Science Report

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What's in your food

BfR MEAL Study Final Report

28 July 2023

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Germany's first Total Diet Study

The BfR MEAL Study is the first Total Diet Study in Germany. The study provides representative occurrence data for foods prepared as usually consumed. This occurrence data is an important data basis for the BfR's exposure assessments and subsequently the assessment of possible risks originating from foods. Furthermore, the data enables consumption recommendations for selected population groups to be derived. In the event of a crisis, the data also forms an important basis for comparison so that any levels of different substances in foods can be quickly and reliably assessed.

Extensive market data was taken into account for purchasing and preparation of foods, which reflected representatively the purchasing behaviour and recipe selection of the population in Germany and were used for preparation of meals.

The list of foods tested (food list) in the BfR MEAL Study covers more than 90 % of the consumption of the German population groups considered. The most commonly consumed foods were chosen from the NVS II´s food intake data (German National Nutrition Survey II; 14-80 years) and the VELS study (Food consumption survey to determine food intake by infants and small children for the estimation of the acute toxicity risk from pesticide residues; <1-4 years). Other rarely consumed foods that showed high levels of certain substances in the past were added as well. The food list comprises 356 foods for the core module, in which the elements and environmental contaminants were investigated. For 151 of these foods, additional pooled samples were investigated, including four regions, two seasons or different production types (organic vs. conventional farming). This resulted in a total sample number of 869 pooled samples in the core module, consisting of 13,552 subsamples. In the two field phases of the study, a total of approx. 56,750 single food items were purchased over a period of 4 years and 8 months; prepared as typically consumed and then analysed for selected substances. The modular design of the BfR MEAL Study considered a total of 336 substances in nine modules: “core module” for elements and environmental contaminants, “mycotoxins”, “perfluoroalkyl substances”, “nutrients”, “pharmacologically active substances”, “pesticide residues”, “substances migrating from food contact materials”, “process contaminants” and “food additives”.

Extensive data was collected or procured to compile the pooled samples representatively. Three consumer studies determined food preparation behaviour, browning degree preferences and preferred kitchen utensils for food preparation. For this purpose, the main person responsible for preparing foods in a household was interviewed. The studies were representative for the German population according to place of residence and size of household.

With the exception of the plasticiser group, the analytical tests of the pooled samples were carried out by external laboratories following a public tender. The analytical requirements, including quality assurance aspects, were discussed and defined in advance in the expert groups for each module and with the international advisory board. The aim was to achieve the lowest possible limits of quantification that could still be reliably determined in all food matrices being analysed.

From the analytical raw data of each substance or substance group, 20-30 % of the results were checked for plausibility. For this purpose, all available food occurrence data from food monitoring was compared with the levels detected in the BfR MEAL Study. Additionally, some food levels were compared with levels from scientific literature (e.g., assessments by the European Food Safety Authority (EFSA) or scientific databases (e.g., World Health Organization (WHO) GEMS/Food database, Federal Nutrient Database).

After scientific publication, the data sets generated in the BfR MEAL Study are made available to the professional public or interested consumers as a public use file via the BfR website.

For example, the BfR already used occurrence data from the BfR MEAL Study in a communication on non-dioxin-like PCBs (communication no. 037/2018), two opinions on iodine (opinion no. 026/2022, opinion no. 005/2021) and in one opinion on sweeteners in soft drinks (opinion no. 006/2023).

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Key statements on the BfR MEAL Study

The BfR MEAL Study and the sustainable establishment of a Total Diet Study (TDS) in Germany will expand the knowledge on levels, exposure, risks and benefits of foods consumed in Germany for a large number of substances. Furthermore, the data situation for scientific policy advice can be improved. The infrastructure and scientific expertise of the MEAL Study Centre can thus be used and further developed at BfR beyond 2022 to improve food safety.

1 The BfR-MEAL study analyses about 300 substances for the health assessment and covers more than 90 % of the foods consumed in Germany.

The BfR MEAL Study and the sustainable establishment of a Total Diet Study (TDS) in Germany can expand knowledge on the levels, exposure, risks and benefits of foods consumed in Germany for a large number of substances. Furthermore, the MEAL Study can improve the data basis for scientific policy advice. The infrastructure and scientific expertise of the MEAL Study Centre can thus be used and further developed at BfR beyond 2022 to improve food safety.

2 The BfR MEAL Study investigates for the first time in Germany systematically foods as typically consumed

The BfR MEAL Study takes into account substances that are added, produced or degraded during processing or preparation of foods. In selected foods, process contaminants (such as acrylamide) are determined by using different preparation methods (e.g., frying or baking), the use of different household appliances (e.g., charcoal, gas and electric grills) and different degrees of browning.

This data basis, which is unique in Germany, enables realistic long-term intake estimation and, in relation to process contaminants, provides consumers with recommendations on how to prepare their food. For the first time, the BfR MEAL Study provides content data for selected additives that enable representative intake estimates for Germany. The analysis of additives and process contaminants in foods typically prepared in households is a useful addition to food monitoring.

3 The BfR MEAL Study investigates for the first time in Germany systematically foods as typically consumed

The design and sample collection of the BfR MEAL Study are based on representative surveys and extensive market share data. They allow differentiation of the samples according to regional, seasonal or production-related (organic/conventional farming) factors, as far as this is relevant for the substance levels. The design of the study with its modular structure aims at logistical synergy effects in purchasing and sample preparation, thus maximising the information yield.

4

The BfR MEAL Study has created an infrastructure that is unique in Germany for dealing with questions that other survey methods are not geared towards.

The continuation of the BfR MEAL Study as a complementary infrastructure to the existing food monitoring would increase consumer safety in Germany by taking more substances into account and reducing uncertainties, e.g., due to processing of foods in households and industry. Food preparation also offers the possibility to describe the simultaneous exposure to several substances in the diet of the population in Germany. This could support research and evaluation approaches, e.g., for multiple exposure to substances. Likewise, the consideration of benefits and risks of different consumption habits or for special population groups could be taken into account in the selection of studied foods (e.g., vegan foods, foods for diets of people with a migration background). Cooperation partners are already accessing the infrastructure of the BfR-MEAL Study (e.g., MRI and BfS).

5

By continuing the BfR MEAL Study, changes and trends in the intake of substances by foods in Germany can also be identified in the future.

The continuous analysis of substances in a TDS is highly suitable for taking into account changes in consumption habits as well as environmental changes and changing regulatory conditions. In addition to food monitoring, the success of risk management measures or the National Reduction and Innovation Strategy for Sugar, Fats and Salt in Ready-to-Eat Products (NRI) can be presented. The effects of changes in regional or global value chains as a result of socio-economic and climatic factors could be examined.

List of abbreviations

ADI	Acceptable daily intake
AMPA	Aminomethyl-phosphonic acid
BfR	German Federal Institute for Risk Assessment (German: Bundesinstitut für Risikobewertung)
BfS	Federal Office for Radiation Protection (German: Bundesinstitut für Strahlenschutz)
BLE	Federal Office for Agriculture and Food (German: Bundesanstalt für Landwirtschaft und Ernährung)
BMEL	Federal Ministry of Food and Agriculture (German: Bundesministerium für Ernährung und Landwirtschaft)
BVL	Federal Office of Consumer Protection and Food Safety (German: Bundesamt für Verbraucherschutz und Lebensmittelsicherheit)
dl-PCBs	Dioxin-like polychlorinated biphenyls
DMMTA	Dimethylated monothioarsenate
EAN	European Article Number
EFSA	European Food Safety Authority
ELISA	Enzyme-linked immunosorbant assay
EsKiMo II	Nutrition Study as KiGGS Module II (German: Ernährungsstudie als Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland (KiGGS)-Modul II)
ETU	Ethylenthiourea
EU	European Union
EURL-SRM	EU Reference Laboratory for Single Residue Methods
FAO	Food and Agriculture Organization
FNS	Food Nutrition Security
GEMS	Global Environment Monitoring System
HPLC-HRMS	High-pressure liquid chromatography-high-resolution mass spectrometry
ICP-MS/MS	Inductively coupled plasma-tandem mass spectrometry
IGW	International Green Week Berlin (German: Internationale Grüne Woche Berlin)
KiESEL	The Children's Nutrition Survey to Record Food Consumption (German: Kinder-Ernährungsstudie zur Erfassung des Lebensmittelverzehrs)
MEAL	Meals for Exposure Assessment and Analysis of Foods (German: Mahlzeiten für Expositionsschätzung und Analytik von Lebensmitteln)
MOSH	Mineral oil saturated hydrocarbons
MOAH	Mineral oil aromatic hydrocarbons
MRI	Max Rubner-Institut
ndl-PCBs	Non-dioxin-like Polychlorinated Biphenyls
NVS II	German National Nutrition Survey II (German: Nationale Verzehrsstudie II)
ÖfIP	Public information platform (German: Öffentliche Informationsplattform)
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyles
PCDD/F	Polychlorinated dibenzodioxins and furans

PFAS	Pefluoroalkyl substances
POP	Persistent organic pollutants
PTU	Propylenthiourea
QS	Quality assurance
QuPPe	Quick polar pesticides method
TDS	Total Diet Study
TMDI	Theoretical maximum daily intake
VELS	Food consumption survey to determine food intake by infants and small children for the estimation of the acute toxicity risk from pesticide residues (German: Verzehrsstudie zur Ermittlung der Lebensmittelaufnahme von Säuglingen und Kleinkindern für die Abschätzung eines akuten Toxizitätsrisikos durch Rückstände von Pflanzenschutzmitteln)
WHO	World Health Organization

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1 Introduction

For the first time in Germany, the BfR MEAL Study (Meals for Exposure Assessment and Analysis of Foods) analysed various substance groups in foods typically prepared in households in a systematic and representative manner.

The BfR MEAL Study design is based on the methodology of a Total Diet Study (TDS). The TDS is an internationally recognised method recommended by the European Food Safety Authority (EFSA) and the World Health Organization (WHO) as well as the Food and Agriculture Organization of the United Nations (FAO) for determining average levels of substances in ready-to-eat foods for exposure assessment (EFSA, FAO, WHO, 2011). The TDS is based on three basic principles:

1. TDS cover a large part of the foods most commonly consumed by the population. However, since less frequently consumed but highly contaminated foods can also have a significant influence on the total intake of a substance, the BfR MEAL study also examines foods, which in the past had high levels. The objective is to represent the average consumption of the population.
2. The selected foods are prepared and processed as consumers handle them every day. The goal is to realistically depict the food before consumption, including the influence of processing and preparation in the household.
3. Similar foods are pooled and homogenised. Since the aim of a TDS is to analyse the entire food spectrum for a large number of substances, similar foods are pooled to perform the analysis cost-effectively.

TDS have now been carried out in more than 50 countries around the world, including France, Portugal and the Czech Republic. They are considered a cost-effective method for determining average levels of desirable and undesirable substances in foods. In Germany, this study design was carried out for the first time and complements the food monitoring of the state investigation offices.

In a joint document from EFSA, FAO and WHO, guidelines for the harmonisation of TDS were recommended and further developed in the European project “TDS Exposure”[1] (Kolbaum et al. 2019). These recommendations formed the basis for the methodological organisation of the first German TDS.

As a partner of “TDS Exposure”, the BfR collected occurrence data in ready-to-eat foods for the three elements copper, manganese and mercury in a pilot study (EFSA 2011; Sachse et al. 2019). The findings of this pilot study were taken into account in the conceptual organisation of the BfR MEAL Study; however, both the range of substances and the number of foods were significantly increased. Therefore, in the BfR MEAL Study, more than 300 individual substances were analysed in 356 foods in two field phases. In the two field phases, separate pooled samples were prepared for different regions, seasons and types of production, depending on the relevance. Consequently, more than 90 % of the foods consumed by the population in Germany could be covered. The foods were analysed for 110 additional substances in addition to the data sets that already exist. or approx. 190

[1] http://www.tds-exposure.eu/

additional substances, data gaps could be reduced, for example through the additional sampling of further foods.

149,499

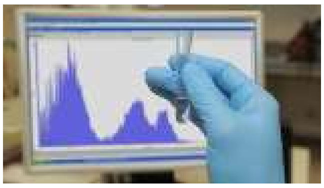
kilometres were covered during purchasing.

4

years and 8 months, the kitchen team processed the purchased foods into ready-to-eat meals.

75

individual ingredients were purchased and processed solely to prepare various recipes for the pool "beef roulade".



>140,000

analysis results were received by the study team from the laboratories.

Figure 1: The BfR MEAL Study in figures (image copyright BfR)

2 Design of the BfR MEAL Study

2.1 Selection of the food list for the core module

The final food list for the BfR MEAL Study for the core module comprised 356 foods and covers more than 90 % of food consumption. In the primary concept for the BfR MEAL Study from 2013, the scope of the food list was estimated at 350 foods. The basis for this estimate was based on experience from the French TDS and from the German pilot study in the "TDS Exposure" project. The food lists determined in those studies were supplemented by foods that are predominantly consumed by infants and young children (e.g., infant formula). The foods were selected in a way that 90 % of the consumption was attained for all age groups (0.4 to < 1 year; 1 to < 3 years; 3 to < 5 years; 14 to < 18 years, 18 to < 65 years; > 65 years) to take into account the different consumption behaviour of all of the described age groups. Beyond the minimum requirement to represent 90 % of the average total food and beverage consumption, foods were selected to attain 90 % in each of the 19 main food groups. This made it possible to avoid individual main groups with low consumption quantities being covered with only very few pools. The representative data from the National Consumption

Survey II (data of the 24 h recalls) (MRI 2008) and data from the VELS Study (MRI 2008, Heseker et al. 2003) served as the data basis for compiling the food list.

After selecting the most frequently consumed foods per age group, the list was supplemented in a next step with foods that are consumed less often but could still be exposure-relevant due to higher levels in the past. Furthermore, foods that have gained relevance due to dietary trends were added (e.g., chia seeds, striped catfish and avocado).

The food list for the BfR MEAL Study also includes foods that certain population groups, such as vegetarians or vegans, prefer to consume. For example, meat substitutes (e.g., tofu, veggie patties) are included in the main food group "Products for non-standard diets and food imitates". However, due to a lack of representative food intake data, not all relevant foods may have been analysed for these special population groups and the mean consumption shown may be less than 90 % of the total consumption of this special population group.

2.2 Regional, seasonal and production-related factors in the core module

Region and season

For selected foods, the extent to which regional or seasonal influences as well as influences due to the type of production have an impact on substance levels was investigated. For this purpose, separate pooled samples (e.g., for two seasons) were produced and analysed for selected foods from the food list.

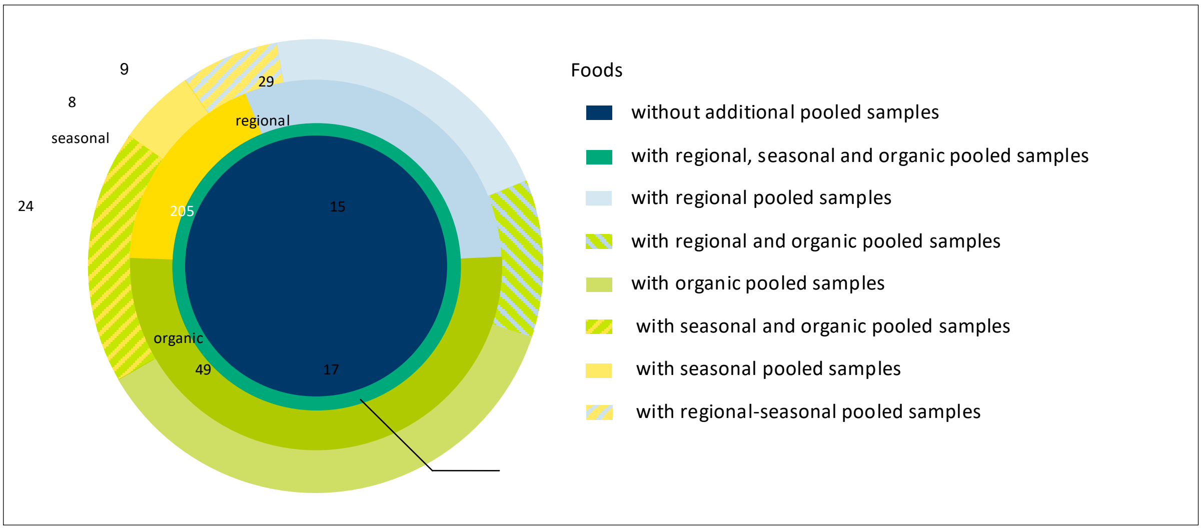


Figure 2: Number of foods in the core module with and without additional pooled samples (n)

Estimates on the number of foods to be carried out was based on the proposals in the primary concept from all BfR units concerned.

The number of pooled samples is also based on the proposals of all BfR units concerned, as well as the module's substance-specific expert groups, recommendations by experts from the Max Rubner-Institut (MRI) and by taking into account information on the origin of fruits and vegetables from the Federal Office for Agriculture and Food (BLE) (see).

Compared to the concept submitted in 2013, the number of foods with separate regional and/or seasonal sampling has decreased, since climate data and data on soil contamination did not support the consideration of six regions as originally planned. After consultations with the BfR MEAL Study's international advisory board, Germany was subdivided into four regions. This decision also took into account the small regional differences in the levels of various substances recorded in eight regions considered in the second French TDS.

In each of the four regions, three sample points were approached in different BIK (classification system for urban areas) community size categories: a large city (> 100,000 inhabitants ●), a medium-sized city (20,000-100,000 inhabitants ●) and a rural area (< 20,000 inhabitants ●), respectively. The number of subsamples purchased per sample point was weighted according to the population share of the respective BIK community size category in the total population of the region. Accordingly, in "Region East", for example, for a regional pooled sample consisting of 15 subsamples, nine subsamples were purchased in the large city, four subsamples in the medium-sized city and two subsamples in the rural area.

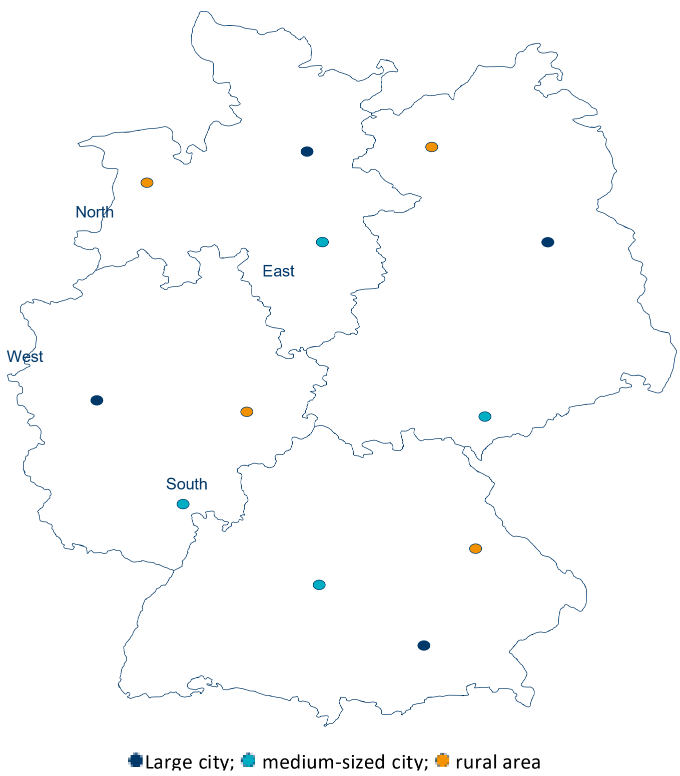


Figure 2: Regions and sample points for the BfR MEAL Study

Sampling took place at different times of the year so that differences between foods could be depicted, e.g., due to import and own cultivation or different import countries. However, seasons for foods were defined with different lengths and at different times of the year, depending on expected variations.

Type of production

Food selection for separate sampling by type of production (organic or conventional farming) was done in stages. In stage 1, foods were selected that showed a high proportion of organically produced products on the market according to market share data. In stage 2, foods were selected for which differences in levels of conventionally and organically produced foods were expected. These decisions were based on information provided by experts from MRI and the expert groups involved in the module, respectively. In stage 3, the selection from stages 1 and 2 was supplemented by frequently consumed foods from different main food groups, whereby the total number of foods for which separate sampling by type of production was carried out was limited to 30 %. For the selected foods (n = 105), pooled samples were prepared exclusively from conventionally produced products and additionally exclusively from organically produced products. All other foods on the food list were regarded as unspecified with regard to the type of production, resulting in pooled samples composed of subsamples from conventional and organic production, based on market share data. Organic production was included in unspecified pools, if the market share data was above 5%. A total of 869 pooled samples were produced for the core module by taking into account several pooled samples for 151 of the 356 foods.

2.3 Number of subsamples per pooled sample in the core module

The number of subsamples for food without additional pooled samples for season, region or production type was set to 20 for the core module. This was done to better account for the variability between products on the market.

For foods with additional pooled samples for different seasons, regions or production types, the number of subsamples was reduced to 15 since a majority of the expected variability was already covered by considering several pooled samples for these foods. The relative width of the 95 % confidence interval was given in the primary concept for the number of 15 subsamples per pooled sample at a standard deviation to mean ratio of 1:3 with ±19 %; for the number of 20 subsamples with ±16 %.

