below is taken from Grocer, (2018) and clearly shows the differences between the data sets. It could be envisaged that using EPoS data would be more accurate, however that does not always provide the full picture, for example some retailers are not included, or the data made available by retailers has limitations.

Table 3. Differences between data collection for grocery market information.

Data crunch: the big three at a glance

	Kantar Worldpanel Take Home Grocery	Nielsen Scantrack	IRI Market Measurement Solutions
Where does the data come from?	30,000 strong demographically representative consumer panel	EPoS data from the Big Four, Waitrose, Iceland, M&S, Booths, Boots, Superdrug, The Co-operative Group, bargain stores, independent and symbol retailers and petrol forecourts	EpoS data from the Big Four, Waitrose, Iceland, M&S, Booths, Boots, Superdrug, The Co-operative Group, bargain stores, independent and symbol retailers and petrol forecourts
What's the methodology?	Panelists scan barcodes of items brought home or purchased online to give a picture of what they're buying	Nielsen buys sales data directly from retailers. It has a panel of independent and symbol retailers which it buys data from and extrapolates	IRI buys sales data directly from retailers. It has a panel of independent and symbol retailers which it buys data from and extrapolates
What are the advantages?	There are no 'gaps' arising from data retailers won't share. Kantar Worldpanel's market read includes Aldi and Lidl	Data is 'real' in the sense that it represents every transaction a retailer has made. Data covers all sales, regardless of whether it was consumed on the go or taken home	Data is 'real' in the sense that it represents every transaction a retailer has made. Data covers all sales, regardless of whether it was consumed on the go or taken home
What are the limitations?	Data only covers products that were brought home after purchase and excludes products consumed outside the home after purchase	Data does not include Aldi and Lidl. Retailers 'mask' sales data pertaining to own label or exclusive products when a proportion of sales through a given retailer pass a specified threshold	Data does not include Aldi and Lidl. Retailers 'mask' sales data pertaining to own label or exclusive products when a proportion of sales through a given retailer pass a specified threshold
Who uses it?	'Kantar Worldpanel works with over 90% of suppliers in the UK grocery market'	'We are the primary supplier of measurement and insight services to more than 300 clients in the UK'	'95% of fmcg, retail and health & beauty companies in the Fortune 100 work with us'

Chart: The Grocer • Created with Datawrapper

8.2.7 Kantar Purchasing data

Kantar data for Scotland for 2021 was provided by FSS (Kantar, 2021). The amounts of purchased goods per food type are shown in Figure 4. All charts are plotted to the same scale, assuming that the reported variable 'nutritional volume' is a consistent unit across all types. For all results reported here, nutritional volume refers to kilograms (solid food) or litres (liquids). Using these data, we see that for a representative sample of the whole Scottish diet the main food is 'Morning goods', followed by 'Ambient cakes & pastries', 'Eggs' and 'Milk'. The rank ordering and the proportion of consumption represented by each category depends on the items included within the category. The proportions can be used to assign purchased items to the shopping basket in a representative way. The groupings can be arbitrary, provided that the measured volumes are comparable. For example, 'Morning goods' includes different types of breads that are consumed at different mealtimes. Some items within this group were originally recorded with 'nutritional volume' equal to the number of servings rather than kg, because the serving sizes were unknown. It was therefore necessary to first convert those items to a common scale (kg or litre) to reduce bias in the overall rankings. These issues were resolved during Part 2 of the project (see Section 10.7.1 below). The categories are designed to describe the purchased form, rather than the consumed form and it is not straightforward to link these groups with the NDNS food codes. Within each of the individual markets, e.g., 'Frozen prepared foods' or 'Canned goods', there will be some item types that are more common than others. For example, frozen chips will be purchased more often than frozen stuffing, even though both are included in ‘Frozen prepared foods’. Therefore, items should be purchased in proportion to their prevalence using supplementary information. This may be obtained as more refined categories of Kantar purchase data, or from other supplementary data that are made available. FSS also provided a breakdown of individual sub-market items within each of the named food types in Figure 4. ‘Morning goods’, for example, includes 28 categories (bagels, croissants, naan bread, scones, teacakes, waffles, etc.). If quantitative sales data are available for the more refined list, then sampling effort can be assigned in the correct proportion to each item.

Previous work using Kantar data has demonstrated that there were no significant differences between Scottish consumers and the rest of the UK (FSS, 2018).

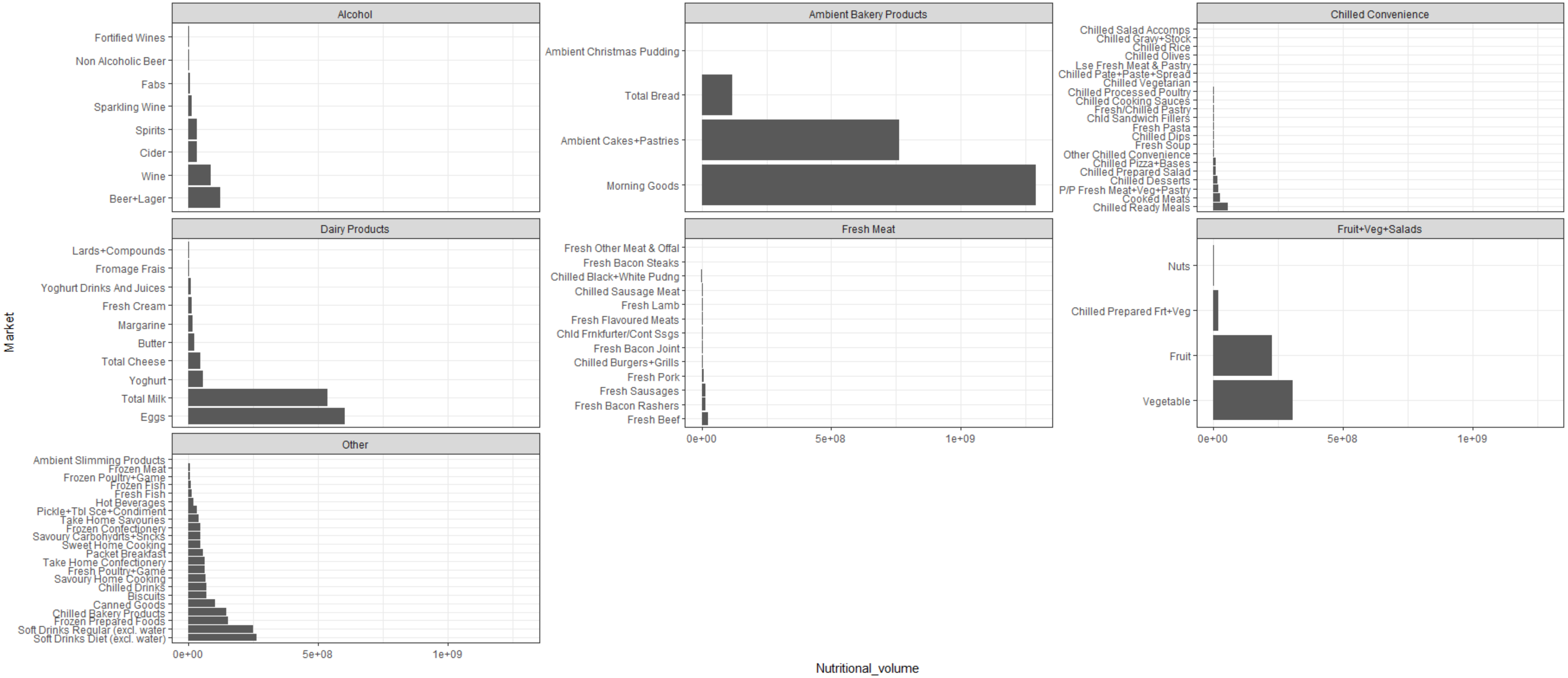


Figure 4. Summary of purchased amounts (recorded as Nutritional volume) by individual markets and market sectors, as presented in the Total Scotland sheet of Kantar data for 2021.

8.2.8 ONS Family Food national and regional purchase surveys

The UK Office for National Statistics (ONS) conducts the Living Costs and Food (LCF) survey on an annual basis, that includes information on food consumption. Dietary data generated from this survey is provided to Defra and is made publicly available (Defra, 2016). Information is collected using a 2-week daily diary of expenditure per individual, that is gathered throughout the year to avoid any bias due to seasonal variations. Information is used for the Retail Prices Index (RPI), but the specific food information is also available to use for studies on food- and drink-based expenditure. Defra uses this within the annual Family Food report (Defra, 2022). Family Food classifies food items into a hierarchical coding scheme of approximately 500 different food codes (Defra, 2014). It continues the collection previously recorded in the National Food Survey (1974-2000), (Defra, 2013). Data including average daily amounts of each food type per person are available up to 2019. These data include specific data for Scotland. The more recent reports publish data tables but only for the main aggregated food categories (cheese, meat, fish, eggs, etc.). However, data from these reports is available for download and also includes individual countries and regions (Defra, 2022a)[1]. Household and eating-out purchase data are reported separately. Data for years 2001-2018/19 are available within the regional data and include a separate datasheet specifically for Scotland (Defra, 2022a and 2022b).

It is noted alongside the data that these and other self-reported diary surveys are affected by underreporting, with some food items being underestimated more than others. In particular, self-reported alcohol purchases may be 40-60% lower than the true levels. Underreporting can be affected by forgetting about extra purchases or other reasons.

8.2.9 Discussion

There is a lot of existing TDS guidance and NDNS survey descriptions available already on-line, including guidance to attempt to standardise protocols. In the practical applications that have been seen in the literature and summarised above, the approach taken to decide which foods to include was similar and was taken from consumption data, either from interviews / recall, from multi-day diary records, from purchasing statistics or a combination of information sources. However, there were broad differences between the number of food items included, the number of food categories defined and the % coverage of food they represented. Many publications and documents referred to a ‘Market basket’ in the reporting of monitoring data. In many cases this term was a substitute for some form of TDS sample, as the description of how the market basket was designed was similar to that of a TDS. There were frequent examples in which the design was not explained in detail. Often, due to

[1] https://www.gov.uk/government/statistical-data-sets/family-food-datasets

practical constraints such as cost/data availability and/or specific requirements the design included a mix of representative elements and targeted purchases.

A common problem when using data to select representative foods is the ambiguity associated with food groups or consumed items. In designing a sampling plan, practical limitations are inevitable but wherever possible this issue of descriptions and coding should be carefully considered. Classification of individual food items should use a standard coding system as far as possible, to allow for data sharing and comparison (particularly to allow results from the Scottish survey to complement data from existing monitoring data). However, as outlined above this has proved difficult even within individual countries where multiple agencies try to combine data from separate sources. In the EU, extensive effort has led to the development of FOODEX and FOODEX2, but the UK NDNS uses a separate food coding system. Data collected on food sales is designed primarily for economic purposes (analysis of sales) so may not readily translate into natural food groupings for dietary assessments.

9. Part 2 – A sampling strategy suitable for the Scottish Surveillance Programme

9.1 General strategy for designing the market basket shopping list

The analysis of options for designing a sampling programme detailed in the first part of this report (and listed in Annex A) details various options that are available and discusses the advantages and limitations of these. Each method has been designed for a specific purpose or a combination of uses and may have been adapted over time in response to changing requirements or emerging risks. Many are already used in national surveillance programs, such as the total diet studies. However, it was found that in all cases individual authorities made localised changes to the standard guidance. In summary, the main issues driving these changes are:

- Budgetary constraints. It can be cost effective to focus limited sampling more on those food items believed to be most susceptible to a particular risk. This can be in addition to an overall surveillance based on overall consumption.
- Limited data availability. In practice it is not always possible to obtain detailed information about the sources of variation in the food supply, or dietary consumption for the population of interest.
- Protection goals. Where the diet of an individual sub-population differs from the overall population, and if those populations are potentially at risk, items that are more highly consumed within that sub-population may be added to the shopping basket.
- Regulatory requirements. Sampling (and testing) may be required for import/export or inspection purposes to monitor adherence to regulations, that are typically specific to food types.

In this report, we identify the particular needs for a national surveillance programme for Scotland and make recommendations as to how the existing best practice can be applied or adapted to meet these needs. The issues listed above will be considered as part of the design process for the shopping basket survey.

The results should allow for a more detailed implementation plan to be created, that meets the needs agreed with FSS.

9.2 Steps to obtain a representative sample

The following steps should be followed in order to obtain a representative sample for monitoring the whole diet. These are expressed as quite high-level decision steps because they depend on the availability of data or in some cases on the nature of the study. To perform general monitoring activities the aim is always to generate samples of consumed items in proportion to their consumption within the population. In addition, sufficient samples are needed to obtain statistically robust results. In practice, as we have found in the literature review, cost constraints often lead to some degree of targeting so that sufficient sample sizes are obtained for the most important food types, populations, sources.

1. Select a population of interest. This can be the national population, or a specific sub-group may be selected if assessment is required based on different consumption patterns and for a targeted risk question (children, elderly, child-bearing age women, elderly, etc.).

2. Select the level of food grouping/aggregation to use in the dietary coverage assessment. The level of refinement is important as it will be used to estimate the level of coverage. Different choices can lead to different shopping lists. As seen in the range of TDS carried out in different countries, this can vary from very general food types such as dairy, to more detailed categories like milk, or even finer scale food types (semi-skimmed milk, UHT whole milk). The chosen food classification and coding systems should be compatible with the consumption or retail data used in assessing the percentage of coverage within the population.

3. Obtain consumption data or retail purchase data for the population. Aggregate the amounts for each of the food categories. If individual diaries are available, it is also possible to reweight the consumptions per individual by their bodyweight. This adjustment means that the sample derived using this approach is more evenly representative across the whole population, removing potential biases from individuals that consume the highest amounts and allowing the diet of the important subgroup of young children to be given more equal weight. This option is not available if using retail data. If the distribution of items consumed is evenly distributed between individuals within the population this would not be a serious issue. Furthermore, if ‘representative’ means representative of the total country’s intake (rather than representative of all individuals), then no weighting is necessary. However, it should be assessed whether items in the shopping list are suitably representative. A clear example is alcoholic beverages, which are primarily consumed by adults and makes up a significant proportion of retail spending. If this category is given a relatively high weight, the samples would be less representative of children’s intake.

4. Rank the items by total amounts, as calculated in step 3 and calculate the relative cumulative totals as a percentage.

5. Select those items that match the required percentage of the total.

6. Assess the list based on expert judgment. If important items are missing, then the list can be adjusted.

7. Steps 1-6 provide a baseline list of food types to include. Further refinement is required to provide a representative sample. Within each food type, use market share data (if available) to select the sub-categories and brands of products to purchase. Any known regional and temporal variations for a product should be accounted for by purchasing that item at the various locations and time of year that are relevant according to the variation. More samples should be purchased in areas of highest population density, if the region of purchase is believed to be influential. In this step,

the factors to consider when assessing variation should be checked. The main sources of variation are listed in Annex C as a guide, although others may be relevant in individual cases. In practice, specific data on variations or market share are not often available, it is necessary therefore to use expert judgment in assigning products and sampling times/locations.

This general algorithm can be used to determine the relative sampling numbers per food type, in proportion to the % coverage of the food. The actual number of items purchased is likely to be influenced by other factors. The cost of purchase and sampling will vary according to food type, and the total sample number is also limited by the total budget. If it is important to estimate the concentration/contamination and its variation within each individual food, then the number of samples should be subject to a minimum number of samples per food. The minimum number should allow a robust statistical estimate per food.

This approach should have utility for both chemical and microbiological sampling, in contrast with the traditional TDS or market basket type of approach, which is used, in the main, for sampling for chemical contamination, residues or for nutritional purposes. A variation of this has been used in a recent study into anti-microbial resistance (AMR) in ready-to-eat foods (Food Standards Agency, 2021b). A subcontractor carried out the sample collection and provided detailed instructions to the shoppers who purchased the samples.