Depending on the food and substance or substance groups, no variability in the levels was expected with regard to season (e.g., process contaminants), region (e.g., additives) or production type (e.g., perfluoroalkyl substances). Regional and/or seasonal pooled samples from the core module were combined proportionally into one stratified pooled sample before the analysis for these substances in a cost-efficient manner. Accordingly, a stratified pooled sample composed of four regions consists of 4 x 15 (60 in total) subsamples and a stratified pooled sample composed of two seasons consists of 2 x 15 (30 in total) subsamples. Stratified pooled samples from the two organic and conventional production types were stratified proportionally when information on the market share of the respective production types was available. If no data on market shares was available, both pooled samples were stratified in equal parts. Therefore, 869 pooled samples were produced from 13,552 subsamples for the core module's element analysis.

For modules in field phase 2, the number of subsamples varies according to the requirements of the respective module (see module sections).

3 Supplementary data basis

The representative depiction of the shopping and preparation behaviour of the population living in Germany was done by taking into account the results of commissioned consumer studies and procured market share data. The information obtained, was used to define the products in the shopping lists (e.g., information on brands, varieties or origin) and to specify the places of purchase, as well as to take into account the preparation of the foods in the study kitchen (e.g., for the selection of kitchen utensils and selection of recipes). The aim was to take the available information into account representatively at pooled sample level.

3.1 Market share data

Subsamples were selected and weighted based on market share data from a household panel representative of the German population (GfK, Growth from Knowledge). The household panel continuously records food and beverage purchases of 30,000 households. Information on the number of production types and places of purchase was cost-efficiently requested at main food group level. This information was supplemented with more detailed queries on selected foods in the food list (e.g., brands, varieties, origin, processing or type of processing). The queries were carried out between 2016 and 2017 and used data collection from the previous twelve months as data basis. Supplementary market share data for the product groups mineral water, potatoes and potato products, beer, sparkling wine, cola drinks, tea and cocoa, sugar/sugar products and honey as well as fats and oils were already available from previous projects for data collection periods between 2007 and 2015.

According to the results of a commissioned consumer study, 77 % of cooking and baking recipes for the typical preparation of foods were selected from recipe books. The recipe books used in the study (five baking books, five general or basic cookbooks, nine theme-based cookbooks) were selected from a top 100 list. The top 100 list was based on sales figures from a retail panel for the relevant product groups for the data collection period 2007-2016. The retail panel covered, among other things, the sales channels of the retail book trade, e-commerce and department stores.

In addition to market share data from household and retail panels, information from the Federal Office for Agriculture and Food (BLE) on the origin and varieties of 29 types of fruits and vegetables was used. The data from the 2015 data collection period provided information on the monthly quantity supplied of different types of fruits and vegetables depending on their origin. The data was collected at five German wholesale stores (Berlin, Frankfurt, Hamburg, Cologne, Munich), whereby the respective quantity supplied represents an estimate within the framework of the market inspection.

3.2 Data on typical household preparation

The aim of the food preparation in the MEAL Study kitchen was to depict the preparation that takes place in German private households. In this context, three representative consumer studies were commissioned in the run-up to the two field phases to fill data gaps on food preparation. This concerns in particular information on food preparation variants (e.g., preparation methods for fries, mixing ratios of fruit and wine spritzers or the composition of mixed salads), and even aspects such as the preferred degree of browning of different foods and the condition (e.g., type, material) of kitchen utensils used, such as pots and pans.

Information on the preparation of 49 foods from nine main food groups was collected via a telephone household survey (computer-assisted telephone interview, sample size n = 1,008) by an external company (aproxima Gesellschaft für Markt- und Sozialforschung mbH) (Hackethal et al., 2023). This included, for example, information on washing various fruits and vegetables before preparation or consumption. The information was integrated into the preparation plans that were available to the kitchen team during preparation.

Information on examples of preferred degrees of browning was collected for 17 foods using an online survey (two online access panels, sample size n = 2,003) (Hackethal et al., 2023; aproxima Gesellschaft für Markt- und Sozialforschung mbH). The results of the survey were applied to other comparable foods and for this purpose an illustrated book was prepared, showing different degrees of browning as visual representations of the respective foods. The pictures were supplemented with information on the number of subsamples to be prepared with the corresponding degree of browning and used by the kitchen team to prepare the dishes.

Information on the type of kitchen utensils used and their material for various preparation processes in the kitchen (including information on cooking pots, frying pans, oven dishes, chopping boards and kitchen knives) was collected using a telephone household survey (computer-assisted telephone interview, sample size n = 1,008) (Hackethal et al., 2023; aproxima Gesellschaft für Markt- und Sozialforschung mbH). Furthermore, information on the preparation method was collected for specific foods on the food list (e.g., preparation methods for coffee, tea and rice, including information on the equipment and utensils used). The results of the survey were integrated into the preparation plans so that the information on the preparation method and the utensils to be selected was saved for each subsample to be prepared.

3.3 Out-of-home consumption

To increase the representativeness of the pooled samples, information on the frequency of out-of-home consumption and the procurement channels of foods consumed out of home was collected for selected foods in the food list (n = 37) (Hackethal et al., 2023). The online survey provided information on categorised preparation locations (e.g., fast-food restaurant, bakery, butcher's or snack bar). In addition, specific providers of meals for out-of-home consumption were retrieved as well (fast-food chains, nationwide chain bakeries, cafés, etc.).

The data was collected in December 2016 via an online survey by a market and social research company (aproxima Gesellschaft für Markt- und Sozialforschung mbH). A sample of 2,006 participants was recruited from two online access panels for the survey.

The results of the online survey defined the number of ready-to-eat subsamples purchased and their place of purchase for selected food items in the shopping lists.

4 Implementation

The implementation of the BfR MEAL Study comprised six steps: selecting foods for the food list, representative purchase of the foods, typical consumer preparation of the foods, pooling and homogenisation of the samples, analysis of the pooled samples and scientific analysis of data collected (Figure 3).

Figure 3: Steps of the BfR MEAL Study

4.1 Setting up the MEAL Study kitchen

The methodology of a TDS is characterised by the analysis of food as ready-to-eat, prepared as consumers would do. This required typical household preparation for a considerable part of the food before analysis.

A study kitchen was set up at Berlin Alt-Marienfelde, specifically for the needs of a TDS to ensure the BfR MEAL Study could be efficiently carried out. The MEAL Study kitchen was divided into the following areas: social rooms, foods receiving, kitchen, scullery, homogenisation, dry storage, frozen and cool storage.

The food receiving area was equipped with a PC workstation attached to a label printer (Brother P-touch 9700PC) and barcode scanner (Inateck BCST-S) as well as a photo box (LIFE of PHOTO LFV-550), which enabled documentation and picking of incoming food. The area had shelves as well as refrigerators and freezers (Asskühl ELI-WELL ID 974) for the intermediate storage of incoming foods. FoodCASE (Premotec GmbH) was used as the central documentation software.

In the kitchen area, two work areas allowed the parallel processing of samples by two kitchen teams. The surfaces in the work areas were made of stainless steel. Induction cookers (MKN CVEKOI2), ovens (MKN Master of Performance electric oven), a microwave (Tarrington House MWD5130), a combi steamer (MKN SpaceCombi MagicPilot) and sinks were available in the work areas for preparation of foods. Based on the information from the preliminary consumer study on the usage of kitchen utensils (see Chapter 3.2), the study kitchen was equipped with standard household cooking equipment and kitchen utensils.

Typical kitchen washing facilities with an attached pass-through dishwasher (Meiko DV 80.2) were installed for cleaning kitchen utensils, blender accessories and sample containers. A laboratory dishwasher (Miele PG8583 D) for washing with demineralised water was also available for further cleaning of work equipment from the homogenisation area.

The homogenisation area was equipped with a drying cabinet (Heratherm OMS100), an ultrapure water system (Merck Milli-Q® Integral 5) and a stationary system for oxygen deficiency monitoring (Dräger VarioGard). To ensure the safety of homogenisation staff during homogenisation with liquid nitrogen, additional mobile sensors (Dräger PAC 6500) were used, which were worn by staff. Dry ice and liquid nitrogen, kept in a 50-litre tank (Apollo 50, Cryotherm), were stored in a lockable shelter outside the study kitchen. Laptop workstations with label printers (Brother P-touch 9700PC) and barcode scanners (Inateck BCST-S) were available for labelling and documenting sample material. Two types of cutting mills (Retsch GM200, Retsch GM300) with different blender container volumes (0.7 L and 4.5 L) were used to homogenise the sample material. Blender containers made of polypropylene (PP), stainless steel or coated stainless steel (BTC titanium-niobium coating or Eifeler Carbon X coating), lids for homogenisation with liquid nitrogen and different blades (solid metal, stainless steel, titanium-coated, stainless-steel blades) were available as accessories for the cutting mills. For homogenisation, the cutting mills accessories (made out of different materials) were adapted depending on the substance investigated and the expected migration.

Two precision balances (Precisa 321 LT 6200C) were used both in the kitchen area and in the homogenisation area. Via an interface the digital transmission of data was enabled. The composition of the cleaning agents used in the study kitchen area was checked to ensure that the cleaning did not adversely affect the analyses.

4.2 Purchasing food and disposing of kitchen waste

Approximately 60,000 individual food items were purchased for the BfR MEAL Study. For some of the foods, levels of regional samples were analysed by preparing separate pooled samples for the four regions north, east, south and west (see Chapter 2.2). For the remaining foods no relevant differences in levels were expected nationwide, after consultation with substance-specific experts. In this case, the foods were purchased exclusively in the Berlin region.

The purchasing team consisted of three people, whereby nationwide purchases were usually carried out by two people. Regional purchases took place in a four-week cycle (one week per region). A funding office set up at the BfR made it possible to pay and account for the food.

Shopping lists sorted by shopping locations were provided for purchasing, including additional required further information on the type of product, brand, variety, type of production, country of origin and quantity purchased. A digital version of the shopping list was available via the FoodCASE smartphone app while shopping. The app also allowed further product information to be digitally recorded, such as the EAN number. Deviations from the shopping list's specifications or additional information, e.g., on the origin of the food were documented in the shopping lists or in the FoodCASE app. Each food item was marked with an individual MEAL-specific barcode sticker immediately after purchase.

The calculation of the required purchase quantities took into account losses during receiving (damaged or spoiled food), kitchen waste, weight yield during food preparation, variations in the net weight of pre-packaged food and losses during homogenisation. Accordingly, a sufficient amount of sample material was ensured while reducing the amount of surplus food. Any unavoidable food waste was given to a food waste disposal service provider for energy production.

Due to the comparatively high purchase volume, selected foods, such as offal or selected fish products, were pre-ordered from the shopping locations as required.

In addition to the foods sampled at shopping locations, tap water samples were taken nationwide. Tap water was taken for this according to a standardised procedure in the MEAL Study kitchen as well as at 29 other publicly accessible taps and filled into sample containers rinsed with ultrapure water. The total of 30 sample points were evenly distributed throughout the large cities, medium-sized cities and rural areas nationwide (categorisation according to the BIK region types).

4.3 Transporting the foods to the MEAL Study kitchen

The food was transported in two vans equipped with shelves, a workstation and cooling/ freezer boxes (EZetil EZC 80 and Dometic CoolFreeze CFX). The van for nationwide shopping was also equipped with an external plug socket and an additional battery, which allowed the foods in the cooling/freezer boxes to be cooled overnight and during longer standstill periods.

In the south, west and north regions, the purchased foods were handed over to a courier twice per shopping week. The courier transported the foods to the MEAL Study kitchen by the morning of the following day. This ensured timely processing of sensitive foods, such as strawberries or salads, and at the same time created storage space in the van for re-purchasing foods in the regions. During the courier’s trips, cooling and freezing of foods was documented with data loggers for temperature monitoring.

Loose and not fully packaged foods were packed in hard-density polyethylene (HDPE) plastic bags for transport to the study kitchen. This was done to avoid cross-contamination through contact with other food packaging or the storage containers. For interim storage of the foods during transport, storage boxes (Euro containers, Auer Packaging EG 43/32, polypropylene) were lined with aluminium foil to avoid contaminations by the storage boxes.

4.4 Receipt of foods and storage

During the receipt of goods, each food item was checked to ensure the correct food was purchased in the required quantity. The minimum durability date and the consumption date were checked, taking into account the planned preparation. In addition, the food was checked for spoilage or damage. Receiving also included photo documentation and registering the foods via the central FoodCASE database, so that further information on the packaging was also subsequently available. The inventory and location were also documented so that they could be traced by the system. For each food item, information on the shopping location, country of origin, brand, variety, type of production and EAN number (if not recorded during purchasing) was documented, if available. The EAN code made it possible to subsequently add information about the food in FoodCASE via an interface to the MINTEL Global New Product Database.

The purchased foods were stored in boxes lined with aluminium foil (see Chapter 4.3) until preparation and, depending on requirements, in three storage areas with different temperatures (dry storage at room temperature, cold storage (target temperature 6 °C) and freezer storage (target temperature -20 °C)).

The homogenised samples were stored at -20 °C until they were sent to the laboratories. The temperatures both during the subsequent transport of the samples from the MEAL Study kitchen to the laboratory location and until analysis were documented and checked.

Depending on the substance group, the storage duration of the pooled samples was determined according to recommendations from the module-related expert groups. For storage-sensitive analytes, such as vitamins, the duration from the preparation of the sample to analysis was minimised.

In the run-up to the first field phase, specifically for vitamin E, a study on storage stability in alkaline and acidic foods was carried out. Broccoli and blueberries were used as representatives for alkaline and acidic foods. Subsequently, the storage duration for all vitamins was set at maximum ten days.

4.5 Food preparation

The typical household preparation of the foods was carried out in the MEAL Study kitchen by two kitchen teams (one cook and one kitchen assistant) in parallel. The kitchen teams received a preparation plan for each subsample, which contained all work instructions or recipe specifications for preparation. This included information on the selection of cookware and kitchen utensils as well. The distribution of the different types of cookware and kitchen utensils was worked out and stipulated according to the results of the preliminary consumer studies (see Chapter 3.2) for each pooled sample. Deviations from specifications in the preparation plan, such as changed cooking times, temperatures or degrees of browning, were documented on the corresponding preparation plans.

Recipe components amounting to less than five percent by weight of the total recipe quantity were defined as basic ingredients. The top 1 brands were purchased as basic ingredients according to the available market share data (see Chapter 3.1) and used according to the specifications in the preparation plans.

In field phase 1, we processed 64% of the subsamples in the study kitchen using different cooking methods. 10 % of the subsamples were only washed and chopped (where applicable) and 26 % of the subsamples were purchased as ready-to-eat foods.

In field phase 2, a total of 53 % of the subsamples were processed in the study kitchen using different cooking methods. 12 % of the subsamples were only washed and chopped (where applicable). The remaining 35 % were purchased as ready-to-eat foods.

The final subsamples to be homogenised were labelled and stored temporarily in glass bowls covered with glass lids (both borosilicate glass) for sample transfer to homogenisation.

4.6 Homogenisation to pooled samples

The subsamples were taken from the glass bowls directly before weighing to the grinding containers or directly before pre-treatment with dry ice or liquid nitrogen. Labels were printed for each pooled sample and the corresponding sample vessels were labelled. An analytical plan provided the necessary information on sample code, laboratory, sample quantity and type of sample container. In preliminary tests with food simulants, a migration from the homogenisation vessels and equipment into the homogenate were monitored. To avoid migration into the homogenate, containers and equipment made of different materials were used. Depending on the substances being analysed, the samples were prepared in several approaches and the tools and utensils to be used were determined for this purpose: for element analyses, blender containers made of plastic, titanium-coated blades, plastic scoops and polypropylene sample containers were chosen. Whereas for analyses on lipophilic substances, stainless-steel containers, stainless-steel blades, stainless-steel scoops and sample containers made of amber glass were used to minimise entries, cross-contamination and losses.

The prescribed subsample quantities were weighed using precision scales and documented in the homogenisation plan. In addition, information on the usage of ultrapure water and the speed of the cutting mills used (see Chapter 4.1) were documented. The pooled samples filled into sample containers were then temporarily stored in the freezer until they were given to the laboratory or transferred to long-term storage (see Chapter 10).

The cutting mill accessories and tools used were cleaned in a multi-stage process in the following order: prewash, cleaning using a pass-through dishwasher, rinse cycle with deionised water in a laboratory dishwasher, cleaning by hand with ultrapure water and drying in a drying cabinet (80 °C).

For foods analysed for thermolabile analytes, temperature increase had to be avoided during homogenisation. Furthermore, for foods containing enzymes that might alter the analyte levels, contact between analyte and active enzyme had to be prevented. By keeping the temperature below 0 °C, enzyme activity was prevented and substances were not altered by enzymes. Foods that are difficult to homogenise, such as nuts, were also embrittled before homogenisation to obtain a uniform homogenate. In all three cases, foods were pre-treated with liquid nitrogen or dry ice was added during grinding. In this case, the following accessories and tools were used: stainless steel container (coated, if necessary), solid metal blade, dry ice lid with exhaust opening, cryo trays and stainless-steel scoops.

In deviation from this, subsamples for mycotoxin analysis were homogenised separately and then the subsample homogenates were weighed in. Furthermore, the sample material for analyses on food contact materials was exclusively filled into cauterised sample containers made of glass and aluminium foil was additionally placed between the glass and the container lid.

5 Analytics

The analyses within the BfR MEAL Study were mainly carried out by external commercial laboratories or state chemicals investigations offices, with the exception of the analyses for plasticisers in the module “Substances migrating from food contact materials”, which were carried out at the BfR. The analytical requirements (type of analytical method, division into batches, limits of detection and quantification, quality assurance aspects, storage suitability of pooled samples, etc.) were discussed and defined within the module-related expert groups. For the definition of the minimum limits of quantification, it was additionally checked for selected substances whether the mean exposure is below the health-based limit if 100 % of the content data are left-censored. However, higher limits of quantification were also accepted if closing existing data gaps was considered essential but the established analytical methods did not allow for a further lowering of the limit of quantification

The analytical services were provided as part of framework agreements following a public invitation to tender via the BLE. In total, framework agreements were concluded with nine contractors (see Table 1).

Table 1: Overview of the analytical methods used in the BfR MEAL Study

Number of methods		36
Laboratories		
	Internal	1
	Commercial laboratories	8
	Other institutions	2
	State investigation offices	1
Number of substance groups analysed		98
Number of individual substances analysed		336

6 Quality assurance

Quality assurance within the BfR MEAL Study was carried out under DIN EN ISO 9001, including internal and external audits. In addition, the international advisory board of the BfR-MEAL Study and the expert groups accompanying the modules served to exchange information with external experts on quality assurance aspects, such as the analysis of quality assurance samples and quality assurance requirements for the laboratories providing the service (see Chapter 7). For internal quality assurance, all work processes in the areas of documentation, purchasing, storage, preparation, homogenisation and cleaning were standardised via a study manual. When work commenced, study staff were trained according to the contents of the study manual via sponsorships. During the field phases, the study manual was available both digitally and as a print version in the MEAL Study kitchen.

Table 2: Quality assurance measures in the BfR Meal Study[1]

Area	Quality assurance measures
Purchasing	- Extensive second-best concept for alternative purchases - Purchasing coordination with connection to scientific staff - Immediate labelling of all food with a barcode, MEAL code and designation for traceability after purchase - Examination and documentation of the refrigerated and frozen transport temperatures using temperature data loggers (EXTECH SD200) - Examination and documentation of the purchased foods in the receiving department - Documentation of deviations from the shopping lists' specifications
Storage	- Checking and documentation of the refrigeration and freezer storage temperatures - Lining storage boxes with aluminium foil - Storage experiments on the stability of tocopherols - Traceability of foods via an individual MEAL code
Preparation	- Weekly preliminary meetings on the pooled samples to be produced - Preparation plan documentation - Selection of cleaning agents, taking into account substances that could potentially interfere with the analytical procedures
Homogenisation	- Washout tests to check the transition of elements from coated and uncoated grinding containers - Checking the cleanliness of the work surfaces, equipment and working materials every working day - Internal calibration of the laboratory scales and checking the alignment of the laboratory scales every working day - Prior cauterisation of sample containers for samples tested for food contact materials - Temperature control or active cooling using dry ice/liquid nitrogen during homogenisation of pooled samples for mycotoxin and vitamin analysis
Analysis	- Additional analyses of quality assurance samples (blind) - Advice on analytical parameters and their quality assurance by substance-specific expert groups - Checking storage and transport temperatures by the contracting laboratories - Accreditation of the laboratories - Evidence of successful participation in round-robin test or interlaboratory comparisons - Evidence of extensive experience in determining analytes in food samples - Possibility of auditing the laboratories - Determination of quality parameters (limit of detection and quantification, measurement uncertainty, work area, linearity, precision, selectivity of the analyte) - Analysing reference materials and independent standard solutions and determining recovery rates
Results	- Plausibility concept

[1] All measures covered by ISO 9001

Alternative purchases were standardised according to the second-best concept. According to this concept, specifications for an alternative purchase (e.g., alternative product or own brand, alternative shopping location or alternative variety) were described in the shopping list depending on the market data used to specify the product.

Quality assurance requirements for the analytical services were specified in the run up to the calls for tenders in the module-related expert groups and listed accordingly in the tender documents (see Table 2). The analytical quality was assured by the laboratories by controlling the stability of the sample preparation, the use of internal standards, regular blank value controls, multi-point calibrations, control of the calibration in the measurement sequence and by keeping quality control charts. Furthermore, laboratory audit was carried out as required and supplementary analyses of quality assurance (QA) samples were performed. For each analyte, 5-10 % of the samples were repeatedly analysed by the laboratory as QA samples under a different sample code (blank). The selection of QA samples took three criteria into account: (1) samples from different main food groups, (2) samples with levels below the limit of quantification and (3) samples with quantified levels. The results of the QA samples were compared with the previously determined levels.

Storage and transport temperatures, limits of detection, measurement uncertainties and price were checked for contractual conformity as part of the audit.

20-30 % of the detected levels of each substance/group were checked for plausibility. This included, among others, results for which data was available for the last 10 years from the German food monitoring authorities. Furthermore, the foods or levels to be tested were selected using the following criteria: 10 % of the foods on the food list with the highest consumption in each main food group, 10 % of the highest detected levels and 10 % of the lowest levels. In addition to the data from food monitoring, levels were compared with data from various databases (e.g., WHO GEMS/Food database), with occurrence data from EFSA opinions or occurrence data from other scientific literature. Levels of the different samples were also compared for foods with several pooled samples for regions, seasons or types of production. After the exposure assessment had been carried out, the ten foods that contribute most to the intake of 10 % of the most highly exposed children and 5 % of the most highly exposed adults were additionally checked for plausibility. If it was not possible to check the plausibility of the occurrence data either on the basis of the literature or by consulting the laboratories and experts, further plausibility samples were sent to the same laboratory to validate the results.

7 International advisory board and expert groups

The BfR MEAL Study was provided with support from an advisory board consisting of national and international experts, particularly with regard to methodological aspects. At the beginning of the BfR MEAL Study, methodological and practical experience on TDS at national level was limited to the EU project "TDS Exposure". The availability of broad international expertise on the methodology of TDS was ensured by specifically recruiting those who had been involved in the implementation of TDS, e.g., in Canada, France, New Zealand and the USA as advisory board members. Furthermore, people from the WHO, FAO and EFSA were requested as members with regard to international networking. At national level, individuals from the Federal Ministry of Food and Agriculture (BMEL), MRI and Federal Office of Consumer Protection and Food Safety (BVL) were also identified as important partners and were involved. Other scientists from universities, federal research institutes and state chemical investigations offices were recruited as members in view of their specific expertise.

The BfR MEAL Study's advisory board was composed of international experts in the field of Total Diet Studies and met six times during the course of the study. The scientific discussions within the advisory board provided valuable impetus for answering methodological questions, thereby providing important external quality management for implementing the

BfR MEAL Study. The MEAL Study centre is, therefore, very well integrated into the international TDS network even beyond the two provisionally planned field phases.

A total of eight expert groups were assigned to the nine modules of the BfR MEAL Study for substance or substance group-specific questions. A joint expert group was formed for the core module and the “perfluorinated alkyl compounds” module. The expert groups provided advice on questions concerning the analytics of the respective substance group, the methodological design of the modules, the selection of substances and advised on the quality assurance of the results. The expert groups consisted of up to seven external national experts in the respective substance groups, preferably recruited from existing BfR committees. In addition to scientists from the MEAL Study centre, the BfR departments sent representatives to the expert groups as well.

In total, the expert groups met for twelve meetings and also participated in the joint concluding event with BfR MEAL Study advisory board members in October 2022.

8 Modules

A modular design was chosen for the BfR MEAL Study. This approach was developed by the BfR to enable synergies between the substance groups in the areas of purchasing, sample preparation and analytics and, therefore, to work cost-efficiently. In each of the nine modules, the methodology of the Total Diet Study was adapted to the requirements of the substance group. This included the aspects food list, purchasing, preparation, sample preparation and analytics. The core module took a central position in the first field phase and provided the highest number of pooled samples (n = 869) by differentiating by region, season and type of production. Modules associated with the core module, such as the nutrient module, used pooled samples from the core module, some of which were combined in a cost-efficient manner (Figure 4).

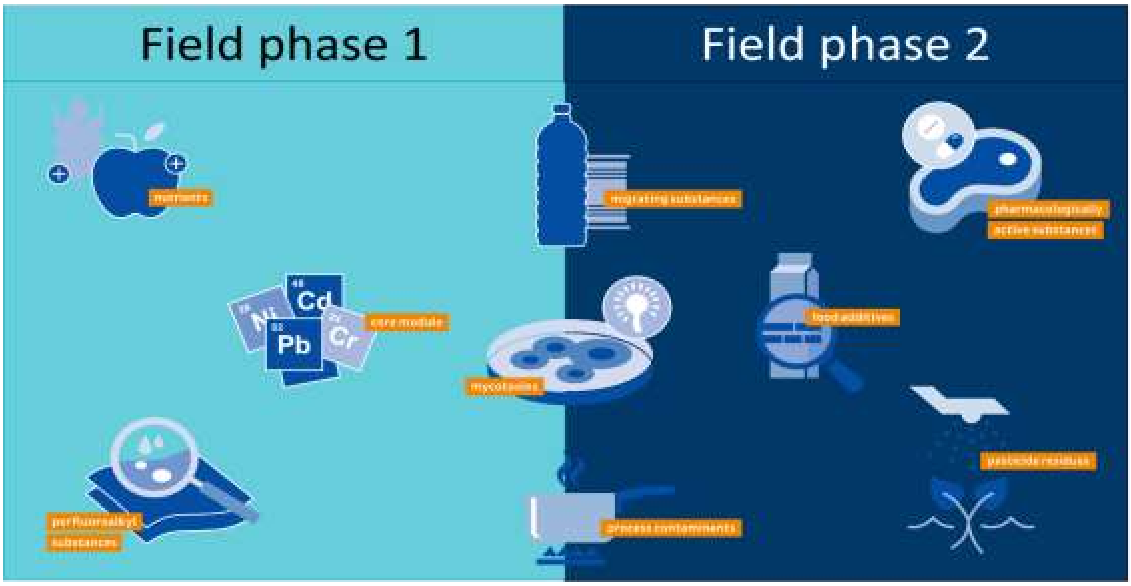


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Figure 4: Modules of the BfR MEAL Study

8.1 Core module

The substances in the core module are listed in Table 3 and include elements and environmental contaminants.

Table 3: Substance list in the core module

Elements[1]	Antimony, aluminium, arsenic (total arsenic, inorganic arsenic and arsenic species: arsenobetaine, dimethylarsinic acid, monomethylarsonic acid), barium, lead, cadmium, cobalt, lithium, nickel, mercury (additionally methyl mercury), silver, thallium, vanadium, tin
Environmental contaminants	Dioxins/furans (PCDD/Fs): 2,3,7,8-TeCDD; 1,2,3,7,8-PeCDD; 1,2,3,4,7,8-HxCDD; 1,2,3,6,7,8-HxCDD; 1,2,3,7,8,9-HxCDD; 1,2,3,4,6,7,8-HpCDD; octachlorodibenzofuran; 2,3,7,8-TeCDF; 1,2,3,7,8-PeCDF; 2,3,4,7,8-PeCDF; 1,2,3,4,7,8-HxCDF; 1,2,3,6,7,8-HxCDF; 2,3,4,6,7,8-HxCDF; 1,2,3,7,8,9-HxCDF; 1,2,3,4,6,7,8-HpCDF; 1,2,3,4,7,8,9-HpCDF; octachlorodibenzodioxin
	Dioxin-like polychlorinated biphenyls (dl-PCBs): PCB 77; PCB 81; PCB 126; PCB 169; PCB 105; PCB 114; PCB 118; PCB 123; PCB 156; PCB 157; PCB 167; PCB 189
	Non-dioxin-like polychlorinated biphenyls (ndl-PCBs): PCB 28; PCB 52; PCB 101; PCB 138; PCB 153; PCB 180
	Polybrominated diphenyl ethers (PBDEs): BDE 28 2,4,4'-tribromodiphenyl ether; BDE 49 2,2',4,5'-tetrabromodiphenyl ether; BDE 47 2,2',4,4'-tetrabromodiphenyl ether; BDE 100 2,2',4,4',6-pentabromodiphenyl ether; BDE 99 2,2',4,4',5-pentabromodiphenyl ether; BDE 154 2,2',4,4',5,6-hexabromodiphenyl ether; BDE 153 2,2',4,4',5,5'-hexabromodiphenyl ether; BDE 138 2,2',3,4,4',5'-hexabromodiphenyl ether; BDE 183 2,2',3,4,4',5',6-heptabromodiphenyl ether; BDE 209 2,2',3,3',4,4',5,5',6,6'-decabromodiphenyls
	Nitrate
	Organotin compounds: tetrabutyltin, tributyltin, dibutyltin, monobutyltin, triphenyltin, diphenyltin, monophenyltin

[1] Bulk and trace elements were partly analysed together with theelements in the core module. For evaluation, bulk and trace elements were assigned to the "nutrient" module

Elements, arsenic species, nitrate and methyl mercury

On the recommendation of the module-based expert group, the elements gallium, germanium, palladium, strontium and tellurium were not included in the list of substances to be analysed. The reasons given were their possible use as an internal standard for the measurement of the other elements in the used multi-method, a lack of reference materials or lack of toxicological relevance. However, due to the desired comparability with food monitoring data, the element thallium was added to the substance list.

All 356 foods in the food list were analysed for the selected elements. For all foods, the additional pooled samples were analysed separately for different regions, seasons and production types, resulting in a total number of 869 pooled samples (see Table 4). Deviating from this, the pooled sample "vegetable crisps" from the main food group "vegetables, vegetable products and mushrooms", which was later included in the food list, was not analysed for nitrate, resulting in 868 instead of 869 pooled samples.

Table 4: Sample structure elements (Fechner et al., 2022) and nitrate[2,2]

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	97	1,540	40
02	Vegetables, vegetable products and mushrooms	152 (151)	2,306 (2,286)	34 (33)
03	Starchy roots or tubers and products thereof	26	410	8
04	Legumes, nuts, oilseeds and spices	24	440	20
05	Fruit and fruit products	64	1,010	22
06	Meat and meat products	101	1,578	35
07	Fish, seafood and invertebrates	39	720	30
08	Milk and dairy products	37	640	23
09	Eggs and egg products	10	150	2
10	Sugar, confectionery and water-based sweet desserts	18	330	15
11	Animal and vegetable fats and oils	13	205	8
12	Fruit and vegetable juices and nectarsFruit and vegetable juices and nectars	12	220	10
13	Water and water-based beverages	41	173	6
14	Coffee, cocoa, tea and infusions	12	210	9
15	Alcoholic beverages	11	190	8
16	Food products for infants and toddlers	15	260	11
17	Products for non-standard diets and food imitates	8	150	7
18	Composite dishes	170	2,670	52

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
19	Seasoning, sauces and condiments	19	350	16
	SUM	869 (868)	13,552 (13,532)	356 (355)

[1] Data in brackets refers to nitrate
[2] Figures subject to change

Total arsenic was analysed according to the sample structure shown for elements (see Table 4). The analysis of inorganic arsenic and organic arsenic species (arsenobetaine (AsB), dimethylarsinic acid (DMA) and monomethylarsonic acid (MMA)) was carried out in "fish, seafood and invertebrates", rice, rice-based products, and rice-based meals in addition to the analyses for total arsenic (see Table 5). In addition to these foods, 19 further pooled samples were analysed in which higher total arsenic levels had previously been detected compared to all the foods analysed (e.g., algae, boletus, bovine liver).

Table 5: Sample structure of inorganic arsenic and organic arsenic species[1] (Hackethal et al., 2021)

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	8	135	6
02	Vegetables, vegetable products and mushrooms	9	136	5
06	Meat and meat products	2	30	1
07	Fish, seafood and invertebrates	39	720	30
16	Food products for infants and toddlers	3	55	3
17	Products for non-standard diets and food imitates	1	20	1
18	Composite dishes	11	315	9
	SUM	73	1,411	55

[1] Figures subject to change

On the recommendation of the expert group, methyl mercury was determined not only in "fish, seafood and invertebrates" but also in mushrooms and mushroom-based dishes (see Table 6). Five foods were analysed in the four different regions.

Table 6: Methyl mercury[1] sample structure (Sarvan et al., 2021)

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
02	Vegetables, vegetable products and mushrooms	6	91	3
07	Fish, seafood and invertebrates	39	720	30
18	Composite dishes	4	60	1

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
	SUM	49	871	34

[1] Figures subject to change

Dioxins/furans (PCDD/Fs), dl-PCBs, ndl-PCBs and PBDEs

Dioxins/furans, polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are persistent organic pollutants. For dioxins/furans and dioxin-like PCBs (dl-PCBs), data from the German federal and state governments' monitoring programmes were supplemented, especially for composite foods and additional main food groups. Less data was available from the monitoring programmes for non-dioxin-like PCBs (ndl-PCBs) and PBDEs, which is why the BfR MEAL Study provides a meaningful database for the health assessment of these substance groups for the first time.

After consultation with the National Reference Laboratory for Dioxins and PCBs in Food and Feed, the analysis of plant-based and low-fat foods was not carried out for reasons of cost efficiency. This excludes cucurbits and several plant-based foods prepared with fats. Samples were prepared for various foods, for different regions, seasons and production types and examined separately (see Table 7).

The list of ten analytically determined PDBEs corresponds to the recommendation of the European Commission regarding monitoring brominated flame retardants in food (European Commission 2014).

Table 7: Dioxins/furans, PCBs und PBDEs[1] sample structure (Stadion et al., 2022)

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	94	1,490	38
02	Vegetables, vegetable products and mushrooms	58	881	18
03	Starchy roots or tubers and products thereof	15	245	7
04	Legumes, nuts, oilseeds and spices	24	440	20
05	Fruit and fruit products	10	175	8
06	Meat and meat products	101	1,578	35
07	Fish, seafood and invertebrates	39	720	30
08	Milk and dairy products	37	640	23
09	Eggs and egg products	10	150	2
10	Sugar, confectionery and water-based sweet desserts	12	220	10
11	Animal and vegetable fats and oils	13	205	8
14	Coffee, cocoa, tea and infusions	9	160	7
15	Alcoholic beverages	11	190	8

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
16	Food products for infants and toddlers	15	260	11
17	Products for non-standard diets and food imitates	8	150	7
18	Composite dishes	170	2,670	52
19	Seasoning, sauces and condiments	19	350	16
	SUM	645	10,524	300

[1] Figures subject to change

Organotin compounds

The aim of the study was to generate a conclusive database for the health assessment of seven organotin compounds (see Table 3). For this purpose, only pooled samples in the main food group “fish, seafood and invertebrates” were analysed (see Table 8).

Table 8: Organotin compounds[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
07	Fish, seafood and invertebrates	39	720	30
	SUM	39	720	30

[1] Figures subject to change

8.2 “Perfluoroalkyl substances” module

Perfluoroalkyl substances (PFAS) were incorporated into the core module as ubiquitously widespread substances. The module-based expert group confirmed the substance list of 16 perfluorocarboxylic and sulfonic acids, including perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) (see Table 9).

Table 9: “Perfluoroalkyl substances” module substance list

Perfluorosulphonic acids	perfluorobutanesulfonic acid (PFBS), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanesulfonic acid (PFHpS), perfluorooctane sulfonic acid (PFOS), perfluorodecane sulfonic acid (PFDS)
Perfluorocarboxylic acids	Perfluorobutanoic acid (PFBA), perfluoropentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDeA), perfluoroundecanoic acid (PFUnA), perfluorododecanoic acid (PFDoA), perfluorotridecanoic acid (PFTrA), perfluorotetradecanoic acid (PFTA)

For 75 foods of the food list, four pooled samples were taken in different regions and analysed separately. If two seasonal pooled samples were produced for the core module, these two pooled samples were combined proportionally into one pooled sample before being analysed for PFAS. If market share data on the number of organically produced products was available for foods of the food list that were not sampled regionally but were sampled organically, the following procedure was performed: the pooled sample from conventional products and the pooled sample from organically produced products were combined into one pooled sample according to its market share. This was only done if the respective market share of organically produced products exceeded the threshold of 5 %. If no information on the market share was available or if the market share of organically produced products fell below the threshold of 5 %, the stratification was omitted and only the conventional pooled sample was analysed. For foods in the main food groups "meat and meat products" and "eggs and egg products", separate pooled samples were prepared additionally for free-range products. After completion of the analyses, occurrence data of 613 pooled samples were available (see Table 10).

Table 10: Perfluoroalkyl substances[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	82	1,420	40
02	Vegetables, vegetable products and mushrooms	90	2,106	33
03	Starchy roots or tubers and products thereof	11	350	8
04	Legumes, nuts, oilseeds and spices	20	380	20
05	Fruit and fruit products	40	890	22
06	Meat and meat products	81	1,668	35
07	Fish, seafood and invertebrates	39	720	30
08	Milk and dairy products	23	580	23
09	Eggs and egg products	4	60	2
10	Sugar, confectionery and water-based sweet desserts	15	300	15
11	Animal and vegetable fats and oils	8	135	8
12	Fruit and vegetable juices and nectars	10	190	10
13	Water and water-based beverages	41	173	6
14	Coffee, cocoa, tea and infusions	9	165	9
15	Alcoholic beverages	8	145	8
16	Food products for infants and toddlers	11	215	11
17	Products for non-standard diets and food imitates	7	150	7
18	Composite dishes	98	2,175	52
19	Seasoning, sauces and condiments	16	350	16
	SUM	613	12,172	355

[1] Figures subject to change

8.3 "Mycotoxins" module

In accordance with the recommendation from the module-based expert group, additional substances to the primary concept were selected such as beauvericin, citrinin, more analytes from the group of trichothecenes, enniatins and *Alternaria* toxins. Therefore, a total of 37 analytes were taken into account in the module (Table 11). The selected mycotoxins were spread over three batches, with batch 1 including all analytes, with the exception of *Alternaria* toxins (batch 2) and ergot alkaloids (batch 3).

Table 11: "Mycotoxins" module substance list

Beauvericin	
Citrinin	
Ochratoxin A	
Patulin	
Zearalenone	
Aflatoxins	Aflatoxin B1, aflatoxin B2, aflatoxin G1, aflatoxin G2, aflatoxin M1
Type A trichothecenes	HT-2 toxin, T-2 toxin, diacetoxyscirpenol
Type B trichothecenes	Deoxynivalenol (vomitoxin), nivalenol, 15-acetyldeoxynivalenol, 3-acetyldeoxynivalenol
Enniatins	Enniatin A, enniatin A1, enniatin B, enniatin B1
Fumonisins	Fumonisin B1, fumonisin B2
Alternaria toxins[3]	Alternariol, alternariol monomethyl ether
Ergot alkaloids[2]	(alpha + beta)-ergocryptine, (alpha + beta)-ergocryptinine, ergocornine, ergocorninine, ergocristine, ergocristinine, ergometrine, ergometrinine, ergosine, ergosinine, ergotamine, ergotaminine

Due to the potentially inhomogeneous distribution of mycotoxins within food batches, an adapted official sampling procedure was applied in which at least three packaging units and a minimum quantity of 1.5 kg of foods were purchased per subsample[4]. Conservatively, the season with a higher number of imports was preferred for sampling as possible influences of imported goods on mycotoxin levels should be considered.

Food samples were taken exclusively in the area of Berlin. If market share data on the number of organically produced products was available, the pooled samples were stratified according to the market shares of organically and conventionally produced products.

In the first year of sampling, a total of 180 foods from the food list of the core module were selected for analysis for mycotoxins (see Table 12). A screening for previously unknown substance-matrix combinations was carried out using an extended TDS-like approach. All substances of an analytical batch were determined in a pooled sample if one mycotoxin of this analytical batch was considered relevant for this food.

[3] Separate analytic batch
[4] This was deviated from for feasibility in individual cases.

Due to a possible influence of climate factors on mycotoxin levels, sampling was continued for two additional years exclusively for a reduced number of foods. Only the food groups with the highest levels determined in the first year of sampling were considered: “grains and grain-based products” and “legumes, nuts, oilseeds and spices”. In addition, all subsamples from pooled samples from the main food group “legumes, nuts, oilseeds and spices” and from pseudograins (e.g., buckwheat, millet), which showed levels above the limit of quantification in year two or year three, were analysed separately for the corresponding mycotoxins. This procedure provides information on the variability within the pooled samples. According to this procedure, aflatoxin M1 and patulin were not analysed in the second and third year of sampling, as these mycotoxins were not relevant for any of the selected main food groups. Furthermore, the group of ergot alkaloids was only analysed in foods in the main food group “grains and grain-based products”.