9.3 Using Dietary consumption versus retail amounts

The guidance on TDS recommends the use of consumption data. It more accurately reflects the true dietary intake for risk assessment. Purchase data includes an unknown proportion of each type that is not consumed and can therefore lead to an overestimate in consumption for some types. As a result, food types for which a larger proportion is wasted will be disproportionately represented relative to food items that are mostly consumed. For this reason, use of data from supermarket loyalty schemes or some market data analysts may be less accurate in estimating exposure, although data from these sources may be easier to obtain and may be a good starting point to inform broad sampling in the first instance to help identify issues.

In practice, TDS shopping lists are compiled using the best data that are available or use an element of targeting to capture additional information about regions or contaminants (see for example the TDS of US FDA, Australia and New Zealand mentioned above).

All survey methods are subject to underreporting, affecting the accuracy of different food groups to varying degrees.

10. Designing the sampling and analysis framework

10.1 Requirements and constraints for a surveillance programme

The main requirement for surveillance is for a non-targeted scheme, so that emerging risks can be identified even if there is no prior knowledge, and to give maximum flexibility in terms of application across a wide variety of uses.

A key part of this study is to ensure that there is a reasonable balance between meeting the needs for chemical testing, but also that the sampling would be suitable for assessing microbiological hazards and food standards (authenticity). The information presented above shows how challenging this may be, and ultimately may not be achievable as compromises may need to be made due to financial and practical or logistical considerations.

Using the information from the review and evaluation in Part 1, an algorithm that may have some utility was proposed. A discussion with FSS followed and an approach can be agreed using Scottish consumer purchase data for the FSS shopping basket survey and information on hazards reported from data sources such as HorizonScan[2].

The optimal approach previously defined in the Tender will:

a) Achieve the first aim of providing assurance, i.e., what approach will give FSS and consumers the most confidence that FSS are sampling the right foods and testing them for the appropriate hazards.

b) Achieves the second aim of gathering information, by providing a good quality and representative dataset from which FSS can draw meaningful conclusions and integrate with other surveillance activities.

c) Benefit from as many of the advantages identified in the various approaches, and as few of the drawbacks, as possible.

This will be developed into a sampling and analysis framework specific to the requirements of the shopping basket survey (Part 3).

A schematic of how this will be achieved is given below in Figure 5.

[2] https://www.fera.co.uk/horizonscan-food-safety-at-your-fingertips

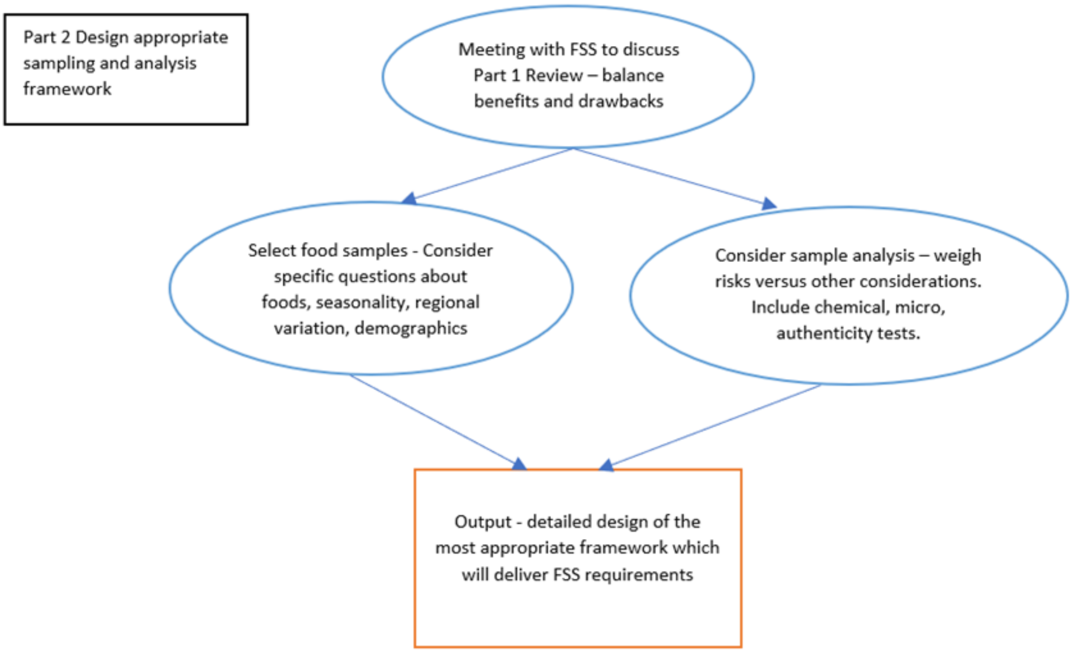


Figure 5. Schematic of steps to design sampling framework.

A number of specific questions will need to be addressed by the framework. These were identified by FSS and are shown below. Using datasets covering nationwide consumer food purchasing will assist with the process of selecting food samples. This data should help determine the foods that are most representative and account for different demographic groups.

10.1.1 Points to consider for selection of food samples:

a) What is in a “typical” food shop?

b) How should seasonal variations be accounted for?

c) How should regional variations be accounted for?

d) What types of retailers should be targeted and in what proportion (e.g. supermarkets vs small retailers)?

e) How should demographic factors (e.g. family size, socio-economic factors, ethnicity) be taken into account when identifying the foods that should be sampled?

f) How broad or specific should the food or food group sampling instructions be and how many samples should be collected of each?

10.1.2 Sample analysis

The following factors should be considered when deciding the analyses the samples should be subjected to:

a) should this be based on empirical risk, theoretical risk, hazards that are legally regulated (or near regulated) in the product, a standard suite of analyses or other factors?

b) What factors should be taken into account when determining the appropriate balance of microbiological, chemical and authenticity (or economic fraud) testing?

These points were discussed with FSS in order to complete Part 2 of the project and develop a detailed design of the most appropriate framework that will deliver FSS requirements as described above.

Following from this the implementation plan can be developed in collaboration with FSS.

The following sections highlight some of these requirements and constraints.

10.2 Sampling Flexibility

Flexibility must be allowed to adapt the shopping basket if required. This should allow adjustments of the food types based on expert opinion if it is assessed that the data-based algorithm does not identify important items. This could happen because of limitations in the data used to estimate the percentage of dietary coverage. The basket should include a broad range of foods, so that the public can be confident their individual diet is sufficiently represented. Another important reason to modify the basket is to include items that may be considered high risk but are consumed in small amounts, or by a small proportion of the population and therefore fall outside the coverage threshold.

It is also important to ensure specific sub-populations’ diets are represented, such as infants and young children, unless there will be other sampling efforts specifically targeted at these. Foods consumed by a small proportion of the population also need to be considered, e.g., special dietetic foods.

10.3 Integration with current sampling systems

Any sampling framework must have the ability to integrate with existing systems. This requires that there is some way to harmonise food descriptions/coding so that food types can be linked if comparing alternative monitoring systems. This is also required to ensure foods are accurately identified from other data sources such as hazard warning or horizon scanning systems.

10.4 Use data of relevance to Scottish diet

It is imperative that the sampling framework use data that directly relates to the Scottish diet**.** It is not strictly necessary to obtain a representative diet 'as consumed', which is recommended for the TDS sampling approaches, because the surveillance program is intended more broadly to capture information about the purchased food items (including concerns linked to safety, nutrition and authenticity) in the marketplace. Sampling approaches specifically designed for risk assessment use consumption diaries in order to quantify the distribution of individual diets. These individual diets are used to calculate individual exposures against which to compare safety limits. Because we are interested more broadly on the population level diet the data on purchases is appropriate. If there may be a requirement to use the data in risk assessment, it would be useful to obtain information about the distribution of individual consumption levels.

10.5 Mathematical or simulation model approaches

There is not currently a requirement to implement the mathematical and simulation approaches described in Part 1 of this report. These models are generally designed to minimise total sampling cost by targeting those samples most likely to be positive. They require detailed data about sampling costs, economic outcomes and businesses for multiple food sectors and sampling methods, which is not generally available. They depend on a simplified model approximation to the true processes involved, with uncertainty about the accuracy or the impact of errors in this approximation. The methods are also highly sensitive to the particular datasets used to build the algorithms, and over time the optimisation steps may result in biased samples (see Section 7.6.3), so would not meet the requirement for a non-targeted approach.

10.6 Recommendations for sample design meeting the requirements

As highlighted in the critical analysis and evaluation of sampling methods (Part 1), market-basket type TDS approaches have been used to collect representative information about the whole populations diet. Many of these studies target the consumed amounts rather than the purchased amounts.

It has been shown that the Scottish diet is similar to the UK diet (FSS, 2018) and therefore the alternative data sources, such as NDNS, may be used to obtain consumption information that approximates the Scottish diet. In principle, useful information may also be obtained by comparing the consumption level data with purchase level data, where there is a directly comparable food type. This may have to be at an aggregated level, such as total milk, total bread, meat, etc. and there are reasons why a meaningful comparison may not be practical. The Kantar categories include duplicated food types that appear in multiple categories, similar foods that appear in multiple categories associated with their purchased form (e.g., Vegetables, Canned Vegetables, Frozen Vegetables reported in different groups) rather than the consumed forms. These issues would make a comparison difficult, so it is recommended to use the purchase data except in exceptional circumstances. Any specific study comparing purchased and consumed data would need to address the uncertainties due to imprecise classifications.

The analysis of current practices in sampling also confirmed that there is no standard solution to the design of market baskets or TDS. Each example includes adjustments to the basic survey design according to the individual requirements, whether that is focusing on a particular sub-population diet or adding in extra food types to target a contaminant or risk of interest.

In order to allow for flexibility and a general purpose approach, rather than targeted on any single sub-population or risk type, the Scottish survey should use the relative percentage of total nutritional volume as a starting point, then use expert judgement to assess extra individual items that should be added to the list.

10.7 Practical example using Kantar purchase data to represent a defined percentage of the Scottish diet

10.7.1 Standardisation of Kantar purchase data

Table 4 and Table 5 present measures of total nutritional volume for the entire population of Scotland taken from Kantar purchase data. In the spreadsheet the description of nutritional volume includes a note that says volume of pack was not available for some items. Specifically, the categories of Loose Bread, Loose Rolls[3], Cakes, Pastries, Morning Goods, and Eggs were measured in servings rather than Kg or Litres. It was therefore necessary to convert these values to a measure that is consistent across all food types. A default serving weight (kg) was assigned to all items within each of these categories that have been recorded as servings. Values were assumed for eggs (0.06kg), cakes & pastries (0.1kg) and morning goods (0.1kg). The amount of total bread is relatively low compared to some other products, but this can be explained by noting that many bread types also appear in the morning goods category. It was decided to combine the morning goods and total bread into a new category (Bakery Goods) and aggregate the total nutritional volume values. Compared to the previous, unadjusted, prioritised food category list (shown in Figure 4), Bakery Products, which previously included morning goods, have lower priority. Similarly, the groups Eggs and Cakes and Pastries have lower priorities. This is due to the reweighting to represent the standardised kg measures.

[3] Loose rolls and loose bread do not appear as categories in the 'Total Market' column. Therefore, these items are not assigned separate weights. They are included as item types within the morning goods category

Table 4. Cumulative percentages of total nutritional volume amounts of individual food types (Market) after ranking the types by nutritional volume, as reported in the Kantar datasheet for Total Scotland, up to 95%.

Market	**Percent of total**	**Cumulative percentage**
Total Milk	14.40	14.40
Vegetables	8.23	22.63
Soft drinks Diet (excl. water)	7.01	29.64
Soft Drinks Regular (excl. water)	6.70	36.34
Bakery products (morning goods* + other bread)	6.65	42.99
Fruit	6.10	49.10
Frozen Prepared Foods	4.04	53.14
Chilled Bakery Products	3.87	57.01
Beer+Lager	3.31	60.31
Canned Goods	2.71	63.03
Wine	2.30	65.33
Ambient cakes+Pastries*	2.04	67.37
Biscuits	1.85	69.23
Chilled Drinks	1.85	71.08
Savoury Home Cooking	1.73	72.81
Fresh Poultry+Game	1.69	74.49
Take Home Confectionery	1.63	76.12
Packet Breakfast	1.54	77.66
Chilled Ready Meals	1.53	79.19
Yoghurt	1.48	80.67
Sweet Home Cooking	1.25	81.92
Savoury Carbohydrts+Sncks	1.22	83.13
Total Cheese	1.22	84.35
Frozen confectionery	1.18	85.53
Take Home Savouries	1.02	86.55
Eggs*	0.97	87.52
Cider	0.91	88.43
Pickle+Tbl Sce+Condiment	0.91	89.34
Spirits	0.84	90.18
Cooked Meats	0.73	90.91
Fresh Beef	0.69	91.60
Butter	0.58	92.18
Chilled Prepared Frt+Veg	0.56	92.74
P/P Fresh Meat+Veg+Pastry	0.53	93.27
Hot Beverages	0.52	93.79
Margarine	0.42	94.21
Chilled Desserts	0.41	94.62
Fresh Bacon Rashers	0.40	95.02

**morning goods, cakes and pastries, eggs have nutritional volume adjusted by approximate serving size, for consistent treatment*

Table 5. Cumulative percentages of total nutritional volume amounts of individual food types (Market) after ranking the types by nutritional volume, as reported in the Kantar datasheet for Total Scotland. Food types with cumulative percentage 95-100% of the total are shown.

Market	Percent of total	Cumulative percentage
Sparkling Wine	0.365	95.382
Fresh Sausages	0.347	95.729
Fresh Cream	0.322	96.051
Fresh Fish	0.312	96.363
Chilled Prepared Salad	0.303	96.665
Yoghurt Drinks And Juices	0.282	96.947
Chilled Pizza+Bases	0.270	97.217
Frozen Fish	0.258	97.474
Fresh Pork	0.250	97.725
Fabs	0.164	97.889
Chilled Burgers+Grills	0.161	98.050
Other Chilled Convenience	0.130	98.180
Fresh Soup	0.124	98.304
Frozen Poultry+Game	0.118	98.422
Chilled Dips	0.113	98.536
Frozen Meat	0.113	98.649
Fresh Pasta	0.108	98.758
Fresh Bacon Joint	0.103	98.861
Chld Frnkfurter/Cont Ssgs	0.097	98.957
Fresh Flavoured Meats	0.096	99.053
Fromage Frais	0.088	99.141
Non Alcoholic Beer	0.087	99.228
Fresh Lamb	0.086	99.314
Chilled Sausage Meat	0.075	99.389
Nuts	0.071	99.460
Chld Sandwich Fillers	0.067	99.527
Chilled Black+White Pudng	0.066	99.593
Fresh/Chilled Pastry	0.052	99.645
Chilled Cooking Sauces	0.050	99.695
Chilled Processed Poultry	0.043	99.739
Fresh Bacon Steaks	0.042	99.780
Chilled Vegetarian	0.039	99.820
Chilled Pate+Paste+Spread	0.037	99.857

Table 5. Contd.

Market	Percent of total	Cumulative percentage
Fortified Wines	0.034	99.891
Lse Fresh Meat & Pastry	0.020	99.911
Fresh Other Meat & Offal	0.019	99.930
Lards+Compounds	0.018	99.948
Chilled Olives	0.015	99.963
Ambient Slimming Products	0.010	99.973
Ambient Christmas Pudding	0.010	99.983
Chilled Rice	0.008	99.992
Chilled Gravy+Stock	0.006	99.998
Chilled Salad Accomps	0.002	100.000

10.7.2 Stepwise approach to sampling design

The following example uses available data to implement the steps outlined in more detail. The numbered steps are directly linked to those listed in Section 9.2. The practical issues are highlighted at each step. When a more refined sample plan is required, each step can be adjusted to make use of more detailed data.