Table 12: Mycotoxins – batch 1[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	127	2,210	44
02	Vegetables, vegetable products and mushrooms	12	205	12
03	Starchy roots or tubers and products thereof	1	15	1
04	Legumes, nuts, oilseeds and spices	45	845	17
05	Fruit and fruit products	11	195	11
06	Meat and meat products	15	270	15
08	Milk and dairy products	10	190	10
10	Sugar, confectionery and water-based sweet desserts	8	155	8
11	Animal and vegetable fats and oils	5	80	5
12	Fruit and vegetable juices and nectars	11	220	11
13	Water and water-based beverages	2	40	2
14	Coffee, cocoa, tea and infusions	7	130	7
15	Alcoholic beverages	5	95	5
16	Food products for infants and toddlers	10	180	10
17	Products for non-standard diets and food imitates	4	75	4
18	Composite dishes	13	230	13
19	Seasoning, sauces and condiments	5	90	5
	SUM	291	5,225	180

[1] Figures subject to change

Table 13: Mycotoxins – batch 2[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	112	1,925	39
02	Vegetables, vegetable products and mushrooms	6	100	6
04	Legumes, nuts, oilseeds and spices	15	260	5
05	Fruit and fruit products	12	210	12
11	Animal and vegetable fats and oils	2	35	2
12	Fruit and vegetable juices and nectars	12	235	12
14	Coffee, cocoa, tea and infusions	1	20	1
15	Alcoholic beverages	5	95	5
16	Food products for infants and toddlers	7	130	7
18	Composite dishes	10	175	10
19	Seasoning, sauces and condiments	3	50	3
	SUM	185	3,235	102

[1] Figures subject to change

Table 14: Mycotoxins – batch 3[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	112	1,925	39
14	Coffee, cocoa, tea and infusions	1	20	1
15	Alcoholic beverages	3	60	3
16	Food products for infants and toddlers	4	75	4
18	Composite dishes	8	145	8
	SUM	128	2,225	55

[1] Figures subject to change

8.4 "Process contaminants" module

In the module "process contaminants", polycyclic aromatic hydrocarbons (PAH), acrylamide, compounds from the monochloropropanediol (MCPD) group and glycidyl fatty acid esters were considered in the list of substances. The list of four compounds from the PAH group referred to in the primary concept was supplemented by 13 further compounds to make a total of 17 compounds on the recommendation of the module-based expert group (Table

15). The data situation on the *N*-nitrosamines included in the list of substances in the primary concept was considered sufficient at that time by the expert group and accordingly *N*-nitrosamines were not included in the list of substances for the module.

Table 15: "Process contaminants" module substance list

Polycyclic aromatic hydrocarbons	**Benzo[c]fluorene, cyclopenta[c,d]pyrene, benzo[a]anthracene, chrysene, 5-methylchrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[j]fluoranthene, benzo[a]pyrene, benzo[e]pyrene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, benzo[g,h,i]perylene, dibenzo[a,l]pyrene, dibenzo[a,e]pyrene, dibenzo[a,i]pyrene, dibenzo[a,h]pyrene**
Acrylamide	
Monochloropropanediol (MCPD) group	3-monochloropropanediol, 2-monochloropropanediol, 3-monochloropropanediol ester, 2-monochloropropanediol ester
Glycidol ester	

The influence of heating processes on food preparation was analysed by preparing standardised pooled samples for different degrees of browning. Browning degree preferences for different foods were collected in advance using a representative online survey (see Chapter 3.2). Degrees of browning selected by more than 2.5 % of the respondents were analysed, as was the lowest degree of browning in each case. In the run-up to the online survey, five different degrees of browning were determined for foods such as toast, fish fingers and fries/chips, and both preparation temperatures and preparation time were determined. This information served as guidelines for the kitchen team when preparing the subsamples. Ultimately, the degree of browning was decisive for completing the subsamples in the study kitchen. This was photo-documented for all subsamples after preparation and additionally compared with the specified degree of browning to ensure that the degrees of browning had been implemented according to the specifications.

Furthermore, samples for different preparation methods were produced and comparatively analysed. On the one hand, this included different preparation methods such as grilling, baking and frying, and also procedures using different preparation equipment, such as grilling with charcoal, electric grilling or grilling with a gas grill. Preparation methods and procedures were selected based on the results of the commissioned consumer studies (see Chapter 3.2) (Hackethal et al., 2023). Accordingly, relevant usage rates were identified for charcoal grill, electric grill and gas grill, but a "smoker" was not considered for preparation in the BfR MEAL Study due to its subordinate role. Each of the pooled samples consisted of five subsamples, whereby identical recipes and the same pieces of meat were selected for comparatively prepared pooled samples.

Acrylamide

The following three overarching goals were formulated for the acrylamide analysis:

1. Creation of a sound data basis on background exposure to acrylamide via foods. For this purpose, all foods of the food list that were heated were analysed.
2. Cooking methods carried out in private households (deep-frying, frying, grilling, baking) were compared since less was known about the influence of preparation in the household on acrylamide formation compared to industrial processes. Wherever

possible, the non-prepared food was compared with the respective prepared food, e.g., comparison of fries/chips purchased from the freezer with fries/chips prepared using a hot air fryer.

3. The measurement of acrylamide levels at different degrees of browning with five subsamples per pooled sample.

A total of 394 pooled samples were therefore analysed for acrylamide (see Table 16).

For comparatively produced pooled samples, the preparation processes (including temperature, duration, fat/oil) were precisely specified in the preparation plans and standardised foods were used. Accordingly, for pooled samples for different cooking methods with the same degree of browning, e.g., potatoes and potato products from the same batch were used to minimise differences due to water content, storage time or aspartic acid levels.

The food was treated with liquid nitrogen before homogenisation to prevent the subsequent breakdown of acrylamide during homogenisation. The samples were kept frozen throughout the homogenisation process.

Table 16: Acrylamide[1]

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	86	795	36
02	Vegetables, vegetable products and mushrooms	24	405	24
03	Starchy roots or tubers and products thereof	33	255	10
04	Legumes, nuts, oilseeds and spices	25	380	18
05	Fruit and fruit products	5	90	5
06	Meat and meat products	48	533	28
07	Fish, seafood and invertebrates	32	445	21
08	Milk and dairy products	4	80	4
09	Eggs and egg products	2	40	2
10	Sugar, confectionery and water-based sweet desserts	7	140	7
14	Coffee, cocoa, tea and infusions	9	80	4
16	Food products for infants and toddlers	9	180	9
17	Products for non-standard diets and food imitates	16	90	4
18	Composite dishes	84	1,045	49
19	Seasoning, sauces and condiments	10	200	5
	TOTAL	394	4,758	226

[1] Figures subject to change

Polycyclic aromatic hydrocarbons

The occurrence of PAHs in foods as environmental contaminants was taken into account by analysing all 356 foods of the food list for PAHs, included in the core module (see Table 17). In addition, foods explicitly selected for the analysis of process contaminants were sampled, such as grilled vegetables, vegetable chips and grilled cheese. For regionally and/or seasonally sampled foods, the four regional pooled samples and/or the two seasonal pooled samples were combined into one representative pooled sample for each food. If separate pooled samples for organic production were prepared for foods in the core module, the two pooled samples for the different production types were also analysed separately for PAHs.

The entry of PAHs in the sense of a process contaminant from heating processes was analysed in 25 selected foods in field phase 2. Different preparation methods for e.g., grilled food, were compared: gas grill, electric grill, charcoal grill, kettle grill and grill with vertically layered charcoal. The substance-specific expert group reported that oil-based marinades in particular have shown an influence on PAH levels in grilled foods in the past. Therefore, different marinade recipes were reproduced representatively in the pooled samples and standardised for different degrees of browning, i.e., the recipes and ingredients for the different degrees of browning were identical. A possible primary entry of PAHs from paprika powder was also taken into account via recipes. Since PAH levels in grilled meat correlate with the fat content of the meat cuts and the proportional fat content of the meat cuts varies, the most frequently grilled meat cuts according to data (for pork: ribs, steak, chops) were weighted equally in each pooled sample.

In addition to meat, pooled samples of smoked fish were also produced. For this purpose, the module-based expert group recommended analysing smoked fish comparatively according to different marketing channels (small smokehouses, packaged smoked fish). Furthermore, fish was smoked comparatively in a pot with beech chips in the MEAL study kitchen.

Table 17: Polycyclic aromatic hydrocarbons[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	57	1,570	40
02	Vegetables, vegetable products and mushrooms	68	2,431	35
03	Starchy roots or tubers and products thereof	14	410	8
04	Legumes, nuts, oilseeds and spices	24	440	20
05	Fruit and fruit products	39	1,100	22
06	Meat and meat products	84	1,763	35
07	Fish, seafood and invertebrates	57	855	30
08	Milk and dairy products	43	705	25
09	Eggs and egg products	4	150	2
10	Sugar, confectionery and water-based sweet desserts	18	330	15
11	Animal and vegetable fats and oils	12	210	8

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
12	Fruit and vegetable juices and nectars	12	220	10
13	Water and water-based beverages	9	144	6
14	Coffee, cocoa, tea and infusions	12	210	9
15	Alcoholic beverages	11	190	8
16	Food products for infants and toddlers	15	260	11
17	Products for non-standard diets and food imitates	8	150	7
18	Composite dishes	82	2,745	52
19	Seasoning, sauces and condiments	16	350	16
	SUM	585	14,233	359

[1] Figures subject to change

Monochloropropanediols and their fatty acid esters and glycidyl fatty acid esters

As part of a decision support project, various foods were analysed for 2-monochloropropanediol (2-MCPD), 3-monochloropropanediol (3-MCPD) and their fatty acid esters in 2016. In addition to this, the BfR MEAL Study aimed to focus on analysing heated foods that had not been considered in the 2016 analysis (Table 18). The module's food list included deep-fried foods (e.g., French fries), smoked foods (e.g., smoked fish), baked foods (e.g., biscuits), preserved foods (tinned fish), fried foods (fish fingers, breaded; pork schnitzel, breaded) and dried foods (e.g., instant noodles). When preparing subsamples for frying (e.g., French fries, sweet potato fries), the frying oil was replaced for each subsample.

Table 18: Monochloropropanediols and their fatty acid esters and glycidyl fatty acid esters[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	16	165	8
03	Starchy roots or tubers and products thereof	24	165	5
06	Meat and meat products	14	70	2
07	Fish, seafood and invertebrates	23	265	12
10	Sugar, confectionery and water-based sweet desserts	2	40	2
18	Composite dishes	3	60	3
19	Seasoning, sauces and condiments	1	20	1
	TOTAL	83	785	33

[1] Figures subject to change

8.5 "Nutrients" module

A total of 20 nutrients were taken into account in the module, including five vitamins, one provitamin, six major elements and eight trace elements (see Table 19).

Table 19: "Nutrients" module substance list

Vitamins and provitamins	Vitamin A (retinol), β-carotene Vitamin E (α-, β-, γ-, δ-tocopherol, tocopherol palmitate and acetate[5]) Vitamin K1, vitamin K2 Folic acid
Major elements	Calcium, chloride, potassium, magnesium, sodium, phosphorus
Trace elements	Chromium, fluoride, iodine, copper, manganese, molybdenum, selenium, zinc

Sampling for the vitamin analyses was carried out exclusively in the Berlin area due to the limited storage stability of vitamins in the pooled samples. For foods that were taken in two different seasons as part of the core module or for which an additional pooled sample was prepared from organically produced foods, both seasonal pooled samples and the organic pooled samples were analysed separately for vitamins (Table 20, Table 21).

Table 20: Vitamin E and vitamin K[1,2] sample structures

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	58	970	40
02	Vegetables, vegetable products and mushrooms	67	1,063	33
03	Starchy roots or tubers and products thereof	20	320	8
04	Legumes, nuts, oilseeds and spices	24	440	20
05	Fruit and fruit products	40	650	22
06	Meat and meat products	59	1,022	35
07	Fish, seafood and invertebrates	30	585	30
08	Milk and dairy products	37 (38)	640 (660)	23
09	Eggs and egg products	4	60	2
10	Sugar, confectionery and water-based sweet desserts	18	330	15
11	Animal and vegetable fats and oils	13	210	8
12	Fruit and vegetable juices and nectars	12	220	10
14	Coffee, cocoa, tea and infusions	4 (3)	70 (50)	3
16	Food products for infants and toddlers	15	260	11
17	Products for non-standard diets and food imitates	8	150	7
18	Composite dishes	101	1,655	52
19	Seasoning, sauces and condiments	18	330	15
	SUM	528	8,975	334

[1] Vitamin K information in brackets
[2] Figures subject to change

[5] designated α-tocopherol

Table 21: Vitamin A and beta-carotene[1] sample structures (Schendel et al., 2022)

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	58 (57)	970 (950)	40
02	Vegetables, vegetable products and mushrooms	67 (66)	1,063 (1,018)	33
03	Starchy roots or tubers and products thereof	20 (19)	320 (305)	8
04	Legumes, nuts, oilseeds and spices	24	440	20
05	Fruit and fruit products	40	650	22
06	Meat and meat products	59 (19)	1,022 (330)	35 (13)
07	Fish, seafood and invertebrates	30 (5)	585 (100)	30 (5)
08	Milk and dairy products	38 (37)	660 (640)	24 (23)
09	Eggs and egg products	4	60	2
10	Sugar, confectionery and water-based sweet desserts	18 (1)	330 (20)	15 (1)
11	Animal and vegetable fats and oils	13	210	8
12	Fruit and vegetable juices and nectars	12	220	10
14	Coffee, cocoa, tea and infusions	3 (4)	50 (70)	2 (3)
16	Food products for infants and toddlers	15	260	11
17	Products for non-standard diets and food imitates	8	150	7
18	Composite dishes	101 (97)	1,655 (1,570)	52
19	Seasoning, sauces and condiments	18 (17)	330 (310)	15 (14)
	SUM	528 (438)	8,975 (7,303)	334 (272)

[1] Beta-carotene information in brackets
[2] Figures subject to change

To improve the data basis for the assessment of folic acid enrichment in foods, information on the variability of folic acid levels in products and their dependence on product age was provided (Table 22). Furthermore, information on the transfer of folic acid from enriched salt during typical consumer cooking processes was collected. Representative pooled samples were compiled exclusively from enriched foods. Folic acid levels in branded products with the highest enrichment within a product group was determined both at the beginning of the best-before date and shortly before the expiry of the best-before date.

Table 22: Folic acid[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	27	27	6
03	Starchy roots or tubers and products thereof	3	3	0
06	Meat and meat products	6	6	1
08	Milk and dairy products	6	6	1
10	Sugar, confectionery and water-based sweet desserts	12	12	2
14	Coffee, cocoa, tea and infusions	6	6	1
16	Food products for infants and toddlers	12	12	2
18	Composite dishes	6	6	2
19	Seasoning, sauces and condiments	6	6	1
	SUM	84	84	17

[1] Figures subject to change

Pooled samples from regional and seasonal sampling were available for the major elements and the two trace elements iodine and fluoride. Regarding major elements, regionality and seasonality were not considered relevant issues. The four regional pooled samples and/or the two seasonal pooled samples were combined into one representative pooled sample and subsequently analysed (see Table 23). In contrast, the regional and seasonal pooled samples for iodine were analysed separately, since soil is known to have an influence on the iodine level in plants and, depending on the season, the foods may originate from different regions. The additional pooled samples from foods of organic production were analysed separately for the major elements and iodine. Therefore, the sampling for iodine corresponded to that of the core module (see Table 4).

Table 23: Sample structure of major elements (excluding phosphorus) (Schwerbel et al., 2021) and fluoride[1]

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	55	1,540	40
02	Vegetables, vegetable products and mushrooms	47	2,306	34
03	Starchy roots or tubers and products thereof	12	410	8
04	Legumes, nuts, oilseeds and spices	24	440	20
05	Fruit and fruit products	29	1,010	22
06	Meat and meat products	47	1,578	35
07	Fish, seafood and invertebrates	30	720	30
08	Milk and dairy products	30	640	23
09	Eggs and egg products	4	150	2

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
10	Sugar, confectionery and water-based sweet desserts	18	330	15
11	Animal and vegetable fats and oils	12	205	8
12	Fruit and vegetable juices and nectars	12	220	10
13	Water and water-based beverages	38	173	6
14	Coffee, cocoa, tea and infusions	12	210	9
15	Alcoholic beverages	11	190	8
16	Food products for infants and toddlers	15	260	11
17	Products for non-standard diets and food imitates	8	150	7
18	Composite dishes	73	2,670	52
19	Seasoning, sauces and condiments	16	350	16
	SUM	493	13,552	356

[1] Figures subject to change

For the trace elements chromium, copper, manganese, molybdenum, selenium and zinc as well as for phosphorus, the analyses were carried out based on the procedure in the core module, i.e., regional pooled samples, seasonal pooled samples and pooled samples exclusively from organically produced foods were analysed separately. The sample structure for trace elements corresponds to the elements analysed in the core module (see Table 4).

8.6 “Substances migrating from food contact materials” module

For the module “substances migrating from food contact materials”, the module-based expert group confirmed the substance groups plasticisers, mineral oil hydrocarbons and 2,4-di-*tert*-butylphenol to be included in the substance list. As early as in the first field phase, the fractions of mineral oil saturated hydrocarbons (MOSH) and the fractions of mineral oil aromatic hydrocarbons (MOAH) were analysed as an environmental contaminant in 355 foods in the core module.

With regard to antimony, the module-based expert group saw no need for analyses of beverages from PET bottles. However, the module-based expert group recommended determining antimony in a broad range of foods to estimate background contamination in foods. Therefore, antimony is included in the list of substances for the core module, even though a distinction was partly made according to the type of packaging.

Table 24: "Substances migrating from food contact materials" module substance list

Plasticisers	Triethyl-2-acetylcitrate, benzyl butyl phthalate, benzophenone, diallyl phthalate, dibutoxy ethyl phthalate, dibutyl sebacate, dicyclohexyl phthalate, di(2-methoxyethyl) phthalate, bis(2-ethylhexyl) adipate, diethylhexyl phthalate, bis(2-ethylhexyl) sebacate, bis(2-ethylhexyl) terephthalate, diethyl phthalate, dimethyl succinate, dihexyl phthalate, diisobutyl adipate, diisobutyl phthalate, diisoheptyl phthalate, diisopentyl phthalate, diisopropyl phthalate, bis(4-methyl-2-pentyl) phthalate, bis(2-methoxyethyl) phthalate, dimethyl phthalate, bis(4-methylpentyl) phthalate, diisohexyl phthalate, di-*n*-butyl phthalate, di-*n*-decyl phthalate, di-*n*-heptyl phthalate, di-*n*-nonylephthalate, di-*n*-octylephthalate, di-*n*-pentyl phthalate, bis(2-ethylhexyl)iso phthalate, di(2-ethylhexyl) maleate, dioctyl maleate, di-*n*-octyl sebacate, bis(2-ethylhexyl)azelate, diethoxyethyl phthalate, diphenyl phthalate, dipropylheptyl phthalate, dipropyl phthalate, *N*-Ethyl-4/2-methylbenzenesulfonamide, *N*-Ethyl-4/2-methylbenzenesulfonamid, *N*-Pentyl-iso-pentylphthalate, tributyl-2-acetylcitrate, *tert*-butylphenyl diphenyl phosphate, tris(2-butoxyethyl) phosphate, tributyl phosphate, tris-2-ethylhexyl phosphate, triisobutyl phosphate, tris(2-ethylhexyl) trimellitate, glycerol triacetate, 2,2,4-trimethyl-1,3-pentanediol-diisobutyrate, erucamide, oleamide, *N*-Oleoylethanolamide, diisodecyl adipate, bis(7-methyloctyl)cyclohexane-1,2-dicarboxylate, diisodecyl phthalate, diisodecyl azelate, diisononyl adipate, diisoctyl azelate, diisononyl phthalate, di-*n*-nonyl phthalate
Mineral oil hydrocarbons	MOSH: ≥C10 to ≤C16, >C16 to ≤C20; >C20 to ≤C25, >C25 to ≤C35, >C35 to ≤C50, >C20 to ≤C40 MOAH: >C10 to ≤C35, >C16 to ≤C25, >C25 to ≤C35, >C35 to ≤C50
2,4-Di-*tert*-butylphenol	4-ethylphenol, *p*-*tert*-butylphenol, 2,6-Di-*tert*-butyl-*p*-benzoquinone, 3,5-Di-*tert*-butyl-4-hydroxybenzaldehyde, 3,5-Di-*tert*-butyl-4-hydroxyacetophenone, 7,9-Di-*tert*-butyl-1-oxaspiro[4.5]-deca-6,9-diene-2,8-dione, 3-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)-methylpropionate, 3-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)propionic acid

Plasticisers

The BfR-based "National Reference Laboratory for Food Contact Materials" analysed samples from the BfR MEAL Study using a specially established method for determining 59 substances from the group of plasticisers in ready-to-eat foods.

A total of 165 foods from all main food groups were examined for the analyses. Water and water-based (hot) beverages such as coffee, tea and other infusions were excluded. Samples were prepared separately for different packaging materials (foil packaging, packaging with twist-off lids, paper/cardboard and loose/unpacked). Furthermore, separate samples were generated for different types of production and samples specifically for out-of-home consumption. A total of 223 samples were analysed for the 59 plasticisers (Table 25).

Table 25: "Plasticisers"[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	37	600	22
02	Vegetables, vegetable products and mushrooms	11	170	7
03	Starchy roots or tubers and products thereof	6	110	5
04	Legumes, nuts, oilseeds and spices	14	235	10
05	Fruit and fruit products	7	115	7
06	Meat and meat products	20	365	18
07	Fish, seafood and invertebrates	19	370	18
08	Milk and dairy products	17	295	14
09	Eggs and egg products	1	15	1
10	Sugar, confectionery and water-based sweet desserts	8	150	7
11	Animal and vegetable fats and oils	10	155	6
12	Fruit and vegetable juices and nectars	6	90	5
15	Alcoholic beverages	8	120	4
16	Food products for infants and toddlers	7	105	3
17	Products for non-standard diets and food imitates	11	165	5
18	Composite dishes	33	595	27
19	Seasoning, sauces and condiments	8	130	6
	SUM	223	3,785	165

[1] Figures subject to change

Mineral oil hydrocarbons

In field phase 1, different fractions of mineral oil hydrocarbons were determined in 355 foods in the core module. Different fractions of mineral oil saturated and aromatic hydrocarbons were evaluated. In accordance with the EFSA recommendation, an additional qualitative verification of the quantitative analysis was carried out for selected pooled samples. This made it possible to identify substance classes that elute together with the fractions but cannot be assigned to this substance group.

The regional and seasonal pooled samples of foodstuffs produced as part of the core module were not analysed separately, but were combined into one stratified pooled sample per food. Pooled samples of a food produced separately by type of production were stratified according to information from market share data on the number of organically produced products. If no market share data was available for the number of organically produced products, only the conventional pooled sample was analysed.

Table 26: Mineral oil hydrocarbons[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	40	1,420	40
02	Vegetables, vegetable products and mushrooms	33	2,136	33
03	Starchy roots or tubers and products thereof	8	380	8
04	Legumes, nuts, oilseeds and spices	20	380	20
05	Fruit and fruit products	22	890	22
06	Meat and meat products	35	1,338	35
07	Fish, seafood and invertebrates	30	720	30
08	Milk and dairy products	24	600	24
09	Eggs and egg products	2	150	2
10	Sugar, confectionery and water-based sweet desserts	15	300	15
11	Animal and vegetable fats and oils	8	135	8
12	Fruit and vegetable juices and nectars	10	190	10
13	Water and water-based beverages	5	140	5
14	Coffee, cocoa, tea and infusions	9	165	9
15	Alcoholic beverages	8	145	8
16	Food products for infants and toddlers	11	215	11
17	Products for non-standard diets and food imitates	7	150	7
18	Composite dishes	52	2,160	52
19	Seasoning, sauces and condiments	16	350	16
	SUM	355	11,964	355

[1] Figures subject to change

2,4-Di-*tert*-butylphenol (2,4-DTBP)

2,4-DTBP was analysed as a representative of non-intentionally added substances (NIAS) from antioxidants. The toxicological relevance of 2,4-DTBP is not certain, but 2,4-DTBP is determined as an exemplary marker for compounds from antioxidants.

In cooperation with the “National Reference Laboratory for Food Contact Materials”, 176 foods from all main food groups were selected from the food list in the core module. Almost all vegetables and vegetable products were excluded from this, as no crossover to the foods was expected based on the matrix. The pooled samples were prepared and analysed separately for different packaging materials (plastic, tin cans, cardboard/paper, loose/unpacked). For selected foods, separate pooled samples were also generated for foods from out-of-home consumption. A total of 211 samples were analysed for 2,4-DTBP (see Table 27).

Table 27: 2,4-Di-*tert*-butylphenol[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	31	515	21
02	Vegetables, vegetable products and mushrooms	2	30	2
03	Starchy roots or tubers and products thereof	6	110	5
04	Legumes, nuts, oilseeds and spices	15	245	10
05	Fruit and fruit products	13	210	8
06	Meat and meat products	14	260	13
07	Fish, seafood and invertebrates	12	235	12
08	Milk and dairy products	19	330	14
10	Sugar, confectionery and water-based sweet desserts	8	150	7
11	Animal and vegetable fats and oils	8	130	6
12	Fruit and vegetable juices and nectars	11	165	6
13	Water and water-based beverages	8	130	5
14	Coffee, cocoa, tea and infusions	4	70	4
15	Alcoholic beverages	12	180	6
16	Food products for infants and toddlers	3	60	3
17	Products for non-standard diets and food imitates	6	105	5
18	Composite dishes	28	510	23
19	Seasoning, sauces and condiments	11	180	8
	SUM	211	3,615	158

[1] Figures subject to change

8.7 "Pesticide residues" module

Extensive data is already available from food monitoring for pesticide residues. Therefore, prioritisation of the substances being analysed in the BfR MEAL Study was carried out according to existing data gaps or uncertainties in existing assessments. Substances were selected for this module for which the theoretical maximum daily intake (TMDI) exhausted 80 % of the acceptable daily intake (ADI) in the past and that had a result rate of at least 1 % in food monitoring. Further, the relevance of substances was assessed that (1) have no established toxicological limits, (2) form toxicologically relevant metabolites during processing, (3) form toxicologically relevant metabolites that are not specific to a single active substance or (4) are of high interest in policy and society. Accordingly, more than 30 individual compounds were considered in the module (Table 28).

Table 28: “Pesticide residue” module substance list

Boscalid, captan, captan (sum), chlorpyrifos, cyantraniliprole, cypermethrin (sum of isomers), cyprodinil, deltamethrin (*cis*-deltamethrin), difenoconazole, dimethoate, fluopyram, hexachlorobenzene, hexythiazox, imazalil, Indoxacarb (sum of *S* and *R* isomers), iprodione, lambda-cyhalothrin, myclobutanil, omethoate, pirimicarb, pirimicarb-desmethyl, pyraclostrobin, pyrimethanil, spinosad, tetrahydrophthalimide, thiabendazole, thiacloprid, trifumuron[6]
Glyphosate, AMPA
Chlorate/perchlorate
Ethylenthiourea (ETU), propylenthiourea (PTU) and chlormequat
Triazole metabolites (1,2,4-triazole, triazole alanine, triazole acetic acid, triazole lactic acid)

The multiple sampling numbers were determined in advance to be able to adequately assess the consumer exposure. The foods were divided into categories, which on the one hand are based on the previous frequency of findings in food monitoring and on the other hand take into account the nature of the food and its significance in nutrition (see Table 29).

Table 29: Categories for multiple sampling in the “pesticide residues” module

Food category	**Explanation**	**Multiple sampling numbers**	
		Multimethod, glyphosate/ AMPA	Chlorate/ perchlorate
Unmixed plant-based foods (e.g., raw fruits/vegetables)	- Highest residues expected for plant protection products - High market variability	2	3 – 4
Mixed plant-based foods (e.g., wine, tea, juices, bread)	- Industrially produced, mixed and distributed on a large scale - Significantly reduced residue variability	2	3
Unmixed animal-based foods (e.g., meat, cheese, milk, honey)	- Residue situation generally lower than in plant-based foods - High level of consumption	2	3
Fish	- Findings on organochlorine compounds in previous monitoring programmes - Low variability	1	1
Composite dishes/complex foods (e.g., pizza, baked goods)	- Heterogeneous composition, strong mixing of diverse ingredients - High dilution effect, low residues expected for plant protection products	1	1
Specific foods with high levels of consumption	- Sugar - Tap water	1	-

Only conventionally produced foods were sampled for the module. This was done in order to avoid a reduction in the average levels of pesticide residues within the pooled samples. Organically produced foods that do not contain pesticide residues might reduce the levels in the pooled samples. An exception were foods for which only very few or no conventional

[6] Analytes are determined using a multimethod

products were available (e.g., grain-based porridges and nut spreads). Due to the complex commodity chains, a regional orientation of the food samples was not necessary according to the expert group.

Multimethod substances, glyphosate and aminomethyl-phosphonic acid (AMPA)

The analyses for multimethod substances as well as glyphosate and AMPA were carried out in all foods in the food list in the core module, with the exception of the foods, spirits, minced meat and mineral water (Table 30).

Table 30: Sample structure for analyses using the multimethod and for glyphosate/AMPA[1]

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	49	900	40
02	Vegetables, vegetable products and mushrooms	63	945	32
03	Starchy roots or tubers and products thereof	14	225	8
04	Legumes, nuts, oilseeds and spices	40	610	20
05	Fruit and fruit products	41	621	22
06	Meat and meat products	39	669	33
07	Fish, seafood and invertebrates	30	600	30
08	Milk and dairy products	35	580	24
09	Eggs and egg products	4	80	2
10	Sugar, confectionery and water-based sweet desserts	16	310	15
11	Animal and vegetable fats and oils	16	240	8
12	Fruit and vegetable juices and nectars	19	285	10
13	Water and water-based beverages	5	76	5
14	Coffee, cocoa, tea and infusions	15	230	8
15	Alcoholic beverages	8	140	6
16	Food products for infants and toddlers	11	220	11
17	Products for non-standard diets and food imitates	11	175	7
18	Composite dishes	52	1,035	52
19	Seasoning, sauces and condiments	16	320	16
	SUM	484	8,261	349

[1] Figures subject to change

Chlorate/perchlorate

The data basis from food monitoring for chlorate and perchlorate levels in a wide range of plant-based foods is very extensive. However, data for foods of animal origin in Germany are only sporadically available. Therefore, the focus was placed on sampling animal-based foods. Accordingly, in addition to honey, foods from the following main food groups were analysed:

“meat and meat products” “fish, seafood and invertebrates”, “milk and dairy products”, “eggs and egg products”, “animal and vegetable fats and oils (Table 31). Furthermore, composite dishes with complex matrices were taken into account and up to three multiple samples were taken for the selected foods.

Table 31: Chlorate/perchlorate sample structure[1]

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	16	310	13
02	Vegetables, vegetable products and mushrooms	2	30	1
03	Starchy roots or tubers and products thereof	9	145	3
06	Meat and meat products	66	1,090	33
07	Fish, seafood and invertebrates	32	640	30
08	Milk and dairy products	60	975	23
09	Eggs and egg products	6	120	2
10	Sugar, confectionery and water-based sweet desserts	8	145	6
11	Animal and vegetable fats and oils	6	90	2
12	Fruit and vegetable juices and nectars	2	30	1
13	Water and water-based beverages	2	30	1
16	Food products for infants and toddlers	7	140	6
18	Composite dishes	38	750	37
19	Seasoning, sauces and condiments	8	160	8
	SUM	262	4,655	166

[1] Figures subject to change

Triazole

Triazole metabolites were considered in the module due to the different entry pathways and the broad occurrence of triazoles in foods as well as the limited data basis on the occurrence in prepared food. The analyses were carried out in 207 pooled samples without multiple sampling and exclusively in foods from conventional production (Table 32). Only foods from the categories “unmixed plant-based foods” and “mixed plant-based foods” were included. Since there is no data available on the storage stability of triazole metabolites for acidic food matrices, these foods (juices, berry mixtures, etc.) were not analysed. As the contract for the analysis of triazoles could only be awarded in a second round of bidding, the drawing of samples had already started when the contract was awarded. Due to the limited storage stability of 1,2,4-triazole, some samples from the ongoing field phase 2 could not be analysed for this substance at the time of contract award and were therefore analysed within a reduced sample size of 50 pooled samples (see Table 32).

Table 32: Triazole metabolite[1] sample structure

No.	Main food group	Pooled samples (n^7/n^8)	Subsamples (n^6/n^7)	Foods (n^6/n^7)
01	Grains and grain-based products	37/16	695/285	37/16
02	Vegetables, vegetable products and mushrooms	28/4	420/60	28/4
03	Starchy roots or tubers and products thereof	7/1	120/20	7/1
04	Legumes, nuts, oilseeds and spices	17/10	260/150	17/10
05	Fruit and fruit products	21/3	335/50	21/3
10	Sugar, confectionery and water-based sweet desserts	13/0	260/0	13/0
11	Animal and vegetable fats and oils	6/6	90/90	6/6
13	Water and water-based beverages	1/0	1/0	1/0
14	Coffee, cocoa, tea and infusions	8/0	125/0	8/0
15	Alcoholic beverages	3/0	60/0	3/0
16	Food products for infants and toddlers	10/0	200/0	10/0
17	Products for non-standard diets and food imitates	7/0	115/0	7/0
18	Composite dishes	40/8	795/160	40/8
19	Seasoning, sauces and condiments	9/2	180/40	9/2
	SUM	207/50	3,656/855	207/50

[1] Figures subject to change

Ethylenthiourea (ETU), propylenthiourea (PTU) and chlormequat

ETU and PTU are reaction products that can form active substances in the dithiocarbamate group through thermal treatment. Usually, they are more toxic compared to the initial compounds. There is little representative data on ETU/PTU levels in foods available. As the analysis could not be contracted out in the call for tenders, the QuPPe method developed in the European Reference Laboratory for Single Residue Methods (EURL-SRM) was established at the BfR. Thus, data on ETU/PTU was collected as part of a special research project at the BfR.

Since the call for tender for the analysis of ETU/PTU and chlormequat was unsuccessful and was, therefore, only carried out at a later date at the BfR, the analysis was carried out on retention samples that had already been taken and were in long-term storage. Since no more sample material was available for the “lye-pretzels, soft” sample, the analysis was carried out on 348 food samples (Table 33). No pooled samples from multiple sampling were analysed.

[7] Triazole alanine, triazole acetic acid, triazole lactic acid
[8] 1,2,4-triazole

Table 33: ETU/PTU and chlormequat[1] sample structure

No.	Main food group	Pooled samples (n)	Subsamples (n)	Foods (n)
01	Grains and grain-based products	39	740	39
02	Vegetables, vegetable products and mushrooms	32	480	32
03	Starchy roots or tubers and products thereof	8	135	8
04	Legumes, nuts, oilseeds and spices	20	305	20
05	Fruit and fruit products	23	351	22
06	Meat and meat products	33	586	33
07	Fish, seafood and invertebrates	30	600	30
08	Milk and dairy products	24	410	24
09	Eggs and egg products	2	40	2
10	Sugar, confectionery and water-based sweet desserts	15	295	15
11	Animal and vegetable fats and oils	8	120	8
12	Fruit and vegetable juices and nectars	10	150	10
13	Water and water-based beverages	5	76	5
14	Coffee, cocoa, tea and infusions	8	125	8
15	Alcoholic beverages	6	110	6
16	Food products for infants and toddlers	11	220	11
17	Products for non-standard diets and food imitates	7	115	7
18	Composite dishes	52	1,035	52
19	Seasoning, sauces and condiments	16	320	16
	SUM	349	6,213	348

[1] Figures subject to change

8.8 "Pharmacologically active substances"

A study on the "Detection of antibiotic residues in selected foods of animal origin" carried out by the Bavarian State Office for Health and Food Safety (Hausmann et Holtmannspötter, 2013) provides data on frequencies and variability of antibiotic residues in various animal-based foods. The data suggest that it is highly unlikely that antibiotic concentrations above the limit of quantification were detected in pooled samples from the BfR MEAL study due to pooling methodology and associated dilution effects. Furthermore, the study's subsamples are processed in the kitchen, which may lead to a degradation of the antibiotic residues contained. Accordingly, these samples were adapted to the circumstances as follows, deviating from the classic TDS design.

Pork and turkey were included in the study since both foods most frequently demonstrated antibiotic residues in previous studies. Trout was added as a third animal matrix, which is also expected to contain residues (Tolmien, 2011). Pharmacologically active substances were selected for which residues could most frequently be detected in the three matrices considered; nine groups of antibiotics with a total of 36 pharmacologically active individual substances were included (Table 34).

Table 34: Substance matrix combinations in the “pharmacologically active substances” module

Substance group	**Matrix**		
Analyte	Pork	Turkey	Trout
Amphenicols			
Florfenicol			×
Quinolone			
Danofloxacin	×	×	×
Enrofloxacin	×	×	×
Ciprofloxacin	×	×	×
Marbofloxacin	×	×	×
Diaminopyrimidine derivates			
Trimethoprim			×
Macrolide			
Tylosin			×
Tilmicosin			×
Tulathromycin			×
Tildipirosin			×
Gamithromycin			×
Erythromycin			×
Penicillin			
Amoxicillin	×		
Benzylpenicillin	×		
Sulfonamide			
Sulfathiazole	×	×	×
Sulfadimidine	×	×	×
Sulfadiazine	×	×	×
Sulfadoxine	×	×	×
Sulfadimethoxine	×	×	×
Tetracyclines			
Chlortetracycline	×	×	×
Tetracycline	×	×	×
Oxytetracycline	×	×	×
Epi-chlortetracycline	×	×	×
Epi-tetracycline	×	×	×
Epi-oxytetracycline	×	×	×

Substance group	Matrix		
Analyte	Pork	Turkey	Trout
Doxycycline	×	×	×
Aminoglycoside			
Streptomycin	×		
Dihydrostreptomycin	×		
Spectinomycin	×		
Gentamycin	×		
Neomycin	×		
Coccidiostats			
Dinitrocarbanilide		×	
Monensin		×	
Lasalocid		×	
Narasin		×	
Maduramicin		×	

The subsamples were analysed as individual samples and not combined into pooled samples, as is usually done for TDS. The number of samples was set at 60 samples per matrix, whereby the representative purchase and preparation of the subsamples corresponded to the procedure in the core module. Furthermore, data on the possible breakdown of antibiotic residues by heating was investigated in a cost-effective way. Only individual sample prepared typically for households were analysed for the corresponding antibiotic group if a level above the limit of detection in the active substance group was determined in the corresponding raw individual sample.

8.9 "Food additives" module

In the BfR MEAL Study's primary concept, the substance selection for the "food additives" module was based on a report by the EU Commission from 2001 on the intake of food additives (CEC 2001). Since 2010, EFSA has continuously published new assessments as part of the programme for the re-evaluation of food additives (EC 2010). In this context, a step-by-step procedure for updating the selection of food additives for the BfR MEAL Study was agreed with the module-based expert group:

1. Creation of a data basis for pre-selecting additives based on the EFSA re-assessments of food additives from 2012-2018 (86 additives/additive groups identified).
2. Pre-selection of relevant substances on the basis of queried data gaps, uncertainties in the assessment or a risk that cannot be excluded (44 substances pre-selected) from EFSA opinions. In the case of excess HBGVs (health-based guidance values) in EFSA re-assessments, exposure assessments based on the German "Datenbank zum Vorkommen von Zusatzstoffen" (database on the occurrence of additives) were taken into account in the pre-selection (Diouf et al., 2014).

3. Prioritisation of food additives based on the pre-selection by the members of the expert group and by EFSA.
4. Compilation of information on the availability of analytical quantification methods for the prioritised food additives.
5. Final selection of food additives taking into account the availability of analytical methods and available capacities in field phase 2.

The award of the analytical service for determining the eight prioritised substances or substance groups was made through a public invitation to tender. The contract was awarded for four food additive groups (Table 35). As part of the BfR MEAL Study's core module, phosphorus, nitrate and aluminium were also determined in all 356 foods on the food list, as these can occur in foods independently of their use as food additives. Consequently, the sampling design in the core module differed from that of the "food additives" module in that the pooled samples for phosphorus, nitrate and aluminium were produced regardless of use in specific use categories in Annex II of Regulation (EC) No 1333/2008 and regardless of a declared additive use.

Table 35: "Food additives" module substance list

Additive group	Food additive
Benzoates (E210–E213)[§]	Benzoic acid, calcium benzoate, potassium benzoate, sodium benzoate
Nitrites (E249, E250)[$]	Potassium nitrite, sodium nitrite
Sorbates (E200, E202)[*]	Potassium sorbate, sorbic acid
Sulphites (E220–E228)[#]	Calcium hydrogen sulphite, calcium sulphite, potassium hydrogen sulphite, potassium metabisulphite, sodium hydrogen sulphite, sodium metabisulphite, sodium sulphite, sulphur dioxide

[§] reported as benzoic acid, [$] reported as NO_2, * reported as sorbic acid [#] reported as SO_2

Four retail chains were selected and their product ranges were checked by visiting the market to create module-specific food lists. The use of additives in the list of ingredients was noticed and the product was photo-documented. Based on the photo documentation, products with additive use were assigned to the food categories in Annex II of Regulation (EC) No 1333/2008. Pooled samples were generated separately for each additive group and for all food categories in Annex II of Regulation (EC) No 1333/2008 for which products with additive use were identified. Accordingly, pooled samples were not prepared for all food categories with authorised use of an additive, but only for the categories for which corresponding products with additive use were identified at the shopping locations. In case of foods with different maximum levels, several pooled samples were prepared under the condition that the same maximum level is defined for the foods in a pooled sample. If individual and combined maximum levels are defined by regulation for two food additive groups (e.g., for sorbates and benzoates), three separate pooled samples were prepared, each for the sole use of one of the two additives and for the combined use of both additives. Furthermore, several pooled samples were generated for one food category in Annex II of Regulation (EC) No 1333/2008 with only one numerical maximum level if the food list in the core module contains several foods for this category (e.g., several pooled samples for various sausage products in category 08.3.2 "heat-treated meat products").

The number of subsamples corresponds to the respective number of products identified in the shopping locations and varied between one and 29 products (median: 15), whereby different products in a pooled sample were weighted equally. In the case of a common use of a food additive group in food (e.g., nitrites in sausages, sulphites in wine), the number of subsamples was limited to 15 or 20 subsamples and the subsamples were weighted according to available market data.

A total of 146 pooled samples were prepared from 1,026 subsamples. These samples provide occurrence data for sorbates (n = 61), benzoates (n = 26), sulphites (n = 35) and nitrites (n = 24) for a total of 39 food categories from Annex II of Regulation (EC) No 1333/2008 (Table 36).

In addition, further pooled samples were analysed for nitrites (n = 67) and benzoates (n = 18) to account for sources outside additive uses. The pooled samples each consisted of 15-20 subsamples (n = 1,416), which were selected and weighted representatively according to market data.