Step	**Description**
Step 1	Kantar sales data were available for this general category, as described above. Total Scotland was selected. No special consideration is given to any sub-population, such as pregnant women, infants, etc. although if required any adjustments could be made at Step 7.
Step 2	Use the market categories as listed in Kantar (see Figure 4, Table 4 and Table 5).
Step 3	The Kantar nutritional volume data is taken as the aggregated amounts with which to partition the samples. These are already aggregated for each category in the data sheet provided.
Step 4	The cumulative totals of nutritional volume as a percent of the overall total are shown in Table 4. Here we only list the items that together cover 95% of the total nutritional volume. If using a hazard adjustment process (see below), this should first be applied to modify the ranked list and generate a new cumulative percentage.
Step 5	If the shopping basket survey should cover 95% of the total according to this measure, then the items in Table 4 (or in a hazard-adjusted list, such as the example in Table 10) are selected.
Step 6	There are items excluded from the 95% coverage threshold list that may be considered to be important for sampling. Examples include fresh bacon rashers, fresh sausages, fresh cream, fresh fish, chilled prepared salad, frozen fish, fresh pork, nuts, etc. Depending on the risks judged to be important and the likelihood that those food categories outside the 95% may be particularly relevant, they may be added into the list based on expert judgment. The list of foods to make up the cumulative list from 95-100% is given in Table 5. An example of a hazard adjusted list in Table 10 also includes food types within the bottom 5% of purchased volumes, that may be added.

<u>Step 7</u>	The list of categories in Table 4 and Table 5 provide a ranking of categories that is based on relative nutritional volume. Some items may be added based on other risk factors in Step 6, but the list also requires further elaboration. First, category headings are broadly defined. Within the 'Total Milk' and 'Vegetable' categories, for example, to obtain a fully representative sample the specific purchased items should match the relative consumptions of sub-categories and also aim to capture the variations in those products that are considered to be important for the final assessment. The Kantar list for Total Milk items includes Buttermilk, Rice Drink, Other Non-Cows Milk, as well as the more common Semi-Skimmed Milk, Skimmed, Whole Milk. The most commonly consumed types should be sampled more than rarely consumed items unless there is to be a reweighting according to other risk factors.

10.7.3 Cumulative list of foods

There are some difficulties categorising some foods, as some food products occur in more than one category. Rice and pasta both appear as a product type in 'savoury carbohydrts+snacks', and olive oil appears in 'savoury home cooking', although these are not obvious from the classification headings alone. Rice and pasta also appear as 'Fresh pasta', and 'Chilled rice'. They will be present in ready meals, which are also categorised as fresh and frozen making it hard to accurately determine the quantity of each consumers purchase. Figure 4 showed the relative purchase amounts of the different food groups, but a tree map is a useful way to visualise the breakdown and how much each category contributes to the diet.

The cumulative Scottish purchase data is shown in Figure 6. This plot is a visual representation of adjusted proportions that are listed in Table 4 and Table 5. All food categories are included, but at the lower end where the foods with very small percentages are purchased (as represented by the nutritional volumes from Kantar) the names of the food items disappear. The treemap allows us to clearly visualise the large contribution, in terms of nutritional volume, that some foods make to the overall amount purchased. In this study it has been presumed that this can be extrapolated to give an overview of the average diet of the Scottish consumer. Many of the items with the highest volumes are not foods that have historically been associated with safety hazards, e.g. soft drinks. Further analysis of hazards reported by food type is therefore required to inform the decisions on which products to sample and how many samples to take, as using volume alone would not be a sensible metric.

The products to the top right hand corner of Figure 6 contribute a very small percentage of products purchased. This region contains many foods that are more likely to have potential hazards associated with them, but they are in this area of the figure as they are purchased in smaller amounts compared to items on the left hand side. This includes fresh meat products, chilled dairy products and nuts, thus indicating that sampling should not necessarily exclude items in this area, because they may be more important to consider than some that are on the left hand side of the diagram. This is related to Step 6 in the list shown above.

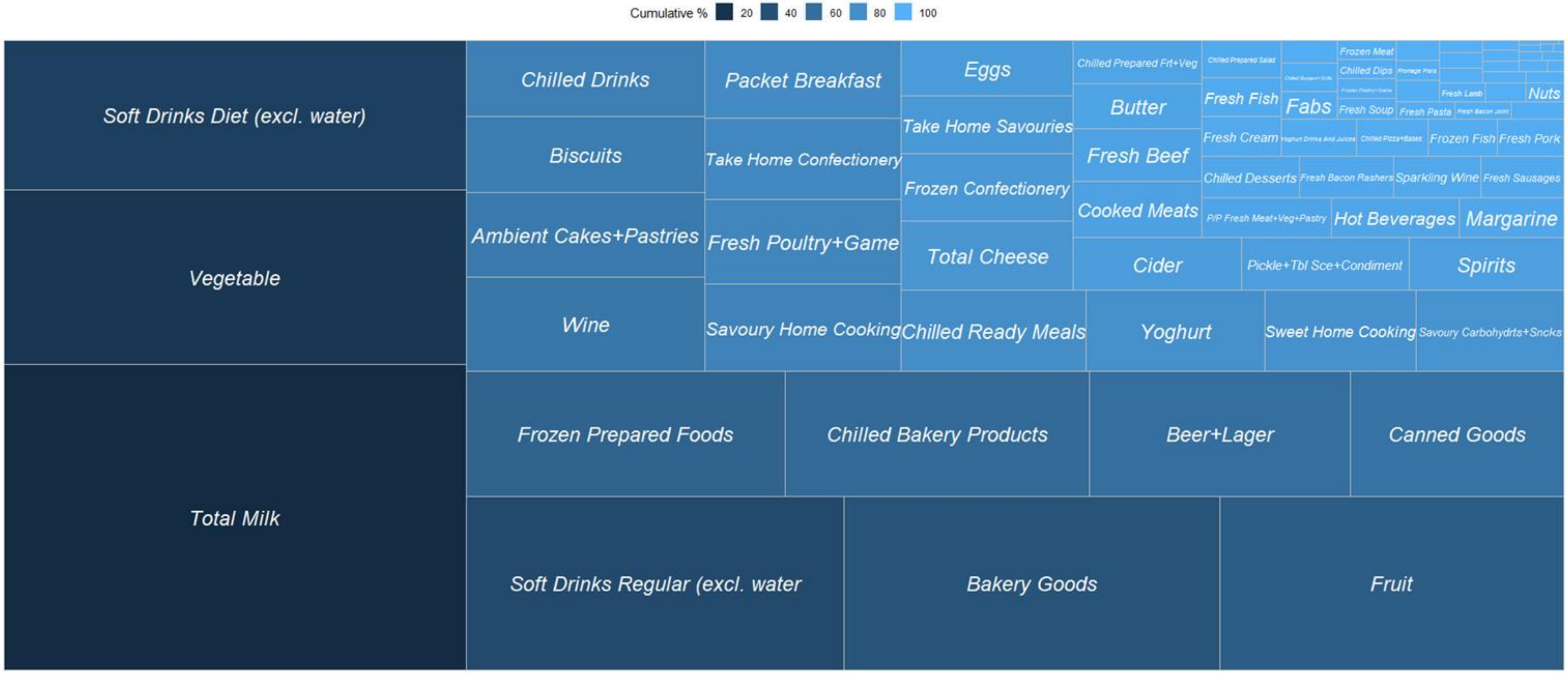


Figure 6. Tree map showing cumulative contribution of foods to Scottish consumers diet, based on Kantar purchasing data.

10.8 Hazard Identification

If the aim is to be representative purely in terms of food purchases, then the simple list and percentages in Table 4 provides a useful starting point. Sample numbers can be selected in proportion to the percentage purchase amounts. If, however, there is a need to prioritise risk from microbiological or chemical hazards it may be required instead to target those food types believed to be most relevant.

A simple approach would be to add any products that appear in the corresponding priority hazards list to the food list, and to ensure there is a sufficient number of samples obtained to estimate the risk from those products. As with the other product types, if a product is subject to any specific known sources of variation, then the sampling should aim to capture those.

A variety of stratified sampling plans could also in theory be developed to optimise the information obtained about a specific population summary (e.g., to minimise the cost to achieve a given level of accuracy). The population summary must first be specified and knowledge of the relative levels of variation of the measured quantity within each stratum is required to optimise these sampling plans. If sampling is to be performed for multiple purposes, these are not necessarily appropriate.

10.9 Use HorizonScan to identify food hazards

The Fera HorizonScan platform was interrogated for a range of foods to identify the most commonly occurring hazards. The food groups were aligned as closely as possible to the Kantar food groups, however as highlighted in 10.7.3 there is a large degree of overlap in the Kantar groups, and the HorizonScan groups may not be as straightforward as first appears.

For example, one Kantar group is ‘Fresh beef’, however from the hazards identified for the ‘Beef’ group from HorizonScan it is clear it includes products that have been processed or prepared in some way as hazards such as allergens are listed. Some groups cover a huge range of products, for example fruit and vegetables. However, the individual products groups themselves, such as bananas or carrots, may be too small to provide any meaningful information. Another example is dried fruit. These fall within the Kantar group ‘sweet home baking’, but are grouped in Fruit & vegetables in HorizonScan, which explains the high number of reports for mycotoxins for this group.

The data has been provided in Excel spreadsheets highlighting as many of the foods listed in Table 4 and Table 5 as was reasonably possible to match. Each spreadsheet lists all the hazards reported, and highlights the top 10 hazards for each, with a summary of this presented as a pie chart.

This information is summarised in Tables D.1 to D.8 in Annex D below. The description of the food from Kantar is given alongside its % representation in the diet calculated from Kantar purchase information and the list in Table 4 and Table 5. The top 10 hazards identified are listed with the relative % of reports associated with each, (as a proportion of all reports within those 10 hazards). In addition, the number of other hazards reported, and the number of reports found are also given. Finally other notable hazards are recorded, particularly where there would be a high risk associated with that hazard such the presence of Listeria or Salmonella. The relative contribution to purchased volume for each food type (from Table 4 and Table 5), is also given to allow an assessment of the contribution that food makes to the diet. Some food types have been grouped together to try and align them more closely with the HorizonScan categories. Some assumptions were made to allow products to be assigned as there was not sufficient detail in the item descriptions to allow them to be perfectly matched to a category. For example, fresh sausages were included in the category 'pork', although in Scotland a significant amount of the sausages purchased are made from beef there was no information on the relative amounts to allow them to be classified separately.

In assessing the hazards, the full list of Kantar products (tables 4 and 5 combined) was initially considered. This means that the group 'fish', for example, has been included, which is important because although it makes up such a small proportion of the purchased goods and was not included in the 95% of the diet (Table 4), many hazards were reported for fish products compared to other foods. This is an example of a food in the top right corner of Figure 6 (Section 10.7.3), but which has potentially higher risk than some others that are ranked higher by purchasing information alone.

The results were grouped initially starting with the most purchased. However, for milk this also includes non-dairy products, such as plant based dairy alternatives. For the soft drinks these are listed as they were among the most purchased, but the products listed from HorizonScan do not match exactly as there was no information for 'soft drinks, diet or regular'. The beverage groups that were listed in HorizonScan have been grouped to try to collate the non-alcoholic beverage information in a sensible manner and include 'chilled drinks'. By grouping some of the food types, these now represent a greater proportion of the foods purchased compared to the listing in Table 4. This could have a bearing when considering how many samples to take when sampling plans are designed, if based on volume alone. But as mentioned in 10.7.3, when the hazards are taken into consideration using volumes alone is not necessarily the optimal choice for sampling. It is not expected that this process will make a significant difference to the food rank ordering[4], but if the grouping of items changes the combined Kantar volume amounts there is an option to recalculate the percentages and update the table.

Finally, all data recorded for allergens has been tabulated (Table D.8, Annex D). The results are recorded by food type and list the total number of undeclared allergens reported in different food categories. The group with the highest number of reported undeclared allergens was 'other prepared food', understandable as this is a broad

[4] As explained below, purchased volume are categorised into discrete intervals, so the purchase score will only change for food types moving with sufficiently increased volume to move into a higher volume category.

category. The next highest was 'cakes, pastries and biscuits', followed by 'chocolate based confectionary' and 'snack foods'. Separating this information should make it easier to understand the frequency of undeclared allergens and the foods most likely to be affected, which would help inform a sampling scheme if a programme of targeted testing was planned.

These tables and the supporting information from HorizonScan, alongside critical review by experts can be used to inform priority ranking and decision making to assist in designing sampling plans. In the next section we describe some relevant methods.

10.10 Risk ranking to determine sampling priority

The results of the HorizonScan outputs in Annex D show the complex nature of hazards associated with food. In many of the listed foods there are multiple examples of potential for microbiological and chemical contamination, as well as the potential for the presence of undeclared allergens.

10.10.1 Risk Ranking of Chemical and Microbiological Hazards in Foods - Research Project and International Workshop

There is no standard method to rank these risks although there have been some recent projects and publications that have attempted to do so. A report of a workshop on risk ranking of chemical and microbiological hazards in foods was published recently (Sand et al, 2023). The purpose of this EFSA funded project was to improve the ability to perform risk ranking of current chemical and microbiological hazards in foods. The work was performed in three work packages (WPs) comprising an overview of chemical and microbiological risk assessment (WP1), development of methods for risk ranking (WP2), and the organisation of an international workshop (WP3). The developmental work consisted of 1) a method for chemical hazards that was also adapted for newer toxicological effect data, and 2) an exposure model applicable to both types of hazards in its design. A challenge identified to risk ranking was the lack of data for many hazards/foods. It was highlighted there is a need to be able to recognise when data are adequate, and what data would be most valuable, to make best use of the available information. The project proposed development of overarching guidance addressing the many types of risk rankings that are possible, e.g. by hazards, or by hazard-food combinations.

10.10.2 A common approach for ranking of microbiological and chemical hazards in foods based on risk assessment

A review paper published by Lindqvist et al (2019) compared and contrasted microbial and chemical risk assessment methodologies in order to evaluate the potential for a common framework for ranking of the risks associated with chemical and microbiological hazards. The paper gave an overview of chemical and microbial risk assessments and highlighted the differences. It showed the importance of including severity in the assessment, for example using the metric Disability Adjusted Life Years

(DALY), which reduced the effect of differences between hazards by presenting risks in terms of a common metric. The paper contains a table summarising the different properties of chemical and microbial hazards that are relevant for risk assessment. It also describes four case studies; Listeria in ready-to-eat (RTE) food; Salmonella in broilers; acrylamide in food and lead in food. Using a combination of chemical risk assessment, microbial risk assessment based on probability and microbial risk assessment based on DALY (2 methods) the hazard food combinations were ranked. In all cases lead in food was ranked as number 1, and Salmonella in broiler as 2. The authors concluded the case studies illustrate that it is possible to estimate and rank chemical and microbiological hazard-food combinations based on average margin of exposure, (MOE) or average yearly risk per person with traditional approaches from each domain. They also highlighted that risk assessments and ranking across hazard types has to be based on a common health metric, and, in line with the Codex risk analysis framework, preferably a health adjusted life years (HALY), e.g. DALY. There are many challenges associated with this, and decisions will need to be made to simplify the problem, but at the same time maintaining the scientific integrity of the assessment and the ranking.

10.10.3 Critical review of methods for risk ranking of food-related hazards, based on risks for human health

A literature review was performed on methodologies for ranking risks related to chemical, microbiological and nutritional hazards in food, on the basis of their anticipated effects on human health (Van der Fels-Klerx et al, 2018). The results showed that a range of risk ranking methodologies are used. They were grouped into eleven main categories, determined primarily by the type(s) of hazard that can be ranked, data needs, and uncertainty. Some methods allow ranking of different hazard types (chemical, microbiological), whereas others allow ranking only within one hazard category.

The categories included: risk assessment, comparative risk assessment, risk ratio method, scoring method, cost of illness, health adjusted life years (HALY), multi-criteria decision analysis, risk matrix, flow charts/decision trees, stated preference techniques and expert synthesis. Examples of the different methods and their relative strengths and weaknesses were summarised.

The paper gives an example of a risk matrix, reproduced below as Figure 7.

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	M	H	H	E	E
Likely	M	M	H	H	E
Possible	L	M	M	H	E
Unlikely	L	M	M	M	H
Rare	L	L	M	M	H

Figure 7. Example of risk matrix from Van der Fels-Klerx et al, 2018

The risk matrix is a simple way to assign risk categories based on a combination of the likelihood of occurrence and the consequence of the hazard for human health. This has the advantage of being easily used and can be applied to both microbiological and chemical hazards. It provides a visualisation for both presence of the hazard and its effects, giving direct insight into the way these two elements contribute to the overall risk of a hazard. For example, a hazard may present a high risk due to a high likelihood (of exposure), although its severity is low. Alternatively, due to its high toxicity, it may present a high risk rank despite low likelihood of exposure. Here, likelihood of exposure is assessed by combining the amounts consumed and the presence/concentration per unit consumed, so likelihood depends on both aspects. All of the reviews assessed discuss microbiological and chemical hazards, and this method can also be applied to the presence of allergens which constitute a severe hazard for vulnerable individuals.

This approach will be used to assess risks from individual hazard types (combining food purchase data with HorizonScan hazard information), and the resulting prioritisation will then be used to inform the sampling guidance.

10.10.4 ANSES tool for ranking chemical and biological hazards

ANSES have created a multi-hazard and multi-food health ranking tool using a step-by-step approach to rank the chemical and biological hazards that can contaminate food, and to prioritise risk situations (food-hazard pairs presenting the greatest risk). They identified 35 biological hazards (21 bacteria, toxins or metabolites; 10 parasites, 4 viruses and non-conventional transmissible agents), 11 families of chemical contaminants (persistent organic pollutants, pesticide residues, etc.) and several thousand food-hazard pairs considered relevant. They defined ranking criteria based on the probability of occurrence of the hazard (number of new cases of disease per year, estimate of the number of cases associated with consumption of the food, etc.) and the severity of the associated adverse effects. Finally, available data was collected, entered and criteria aggregated within the tool.

Due to the large amount of available data and possible food-hazard combinations, ANSES tested the tool's application and potential for a limited number of hazards and food-hazard pairs for both chemical and biological aspects.

ANSES opinion and report on the prioritisation of biological and chemical hazards in order to optimise food health and safety (ANSES, 2019b) describes the optimisation of the surveillance programme for chemical contaminants programme and provides some good examples of a matrix framework shown as a risk dashboard to highlight food / hazard combinations where attention (sampling) is required. An example is shown in Figure 8. The diagrams highlight the areas where they suggest maintaining sampling/regulations (green), reduce (yellow) and strengthen or increase (red). Some examples of where it shows main areas to increase testing are food for children and infants, processing contaminants in a range of foods, and for PCBs, PCDDF in eggs. This matrix approach will be used as a basis for the sampling framework for the Scottish market basket study.

A second report on the Methodology for risk ranking chemical and microbiological hazards was published in 2020 (ANSES, 2020). It is an extremely comprehensive and detailed document that include risk summaries for a wide range of microbiological and chemical food hazard combinations.

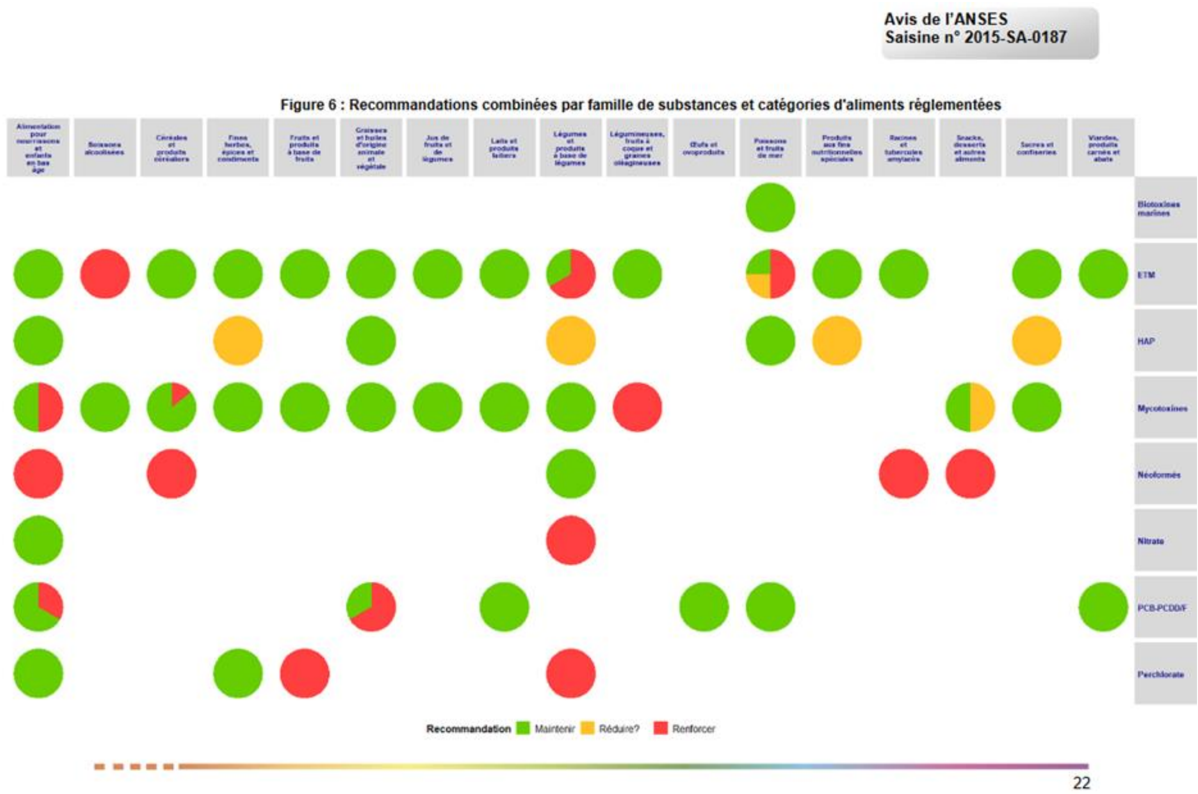


Figure 8. Example of collated data for sampling, developed by ANSES (ANSES, 2019b).

10.10.5 Dietary-exposure assessment of chemicals in food

EFSA have published many risk assessments for chemicals in food. A recent publication considered about 100 European risk assessments for chemical contaminants, many of those published by EFSA. The authors identified several chemical contaminants that pose a potential risk to average European adults. These were persistent environmental pollutants: dioxins and dl-PCBs, PFOS, PFOA and a brominated flame retardant (BFR), process contaminants: acrylamide, furans and ethyl carbamate (for alcohol drinkers) and heavy metals and nickel. From the large number of natural toxins, only aflatoxins and pyrrolizidine alkaloids were suggested to pose potential chronic risks (Eskola et al, 2020). The authors tried to rank the chemicals, based on chronic risks from the contaminants. Process contaminants were ranked first, followed by mineral oil aromatic hydrocarbons (MOAH), aflatoxins, halogenated POPs and nickel, then pyrrolizidine alkaloids. The authors stated that PFOS and PFOA and metals were of lower concern. This was a simplified ranking that did not take account of the uncertainties in the EFSA opinions.

11. Part 3. Designing the sampling and analysis framework

11.1 Generating risk scores within a risk matrix

The example below (Figure 9) is the proposed format to try to rank sample and hazard combinations to target for sampling. It was developed by adapting the risk ranking ideas described in the previous section. Details of the scoring algorithm and risk classification are presented below.

Milk	No. top 10 hazards	% of top 10 hazard reports	Consequences Score	Hazard Occurrence Score	Purchase Score	Likelihood Score	Risk
Listeria monocytogenes	121	18	5	4	5	20 = Likely	E
Decomposed/altered organolepsis		17	1	4	5	20 = Likely	M
Campylobacter		14	5	4	5	20 = Likely	E
E. coli		12	5	3	5	15 = Possible	E
Other processing issues		8	3	2	5	10 = Unlikely	M
Other microbiological contaminants		7	3	2	5	10 = Unlikely	M
Other inorganic contaminants		7	3	2	5	10 = Unlikely	M
Mislabelling		6	1	2	5	10 = Unlikely	L
Inadequate thermal processing		6	3	2	5	10 = Unlikely	M
Bacillus cereus (presumptive)		5	3	2	5	10 = Unlikely	M

Figure 9. Example of risk ranking in grid form, based on the top 10 HorizonScan hazards for milk. Risk categories are defined from the risk matrix by matching the individual Consequence Score and the Likelihood Score

For each food category listed in the Kantar table, an overall risk score is defined from a look-up table (risk matrix) like the one shown in Figure 7. To determine the risk classification in this risk matrix, two scores are first generated using the relevant features that we want to include:

- Consequence Score. This determines the column of the risk matrix and is set by expert judgment based on the severity of the hazard and food combination.
- Likelihood Score = Hazard Occurrence Score x Purchase Score. This determines the row within the risk matrix. Category boundaries must be selected to map the values of this product (1-25) onto the likelihood classes (Table 9).

Note that the purchase score is linked to the Kantar volume data (e.g. Total milk), rather than hazard data, so it is necessary to associate each purchased food with a food for which there is a hazard list (e.g. Milk, as shown in Figure 9). Where this is not possible, the Kantar food type will be assigned missing values for the scores and risk rating, which can be seen in the output files, but they will be excluded from the summary graphs. Examples of items not linked to hazard data include ‘Take Home

Confectionary', 'Sweet Home Cooking', 'Hot Beverages', 'Chilled Desserts' and various others[5].

The number of levels in each of the component scores is arbitrary. The more levels included, the finer the granularity produced in the final scores. However, for simplicity of assignment and interpretation they should be limited to meaningful groups. For consistency with earlier work the examples shown here use the 5-level classifications for consequences and likelihood. These can be refined as necessary. The scores assigned to consequences are listed in Table 6. To assist with assignments, it may also be useful to add some extra comments including examples of the types of hazards meeting each of the given score levels (e.g., Severe hazard could include 'potentially fatal'). This would improve consistency between food types and hazards but requires expert judgment.

Table 6. Consequence scores used in generating the risk classifications

Consequences Score	Definition
5	Severe hazard
4	Major hazard
3	Moderate hazard
2	Minor hazard
1	Insignificant hazard

The Hazard Occurrence Score is based on the number of reports from HorizonScan. It is an indicator of the relative occurrence probability of a given hazard per unit of product. We have set these according to the percentage of the top 10 HorizonScan occurrences (ranked by number of alerts) occurring for each hazard/food combination considered. In the example seen in Figure 9, there were 121 hazards reported for milk, with 18% of these relating to listeria. Some alerts are associated with issues that are not necessarily health related (e.g. Other processing issues: 8%). These are classified as 'Other' when we summarise in terms of general hazard types. The Occurrence Score levels are shown in Table 7. Again, we have used the labels as shown in Table 4, but these could be refined as necessary. Note that food categories with more alerts overall are not treated as being riskier than food types with fewer alerts, because we have rescaled independently to give percentages that add to 100% within each food type.

[5] As future hazard data become available, or Kantar categories refined, it will be possible to update the underlying data links between purchased foods and hazard records

Table 7. Score levels for Hazard Occurrence Score and their definitions based on the HorizonScan alerts

Hazard Occurrence Score	Definition	Rule for score (% of top 10 hazard alerts)
5	Almost certain	>60%
4	Likely	14-60%
3	Possible	10-14%
2	Unlikely	5-10%
1	Rare	<5%

Finally, the Purchase Score is derived from the purchase frequency based on ranking in cumulative Kantar table. Rather than using the measured proportions directly (suitably scaled to match the scoring system), the scores were assigned using a non-linear mapping. This allows for more influence from low-volume food categories, in cases where these are considered high-risk, and does not allow those with very large volume to dominate the sampling. The non-linear scoring is shown in Table 8. It also allows for those items that do not appear in the Kantar list (or appear with extremely low total percentage) to be included in the risk calculation. Any food types with large numbers of HorizonScan alerts could then be assigned a risk score. However, if the purchase score is low, the risk will never be particularly high. This is because of the independent rescaling of top 10 alerts used in deriving the Hazard Occurrence Score, meaning that there is not a large variation in the occurrence scores between food types and the consequences score of the top hazards is the main determinant of the hazard importance score.

For selected items that have been assessed using HorizonScan alerts but do not appear directly in the Kantar list we have manually added them and set a nominal percentage value equal to the lowest positive percentage value (across other food types) so the Purchase Score for these extra items is always 0.1.

Using several factors to calculate a score should allow more differentiation. The rankings may be sensitive to the chosen category/score threshold levels, so a degree of experimentation should be performed before arriving at the final levels.

The score thresholds can be updated as required to fine tune these recommendations once the final scoring system is in place and periodic review of the performance of the framework is recommended based on practical experience.

The Hazard Score and Consequence Score can also be used to adjust the sample numbers to individual food items in the Kantar list. The percentage purchased volumes previously listed are reweighted by the hazard importance score, given by

Hazard Importance Score = Consequence Score x Hazard Occurrence Score

Because there are multiple hazard groups, this could be generalised to give more or less importance weighting to individual hazards. The examples shown in Table 10 have given equal weight to the hazard types considered.

Table 8. Score levels for Purchase Score and their definitions based on the Kantar purchased volume data

Purchase Score	Kantar total percent
5	>5%
4	1-5%
3	0.99-0.50%
2	0.49-0.2%
1	0.19-0.1%
0.1	<0.1%

Table 9. Categories associated with the calculated likelihood scores, to link into the risk matrix risk classifications

Likelihood Score	Likelihood category (row in risk matrix)
21-25	Almost Certain
16-20	Likely
11-15	Possible
6-10	Unlikely
1-5	Rare

The adjusted sampling percentages will help target where sampling effort should be focussed, based on more than just the volume of the food product as this could result in resources being used where there is little or no risk (e.g., soft drinks). We see for example that Wine has a lower priority than based on product volume alone, due to having a relatively low importance score of 2.6, whereas those with relatively high hazard importance scores have increased priority (e.g., Take home savouries increased from 1.02% to 1.79%). Soft drinks were assigned a low hazard importance and have reduced sampling importance as a result. The hazard data these were linked to is ‘fruit flavoured soft drinks’. The last six rows of the updated sampling table correspond to those added food types that were not included in the Kantar purchase data summaries, and these are shown with greater precision to make clear that they are positive. However, due to their low volume in the sales data, their hazard adjustments are very small. The updated treemap for the hazard adjusted sampling percentages is shown in Figure 10 and can be compared against the original unadjusted version in Figure 6.