Table 36: Food additives[1] sample structure

Category	Food category	Benzoates[a]	Sorbates[a]	Sulphites[a]	Nitrites[a]
01.7.1	Unripened cheese		1 (14)		
01.7.2	Mature cheese		1 (4)		
02.2.2	Other fat and oil emulsions, including spreadable fats		2 (19)		
04.1.1	Whole fresh fruit and vegetables			4 (60)	
04.2.1	Fruit and vegetables, dried		1 (7)	4 (12)	
04.2.2	Fruit and vegetables in vinegar, oil or brine	3 (15)	3 (13)	2 (16)	
04.2.4.1	Preparations made from fruit and vegetables		3 (8)	2 (30)	
04.2.5.1	Extra jam and extra jelly		1 (5)		
04.2.5.2	Jams, jellies, marmalades and chestnut purée		1 (9)		
04.2.5.3	Other similar spreads made from fruit or vegetables		1 (12)		
04.2.6	Processed potato products		2 (15)	3 (30)	
05.2	Other confectionery, including small breath refreshers		1 (2)	2 (2)	
05.4	Garnish, coatings and fillings		3 (23)		
06.4.4	Potato gnocchi		1 (1)		
06.4.5	Pasta fillings		1 (1)		
06.7	Pre-cooked or processed cereal food		1 (2)		
07.1	Bread and bread rolls		2 (12)		
07.2	Pastries		8 (35)		
08.3.1	Non-heat treated processed meat				3 (45)
08.3.2	Heat treated processed meat	1 (1)	1 (1)		20 (273)
08.3.4	Traditionally cured meat products				1 (15)
09.1.2	Molluscs and crustaceans, unprocessed			1 (3)	

Category	Food category	Benzoates[a]	Sorbates[a]	Sulphites[a]	Nitrites[a]
09.2	Fish and fishery products, including molluscs and crustaceans, processed	3 (6)	3 (5)	1 (1)	
09.3	Fish roe	1 (1)	1 (1)		
12.3	Vinegar			1 (20)	
12.4	Mustard			2 (9)	
12.6	Sauces	3 (11)	4 (32)		
12.7	Salads and savoury spreads	10 (36)	12 (47)		
14.1.4	Flavoured drinks	5 (21)	6 (42)	1 (1)	
14.2.2	Wine		1 (2)	3 (51)	
14.2.3	Cider and perry			1 (13)	
14.2.4	Fruit wine			1 (1)	
14.2.5	Mead			1 (1)	
14.2.6	Spirits			1 (1)	
14.2.7.1	Flavoured wine			1 (6)	
14.2.7.2	Flavoured wine-based drinks			1 (16)	
14.2.7.3	Flavoured wine-based cocktails			1 (10)	
14.2.8	Other alcoholic beverages			1 (3)	
15.1	Potato, grain, flour or starch-based snacks			1 (4)	

[a] Number of samples (number of subsamples)
[1] Figures subject to change

In addition, an extension of the “food additives” module provides levels of sweeteners in sweetened soft drinks. This extension was carried out at the request of the BMEL against the background of the “National Reduction and Innovation Strategy” and due to a slight increase of soft drinks sweetened exclusively with sweeteners. The results are summarised in opinion no. 006/2023.

The random sample comprised market-relevant soft drinks. Products were selected based on the MRI’s product monitoring from 2019, which classified 271 sweetened soft drinks as relevant to the market (Demuth et al., 2020). The use of sweeteners was documented for 95 products. Due to changes in product availability, a total of 92 energy-reduced soft drinks or soft drinks without added sugar from seven product groups were analysed (Table 37).

The soft drinks were mainly purchased from food retailers in the Berlin area, but also via the internet and in the northern region when soft drinks were not available in local retail stores. For soft drinks, it was assumed that the sweetener levels in a branded product did not differ across Germany. Using a multimethod, nine sweeteners (acesulfame K, aspartame, cyclamate, neohesperidin-DC, neotame, saccharin, sucralose, steviol glycosides [stevioside, rebaudioside A] and advantame) were determined in the samples.

Table 37: Sample of soft drinks, including number of detected sweeteners[1]

Product group	Energy-reduced		No added sugar		SUM	
	n	Number Sweetener Median (Min-Max)	n	Number Sweetener Median (Min-Max)	n	Number Sweetener Median (Min-Max)
Cola/cola-mixed drinks	1	2	37	3 (2–4)	38	3 (2–4)
Energy drinks	0	-	2	2 (2–2)	2	2 (2–2)
Fruit drinks	0	-	4	3 (2–3)	4	3 (2–3)
Isotonic drinks	4	2 (2–2)	0	-	4	2 (2–2)
Lemonades	4	3 (2–4)	30	3 (2–5)	34	3 (2–5)
Cold tea drinks	5	1 (1–1)	3	2 (2–3)	8	1 (1–3)
Flavoured water	2	3 (3–3)	0	-	2	3 (3–3)
SUM	16		76		92	

[1] Figures subject to change

9 Satellite studies

The BfR MEAL Study's infrastructure was used by external cooperation partners for additional satellite studies. For this purpose, sample material was produced for the satellite studies as part of the BfR MEAL Study and analysed to answer additional questions at the expense of the external partners. A total of five satellite studies were incorporated into the BfR MEAL Study as cooperation.

9.1 Investigation of radionuclides

The Federal Office for Radiation Protection (BfS) analysed various natural radionuclides in representative pooled samples from the BfR MEAL Study. Of the 356 foods on the food list for the core module, 210 pooled samples were investigated by the BfS. Main food groups, such as "composite dishes" and "sugar, confectionery and water-based sweet dessert", were not considered. The values for such main food groups were calculated based on the initial products/ingredients. Similarly, drinks containing largely water were not analysed because an investigation of natural radionuclides had already been carried out elsewhere. In the first field phase, about 2 kg of sample material per pooled sample were provided for radionuclide analysis. The sample processing and the measurement of the five radionuclides (uranium [U-234, U-238], radium [Ra-226, Ra-228] and lead [Pb-210]) were carried out at the BfS. After handover, the sample material was dried, incinerated and by microwave digestion prepared for radiochemical processing and analysis of radionuclides. The analyses were completed in 2022. An assessment of the exposure to these radionuclides for German population groups is being carried out in a cooperation between BfS and BfR.

9.2 Investigation of an extended nutrient spectrum

In cooperation with the Institute for Nutritional Behaviour at the Max Rubner-Institut (MRI), nutrient levels in foods were determined in 130 pooled samples. The obtained data will be integrated into the German Nutrient Database "Bundeslebensmittelschüssel". The pooled samples were analysed for nutrients considered in the BfR MEAL Study as well as for other nutrients. These included, e.g., various water- and fat-soluble vitamins, amino acids, other elements and cholesterol. Their analyses were commissioned separately by the MRI.

9.3 PFAS precursors

The already existing cooperation with the Fraunhofer Institute for Molecular Biology and Applied Ecology IME was extended by a satellite study. Within the satellite study,38 precursor of perfluoroalkyl substances (e.g., F 53B, PAP, diPAP) were analysed in pooled samples from the BfR MEAL Study. The analyses were carried out in the "Trace Analysis and Environmental Monitoring" department at the Fraunhofer Institute. The analytical method for determining PFAS and PFAS precursors was adapted and validated as part of the satellite study. The analyses were carried out in the matrices cow milk, infant formula, potatoes and mineral water using high-performance liquid chromatography coupled to a high-resolution mass spectrometer (HPLC-HRMS) (Bihlmeier, 2021). Within the BfR MEAL Study itself,16 perfluoroalkyl substances were analysed.

9.4 Mycotoxin rapid test

Samples from the BfR MEAL Study were used to validate an enzyme-linked immunosorbent assay (ELISA)-based rapid test for determining mycotoxins in cooperation with the Institute of Veterinary Food Science (Department of Veterinary Medicine) at the Justus Liebig University of Giessen and the Institute for Food Quality and Safety at the University of Veterinary Medicine Hannover. For this purpose, 20 pooled samples and subsamples from the BfR MEAL Study of the main food group "grains and grain-based products" were analysed for the mycotoxins alternariol and altenuene using the ELISA-based rapid test (Bauer et al., 2016). As part of the BfR MEAL Study, the mentioned samples were already analysed for alternariol using HPLC-MS/MS. The results obtained by ELISA should be confirmed by comparison with the results of the BfR MEAL Study, therefore validating the ELISA rapid test.

9.5 Arsenic species

Selected pooled samples were already analysed for total arsenic, inorganic arsenic, arsenobetaine, dimethylarsinic acid and monomethylarsonic acid/methylarsonic acid as part of the BfR MEAL Study (Hackethal et al., 2023). In addition to these investigations, 115 pooled samples from the BfR MEAL Study are being further analysed in a satellite study by the "Environmental Geochemistry" working group at the University of Bayreuth for dimethyl monothioarsenate (DMMTA) using inductively coupled plasma-tandem mass spectrometry (ICP-MS/MS)

10 Long-term storage of samples

Sample material was stored long-term at -20 °C at an external service provider to answer further questions which may arise in the future. For long-term storage, sample material was stored in sample containers made of glass and polypropylene during the two field phases. A working group set up at the BfR decides on internal and external research applications that require sample material for investigating stable substances.

For various triazoles and ETU/PTU as part of the "pesticide residues" module (see Chapter 8.7), no service providers for analytical investigations were available at the beginning of field phase 2. Various triazoles and ETU/PTU could still be successfully integrated into the study at a later stage by using retaining samples and the efforts of the BMEL to provide internal standards free of charge.

In addition, further issues are being investigated with the help of sample material from long-term storage:

1. The NRL for feed additives analysed various pooled samples from the main food group "milk and dairy products" as part of establishing the method to determine quinolizidine alkaloids.
2. Pooled samples from the main food group "fish, seafood and invertebrates" are being analysed for halogenated persistent organic pollutants (POPs).
3. Sample material is provided for the planned determination of bisphenols in food.

In future, answering other questions with stored samples from the BfR MEAL Study will be still possible. Self-funded project outlines can be submitted to the BfR.

11 Use of the data

The primary objective of the BfR MEAL Study is to generate occurrence data for BfR exposure assessments within the framework of risk assessments. Furthermore, published occurrence data from the BfR MEAL Study are also made available to other organisations, such as EFSA and the Food and Agriculture Organization of the United Nations (FAO), for assessment purposes. In addition to this, all occurrence data as results of the study will be gradually made available to the scientific public free of charge as public use files.

Furthermore, the BfR provided consistent and target group-specific communication to go alongside the study (see Figure 5). Defined target groups for communications are government institutions, associations, the international and national experts as well as the media and members of the public who are interested. Two primary objectives are pursued: communication of the approach and objectives of the study and communication of specific results.

Figure 5: Communication media for the target groups of the BfR MEAL Study

11.1 Decrees and assessments

In accordance with the main objective of the study, data from the BfR MEAL Study is used for responses to decrees of the BMEL or BMUV or the BVL. For example, data from the BfR MEAL Study was used in the following BfR opinions:

In 2018, preliminary results of the BfR MEAL Study were used for the first time to further classify elevated detected levels of non-dioxin-like polychlorinated biphenyls (ndl-PCBs) in feed. It demonstrated a much lower ndl-PCB level in eggs, turkey and chicken meat compared to the individual maximum level excess amounts detected in connection with the incident. This suggested that the ndl-PCB incident was a temporal and localised event (communication no. 037/2018).

In February 2021 and March 2022, model calculations were used to assess whether an increase in the legal maximum amount of iodine in table salt could reduce the risk of insufficient iodine intake without at the same time leading to the tolerable daily maximum intake being exceeded. Based on the occurrence data on iodine from the BfR MEAL Study, it was shown that the iodine intake of the German population is not sufficient to ensure an adequate iodine supply. In line with this, the BfR recommends increasing the use of iodised salt in households and in industrial and artisan foods (opinion no. 005/2021 and No. 026/2022).

As part of the “National Reduction and Innovation Strategy for Sugar, Fats and Salt in Processed Foods”, sugar levels in drinks, among other things, should be reduced. As shown by the MRI’s product monitoring, the sugar levels in soft drinks decreased slightly between 2018 and 2019, while the number of soft drinks sweetened exclusively with sweeteners increased slightly. The number of sweeteners used was determined in market-relevant soft drinks through an extension of the BfR MEAL Study's "food additives" module. As part of this module extension, a total of nine sweeteners (acesulfame K, aspartame, cyclamate, neohesperidin-DC, neotame, saccharin, sucralose, steviol glycosides, advantame) were analysed in 92 market-relevant soft drinks. The range of levels could be shown and the use of only one or several sweeteners could be described (opinion no. 006/2023).

11.2 Excess maximum levels

Possible excess of EU-wide maximum levels for samples were reported to the BMEL in the course of the study for further consideration (Table 38). Due to the pooling methodology (with the exception of sweeteners in soft drinks), the BfR MEAL Study is only suitable to a limited extent for indicating any excess of maximum levels. However, the study can give an indication of possible problem areas that should subsequently be analysed in more detail, considering the analytical uncertainty of measurement.

In addition to the possible maximum level excess, undeclared levels of cyclamate and saccharin were also found in soft drinks.

Table 38: Maximum level and maximum residue level excess notifications

Module	Substance	Matrix	Level	Maximum level/maximum residue level
Food additives	Sulphites	Crab meat	125 mg/kg	50 mg/kg
	Acesulfame K	Soft drink	365 mg/L	350 mg/L
	Cyclamate	Soft drink	263 mg/L	250 mg/L
	Cyclamate	Soft drink	259 mg/L	250 mg/L
	Benzoates	Soft drink	154 mg/L	150 mg/L
	Benzoates	Fish products	2227 mg/kg	2000 mg/kg
Core module	Ndl-PCB (ICES-6)	Spiny dogfish	190 ng/g	200 ng/g
	Copper	Chia seeds	16.5 mg/kg	10 mg/kg
		Beef liver	66.4–119 mg/kg	30 mg/kg
		Sheep’s liver	68.1–77.6 mg/kg	30 mg/kg
		Red deer/roe deer	2.35 mg/kg	0.01 mg/kg
		Wild boar	2.03 mg/kg	0.01 mg/kg
		Honey	0.265–0.355 mg/kg	0.01 mg/kg
Mycotoxins	Aflatoxins B1	Buckwheat	2.66 µg/kg	2 µg/kg
		Chia seeds	4.22 µg/kg	2 µg/kg
		Pistachios	7.53 µg/kg	8 µg/kg
	Ochratoxin A	Buckwheat	5.86 µg/kg	3 µg/kg
Pesticide residues	Chlorate	Liver sausage	105 µg/kg	10 µg/kg
		Boiled sausage	77 µg/kg	
		Salad dressings	51 µg/kg	
		Raw cured meat products	38 µg/kg	
		Cheesecake	31 µg/kg	
		Vegetable mix	30 µg/kg	
		Burger	28 µg/kg	
		Cream cakes	24 µg/kg	
		Finely chopped boiled sausage, poultry	23 µg/kg	
		Rice pudding	20 µg/kg	
		Finely chopped boiled sausage	19 µg/kg	
		Butter	19 µg/kg	
	Chlorpyrifos	Dates	22 µg/kg	10 µg/kg
Pharmacologically active substances	Trimethoprim	Trout	100 µg/kg	50 µg/kg

11.3 Scientific publications

The substance levels determined in the BfR MEAL Study are of interest to the public. On the one hand, for people from science and research with an interest in method development, analytics or the risk assessment of these substances. On the other hand, for specific population groups who are interested in levels of substances in foods for nutritional therapy reasons, e.g., identification of foods with low potassium and phosphorus levels to be implemented to the diet in case of impaired kidney function.

The determined levels are published with a scientific description in scientific journals (Table 39) to be available to the scientific community and the public. This enables the classification of the levels in comparison with nationally or internationally determined values from other data sources.

A working group was convened with representatives from the BfR's units and public relations department to give priority to the publication of substances that are particularly relevant for policy advice and scientific discourse. Here, completely available data sets could be prioritised at regular intervals. After a subsequent plausibility check of the obtained results, the units determined the extent to which the data should be published: as only occurrence data, occurrence data with additional exposure assessment or as a complete risk assessment. At the same time, this body also determined the type of publication: as an opinion, communication or an article in a scientific journal.

Table 39: Publications on the BfR MEAL Study (last update 2023)

Publications on occurrence data
Stadion, M. et al. (2023): Corrigendum to "The first German total diet study (BfR MEAL Study) confirms highest levels of dioxins and dioxin-like polychlorinated biphenyls in foods of animal origin title of article". *Food Chemistry* X, 16, 100459.
Schendel, S. et al. (2022): Results of the BfR MEAL Study: Highest levels of retinol found in animal livers and of β-carotene in yellow-orange and green leafy vegetables. *Food Chemistry* X, 16, 100458.
Stadion, M. et al. (2022): The first German total diet study (BfR MEAL Study) confirms highest levels of dioxins and dioxin-like polychlorinated biphenyls in foods of animal origin. *Food Chemistry* X, 16, 100459.
Fechner, C. et al. (2022): Results of the BfR MEAL Study: In Germany, mercury is mostly contained in fish and seafood while cadmium, lead, and nickel are present in a broad spectrum of foods. *Food Chemistry* X, 14, 100326.
Schwerbel, K. et al. (2022): Results of the BfR MEAL Study: The food type has a stronger impact on calcium, potassium and phosphorus levels than factors such as seasonality, regionality and type of production. *Food Chemistry* X, 13.
Hackethal, C. et al. (2021): Total arsenic and water-soluble arsenic species in foods of the first German total diet study (BfR MEAL Study). *Food Chemistry* 346.
Ptok, S. et al. (2020): Cadmium und Blei in Lebensmitteln expositionsrelevanter Lebensmittelgruppen – Ergebnisse der BfR-MEAL-Studie (Cadmium and lead in foods of exposure-relevant food groups – results of the BfR MEAL Study). *14. DGE-Ernährungsbericht* 142–179.
Exposure assessment publications based on BfR MEAL data
Kolbaum, A. E. et al. (2023). Long-term dietary exposure to copper in the population in Germany – Results from the BfR MEAL study. *Food and Chemical Toxicology* 176, 113759.
Hackethal, C. et al. (2023): Chronic dietary exposure to total arsenic, inorganic arsenic and water-soluble organic arsenic species based on results of the first German total diet study. *Science of the Total Environment* 859, 160261.
Sarvan, I. et al. (2021): Exposure Assessment of methylmercury in samples of the BfR MEAL Study. *Food and Chemical Toxicology* 149.
Study methodology publications
Hackethal, C. et al. (2023): Filling data gaps to refine exposure assessments by consideration of specific consumer behaviour. *Deutsche Lebensmittel-Rundschau,* ZKZ9982:227-288.

Kolbaum, A. E. et al. (2023): Reusability of Germany's total diet study food list upon availability of new food consumption data – comparison of three update strategies. *Journal of Exposure Science & Environmental Epidemiology*.

Kolbaum, A. E. et al. (2022): Collection of occurrence data in foods – The value of the BfR MEAL study in addition to the national monitoring for dietary exposure assessment. *Food Chemistry* X, 13, 100240.

Stehfest, S., Sarvan, I., Greiner, M. (2021): Die BfR-MEAL-Studie (The BfR MEAL Study). *Lebensmittelchemie* 2/2021, 59–62.

Bürgelt, M., Ptok, S., Greiner, M., & Lindtner, O. (2019). Die BfR-MEAL-Studie: Was im Essen steckt (The BfR MEAL Study: What's in your food). *pädiatrische praxis* 91, 359–367.

Bürgelt, M., Ptok, S., Greiner, M., & Lindtner, O. (2018). Die BfR-MEAL-Studie: Was im Essen steckt (The BfR MEAL Study: What's in your food). *tägliche praxis* 61, 171-179.

Bürgelt, M., Ptok, S., Greiner, M., & Lindtner, O. (2018). Die BfR-MEAL-Studie: Was im Essen steckt (The BfR MEAL Study: What's in your food). *internistische praxis* 60, 1–9.

Sarvan, I., Bürgelt, M., Lindtner, O., & Greiner, M. (2017). Expositionsschätzung von Stoffen in Lebensmitteln: Die BfR-MEAL-Studie – die erste Total-Diet-Studie in Deutschland (Exposure assessment of substances in foods: The BfR MEAL Study – the first total diet study in Germany). *Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz* 60, 689–696.

Bürgelt, M., Sarvan, I., Greiner, M., & Lindtner, O. (2016). Was im Essen steckt – die MEAL-Studie des Bundesinstituts für Risikobewertung (What's in your food – the MEAL Study by the Federal Institute for Risk Assessment). *UMID: Umwelt und Mensch – Informationsdienst* 2, 38–43.

Bürgelt, M., Sarvan, I., Greiner, M., & Lindtner, O. (2016). Was im Essen steckt – die BfR-MEAL-Studie (What's in your food – The BfR MEAL Study). *DGEInfo* 10, 146–150.

Published BfR opinions and BfR communications

BfR (2022): Nickel: estimate of long-term intake via food based on the BfR MEAL Study. BfR communication no. 033/2022 issued 22 November 2022.

BfR (2023): Sugar alternatives: how much sweetener is there in soft drinks? BfR opinion no. 006/2023 issued 07 February 2023.

BfR (2022): Exposition gegenüber ndl-PCB und dl-PCB über Lebensmittel aus der BfR-MEAL-Studie. Erlass des Bundesministeriums für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV) (Exposure to ndl-PCB and dl-PCB via food from the BfR MEAL study. Decree of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)).

BfR (2022): Declining iodine intake in the population: model scenarios to improve iodine intake in children and adolescents. BfR opinion no. 026/2022 issued 17 Ocotber 2022.

BfR (2021): Declining iodine intake in the population: model scenarios to improve iodine intake. BfR opinion no. 005/2021 issued 9 February 2021.

BfR (2018): Non-dioxin-like PCBs are undesirable in food and feed. BfR communication no. 037/2018 issued 3 December 2018.

Other publications

BfR (2022): Kochen für die Wissenschaft (Cooking for science). BfR2GO 01/2022, 12.