Table 10. Reweighted sampling percentages (Adjusted Percent Total) derived by modifying the purchase volume of individual food types according to the Hazard Importance Score. In this example all hazard types are assigned equal weights. These values are also included in supplementary material to this report (in the file “hazard_adjusted_sampling_percentages.csv”)

Category	Percent Total	Weighted Hazard Importance Score	Adjusted Percent Total	Cumulative Percent
Total Milk	14.40	8.3	20.14	20.14
Bakery Goods	6.65	6.8	7.62	27.76
Frozen Prepared Foods	4.04	9.9	6.74	34.50
Vegetable	8.23	4.8	6.65	41.15
Chilled Bakery Products	3.87	9.9	6.45	47.60
Fruit	6.10	4.8	4.94	52.54
Soft Drinks Diet (excl. water)	7.01	3.4	4.02	56.55
Soft Drinks Regular (excl. water	6.70	3.4	3.84	60.39
Ambient Cakes+Pastries	2.04	9.9	3.41	63.80
Biscuits	1.85	9.9	3.09	66.89
Savoury Home Cooking	1.73	9.9	2.89	69.77
Beer+Lager	3.31	4.8	2.68	72.45
Chilled Ready Meals	1.53	9.9	2.55	75.00
Canned Goods	2.71	4.8	2.19	77.19
Packet Breakfast	1.54	8.3	2.15	79.34
Fresh Poultry+Game	1.69	6.4	1.82	81.16
Take Home Savouries	1.02	10.4	1.79	82.95
Yoghurt	1.48	6.8	1.70	84.64
Savoury Carbohydrts+Sncks	1.22	7.6	1.56	86.21
Total Cheese	1.22	6.8	1.39	87.60
Chilled Drinks	1.85	3.4	1.06	88.66
Eggs	0.97	6.3	1.03	89.69
Wine	2.30	2.6	1.01	90.70
Cider	0.91	6.2	0.95	91.65
Cooked Meats	0.73	7.7	0.94	92.60

P/P Fresh Meat+Veg+Pastry	0.53	9.9	0.88	93.48
Spirits	0.84	5.8	0.82	94.30
Fresh Beef	0.69	6.4	0.75	95.04
Butter	0.58	6.4	0.63	95.67
Fresh Bacon Rashers	0.40	6.9	0.46	96.13
Margarine	0.42	6.4	0.46	96.59
Chilled Prepared Frt+Veg	0.56	4.8	0.45	97.04
Fresh Fish	0.31	8.5	0.45	97.49
Fresh Sausages	0.35	6.4	0.37	97.86
Frozen Fish	0.26	8.5	0.37	98.23
Fresh Pork	0.25	6.9	0.29	98.52
Chilled Burgers+Grills	0.16	6.4	0.17	98.70
Yoghurt Drinks And Juices	0.28	3.4	0.16	98.86
Sparkling Wine	0.37	2.6	0.16	99.02
Frozen Poultry+Game	0.12	6.4	0.13	99.15
Frozen Meat	0.11	6.4	0.12	99.27
Fresh Bacon Joint	0.10	6.9	0.12	99.39
Chld Frnkfurter/Cont Ssgs	0.10	6.9	0.11	99.50
Fromage Frais	0.09	6.8	0.10	99.60
Fresh Soup	0.12	4.8	0.10	99.70
Chilled Sausage Meat	0.07	6.9	0.09	99.79
Non Alcoholic Beer	0.09	4.8	0.07	99.86
Fresh Bacon Steaks	0.04	6.9	0.05	99.91
Chilled Processed Poultry	0.04	6.4	0.05	99.95
Fortified Wines	0.03	2.6	0.01	99.97
Chilled Olives	0.01	4.8	0.01	99.98
Chilled Rice	0.01	5.4	0.01	99.99
Infant food	0.002	7.3	0.002	99.99
Infant formulae	0.002	6.7	0.002	99.99
Herbs & spices	0.002	6.5	0.002	99.99
Food & dietary supplements	0.002	5.8	0.002	100.0
Frozen dairy	0.002	5.8	0.002	100.0
Honey	0.002	4.8	0.002	100.0

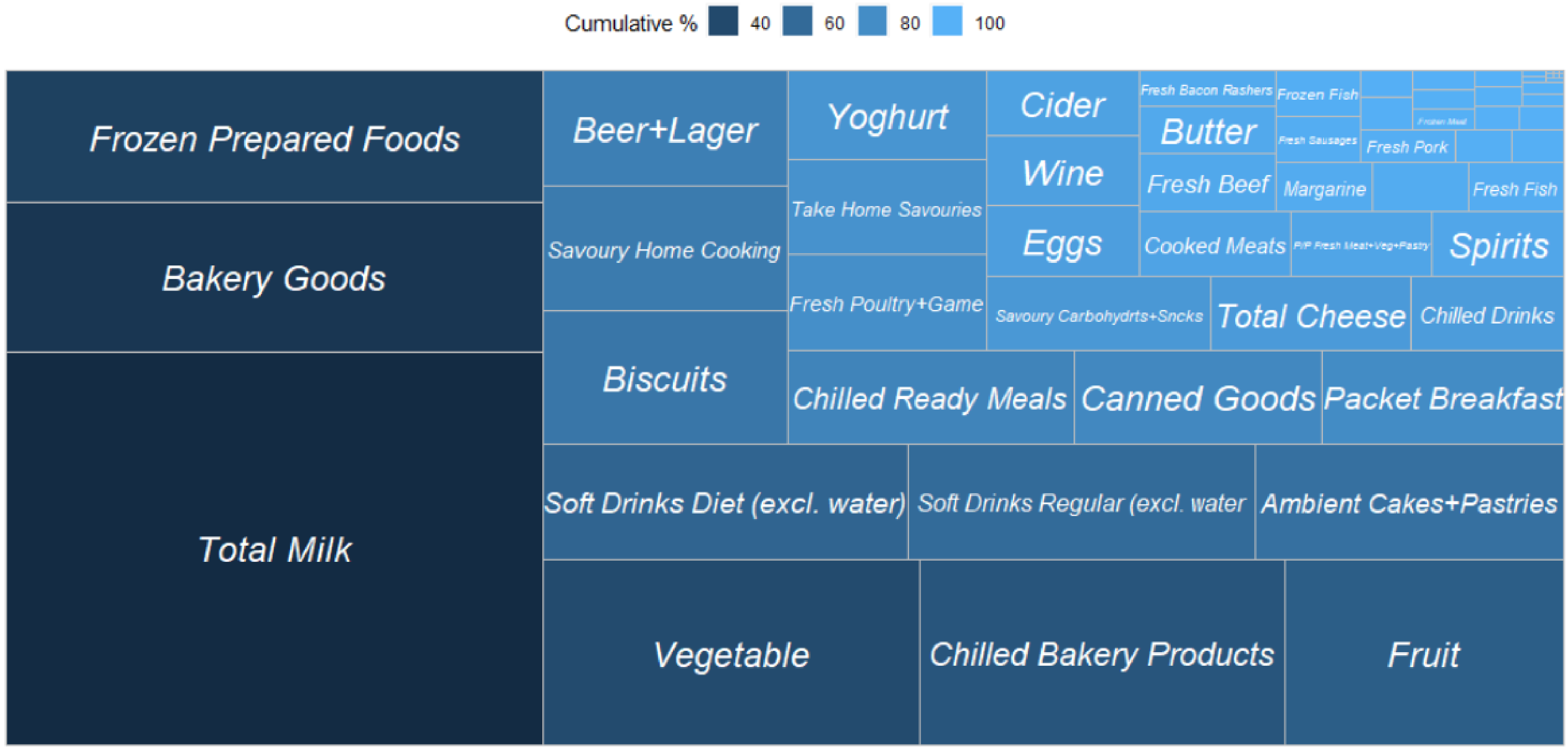


Figure 10. Tree map showing cumulative contribution of foods to Scottish consumers diet, based on Kantar purchasing data, but adjusted for hazard weightings.

11.2 Risk dashboard for hazard type and food type groups

The scoring algorithm and risk assignment algorithm described in Section 11.1 generates a large number of risk values, because the combination of all hazard types appearing in the HorizonScan top 10 hazards, combined with all Kantar food types plus the added food categories, generates a large number of combinations. As in the work of ANSES (2019b), introduced in Section 10.10.4, it is convenient to summarise these results in terms of more general hazard types and food groups. Hazard types were assigned to one of the following classes:

Chemical contaminants, Colours, Food additives, Inorganic contaminant/metal, Microbiological, Microbiological (hygiene indicator/coliform), Mycotoxins, Natural or plant toxins, Other - authenticity, Other - labelling/documents, Other - processing, Other - unauthorised, Other contaminants Pesticides, Processing contaminants, Undeclared allergens, Veterinary drugs

Each food type was also assigned to one of the following classes:

Alcoholic drinks, Bakery and breakfast goods, Dairy, Drinks – non alcoholic, Fruit and vegetables, Herbs and spices, Honey, Infant, Meat and fish, Ready-to-eat and snacks, Rice, Supplements

Two hazard groups were excluded ("Other contaminants - not chemical" and "Microbiological - spoilage") as these were not considered to be safety issues. The numbers within each group were then used to summarise in a similar format to the example in Figure 8. This provides an overview of all food categories in the shopping basket and the general hazard types to be targeted. The assignment of hazards and food types to these general groups is subject to further checking and refinement, according to the needs of FSS. For example, missing scores can occur in the intermediate calculations, which can mean that the food type and hazard combination does not appear in the compiled HorizonScan lists, or that the hazard or food type has not been assigned to one of the broader categories. These combinations with missing entries will not contribute to the summary dashboard display or sample size assignment list, although they can be seen with missing (NA) entries in the more detailed data for checking. For the current example, see the file "risk_matrix_scores_to_check.csv" in the supplementary material for this report.

The risk scoring approach based on the risk matrix (Section 11.1) led to the dashboard shown in Figure 11. Because this gives more weight to the low-volume products, by using a score higher than 0.1 or 1 for many product types that have relatively low purchase volumes, combined with the wide band defining the medium risk scenario (Figure 7) there are many food items classed as medium or high. This illustrates the importance of selecting appropriate weightings for the individual component scores, risk category allocations, and careful calibration of the algorithm. The proportions in the pie-charts represent the fraction of the individual (product/hazard) pairs within each group that have a given colour-coded risk score. Any Kantar food group that does not appear in the data on top10 hazards, as extracted from HorizonScan, is not included in these risk calculations. For example, 'Take Home Confectionary' and 'Sweet Home Cooking' are excluded. The [Ready-to-eat and snacks:Undeclared allergens], [Bakery and breakfast Goods:undeclared allergens], [Ready-to-eat and snacks:Microbiological] and [Dairy:Microbiological] combinations are examples with the largest proportion of high and medium risk items according to these summaries. The groups that have low purchase volume in the Kantar data and have been added (Herbs and spices, Honey, Infant) include some cases of low or medium risk foods for microbiological risks (Herbs & spices, Infant) or other contaminants (Honey). Other hazard types have medium or high risk due to the weight given to the severity classification, despite the low purchase volumes. For more detailed follow-up assessments, the specific combinations of food and hazard can be examined in the raw data to see exactly which hazards are involved and how the individual risk classifications were arrived at. Results are derived as explained above from the Kantar survey summaries and from 2 additional input files defining: (1) the link between the purchased items and hazard food items, and (2) the hazard statistics tables. These files are available in the supplementary materials as "kantar_adjusted_link_to_hazard.csv" and "top10_hazards.csv" respectively.

Figure 11. Risk dashboard calculated from individual food items, percent of total purchased items (Kantar) and hazard data (HorizonScan). Each pie-chart represents

proportions of generated risk scores in the different risk categories, within a particular family of hazard type and broad food type. The risk classifications were calculated using the risk matrix approach. Purchased volume scores are based on the Kantar proportions but use a non-linear mapping.

11.3 Limitations of the data outputs

As mentioned, the descriptions of the food types did not always match between the HorizonScan and Kantar data sets. A further drawback was the lack of granularity in the data outputs from the HorizonScan.

11.3.1 Microbiological hazards

It was noted that many important pathogens such as *Staphylococcus aureus*, viruses, *Clostridium botulinum* and *C. perfringens* were not specifically listed. There were reports for ‘Other Micro contaminants’, where no specific organism was mentioned. It is presumed these reports were for pathogens, as reports for spoilage and hygiene indicators/coliforms did tend to be reported. The latter have categorised as a separate category that can be given a lower priority in any sampling plan.

11.3.2 Chemical hazards

There is a question about how to deal with a large group of compounds such as pesticides. The current dashboard presents the results with all pesticides classed as ‘3’- medium risk’. It is difficult to easily obtain more detail about the severity of any report on pesticides, this can only be obtained by referring to the original individual issue report that HorizonScan links to on other alert systems, e.g. RASFF. Looking at the RASFF classifications these form a 5 point scale for severity, based on the pesticide, the concentration found and the product it has been detected in. The dashboard model was rerun using a high severity score for pesticides, to simulate a ’worst case scenario’. This resulted in very high risk flags across many products which could be deemed to skew the effort for sampling. Therefore, it seemed reasonable to use the medium risk assessment. It should also be borne in mind that pesticides and veterinary residues are both subject to Statutory Monitoring programmes and therefore a large number of samples are collected and tested for these chemical hazards, so may not be within the scope of this sampling programme anyway.

Other known food chemical contaminants did not feature in the outputs. Most notable was acrylamide. It is unclear what the reason for this was, but it is possible that although a high level of industry monitoring is conducted, results are not reported via alert systems and are therefore not picked up by HorizonScan.

It is possible to search HorizonScan for specific contaminants or hazards of interest. A search for ‘acrylamide’ found ~120 reports of acrylamide in foods. The search results have been saved in an Excel sheet and supplied separately. The majority were snack foods and processed cereal products, mainly pastries, biscuits, cakes, etc. Therefore, where there are known gaps in hazard information, this ‘reverse search’ can be carried out to obtain information of the types of products to target in any sampling campaign. This can also be used for the non-reported microbiological hazards mentioned above.

Initial searches were not carried out this way to avoid adding known bias to the outputs, ensuring the searches were food commodity based rather than by known hazard.

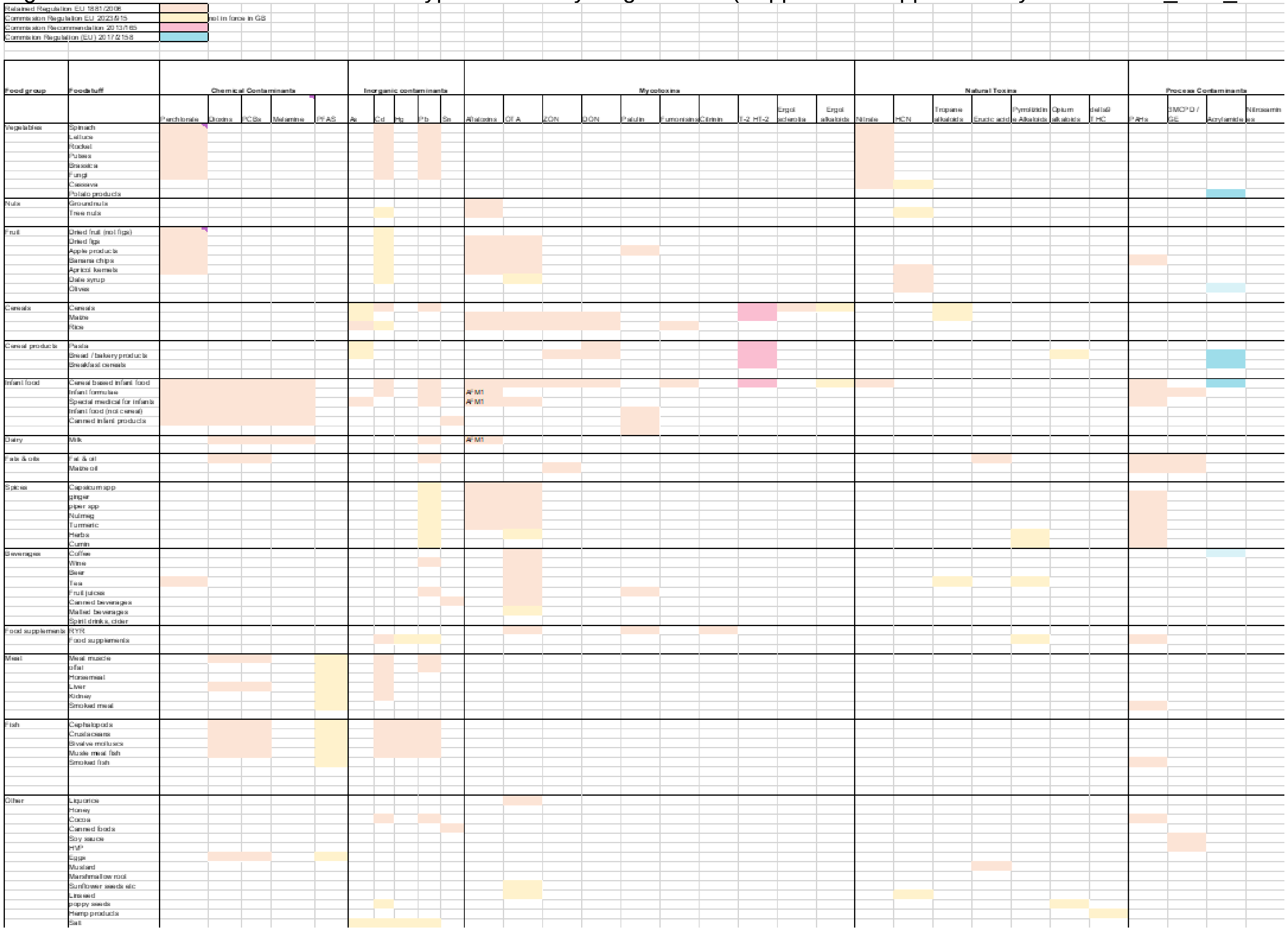
11.4 Gap analysis for hazard type and food type groups

In addition, a gap analysis will be required for hazards where there are no reports of occurrence because they are emerging topics or methods have not been established. In the first instance a matrix of contaminant:food types included in Regulations has been produced (Figure 12, supplied as separate Excel file). This includes those contaminants included in Retained EU Regulation 1881/2006 (REUL, 2006), and EU Regulation 2023/915 (EU Commission, 2023) implemented since EU Exit. The maximum levels introduced since EU Exit do not apply in GB, but will be important for any products exported to the EU. This highlights where samples should be taken to check for compliance for enforcement of maximum levels, or where Indicative Levels such as for T-2 and HT-2 toxins (EU Commission, 2013), or Benchmark Levels for example for acrylamide apply (REUL, 2017).

For emerging or non-regulated contaminants, a second list or dashboard can be produced with other suggested hazard:food pairs that could be included in the framework. Information to allow selection of these would be based on previous work such as the Review of Priority Chemical Contaminant Risks, Food Production and Consumer Diets in Scotland' (FSS, 2018) as well as scanning literature (peer reviewed and grey), industry news, alerts, intelligence or other sources of information such as information to be issued to Local Authorities by FSA. This would make use of risk assessments such as those published by EFSA and FSA. Where there are clear gaps in the evidence or body of data to allow risk assessment, this should trigger some sampling activity to provide data to determine what level risk is associated with any given hazard:food pair. This would then feed into future sampling plans as the data could be fed into the dashboards as described above and would flag if further sampling was required.

An example of these types of hazard:food pairs would be nitrosamines in processed meats and other products. EFSA published a risk assessment of N-nitrosamines in food in January 2023 (EFSA, 2023), they concluded based on the data in the EFSA contaminant database that 10 carcinogenic N-nitrosamines occurring in food (TCNAs) raises a health concern. No data from Scotland (or any UK data) were included in the data sets. Therefore, it would be informative to carry out sampling and analysis to determine the situation in Scotland. Other examples would include PFAS in different foods, these are included in Regulation EU 2023/915 but there is limited data for Scottish foods. Another example maybe for specific pesticides if regulations change, although these may be covered by the Statutory Monitoring Plans. More targeted sampling for specific hazards (e.g. viruses or presence of algal toxins in seafood, or environmental chemicals) in response to outbreaks or incidents could also be carried out, such PAHs in shellfish following an oil spill, or sewage discharges.

Figure 12. Matrix of contaminant : food type covered by Regulations. (Supplied as Supplementary file: Contam_food_matrix.xls)



12. Conclusions

A general strategy has been developed to produce a priority list specifying relative sampling effort, by food type, for use within a non-targeted surveillance program. This has taken elements from existing international food surveillance programs and guidance, but due to the general-purpose requirements we have not assumed any particular hazard or other measured property is more important than another.

Flexibility is built into the solution to allow for expert input and changing priorities. Purchasing data is based on Kantar summaries, as these data are readily available, frequently updated, and cover a wide range of products. For each food type, the total purchased volume is linked to the hazard reports in HorizonScan to identify the most prevalent hazards. It is important to check that important items are included in the generated priority list, covering each of the different properties to be assessed, and that the hazard scores are appropriate. Some experimentation with the generated designs and fine-tuning of the scoring system and grouping is recommended before the final survey designs are generated. However, the derived priority lists are primarily based on total purchases within the population. Adjustments based on expert assigned scores for hazard severity resulted in some relatively minor changes, which can lead to efficiency gains. For example, it reduced the number of soft drinks samples, where the expectation of positive tests is lower than some other product types. Overall, the prioritisation will still lead to a high percentage coverage of the total diet and be able to identify emerging risks. The expert scores may be more useful for their impact when visualising, and prioritising, the main types of hazards to test for within each food group, via the dashboard.

Decisions about absolute sample numbers will factor in information about total budget versus individual measurement costs for individual hazards of most relevance. To calculate an optimal sample size for each given hazard type, prior information would also be required about the variation in existing levels, as well as the required accuracy. These data were not available within this project.

A final sampling plan will include detailed instructions for the type of foods to purchase for sampling, using our priority list as the starting point. This should be based on market share with respect to brands, retail outlets and spatial/temporal population purchasing habits for each food type.

Annex A: Comparison Table of different sampling approaches

Type of sampling programme	Description	Pros – what can be achieved	Cons – what is not achieved	Cost and ability to meet needs to uncover issues
Total Diet Study	Total diet studies (TDS) can provide initial, population average, exposure estimates for food constituents, such as contaminants, which act as a baseline for any future measures aimed at reducing exposure at the population level. TDS allow exposure time trends to be monitored and can be used to determine the effectiveness of regulatory controls for different food types, e.g., to assess the impact of pollution control measures. An overview of population and population subgroups' exposures to contaminants can be gained using TDS data. EFSA 2011 points out that there is flexibility and some TDS include less aggregated food groups and regional variations. 'TDS for screening' or 'TDS for refined assessments'. TDS is generally considered useful to complement other monitoring programs.	Representative, robust, can be used for population exposure estimates, uses food that is prepared and as consumed, therefore give true reflection of consumption. Harmonised guidance is available on how to carry out TDS. % food consumed in kg / person or number of food items to include are defined. Potential cost savings due to analysing relatively few representative samples for multiple nutrients and contaminants. Can provide good sampling coverage of a larger number of samples from a product category if analytical methodology is sufficiently sensitive. Good for nutritional and proximate analysis.	Costly. Time consuming – samples need to be cooked and prepared as consumed. Use of 'pooled' samples can result in dilution and can mean that some problems are not uncovered e.g. because concentrations are diluted below the LOD or cannot be linked to specific food components. May not provide data for 100% of diet or food consumed per capita. Require analytical methods that may not be used routinely, i.e. with greater sensitivity, more clean-up to deal with matrix and dilution effects. Only quantifies population average levels, so it is not suitable for assessing acute risks or effects that are relevant to the extreme high/low level consumers.	High cost Possible long lead times to plan and organise. Not responsive to emerging risks, however retained samples could be tested retrospectively as issues arise.

Duplicate Diet Study	Duplicate diet (DD) or duplicate portion studies are useful to provide realistic estimates of an individual's dietary intake over defined periods. Participants collect a duplicate of the food (and sometimes drink) that they consume throughout the defined period, providing a snapshot of their daily diet. The food collected is used to form a composite sample that can be used for analysis. A high degree of cooperation is required from participants. DD contents may be influenced by the individual's preferences during the period of collection and subject to anomalies arising where the participant consumes food that is not a regular part of their normal diet.	Can be used for exposure estimates, uses food after preparation and therefore as consumed. Can be used in conjunction with biomonitoring to develop biomarkers / correlate exposure. No need for cooking / culinary preparation within the laboratory. Captures the complete diet of an individual, including food eaten away from the home or takeaway/ home delivery. Effects of local contamination and geology or food habits may be noticeable.	A large number of participants are needed to generate statistically robust data. Behaviour of participants can change during the study as the individual may not follow their usual diet, but be biased e.g. towards more healthy choices because they are being monitored. Although the overall composition of the samples will be known, DDs cannot attribute exposures to different food groups. Sample transport and preparation logistics can be difficult. Analysis issues same as for TDS. Very sensitive methods are required, samples not typical of one food matrix or food group could cause issues.	High cost. Possible long lead times to plan and organise, gain informed consent from participants (if including biomonitoring), and providing training to ensure compliance. Contaminants may not be detected due to dilution effects. Not responsive to emerging risks, however retained samples could be tested retrospectively as issues arise.
Market Basket Survey	The term market basket survey is used to describe the process of obtaining samples at a retail level that can be used for purposes of monitoring or surveillance. Descriptions of market basket survey vary from surveys to focus on a narrow range of products, e.g. mycotoxins in dried fruit sold in a	Can be fairly quick to organise, can be used for crude exposure estimates. Data for individual food items can be generated. If individual items are analysed, then routine laboratory methods will be applicable.	Only gives a 'snapshot' picture relating to when the samples were collected. Will not be statistically robust without carefully designing the survey (difficult to do properly unless all the important levels of variation	Can be economical in terms of cost if targeted to certain foods or population groups. May have similar analytical issues as above.

	particular location, through to a wider scope design whereby a range of foods and analytes are considered (almost identical to TDS). The survey will usually be conducted within a restricted time period, using a limited number of retail outlets / locations. Such surveys can however be organised relatively quickly and are comparatively inexpensive. Market basket surveys can be used in a similar way to TDS to compare data and look for time trends if similar protocols are used each time.		relevant to the study/studies are known in advance). Requires good data on population purchase or consumption behaviour. If based on purchase information should be borne in mind not all foods purchased will be consumed, and the unused portion is difficult to estimate. Food is not usually cooked before analysis and so will not give results as consumed; however, since cooking can result in breakdown of some compounds, this may be an advantage in terms of uncovering a problem.	Less well defined than TDS or DD but there seems to be a lot of crossover of terms and applied use with TDS in particular.
Targeted Sampling	Targeted sampling is used when a problem such as an incident, adverse event (e.g. poor harvest) or when a breakdown of control has been identified. This term is used to reflect the samples that are taken in response to incidents, e.g. reports of contaminant X in product Y. In statistical terms this may also be described as oversampling, where there is an increased probability/belief of finding something of interest. Results from targeted sampling	Can be used to establish detailed information to assess the extent of a problem following an incident. Quick to organise, implement and report. Routine methods can be used where available, or new methods are easier to establish for limited analyte / matrix combination. Useful tool to use in the event of finding non-compliance.	Not useful for population exposure estimates, as data only relates to specific target commodity and therefore does now allow full exposure from all sources to be assessed. Sampling design targeted to find higher incidence of positives so results may be skewed / biased.	Cost effective, provides good but limited information.

	exercises are likely not to be suitable for population exposure estimates, since they will have a higher proportion of elevated results compared with typical or representative samples.	Provide snapshot of particular commodity / contaminant situation so can be used to benchmark and allow for changes to be measured following mitigation or other measures being introduced e.g. regulations or change in practices.		
Risk Based Sampling	Risk based sampling is a particular type of targeted sampling scheme. Risk based sampling plans can save money because a smaller number of samples is needed because not all products have the same risk. Generally it is more focused on high-risk products, which are those that need more regular monitoring to assure the food safety in the food chain. The costs for overall food control are also reduced, because important problems are discovered at an earlier stage, meaning that preventive activities can be applied sooner. Overall sampling goals, strategies and directions improve when there is a risk-based reasoning behind the development of the sampling plan. The sampling plan should be dynamic, i.e. regularly adjusted based on the results and the risk level of the different products and food business operators (FBOs) covered by the	Sampling plans can be weighted to increase the proportion of samples where risk of non-compliance is higher. Factors that may increase likelihood of non-compliance include: • Food business operators (FBOs) with poor quality standards • FBOs with history of non-compliance • Known (mis-)use of agricultural chemicals • Local conditions – e.g. weather, crop quality • Products imported from countries with poor food control systems or from regions with a history of non-compliance Similarly, plans may be weighted downwards where risk is low, e.g.:	Data generated may give a misleading estimate of population exposure, either too high through targeted sampling, or too low through reduced sampling in areas presumed to be low risk. Where sampling is reduced over time the accuracy of future predicted risks may reduce. This may lead to incidents of non-compliance not being detected or complacency due to perceived lack of checks could develop within the supply chain.	Cost effective, but needs to be constantly monitored, evaluated and modified to respond to changes and current situation.

	plan. Whilst a risk based plan is cost effective, it will not necessarily be representative.	• FBOs operating to high quality standards, or under close control of a reputable trades association.		
Untargeted Screening	Analysis of samples, either individual or composite (e.g. TDS) for known and unknown compounds using a range of analytical tools and software applications to look for unusual or non-conforming results.	Produces huge amounts of data, which can be searched at a later date as new issues arise. Non-targeted analysis can look for patterns or fingerprints, so can determine differences from 'normal' or can be used to screen for more targeted lists of compounds or classes of compounds of concern particularly where analytical standards may not be available. Can alert to possibility of previously unforeseen issues, e.g. fipronil in eggs, that can be followed up with targeted sampling and analysis. Can be used for rapid screening to generate a 'suspect list'.	Requires expensive and specialised instruments. Requires trained personnel able to process the data. Requires large data storage capability. May have higher detection limits than targeted methods so may miss low level contamination. Could result in false negatives or positives due to experimental design.	Very high cost
Sampling to check for Regulatory Compliance	Methods to check for regulatory compliance generally use raw foods and will focus on target components. Often the required numbers of samples and the analyte / matrix combinations are pre-determined by Regulations or agreed protocols.	On-going pre-determined sampling means there is a chance of detecting non-compliance so reduces incentive for non-compliant use of regulated products. Incidence of positives is generally very low.	Can be inflexible / not responsive to new or emerging issues (programme is designed to check for known issues or control of regulated products).	High cost as usually large numbers of samples are involved. Although this cost can be transferred from Regulators to FBOs.

	For veterinary medicines, urine or tissues seldom consumed may be used to check for illegal use. A large number of samples of liver or kidney may be analysed compared to proportion consumed since these are the target organs for many pharmaceuticals and allow highest chance of detection of misuse. Samples are generally analysed without preparation since processes such as cooking may result in a breakdown of compounds and result in failure to uncover non-compliance.	If used at import point can be used to prevent non-compliant food reaching the marketplace. Testing requirements well defined, allows use of well-established methods, or means method developments can be targeted appropriately.	Depending on where sampling is carried out may produce data after product is already on the market or has been consumed – in this case data is for statistical purposes only and not for consumer protection. Low incidence of positives may lead to complacency in testing regimes. Only looks for known issues so smaller chance of detecting unusual or unexpected results.	Positive findings while not used for immediate consumer protection can be used to inform future risk based or targeted sampling.