BMEL (2021): Wissenschaft für den gesundheitlichen Verbraucherschutz (Science for consumer health protection). Forschungsfelder 01/2016, 20–21.1

BMEL (2021): Schwer verdaulich (Difficult to digest). Forschungsfelder 02/2021, 25.[1]

BfR (2020): Spuren von Jod (Traces of iodine). BfR2GO 02/2020, 4

BfR (2019): Das BfR als Topfgucker (The BfR as pot watcher). BfR2GO 01/2019, 28

BMEL (2019): Innere Werte (Inner values). Forschungsfelder 03/2019, 16–17.1

Bürgelt, M., & Kaiser, A. (2017). An die Töpfe, fertig, los (To the pots, set, go)! In *BfR MAGAZIN – Die Mitarbeiterzeitschrift des BfR* 1, 4–5 (online not accessible)

BfR (2017): BfR-MEAL-Studie (The BfR MEAL Study). *BfR2GO* 01/2017, 4–5

BfR (2016): Was im Essen steckt – die BfR-MEAL-Studie (What's in your food – The BfR MEAL Study). *BfR-Jahresbericht* 2015

11.4 Provision of data and public use file

In addition to scientific publications, the results of the BfR MEAL Study are gradually available free of charge as public use files. The download via the BfR website provides the data in table format (https://www.bfr-meal-studie.de/en/public-use-file-en.html). In addition to information on occurrence data, the data also contains information on the data structure.

The communication and publication of TDS data is a particular challenge in view of the complexity of the metadata on the one hand and the general requirements according to FAIR criteria on the other. The BfR is developing contemporary solutions for indexing and providing TDS results (FNS-Cloud project 863059; FoPro+: BfR-EXPO-08-60-0103-01.P540) as part of an international collaboration. International standards are being set by aligning these systems with the BfR MEAL Study.

11.5 Events

In January 2023, the BfR MEAL Study was present at a stand at the Berlin International Green Week (German: Internationale Grüne Woche Berlin). The International Green Week is an international trade fair which is annually held in Berlin. Numerous attractions were presented to the visitors of the stand in order to introduce the BfR MEAL Study. A live cooking show with TV chef Tino Schmidt was one of this attraction. Within the live cooking show, scientists of the BfR MEAL Study team presented selected results of the study which could be used from consumers as advice for everyday life.

In previous years, the following formats were used at the International Green Week (IGW) to reach different stakeholders:

- Interview and presentation of the study kitchen as part of the first digital IGW (2021)
- Live link to the study kitchen as part of the BMEL stage programme (2020)
- Satellite status of the BfR MEAL Study (2017)
- BfR Forum as part of IGW (2016)

In October 2022, a conference (6th International Workshop on Total Diet Studies) and a tutorial on TDS were organised and conducted jointly with the WHO. Current developments and results of various TDS were presented and discussed as part of the conference. The event was preceded by a four-day online tutorial on planning and implementing TDS organised by the WHO and BfR. 20 representatives from countries that want to conduct their own national TDS in the future took part and were able to gain detailed knowledge on how to conduct TDS.

After the MEAL Study kitchen was set up, the official kitchen opening took place in autumn 2016 in the presence of the parliamentary state secretary, members of the Bundestag and a number of other guests. “To the pots, set, go!” was the motto that heralded the field phase of the BfR MEAL Study and presented the study to the expert public with the aim of providing broad information, particularly with regard to potential collaborations.

In autumn 2015, the first public information platform (ÖfIP) took place at the invitation of the BfR, during which interested stakeholders of the BfR MEAL Study were able to establish a dialogue, gaining and exchanging information about cooperation opportunities.

11.6 Online communication

Information on the BfR MEAL Study is available via a dedicated website. Under the domain "www.bfr-meal-studie.de/en/meal-homepage", target group-specific information on the study can be accessed by a scientific audience, government organisations and associations, the press and the general public. A newsletter provided interested parties with supplementary information on current developments, events and study results during the two field phases.

The study website also provides free and publicly accessible access to a database with the occurrence data from the study (public use files).

The BfR also regularly publishes up-to-date information on the BfR MEAL Study on social media. The respective BfR accounts, e.g., on Twitter, Instagram, Mastodon and LinkedIn, are used for this purpose to reach the interested audience.

The BfR has created a virtual tour of the BfR MEAL Study. A 360-degree tour gives the opportunity to look around the study rooms intuitively on a PC, tablet or smartphone. Short videos, infographics, texts and images explain the goals, the study methodology and the course of the study. The virtual tour is available on the study website.

11.7 Print and multimedia communication

The BfR regularly provides press to go alongside the study in the form of press releases, communications and FAQs. Furthermore, articles in the BfR's Science Magazine BfR2GO (see Figure 6) as well as its own publications, such as flyers, brochures and infographics provide political actors, associations and the interested public with target group-specific communication formats and introductory information. A selection of these print formats is available in the press section of the study website.

Spuren von Jod

Seit Jahrhunderten verdampft Meerwasser in der Sonne der französischen Camargue-Küste in weiß und rötlich schimmernden Becken zu Salzkristallen – Meersalz. Salz ist in der Küche unverzichtbar. Und nicht nur dort. Auch für unsere Gesundheit spielt es eine Rolle: Es liefert Jod, ein für uns lebensnotwendiges Spurenelement. Weil viele Lebensmittel arm daran sind, wird Speisesalz in Deutschland seit den 1980er-Jahren jodiert. Auch Fleur de Sel und Sel gris landen teils in angereicherter Form im Supermarktregal, da bei der Gewinnung wenig vom Jod aus dem Meer übrig bleibt. Mangelerkrankungen sollen u. a. mit dieser Anreicherung vorgebeugt werden. Wie steht es um die Jodversorgung in Deutschland? Im Vergleich zum Bedarf nimmt ein Teil der Bevölkerung zu wenig von dem Element über Lebensmittel auf. Dies hat das BfR kürzlich mit seiner MEAL-Studie bestätigt. Dazu untersuchte es die am häufigsten gegessenen Lebensmittel als zubereitete Mahlzeiten und stellte gegenüber, wie viel wir davon im Schnitt essen. Demnach sind Schwangere und Stillende Risikogruppen, weil sie einen höheren Bedarf haben, ebenso Jugendliche und Vegetarier aufgrund ihrer Ernährungsweise. Jodiertes Tafelsalz ist und bleibt daher in Küche und Lebensmittelproduktion unverzichtbar.

Mehr erfahren:
www.bfr-meal-studie.de

BfR-MEAL-Studie

Mahlzeiten für die Expositionsschätzung und Analytik von Lebensmitteln
Die BfR-MEAL-Studie analysiert erstmals in Deutschland systematisch und repräsentativ Lebensmittel im verzehrfertigen Zustand und folgt in ihrer Methodik einer sogenannten Total-Diet-Studie (TDS). TDS werden von der Ernährungs- und Landwirtschaftsorganisation der Vereinten Nationen (FAO) und der Weltgesundheitsorganisation (WHO) empfohlen, um mittlere Gehalte an Stoffen in der durchschnittlichen Ernährung des Menschen zu ermitteln. Die ersten Ergebnisse der BfR-MEAL-Studie werden voraussichtlich zu Beginn des Jahres 2019 vorliegen und dafür genutzt werden, die Aufnahme von Stoffen über Lebensmittel zu schätzen.

Kochen für die Wissenschaft

Die Identifizierung und Charakterisierung stofflicher Risiken sind Teil der Bewertungsarbeit des BfR. Zentral ist die Frage, inwiefern wir potenziell gesundheitsschädlichen Stoffen ausgesetzt sind. In welchen Mengen nehmen wir im Durchschnitt unerwünschte, aber auch erwünschte Stoffe über unsere Nahrung auf? Sind bestimmte Lebensmittel je nach Saison, Anbauweise oder Region unterschiedlich stark belastet? Welche gesundheitlichen Auswirkungen hat die Art der Zubereitung auf die Lebensmittel? Antworten liefert die im Jahr 2015 gestartete BfR-MEAL-Studie (Mahlzeiten für die Expositionsschätzung und Analytik von Lebensmitteln) – die erste Total-Diet-Studie Deutschlands. Mithilfe dieser wissenschaftlichen Methode wird ermittelt, in welchen Konzentrationen Stoffe durchschnittlich in verzehrfertigen Lebensmitteln vorhanden sind. Ziel ist, für das deutsche Ernährungsverhalten repräsentative Gehaltsdaten zu erhalten und Lebensmittelrisiken besser zu erkennen und zu quantifizieren. Das Studienteam kaufte dafür im Laufe der Studie rund 60.000 Lebensmittel ein, bereitete sie zu und analysiert sie auf knapp 300 Stoffe, darunter Mykotoxine, Pflanzenschutzmittel-Rückstände und Nährstoffe. Damit ist die BfR-MEAL-Studie eine im weltweiten Vergleich sehr umfangreiche Total-Diet-Studie.

Mehr erfahren:
www.bfr-meal-studie.de

Topfgucker

Was steckt in unserem Essen? Antworten sucht die BfR-MEAL-Studie. Die Studie untersucht in Deutschland zum ersten Mal großflächig, wie viel von welchen Stoffen in zubereiteten Lebensmitteln enthalten ist.

Figure 6: Summary of the articles on the BfR MEAL Study in BfR2GO

12 Budget and costs

The total budget made available to BfR to carry out the study until end of 2022 amounts to € 13,157,000. By the end of 2022, € 10,785,000 of this budget had been used. For 2023 and 2024, further funds of € 452,000 and € 445,000 have been approved and applied for respectively, to further verify the plausibility of data already collected and to publish this data. This means that funds amounting to € 11,682,000 are expected to be spent by the end of 2024.

55 % of the funds disbursed up to and including 2022 were used for personnel (including travel expenses). A further 33 % of the funds were used for analysing samples (see Figure 7). 5 % were used to purchase food and another 3 % for procuring two vehicles and equipment for them. A further 3 % of the funds disbursed up to the end of 2022 were spent on public relations; 1 % of the funds were used for IT services, notably for adaptations of the FoodCASE documentation software.

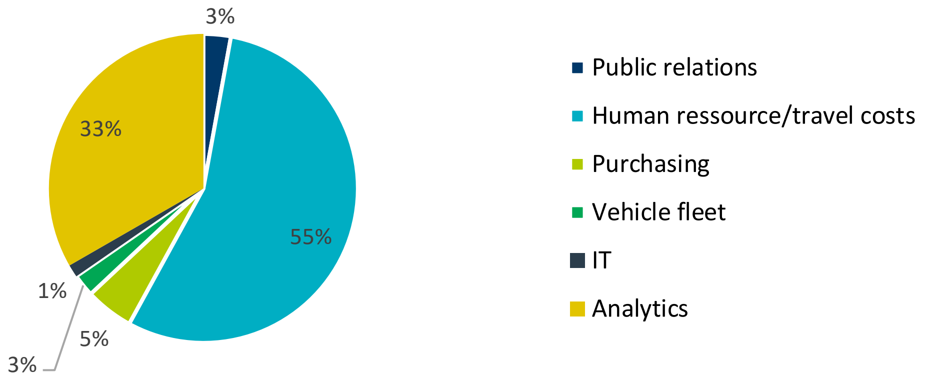

Figure 7: Cost structure of the BfR MEAL Study up to the end of 2022 (%)

Overall, 36 % of the funds disbursed by the end of 2022 were awarded to third parties. This mainly includes food sample analyses at external commercial laboratories and state chemical investigation offices (71 % of the funds for awarding to third parties) (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Furthermore, about one fifth of the third-party funds were used to obtain market share data, use commercial product databases and to commission consumer studies. The grouped costs nemd “Other” includes e.g., costs for maintenance and repair of equipment and vehicles, costs for courier trips during nationwide purchasing, and costs for long-term external storage of study samples.

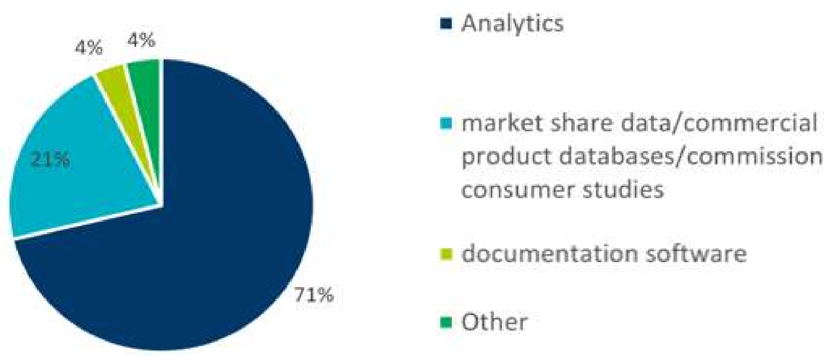

Figure 9: Cost structure of funds awarded to third parties (%)

A total of 8 % of the total costs were spent on procuring market share data (approx. 5 %), using a product database (approx. 1 %) and additional consumer studies (approx. 1 %).

13 Outlook

As already demonstrated in the TDS exposure project and implemented in other countries (e.g., Korea, USA, New Zealand, France), TDS are suitable in terms of their methodology to illustrate changes and trends in the levels of substances in foods by purchasing foods in different time periods followed by preparation and chemical analyses of the samples.

Furthermore, changes in consumption habits might make it necessary to supplement the food list for future exposure assessments (see Kolbaum et al., 2023). The BfR's KiESEL and EsKiMo II studies already provide updated consumption data for children and adolescents, which can also be supplemented by up-to-date data for the adult population in the future. Therefore, the BfR MEAL Study could be expanded in Germany in the future (similar to the French "Infant TDS"[9]) by a child MEAL Study or similar supplementary modules to take into account changed consumption habits of certain age groups.

New substances are continuously getting in the focus of risk assessments and the public, which can be considered by expanding the range of substances of a TDS.

With the TDS approach, occurrence data can be efficiently provided as a supplement to data from food monitoring (see Kolbaum et al., 2022). In particular, foods that are not included in

[9] https://www.anses.fr/en/content/infant-total-diet-study-itds

the food monitoring programme can be investigated, as well as substances that are produced during food preparation.

Special population groups

In addition to the age and gender groups already considered, combinations of substances and foods that are decisive for special risk groups or special consumption behaviour can be further analysed. Possible foods to be analysed could, for example, relate to the following population groups:

- People who follow vegetarian or vegan diets (e.g., meat substitutes) in conjunction with consumption surveys in COPLANT study (“Cohort on PLANT-based Diets”; a cohort study on plant-based nutrition in all German-speaking countries).
- People with a migration background.
- People with food allergies or intolerances.
- Occupational groups or people who consume more of selected foods (e.g., hunters and fishermen).
- People who frequently eat meals from group catering (e.g., senior citizens and children).

Changes to levels during processing at home

The weight yield in kitchen processing and preparation of foods can be described by processing and process factors.

These factors can fill important data gaps in the risk assessment of substances. Similarly, factors derived in MEAL could be used in BfR or EFSA databases to convert ready-to-eat foods to unprocessed foods or update nutrient calculations in the MRI’s German Nutrient Database.

International cooperation

The BfR MEAL Study was designed so that the methodology of TDS was further adapted to the needs of risk assessment. This includes an improved, representative depiction of consumer behaviour during preparation, a focus on substances relevant to the assessment and the optimisation of logistical processes with regard to priority assessment questions. The BfR enjoys international recognition through the establishment of a pioneering TDS. Therefore, the MEAL Study Centre is predestined to perform the tasks of an international competence centre for TDS. The Study Centre works in close cooperation with the WHO and EFSA, promotes strategies for methodological harmonisation and further development of TDS already developed in the EU project “TDS Exposure” and with interested scientists around the world.

14 Literature

Aproxima, https://www.aproxima.de/, last visited on 12 July 2023.

Bauer, J.I., Gross, M., Gottschalk, C., Usleber, E. (2016). Investigations on the occurrence of mycotoxins in beer. Food Control 63, 135–139.

Bihlmeier, A. (2021). Optimierung von Analysemethoden zur Bestimmung der Gehalte von Per- und Polyfluoralkylsubstanzen in Proben der BfR-MEAL-Studie, Masterarbeit, Institut für Lebensmittelchemie und Lebensmittelbiotechnologie, Justus-Liebig-Universität Gießen (Optimisation of analytical methods to determine the levels of per- and polyfluoroalkyl substances in samples of the BfR MEAL Study, master thesis, Institute of Food Chemistry and Food Biotechnology, Justus Liebig University Giessen).

Bürgelt, M., Ptok, S., Greiner, M., & Lindtner, O. (2019). Die BfR-MEAL-Studie: Was im Essen steckt (The BfR MEAL Study: What's in your food). Pädiatrische Praxis 91, 359–367.

Bürgelt, M., Ptok, S., Greiner, M., & Lindtner, O. (2018). Die BfR-MEAL-Studie: Was im Essen steckt (The BfR MEAL Study: What's in your food). Tägliche Praxis 61, 171–179.

Bürgelt, M., Ptok, S., Greiner, M., & Lindtner, O. (2018). Die BfR-MEAL-Studie: Was im Essen steckt (The BfR MEAL Study: What's in your food). Internistische Praxis 60, 1–9.

Bürgelt, M., Sarvan, I., Greiner, M., & Lindtner, O. (2016). Was im Essen steckt – die MEAL-Studie des Bundesinstituts für Risikobewertung (What's in your food – the MEAL Study by the Federal Institute for Risk Assessment). UMID: Umwelt und Mensch – Informationsdienst 2, 38–43.

Bürgelt, M., Sarvan, I., Greiner, M., & Lindtner, O. (2016). Was im Essen steckt – die BfR-MEAL-Studie (The BfR MEAL Study: What's in your food). DGEInfo 10, 146–150.

CEC (2001): Commission of the European Community. Report from the Commission on dietary food additive intake in the European Union. COM 542 final. Brussels (Belgium).

Demuth, I., Busl, L., Ehnle-Lossos, M., Elflein, A., Goos-Balling, E., Werner, R., Hoffmann, I. (2020). Ergebnisbericht Produktmonitoring 2019 (Product monitoring results report 2019). Karlsruhe: Max Rubner-Institut.

Diouf, F., Berg, K., Ptok, S., Lindtner, O., Heinemeyer, G., & Heseker, H. (2014). German database on the occurrence of food additives: application for intake estimation of five food colours for toddlers and children. Food additives & contaminants. Part A, Chemistry, analysis, control, exposure & risk assessment 31(2), 197–206.

EFSA, European Food Safety Authority, FAO, Food and Agriculture Organization of the United Nations, & WHO, World Health Organization. (2011). Towards a harmonised Total Diet Study approach: A guidance document. EFSA Journal 9(11), 2450.

European Commission. (2014). COMMISSION RECOMMENDATION of 3 March 2014 on the monitoring of traces of brominated flame retardants in food. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.065.01.0039.01.ENG.

EU Commission (2010): Regulation (EU) No 257/2010 of 25 March 2010 setting up a programme for the re-evaluation of approved food additives in accordance with Regulation

(EC) No 1333/2008 of the European Parliament and of the Council on food additives. http://data.europa.eu/eli/reg/2010/257/oj.

GfK, https://www.gfk.com/home, last visited on 12 July 2023.

Fechner, C., Hackethal, C., Höpfner, T., Dietrich, J., Bloch, D., Lindtner, O., Sarvan, I. (2022): Results of the BfR MEAL Study: In Germany, mercury is mostly contained in fish and seafood while cadmium, lead, and nickel are present in a broad spectrum of foods. Food Chemistry X 14, 100326.

Hackethal, C., Kirsch, F., Schwerbel, K., Kolbaum, A. E., Götte, S., Schwerdtle, T., Lindtner, O., Sarvan, I. (2023): Filling data gaps to refine exposure assessments by consideration of specific consumer behaviour. Deutsche Lebensmittel-Rundschau, ZKZ9982: 277-288.

Hackethal, C., Pabel, U., Jung, C., Schwerdtle, T., Lindtner, O. (2023): Chronic dietary exposure to total arsenic, inorganic arsenic and water-soluble organic arsenic species based on results of the first German total diet study. Science of the Total Environment 859, 160261.

Hackethal, C., Kopp, J.F., Sarvan, I., Schwerdtle, T., Lindtner, O. (2021): Total arsenic and water-soluble arsenic species in foods of the first German total diet study (BfR MEAL Study). Food Chemistry 346.

Hausmann, B., Holtmannspötter, H. (2013). Erfassung von Antibiotikarückständen in ausgewählten Lebensmitteln tierischer Herkunft (Detection of antibiotic residues in selected foods of animal origin). In Bayerisches Landesamt für Gesundheit und Lebensmittelsicherheit (LGL) (Ed.), Schriftenreihe Lebensmittelsicherheit in Bayern. Erlangen.

Heseker, H., Oepping, A., Vohmann, C. (2003). Consumption study to determine the food intake of infants and young children for the estimation of an acute toxicity risk from pesticide residues (VELS). Paderborn DE: University of Paderborn.

Kolbaum, A. E., Sarvan, I., Bakhiya, N., Spolders, M., Pieper, R., Schubert, J., Jung, C., Hackethal, C., Sieke, C., Grünewald, K.-H., Lindtner, O. (2023). Long-term dietary exposure to copper in the population in Germany – Results from the BfR MEAL study. Food and Chemical Toxicology 176, 113759.

Kolbaum, A. E., Ptok, S., Jung, C., Libuda, L., Lindtner, O. (2023). Reusability of Germany´s total diet study food list upon availability of new food consumption data – Comparison of three update strategies. Journal of Exposure Science & Environmental Epidemiology.