Country	Date of report	Consumption informed by	% coverage of diet	No. Foods	No. Food Groups	Areas covered
Sweden Market Basket 2015	2017	National Food Production and trade statistics in combination with population statistics – used to calculate per capita (population) mean intakes *Described as Markey Basket Study – distinction made between TDS and MB as foods not cooked, although a pilot study to include some cooking was carried out. Foods included 1.5g/p/day	90	Basket represents more than 130 food items	12	Nutrients, and range of chemical contaminants. Whole population, results calculated per capita. Sample purchase carried out in one region as previous data showed no significant difference between regions.
Brazil	2008	Recent household food budget survey conducted by the Brazilian Institute for Geography and Statistics (Aveglianol et al, 2008 and Levy et al, 2011).	72	71	30	Essential and toxic elements
Hong Kong	2013	Food consumption data were taken from the Hong Kong population-based Food Consumption Survey (FCS) conducted by the CFS in 2005–2007 (FEHD 2010). Data were obtained by two non-consecutive 24-h dietary intake questionnaires of 5008 Hong Kong adults aged 20–84 years through a quota sampling by gender and age groups.	24	71		Targeted for PBDEs only so only sampled foods of animal origin and fatty foods (Chen et al, 2013).

		Hong Kong TDS – series of 10 reports outlining methodology and reports of contaminants tested.				Centre for Food Safety, Hong Kong Total Diet Study 2023.
Italy	2013	Based on the results of the National Food Consumption Survey INRAN-SCAI 2005-06. 1329 households were randomly selected after geographical stratification of the national territory. Food consumption of 3323 subjects was assessed on three consecutive days through individual estimated dietary records. Market share data used to inform sample purchase.	99.7	51	13	4 geographical areas. Several subpopulations. Trace elements, element species, and radionuclides.
EU (four countries)	2010	Monthly market baskets designed for infants first 9 months of life. Calculated by monetary value not true market share.	100	62 products infant formula 35 products (other baby foods)	30 baskets 13 baskets	Designed to cover typical diet of infants not breast fed on a month by month basis. Simulated move to weaning foods. Designed to assess exposure to chemicals.
Wales	2003	Shopping list based on items of microbiological concern, rather than being representative of consumption frequency, therefore a targeted approach. Specifically for micro sampling not used for chemical hazards				Microbiological risks
Germany	2019	Current and comprehensive consumption data were used from the	90	356	19	Range of nutrition and chemical contaminant tests.

		National Nutrition Survey II (NVS II; n = 13,926; 24 h recalls; 14 to 80 years) (Heuer, Krems, Moon, Brombach, & Hoffmann, 2015) and consumption survey for children (VELS, n = 804; 24 h recalls; 0.5 to < 5 years) (Banasiak, Heseker, Sieke, Sommerfeld, & Vohmann, 2005) to establish the MEAL food list. Due to missing data, consumption habits of 5 to 13 years old children were not explicitly considered to derive the MEAL food list.				Foods rarely consumed (<10%) also included. Sample seasonally, by region and food production type (organic versus conventional)
Germany	2022	The foodstuffs examined are part of a representative “market” basket derived from national consumption studies (market basket monitoring). Each foodstuff chosen is analysed for certain substances which may occur as residues or contaminants in or on the product, and which have been specified in advance.		35		9000 tests are conducted on foodstuff, per product a minimum of 50 samples will be tested.
Finland	2004	Market basket diet based on 1997 Dietary Survey of Finnish Adults, a 24 hour recall study with 2862 participants. Foods included in the study were those with consumption that exceeded 0.5g/p/day.	>90 (based on consumption data for Sweden)	228	10 + alcohol	Average intake of nutrients and contaminants. Data for dioxins and PCBs.
France	2018	Broad range of food stuffs included. 5484 products purchased.	97	457	38	Targeted for infants and children under 3 years. Dietary exposure assessed

						for 500 substances. Risk assessed for 400 substances, including 281 pesticide residues.
Netherlands	2020	Most recent published study to monitor the food consumption and intake of energy and nutrients of the general Dutch population 1-79 years old (Dutch National Food Consumption Surveys (DNFCS, 2023). Data was collected in 2012 to 2016. Data collected by Kantar, general questionnaire and where possible digital versions. Specific questionnaires sent for different age groups. Studies for infants based on 232 children collected on 2 non-consecutive days. Subsequent study for 2019-2021 available, 3570 people.	96-98 87-88	164 composite samples 130 foods 213 subsamples	18 food groups and 59 subgroups 88 composite samples	For infants, chemical contaminants and nutrition. Young children and population aged 7-69 years. Targeted for mycotoxins so omitted some foods with no mycotoxin risk (hence why <90% coverage).
USA	2013	Sampling design for location and population coverage, used Census population estimates. a three-stage, stratified, probability-proportional-to-size (PPS) sample election process; 1) county selection (based on population density); 2) supermarket outlets within selected counties (based on annual sales); and 3) specific brands of foods (based on market share data). In the first stage, Census regions (4), divisions and				Used for nutrient analysis. Food samples which are collected nationally according to a statistically rigorous sampling approach are consistent with national representativeness and allow better estimates of the mean and variability than convenience sampling or less rigorous options. Takes

		states were used to obtain a self-weighting sample of population centres, ensuring geographic dispersion across the 48 conterminous states; 48 locations were selected, with nested subsets of 24, 12 and 6 locations.				account of coverage of stores and brands
Canada	2012	24-hr recall of food consumption of 12,796 individuals conducted in 1970s.		140 composites	Not analysed as groups	Based on food consumption data not ‘food disappearance’ data so should be more accurate for dietary calculations

Annex C: Factors to consider as sources of variability to ensure samples are representative:

The topics listed below are examples of factors to consider when designing a representative sampling plan. The list is not exhaustive and important specific factors may relate to certain types of products.

Geographical balance

There may be a wide diversity of soil and climatic conditions, resulting in significant variance in food composition, in requirements for the use of agricultural chemicals, and in the presence of contaminants that may be present. Historic use of pesticides in specific regions may have an impact on production.

Seasonal effects

Seasonal variations can result in variations in food composition and the need to use agricultural chemicals. Where foods are produced in only one season, this is not so important to consider, but where there is more than one season this should be covered in an annual plan. The collection of samples needs to be organized, in terms of timing and frequency, to reflect production

Physiological state and maturity

The states of maturity of plants and animal foods can cause variation in composition, but is less likely to have a significant impact in terms of chemical residues and contaminants. It is nevertheless important to take this into account, especially if early harvest may mean that products are harvested closer to the time of application of agricultural chemicals. Storage of foods can affect composition of foods in terms of water and other factors that may have an impact on some contaminants such as mycotoxins.

Cultivar and breed

These may be a significant source of variation for residues and contaminants and any sampling plan needs to account for this factor.

Scale and method of production

Large corporate producers may use different methods compared with small family farmers. In addition, members of trades associations or those producing to specific quality standards (Global Gap etc) may use different methods. Organic production is another example that may result in differences in finished product.

Table D.1 Dairy and oils

Product	% total food purchased	Top 10 Hazards	No. Top 10 hazard reports	% of top 10 hazard reports	Hazard Severity H / M / L	Other notable hazards
Total Milk	14.4	Listeria monocytogenes	121	18	H	28 other hazards
		Decomposed/altered organolepsis		17	L	37 reports
		Campylobacter		14	H	Adulteration
		E. coli		12	H	Other micro (Salmonella, Staphylococcus, Enterobacteriaceae)
		Other processing issues		8	M	
		Other microbiological contaminants		7	M	
		Other inorganic contaminants		7	M	
		Mislabelling		6	L	
		Inadequate thermal processing		6	M	
		Bacillus cereus (presumptive)		5	L	
Yoghurt	1.48	Foreign bodies	154	47	L	22 other hazards
		Pesticides		16	M	36 reports
		Milk/dairy - undeclared		6	H	Allergens undeclared – gluten, egg, soya
		Fungal moulds and yeasts		6	L	Other micro
		E. coli		5	H	Inadequate thermal processing / expiry date change
		Decomposed/altered organolepsis		5	L	
		Multiple and other allergens - undeclared		5	H	

		Listeria monocytogenes		5	H	
		Other processing issues		4	L	
		Tree nuts - undeclared		4	H	
Cheese	1.22	Listeria monocytogenes	1506	46	H	40 other hazards 268 reports Other micro Pesticides Allergens undeclared – milk/dairy Allergens undeclared – multiple, other, soya, mustard, gluten
		E. coli		20	H	
		Foreign bodies		9	L	
		Fungal moulds and yeasts		7	M	
		Salmonella (unspecified or other spp)		7	H	
		Fraudulent health certificate/documentation		3	L	
		Adulteration/substitution		3	L	
		Mislabelling		2	L	
		Egg - undeclared		2	H	
		Other microbiological contaminants		2	L	
Butter (and ghee) / margarine	0.58 (Butter)+ 0.42 (Margarine)	Listeria monocytogenes	66	29	H	16 other hazards 24 reports Other micro (E. coli, and others) 3-MCPD
		Coliform bacteria (unspecified)		15	M	
		Adulteration/substitution		9	L	
		Other organic contaminants		9	M	
		Gluten or wheat - undeclared		8	M	
		Foreign bodies		8	L	
		Mislabelling		8	L	
		Other processing issues		6	L	
		Milk/dairy - undeclared		4	H	
		Salmonella (unspecified or other spp)		4	H	
Vegetable oils	*included in margarine	Sudan dyes	178	27	M	9 other hazards 18 reports
		Adulteration/substitution		14	L	

	and processed foods	Other PAHs		12	M	Mineral oil Colours
		Benzo(a)pyrene		11	M	
		Pesticides		11	M	
		3-MCPD		9	M	
		Fraudulent health certificate/documentation		7	L	
		Mislabelling		4	L	
		Other organic contaminants		3	M	
		Unauthorised novel foods		2	M	
Eggs	0.97 (also used in processed foods)	Salmonella (unspecified or other spp)	210	39	H	20 other hazards 36 reports Dioxins Other micro
		Salmonella typhimurium, Salmonella enteritidis		39	H	
		Veterinary drugs		5	M	
		Fraudulent health certificate/documentation		3	L	
		Other microbiological contaminants		3	M	
		Other processing issues		2	L	
		Insufficient controls		2	L	
		PCBs (sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES – 6))		2	M	
		Expiry date changes		2	L	
		Pesticides		2	M	
		Pesticides	978	75	L	25 other hazards

Frozen Dairy		Milk/dairy undeclared		5	H	86 reports Egg undeclared, food additives, aerobic colony count, colours, insufficient processing controls.
		Foreign bodies		4	L	
		Multiple allergens undeclared		3	H	
		Coliform bacteria		3	L	
		Tree nuts undeclared		3	H	
		Peanuts undeclared		2	H	
		Listeria monocytogenes		2	H	
		Gluten or wheat undeclared		2	H	
		Soya undeclared		1	H	

Table D.2 Meat and Fish

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Poultry & game	1.69 + 0.118 (frozen poultry) + 0.434 (chilled processed poultry) **Total = 1.85**	Salmonella (unspecified or other species)	1714	46	H	24 other hazards 56 reports Insufficient controls Pesticides Other micro Inadequate thermal processing / other processing issues
		Salmonella typhimurium / Salmonella enteritidis		41	H	
		Listeria monocytogenes		4	H	
		Decomposed / organolepsis		2	L	
		Campylobacter		2	H	
		Mislabelling		2	L	
		Vet drugs		1	M	
		Foreign bodies		1	L	
		Fraudulent document		1	L	
		E coli		1	H	
Fresh beef	0.69 + 0.35 (fresh sausages) + 0.16 (chilled burgers) + 0.113 (frozen meat) **Total = 0.96**	E. coli	632	45	H	28 other hazards 64 reports Other micro (Salmonella) Sulfur dioxide and sulphites Decomposition Undeclared allergens
		Salmonella (unspecified or other spp)		18	H	
		Foreign bodies		11	L	
		Listeria monocytogenes		9	H	
		Veterinary drugs		4	M	
		Produced without inspection		4	L	
		Other processing issues		3	L	
		Mislabelling		2	L	
		Insufficient controls		2	L	
		Fraudulent health certificate/ documentation		2	L	

Pork	0.4 (bacon rashers) + 0.35 (fresh sausages) + 0.25 (fresh pork) + 0.103 (fresh bacon joint) + 0.097 (Chld Frnk) + 0.075 (Chld saus meat) + 0.042 (fresh bacon steaks) = **1.32**	Listeria monocytogenes Salmonella (unspecified or other spp) Product has decomposed/altered organolepsis Foreign bodies Veterinary drugs Salmonella typhimurium, Salmonella enteritidis Adulteration/substitution Produced without inspection Fraudulent health certificate/documentation E. coli	463	37 20 11 9 7 4 3 3 3 3	H H L L M H L L L H	33 other hazards 98 reports Undeclared allergens – milk/dairy, soya, gluten, mustard. Other micro PAHs
Cooked meats	**0.73** (includes cooked products of all meats above)	Listeria monocytogenes Salmonella (unspecified or other spp) Foreign bodies Multiple and other allergens - undeclared Product has decomposed/altered organolepsis Mislabelling Salmonella typhimurium, Salmonella enteritidis Milk/dairy - undeclared E. coli Gluten or wheat - undeclared	1794	31 28 10 6 5 5 4 4 4 3	H H L H L L H H H H	50 other hazards 482 reports Other microbiological Undeclared allergens Pesticides Insufficient controls/ processing issues PAHs Veterinary Drugs
Fish		Listeria monocytogenes	2329	20	H	59 other hazards

	0.311 (fresh fish) + 0.26 (frozen fish) **Total = 0.57**	Histamine		16	M	719 reports Processing / inspection issues. Other micro – C. botulinum next highest. Pesticides Cadmium Undeclared allergens – dairy, mustard, soya Carbon monoxide Benzo(a)pyrene & PAHs
		Mercury		14	H	
		Product has decomposed/altered organolepsis		13	L	
		Salmonella (unspecified or other spp)		9	H	
		Parasitic infestation with nematodes		7	M	
		Veterinary drugs		6	M	
		Mislabelling		5	L	
		Coliform bacteria (unspecified)		5	M	
		Fraudulent health certificate/documentation		5	L	

Table D.3 Drinks – non-alcoholic

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Fruit flavoured soft drinks	Chilled drinks and Yoghurt drinks and juices 1.85 + 0.28 **Total = 2.13**	Colours for use in foodstuffs Other processing issues Other food additives (other than colours and sweeteners) Product has decomposed/altered organolepsis Mislabelling Adulteration/substitution Unauthorised food/feed additive Warning letter Fungal moulds and yeasts Foreign bodies	186	34 12 11 11 7 7 5 5 5 3	M L L L L L L L L L	18 other hazards 38 reports Pesticides Other micro Undeclared allergens – dairy, nuts, sulphite, celery
Other beverages (not canned)		Other processing issues Adulteration/substitution Mislabelling Colours for use in foodstuffs Foreign bodies Milk/dairy - undeclared Unauthorised novel foods Unauthorised food/feed additive Other food additives (other than colours and sweeteners) Pesticides	276	19 19 10 9 9 8 7 7 6 6	L L L M L H M M L M	39 other hazards 135 reports Fungal moulds and yeasts Other micro Undeclared Allergens – gluten, soya, nuts. Fraudulent documentation Inadequate thermal processing

Apple juice		Patulin	88	44	M	None
		Foreign bodies		16	L	
		Arsenic		15	M	
		Other processing issues		8	L	
		Adulteration/substitution		7	L	
		Fungal moulds and yeasts		4	L	
		Mislabelling		2	L	
		Product has decomposed/altered organolepsis		2	L	
		Insufficient controls		1	L	
		Unapproved premises		1	L	
Orange juice		Pesticides	23	48	M	None
		Coliform bacteria (unspecified)		9	M	
		Product has decomposed/altered organolepsis		9	L	
		Other processing issues		9	L	
		Mislabelling		9	L	
		Multiple and other allergens - undeclared		4	H	
		Milk/dairy - undeclared		4	H	
		Produced without inspection		4	L	
		Adulteration/substitution		4	L	
Other mixed fruit juices and Conc juices		Colours for use in foodstuffs	170	19	M	63 reports 27 other issues
		Sulphite - undeclared		16	M	
		Adulteration/substitution		12	L	
		Product has decomposed/altered organolepsis		12	L	
		Foreign bodies		9	L	
		Pesticides		9	M	

		Patulin		9	M	
		Other processing issues		5	L	
		Fungal moulds and yeasts		5	L	
		Arsenic		4	M	

Table D.4 Bread, Morning goods and breakfast goods

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Breads	6.65 (morning goods)	Pesticides	514	32	M	32 other hazards 95 reports Next 4 items: Salmonella Undeclared Allergen – mustard Melamine and cyanuric acid Undeclared allergen – tree nuts and lupin Other hazards: Other micro
		Foreign bodies		23	L	
		Fungal moulds and yeasts		13	L	
		Multiple and other allergens - undeclared		7	H	
		Egg - undeclared		6	H	
		Milk/dairy - undeclared		5	H	
		Other processing issues		4	L	
		Gluten or wheat - undeclared		4	M	
		Sesame - undeclared		3	H	
		Soya - undeclared		3	H	
Pastries, biscuits cakes	3.87 (Chilled bakery products) 2.04 (Ambient cakes & pastries) 1.85 (Biscuits) **Total = 7.76**	Foreign bodies	1407	16	L	52 other hazards 708 reports Next 4 hazards: L. monocytogenes Mislabelling Adulteration/subsititution Mycotoxins Other natural toxins Allergen – undeclared gluten Other hazards: Organic contaminants including acrylamide, 3-MCPD, aflatoxins, other natural toxins.
		Pesticides		14	M	
		Milk/dairy - undeclared		14	H	
		Multiple and other allergens - undeclared		13	H	
		Colours for use in foodstuffs		12	M	
		Tree nuts - undeclared		9	H	
		Peanuts - undeclared		8	H	
		Salmonella (unspecified or other spp)		5	H	
		Fungal moulds and yeasts		5	L	
		Egg - undeclared		4	H	

						Other micro including norovirus. Other undeclared allergens – soya, lupin, sesame,
Breakfast cereals	1.54 (packet breakfast)	Pesticides Foreign bodies Colours for use in foodstuffs Adulteration/substitution Tree nuts - undeclared Multiple and other allergens - undeclared Peanuts - undeclared Milk/dairy - undeclared Gluten or wheat - undeclared Salmonella (unspecified or other spp)	212	24 15 12 11 11 8 6 5 4 4	M L M L H H H H M H	24 other hazards 73 reports Next 4 hazards: Tropane alkaloids (atropine & scopolamine) Ochratoxin A Hydrocyanic acid Other hazards: Mycotoxins Other micro Undeclared allergens – soya, sesame.

Table D.5 Ready to eat foods and snacks

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Ready to eat meals	4.04 (frozen prepared food) 1.73 (Savoury home cooking) 1.53 (chilled ready meals) 0.53 (p/p/ Fresh meat+veg+pastry **Total = 7.83**	Foreign bodies Multiple and other allergens - undeclared Listeria monocytogenes Pesticides Coliform bacteria (unspecified) Salmonella (unspecified or other spp) Milk/dairy - undeclared Egg - undeclared E. coli Mislabelling	521	21 16 14 12 8 7 7 5 5 5	L H H M M H H H H L	38 other hazards 197 reports Undeclared allergens – gluten, soya, celery, crustaceans, mustard, peanuts, sesame, tree nuts, fish Aerobic colony count / other micro Inadequate thermal processing Decomposition

Snack foods	1.02 (Take home savouries)	Colours for use in foodstuffs Milk/dairy - undeclared Pesticides Salmonella (unspecified or other spp) Multiple and other allergens - undeclared Foreign bodies Aflatoxin B1+B2+G1+G2 Hydrocyanic acid, including hydrocyanic acid bound in cyanogenic glycosides Peanuts - undeclared Gluten or wheat - undeclared	643	17 17 12 11 9 8 7 7 6 6	L H M H H L H H H M	49 other hazards 341 reports Undeclared allergens – tree nuts, mustard, egg, sulphite, sesame, soya Acrylamide Ochratoxin A Other micro Unauthorised food /novel food
Cereal snacks	1.22 (Savoury Carb+snacks)	Colours for use in foodstuffs Pesticides Tropane alkaloids - atropine Tropane alkaloids - scopolamine Gluten or wheat - undeclared Milk/dairy - undeclared Foreign bodies Mislabelling Adulteration/substitution Aflatoxin B1+B2+G1+G2	602	24 22 16 14 5 5 4 4 3 3	L M H H M H L L L H	37 other hazards 148 reports

Table D.6 Fruit & vegetables and cereals / savoury goods

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Fruit & vegetables	8.23 (vegetables, includes potatoes) 6.10 (fruit) 2.71 (canned goods, but includes soups, past etc.) 0.56 (chilled prepared fruit & veg) + fresh soup (0.124) **Total = 17.72**	Pesticides Aflatoxin B1+B2+G1+G2 Listeria monocytogenes Salmonella (unspecified or other spp) Sulphite - undeclared Product has decomposed/altered organolepsis Ochratoxin A Foreign bodies Adulteration/substitution Lead	7238	72 5 4 4 3 3 3 2 2 2	M H H H M L M L L H	65 other hazards 1349 reports Next 4 hazards: E. coli Sulphur dioxide and sulphites Unauthorised food / feed additive Infestation Other hazards Cadmium, Norovirus & Hepatitis A, Other micro, Aflatoxin B1 HCN
Unprocessed cereals		Pesticides Aflatoxin B1+B2+G1+G2 Decomposed/altered organolepsis Infestation (insects, mites etc.) Ochratoxin A Aflatoxin B1 Foreign bodies Fungal moulds and yeasts Gluten or wheat - undeclared	1090	42 16 15 7 5 5 4 3 2	M H L L M H L M L	46 other hazards 149 reports Tropane alkaloids Deoxynivalenol PAHs Mineral oil Other micro – Salmonella, Listeria

		Genetically modified material		1	L	
Flour	Included in savoury home cooking	Pesticides Ochratoxin A Infestation (insects, mites etc.) E. coli Ergot alkaloids Soya - undeclared Aflatoxin B1+B2+G1+G2 Salmonella (unspecified or other spp) Gluten or wheat - undeclared Tropane alkaloids - atropine	170	20 15 14 11 9 7 7 6 6 5	M M L H M H H H H H	28 other hazards 81 reports Tropane alkaloids – scopolamine Ergot alkaloids Deoxynivalenol Other micro
Rice	Included in savoury carbohydrates & snacks, chilled convenience, frozen veg. Chilled rice = 0.008%	Pesticides Aflatoxin B1+B2+G1+G2 Decomposed/altered organolepsis Infestation (insects, mites etc.) Ochratoxin A Aflatoxin B1 Foreign bodies Genetically modified material Fungal moulds and yeasts Adulteration/substitution	713	52 12 12 5 5 4 4 2 2 2	M H L L M H L L M L	19 other hazards 50 reports Next 4 hazards: Documentation / letter Mineral oil Arsenic Lead Other issues: Undeclared allergens Cadmium

Table D.7 Drinks - alcoholic

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Wine	2.30 + 0.365 (Sparkling wine) = **2.67**	Product has decomposed/altered organolepsis	380	48	L	10 other hazards 24 reports
		Adulteration/substitution		21	L	Other micro / fungal yeasts
		Other food additives (other than colours and sweeteners)		6	L	Undeclared allergens – dairy, gluten
		Sulphite - undeclared		6	M	Colours
		Foreign bodies		5	L	Lead
		Other processing issues		4	L	Ochratoxin A
		Sulphur dioxide and sulphites (E220-4, E226-8)		4	M	
		Unauthorised food/feed additive		3	L	
		Fraudulent health certificate/documentation		2	L	
		Pesticides		1	M	
Beer	**3.31**	Foreign bodies	116	27	L	5 other hazards 6 reports
		Adulteration/substitution		22	L	
		Other processing issues		15	L	
		Gluten or wheat - undeclared		13	M	
		Mislabelling		9	L	
		Other inorganic contaminants		4	M	
		Tree nuts - undeclared		3	H	

		Unauthorised novel foods Nitrosamines Milk/dairy - undeclared		3 2 2	M H H	
Spirits	**0.84**	Adulteration/substitution Ethyl carbamate Milk/dairy - undeclared Foreign bodies Fraudulent health certificate/documentation Other processing issues Tree nuts - undeclared Unauthorised food/feed additive Import refusal Other food additives (other than colours and sweeteners)	71	31 16 14 8 7 6 6 4 4 4	M M H L L L H L L L	13 other hazards 16 reports Colours Sulphite undeclared
Cider, perry	**0.91**	Other processing issues Lead E. coli Patulin Unauthorised food/feed additive Mislabelling Sulphite - undeclared Other food additives (other than colours and sweeteners) Insufficient controls	13 (9 hazards)	31 15 7 7 8 8 8 8 8	L H H M L L M L L	None
Flavoured alcohol beverages (Fabs)	**0.164**					

Table D.8 Special Foods and others

Product	Percent of total food purchased	Top 10 Hazards	No Top 10 hazard reports	% of top 10 hazards	Hazard Severity H / M / L	Other notable hazards
Food & dietary supplements		Pesticides Unauthorised food/feed additive Unauthorised novel food Other organic contaminants Adulteration or substitution Other natural toxins Other processing issues Salmonella Fraudulent documents / health certificate Mislabelling	2429	26 20 16 10 8 8 5 3 2 2	L L L M L M L H L L	54 other hazards 576 reports Lead Milk / dairy undeclared PAHs Sulphite Irradiation Colours Wheat or gluten undeclared Hepatitis A Mercury Hydrocyanic acid
Herbs & spices		Pesticides Salmonella (unspecified or other spp) Aflatoxin B1+B2+G1+G2 Other natural toxicants Product has decomposed/altered organolepsis Colours for use in foodstuffs Adulteration/substitution Ochratoxin A Bacillus cereus (presumptive) E. coli	2318	36 35 7 7 4 3 2 2 2 2	M H H H L M L M H H	51 other hazards 719 reports PAHs Lead, sudan dyes, other allergens, other microbiological, Listeria

Infant food		Foreign bodies	48	40	L	8 other hazards
		Cadmium		15	L	8 reports
		Soya - undeclared		13	H	
		Ochratoxin A		8	M	
		Pesticides		6	M	
		Gluten or wheat - undeclared		6	H	
		Milk/dairy - undeclared		4	H	
		Multiple and other allergens - undeclared		4	H	
		Other microbiological contaminants		2	H	
		Unauthorised food/feed additive		2	M	
Infant formulae		Salmonella (unspecified or other spp)	124	24	H	26 other hazards
		Cronobacter spp. (Enterobacter sakazakii)		19	H	30 reports
						Colours
		Other processing issues		17	L	Sulphite undeclared
		Foreign bodies		10	L	
		Other microbiological contaminants		7	L	
		Pesticides		7	M	
		Adulteration/substitution		5	L	
		Fraudulent health certificate/documentation		5	L	
		Mislabelling		3	L	
		Product has decomposed/altered organolepsis		4	L	

Honey		Adulteration/substitution	217	47	L	10 other hazards 18 reports Natural toxins, Sweeteners, unauthorised novel foods, Clostridium botulinum, None
		Veterinary drugs		18	M	
		Pesticides		12	M	
		Inadequate thermal processing		8	L	
		Fraudulent health certificate/documentation		5	L	
		Other processing issues		3	L	
		Foreign bodies		2	M	
		Milk/dairy - undeclared		2	H	
		Mislabelling		2	L	
		Other organic contaminants		1	M	

Table D.9 Undeclared Allergens Reported in Foods

Food type	Allergens (undeclared)	No. Reports	Total reports	% Total
Other prepared foods	Multiple and other allergens	262	861	31
	Milk/dairy	159		19
	Egg	92		11
	Soya	66		8
	Gluten or wheat	66		8
	Mustard	53		6
	Tree nuts	36		4
	Celery	29		3
	Fish	28		3
	Crustaceans	20		2
	Sesame	20		2
	Peanuts	19		2
	Sulphite	10		1
	Lupin	1		1
Pastries, biscuits, cakes etc.	Milk/dairy	193	799	24
	Multiple and other	179		23
	Tree nuts	123		16
	Peanuts	111		14
	Egg	59		7
	Gluten or wheat	50		6
	Soya	41		5
	Sulphite	16		2
	Lupin	13		2
	Sesame	8		1
	Fish	3		0
	Mustard	2		0

	Celery	1		0
Chocolate-based confectionery (except spreads)	Milk/dairy	164	413	40
	Tree nuts	79		19
	Peanuts	62		15
	Multiple and other allergens	62		15
	Gluten or wheat	19		4
	Egg	9		2
	Soya	7		2
	Sulphite	7		2
	Sesame	4		1
Snack foods	Milk/dairy	106	350	30
	Multiple and other allergens	58		17
	Peanuts	39		11
	Gluten or wheat	38		11
	Tree nuts	34		10
	Mustard	22		6
	Sulphite	19		5
	Egg	13		4
	Sesame	10		3
	Soya	8		2
	Crustaceans	2		1
	Fish	1		0
Other sauces (various, usually in jars)	Multiple and other allergens	82	326	25
	Peanuts	47		15
	Milk/dairy	47		14
	Mustard	27		8
	Sulphite	24		7
	Egg	23		7
	Soya	19		6
	Fish	14		4

	Gluten or wheat	14		4
	Celery	13		4
	Tree nuts	8		3
	Sesame	5		2
	Crustaceans	3		1
Gluten-free products	Gluten or wheat	135	197	69
	Milk/dairy	22		11
	Multiple and other allergens	13		7
	Soya	10		5
	Tree nuts	7		4
	Peanuts	3		2
	Sulphite	2		1
	Egg	2		1
	Fish	1		0
	Mustard	1		0
	Sesame	1		0
Meat products and meat preparations - other	Multiple and other allergens	72	187	38
	Gluten or wheat	25		13
	Milk/dairy	25		13
	Soya	18		10
	Egg	9		5
	Mustard	9		5
	Tree nuts	8		4
	Celery	7		4
	Sesame	5		3
	Sulphite	5		3
	Fish	3		2
	Molluscs (shellfish, squid etc.)	1		0

Milk products - ice-cream (& similar frozen confections)	Milk/dairy Multiple and other allergens Tree nuts Peanuts Gluten or wheat Soya Egg	47 29 26 21 17 15 11	166	28 17 16 13 10 9 7
Breads	Multiple and other allergens Egg Milk/dairy Gluten or wheat Sesame Soya Mustard Tree nuts Lupin Peanuts Sulphite Crustaceans Celery	36 28 23 20 17 17 7 5 5 2 1 1 1	163	22 17 14 12 11 10 4 3 3 1 1 1 1
Food and dietary supplements	Milk/dairy Sulphite Multiple and other allergens Gluten or wheat Soya Peanuts Crustaceans Fish Tree nuts	41 27 27 18 14 13 9 4 2	156	

	Mustard	1		

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