Kolbaum, A. E., Jaeger, A., Ptok, S., Sarvan, I., Greiner, M., Lindtner, O. (2022). Collection of occurrence data in foods – The value of the BfR MEAL study in addition to the national monitoring for dietary exposure assessment. Food Chemistry X, 13, 100240.

Kolbaum AE, Berg K, Müller F, Kappenstein O, Lindtner O. (2019) Dietary exposure to elements from the German pilot total diet study (TDS). Food Additives & Contaminants Part A. 36(12):1822-1836.

BfR communication no. 037/2018 issued 3 December 2018:Non-dioxin-like PCBs are undesirable in food and feed. https://www.bfr.bund.de/cm/349/non-dioxin-like-pcbs-are-undesirable-in-food-and-feed.pdf

MRI. (2008). Nationale Verzehrsstudie II. Ergebnisbericht Teil 1. Die bundesweite Befragung zur Ernährung von Jugendlichen und Erwachsenen. (The German National Nutrition Survey II. Results report part 1. The nationwide survey on the nutrition of adolescents and adults). Karlsruhe.

Ptok, S., Lindtner, O., Pabel, U., Hackethal, C., Berg, T., Greiner, M. (2020): Cadmium und Blei in Lebensmitteln expositionsrelevanter Lebensmittelgruppen – Ergebnisse der BfR-MEAL-Studie (Cadmium and lead in foods of exposure-relevant food groups – results of the BfR MEAL Study). 14. DGE-Ernährungsbericht 142–179.

Sachse, B., Kolbaum, A. E., Ziegenhagen, R., Andres, S., Berg, K., Dusemund, B., Hirsch-Ernst, K. I., Kappenstein, O., Müller, F., Röhl, C., Lindtner, O., Lampen, A. (2019) Dietary Manganese Exposure in the Adult Population in Germany—What Does it Mean in Relation to Health Risks? Molecular Nutrition and Food Research 63, 16, 1900065.

Sarvan, I., Kolbaum, A. E., Pabel, U., Buhrke, T., Greiner, M., Lindtner, O. (2021): Exposure Assessment of methylmercury in samples of the BfR MEAL Study. Food and Chemical Toxicology 149.

Sarvan, I., Bürgelt, M., Lindtner, O., Greiner, M. (2017). Expositionsschätzung von Stoffen in Lebensmitteln: Die BfR-MEAL-Studie – die erste Total-Diet-Studie in Deutschland (Exposure assessment of substances in foods: The BfR MEAL Study – the first total diet study in Germany). Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz 60, 689–696.

Schendel, S., Berg, T., Scherfling, M., Drößer, C., Ptok, S., Weißenborn, A., Lindtner, O., Sarvan, I. (2022): Results of the BfR MEAL Study: Highest levels of retinol found in animal livers and of β-carotene in yellow-orange and green leafy vegetables. Food Chemistry X, 16, 100458.

Schwerbel, K., Tüngerthal, M, Nagl, B., Niemann, B., Drößer, C., Bergelt, S., Uhlig, K., Höpfner, T., Greiner M., Lindtner, O., Sarvan, I. (2022): Results of the BfR MEAL Study: The food type has a stronger impact on calcium, potassium and phosphorus levels than factors such as seasonality, regionality and type of production. Food Chemistry X, 13.

Stadion, M., Hackethal, C., Blume, K., Wobst, B., Abraham, K., Fechner, C., Lindtner, C., Sarvan, I. (2023): Corrigendum to “The first German total diet study (BfR MEAL Study) confirms highest levels of dioxins and dioxin-like polychlorinated biphenyls in foods of animal origin title of article”. Food Chemistry X, 16, 100459.

Stadion, M., Hackethal, C., Blume, K., Wobst, B., Abraham, K., Fechner, C., Lindtner, C., Sarvan, I. (2022): The first German total diet study (BfR MEAL Study) confirms highest levels of dioxins and dioxin-like polychlorinated biphenyls in foods of animal origin. Food Chemistry X, 16, 100459.

Stehfest, S., Sarvan, I., Greiner, M. (2021): Die BfR-MEAL-Studie (The BfR MEAL Study). Lebensmittelchemie 2/2021, 59–62.

BfR opinion no. 006/2023 issued 7 February 2023: Sugar alternatives: How much sweetener is there in soft drinks? https://doi.org/10.17590/20230414-150752-0

BfR opinion no. 026/2022 issued 17 October 2022: Declining iodine intake in the population: model scenarios to improve iodine intake in children and youths.

https://doi.org/10.17590/20230116-122505BfR opinion no. 005/2021 issued 09 February 2021 Declining iodine intake in the population: model scenarios to improve iodine intake in children and youths.
https://doi.org/10.17590/20230113-115339

Tolmien, I. (2011): Validierung eines Multiuntersuchungsverfahrens zum Nachweis von Antibiotika in Fischen und Krebstieren, sowie Untersuchungen zur Rückstandssituation bei Fischen und Krebstieren in Aquakulturen. Dissertation, TiHo Hannover (Validation of a multi-test method for the detection of antibiotics in fish and crustaceans, as well as investigations into the residue situation in fish and crustaceans in aquaculture. Dissertation, TiHo Hannover). DVG-Verlag, ISBN 978-3-86345-024-3.

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Annex

A1 Substance list for the BfR MEAL Study (last update 2023)

Core module (elements and environmental contaminants)	Elements: aluminium, antimony, arsenic, barium, lead, cadmium, cobalt, lithium, methyl mercury, nickel, nitrate, mercury, silver, thallium, vanadium, tin
	Arsenic species: inorganic arsenic, arsenobetaine (AsB), dimethylarsinic acid (DMA), monomethylarsonic acid (MMA)
	Organotin compounds: tetrabutyltin (TeBT), tributyltin (TBT), dibutyltin (DBT), monobutyltin (MBT), triphenyltin (TPT), diphenyltin (DPT), monophenyltin (MPT)
	Dioxins/furans, dioxin-like polychlorinated biphenyls (dl-PCB), non-dioxin-like polychlorinated biphenyls (ndl-PCB)
	Polybrominated diphenyl ethers (PBDE)
Perfluoroalkyl substances (PFAS)	Perfluorooctane sulfonic acid, perfluorooctanoic acid
Mycotoxins	Aflatoxins, alternaria toxins, beauvericin, citrinin, enniatins, ergot alkaloids, fumonisins, ochroatoxin A, patulin, type A trichothecenes, type B trichothecenes, zearalenone
Process contaminants	Acrylamide, glycidol, polycyclic aromatic hydrocarbons (PAH), 2- and 3-MCPD group
Food additives	Benzoates: benzoic acid, calcium benzoate, potassium benzoate, sodium benzoate
	Nitrites: potassium nitrite, sodium nitrite
	Sorbates: potassium sorbate, sorbic acid
	Sulphites: calcium hydrogen sulphite, calcium sulphite, potassium hydrogen sulphite, potassium metabisulphite, sodium hydrogen sulphite, sodium metabisulphite, sodium sulphite, sulphur dioxide
Nutrients	Vitamins: vitamin A (retinol), vitamin E (tocopherols), vitamin K1, vitamin K2, β-carotene, folic acid
	Bulk elements: calcium, chloride, potassium, magnesium, sodium, phosphorus
	Trace elements: chromium, copper, fluoride, iodine, mangan, molybdenum, selenium, zinc
Pesticide residues	Boscalid, captan/tetrahydrophthalimide, chlorate, chlormequat, chlorpyrifos, cyantraniliprole, cypermethrin, cyprodinil, deltamethrin, difenoconazole, dimethoate, ethylenthiourea (ETU), fluopyram, glyphosate/aminomethyl-phosphonic acid (AMPA), hexachlorobenzen, hexythiazox, imazalil, indoxacarb, iprodion, lambda-cyhalothrin, myclobutanyl, omethoat, perchlorate, pirimicarb, pirimicarb-desmethyl, propylenthiourea (PTU), pyraclostrobin, pyrimethanil, spinosad, thiabendazole, thiacloprid, triflumuron, 1,2,4-triazole, triazole acetic acid, triazole alanine, triazole lactic acid
Pharmacologically active substances	Aminoglycosides: dihydrostreptomycin, gentamycin, neomycin, spectinomycin, streptomycin
	Amphenicoles: florfenicol
	Chinolones: ciprofloxacin, danofloxacin, enrofloxacin, marbofloxacin
	Diaminopyrimidine derivates: trimethoprim
	Coccidiostats: dinitrocarbanilides, lasalocid, maduramycin, monensin, narasin
	Macrolides: erythromycin, gamithromycin, tildipirosin, tilmicosin, tulathromycin, tylosin
	Penicillins: amoxicillin, benzylpenicillin
	Sulfonamides: sulfadiazine, sulfadimethoxine, sulfadimidine, sulfadoxine, sulfathiazol
	Tetracyclines: chlortetracycline, doxycycline, epi-chlortetracycline, epi-tetracycline, epi-oxytetracycline, oxytetracycline, tetracycline
Substances migrating from food contact materials	Mineral oil saturated hydrocarbons (MOSH), mineral oil aromatic hydrocarbons (MOAH)
	Plasticisers
	2,4-di-tert-butylphenol

A2 Overview of the analysis methods used

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
MOSH >C10-≤C16	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOSH >C16-≤C20	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOSH >C20-≤C25	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOSH >C25-≤C35	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOSH >C20-≤C35	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOSH >C20-≤C40	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOSH >C35-≤C50	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	Bicyclohexyl	Commercial laboratory
MOAH >C16-≤C25	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	TBB	Commercial laboratory
MOAH >C25-≤C35	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	TBB	Commercial laboratory
MOAH >C10-≤C35	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	TBB	Commercial laboratory
MOAH >C35-≤C50	MOSH/MOAH	Substances migrating from food contact materials	LC-GC-FID	22	TBB	Commercial laboratory
Dipropyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BP-D5	Internal
Di-n-butyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Diisobutyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Bis(2-methoxyethyl) phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEEP-D4	Internal
Di-n-pentyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHP-D4	Internal
n-pentyl isopentyl phthalate	Plasticisers	Substances migrating from	GC-MS/MS	36	IS DNBP-D4	Internal

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
		food contact materials				
Butyl benzyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BBP-D4	Internal
Dicyclohexyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DCHP-D4	Internal
Dihexyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHP-D4	Internal
Bis(4-methylpentyl)phthalate [Diisohexyl phthalate]	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BBP-D4	Internal
Diisoheptyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHP-D4	Internal
Di-n-heptyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BBP-D4	Internal
Bis(2-ethylhexyl) terephthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS; LC-MS/MS	36	IS DEHA-D8	Internal
Di-n-octyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNNP-D4	Internal
Di(butoxyethyl) phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BBP-D4	Internal
Tris(2-butoxyethyl) phosphate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEEP-D4	Internal
Di-n-decyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNDP-D4	Internal
Diphenyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DCHP-D4	Internal
Diethyl succinate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DES-D4	Internal
Glycerol triacetate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS TRIACETIN-D5	Internal
Diisobutyl adipate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
2,2,4-Trimethyl-1,3-pentanediol-diisobutyrate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4; IS DNBP-D4	Internal

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Dibutyl sebacate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Triethyl 2-acetylcitrate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4	Internal
Bis(2-ethylhexyl) adipate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHA-D8	Internal
Bis(2-ethylhexyl) sebacate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHA-D8	Internal
Tributyl 2-acetylcitrate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Tris(2-ethylhexyl)trimellitate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNDP-D4	Internal
Benzophenone	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BP-D5	Internal
Tributyl phosphate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4; IS DEHA-D8	Internal
Erucamide	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS OEA-D4	Internal
Di-propylheptyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHA-D8	Internal
N-Oleoylethanolamide	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS OEA-D4	Internal
tert-Butylphenyl diphenyl phosphate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNNP-D4	Internal
Di-ethylhexyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHP-D4	Internal
Oleamide	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS OEA-D4	Internal
Di(2-ethylhexyl) maleate [dioctyl maleate]	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHA-D8	Internal
Diisopropyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4	Internal
Di-n-nonyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNNP-D4	Internal

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Bis(4-methyl-2-pentyl)phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Di-ethoxyethyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEEP-D4	Internal
Bis(2-ethylhexyl) azelate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHP-D4	Internal
Diethyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4	Internal
Diethylhexyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS BBP-D4	Internal
Bis(2-ethylhexyl) isophthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHP-D4	Internal
Triisobutyl phosphate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4; IS DNBP-D4	Internal
Diisopentyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Di-n-octyl sebacate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHA-D8	Internal
Dimethyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4	Internal
Tris(2-ethylhexyl) phosphate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DEHA-D8	Internal
Diallyl phthalate	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DAP-D4	Internal
n-Ethyl-4/2-methyl-benzenesulfonamide	Plasticisers	Substances migrating from food contact materials	GC-MS/MS	36	IS DNBP-D4	Internal
Diisononyl phthalate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal
Diisodecyl phthalate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal
Bis(7-methyloctyl) cyclohexane-1,2-dicarboxylate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal
Diisononyl adipate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Diisodecyl adipate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal
Diisodecyl azelate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal
Diisoctyl azelate	Plasticisers	Substances migrating from food contact materials	LC-MS/MS	36	IS DINCH-D4	Internal
NIAS	NIAS	Substances migrating from food contact materials	GC-MS	37	D3 2,4 Dimethylphenol 3,5,6; D18 2,4 Di-*tert*-butylphenol	Other research institute
Aluminium	Aluminium	Core module	ICP-OES	2	Yttrium	Commercial laboratory
Antimony	Antimony	Core module	ICP-MS	1	Indium	Commercial laboratory
Arsenic	Arsenic & arsenic species	Core module	ICP-MS	1	Niobium	Commercial laboratory
Inorganic Arsenic	Arsenic & arsenic species	Core module	HPLC-ICP-MS/MS	8	/	Other research institute
Arsenobetaine	Arsenic & arsenic species	Core module	HPLC-ICP-MS/MS	8	/	Other research institute
Cacodylic acid	Arsenic & arsenic speciations	Core module	HPLC-ICP-MS/MS	8	/	Other research institute
Monomethylarsonic acid	Arsenic & arsenic speciations	Core module	HPLC-ICP-MS/MS	8	/	Other research institute
Barium	Barium	Core module	ICP-MS	1	Indium	Commercial laboratory
Lead	Lead	Core module	ICP-MS	1	Rhenium	Commercial laboratory
Cadmium	Cadmium	Core module	ICP-MS	1	Niobium	Commercial laboratory
Cobalt	Cobalt	Core module	ICP-MS	1	Indium	Commercial laboratory
Lithium	Lithium	Core module	ICP-MS	1	Niobium	Commercial laboratory
Methyl mercury	Methyl mercury	Core module	ICP-MS	9	Iridium	Commercial laboratory
Nickel	Nickel	Core module	ICP-MS	1	Niobium	Commercial laboratory
Mercury	Mercury	Core module	Solids analyser	4	/	Commercial laboratory
Silver	Silver	Core module	ICP-MS	1	Indium	Commercial laboratory
Thallium	Thallium	Core module	ICP-MS	1	Rhenium	Commercial laboratory
Vanadium	Vanadium	Core module	ICP-MS	1	Niobium	Commercial laboratory
Tin	Tin	Core module	ICP-MS	1	Rhodium	Commercial laboratory
Nitrate	Nitrate	Core module	Enzymatic	6	/	Commercial laboratory
2,3,7,8-TeCDD	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,7,8-PeCDD	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
1,2,3,4,7,8-HxCDD	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,6,7,8-HxCDD	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,7,8,9-HxCDD	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,4,6,7,8-HpCDD	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
OCDF Octachlorodibenzofuran	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
2,3,7,8-TeCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,7,8-PeCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
2,3,4,7,8-PeCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,4,7,8-HxCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,6,7,8-HxCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
2,3,4,6,7,8-HxCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,7,8,9-HxCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,4,6,7,8-HpCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
1,2,3,4,7,8,9-HpCDF	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
OCDD Octachlordibenzodioxin	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 77	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 81	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
PCB 126	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 169	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 105	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 114	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 118	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 123	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 156	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 157	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 167	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 189	Dioxine & dl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 28	ndl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 52	ndl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 101	ndl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 138	ndl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 153	ndl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
PCB 180	ndl-PCBs	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 28 2,4,4´-Tribromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
BDE 49 2,2',4,5'-Tetrabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 47 2,2´,4,4´-Tetrabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 100 2,2´,4,4´,6-Pentabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 99 2,2´,4,4´,5-Pentabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 154 2,2´,4,4´,5,6-Hexabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 153 2,2´,4,4´,5,5´-Hexabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 138 2,2',3,4,4',5'-Hexabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 183 2,2´,3,4,4´,5´,6-Heptabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
BDE 209 2,2´,3,3´,4,4´,5,5´,6,6´-Decabromdiphenyl ether	PBDE	Core module	GC-HRMS	7	13-C labelled	State chemicals investigations office
Monobutyltin (MBT)	Organotin compounds	Core module	GC-MS	10	d9-MBT	Commercial laboratory
Monobutyltin (MBT) – Sn	Organotin compounds	Core module	GC-MS	10	d9-MBT	Commercial laboratory
Dibutyltin (DBT)	Organotin compounds	Core module	GC-MS	10	d27-TBT	Commercial laboratory
Dibutyltin (DBT) – Sn	Organotin compounds	Core module	GC-MS	10	d27-TBT	Commercial laboratory
Tributyltin (TBT)	Organotin compounds	Core module	GC-MS	10	d27-TBT	Commercial laboratory
Tributyltin (TBT) – Sn	Organotin compounds	Core module	GC-MS	10	d27-TBT	Commercial laboratory
Tetrabutyltin (TTBT)	Organotin compounds	Core module	GC-MS	10	d36-TTBT	Commercial laboratory
Tetrabutyltin (TTBT) – Sn	Organotin compounds	Core module	GC-MS	10	d36-TTBT	Commercial laboratory
Monophenyltin (MPhT)	Organotin compounds	Core module	GC-MS	10	d5-MPhT	Commercial laboratory
Monophenyltin – Sn	Organotin compounds	Core module	GC-MS	10	d5-MPhT	Commercial laboratory
Diphenyltin (DPhT)	Organotin compounds	Core module	GC-MS	10	d5-MPhT	Commercial laboratory
Diphenyltin (DPhT) – Sn	Organotin compounds	Core module	GC-MS	10	d5-MPhT	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Triphenyltin (TPhT)	Organotin compounds	Core module	GC-MS	10	d15-TPhT	Commercial laboratory
Triphenyltin (TPhT) – Sn	Organotin compounds	Core module	GC-MS	10	d15-TPhT	Commercial laboratory
Acesulfame K	Sweeteners	Food additives	LC-MS/MS	62	Acesulfame K-d4	Commercial laboratory
Advantame	Sweeteners	Food additives	LC-MS/MS	62	Advantame-d3	Commercial laboratory
Aspartame	Sweeteners	Food additives	LC-MS/MS	62	Aspartame-d6	Commercial laboratory
Cyclamate	Sweeteners	Food additives	LC-MS/MS	62	Cyclamate-d11	Commercial laboratory
Neohesperidin-DC	Sweeteners	Food additives	LC-MS/MS	62	Neohesperidin-DC-d3	Commercial laboratory
Neotame	Sweeteners	Food additives	LC-MS/MS	62	Neotame-d3	Commercial laboratory
Saccharin	Sweeteners	Food additives	LC-MS/MS	62	Saccharin-d4	Commercial laboratory
Rebaudioside A	Sweeteners	Food additives	LC-MS/MS	62	-	Commercial laboratory
Stevioside	Sweeteners	Food additives	LC-MS/MS	62	-	Commercial laboratory
Sucralose	Sweeteners	Food additives	LC-MS/MS	62	Sucralose-d6	Commercial laboratory
Benzoates	Benzoates	Food additives	HPLC-UV	49	-	Commercial laboratory
Sorbates	Sorbates	Food additives	HPLC-UV	48	-	Commercial laboratory
Sulphites	Sulphites	Food additives	Enzymatic/by distillation	50	-	Commercial laboratory
Nitrites	Nitrites	Food additives	Enzymatic/IC	51	-	Commercial laboratory
Aflatoxin B1	Aflatoxins	Mycotoxins	IAC-LC-FLD	19	Deuterated	Commercial laboratory
Aflatoxin B2	Aflatoxins	Mycotoxins	IAC-LC-FLD	19	Deuterated	Commercial laboratory
Aflatoxin G1	Aflatoxins	Mycotoxins	IAC-LC-FLD	19	Deuterated	Commercial laboratory
Aflatoxin G2	Aflatoxins	Mycotoxins	IAC-LC-FLD	19	Deuterated	Commercial laboratory
Aflatoxin M1	Aflatoxins	Mycotoxins	IAC-LC-FLD	19	Deuterated	Commercial laboratory
Ochratoxin A	Ochratoxin A	Mycotoxins	IAC-LC-FLD	19	Deuterated	Commercial laboratory
Patulin	Patulin	Mycotoxins	LC-MS/MS	19	Internal standard*(13-C patulin)	Commercial laboratory
Deoxynivalenol (DON)	Deoxynivalenol (DON)	Mycotoxins	LC-MS/MS	19	13-C-labelled internal standards	Commercial laboratory
Zearalenone	Zearalenone	Mycotoxins	LC-MS/MS	19	Internal standard* zearalanone	Commercial laboratory
Fumonisin B1	Fumonisins	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Fumonisin B2	Fumonisins	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Beauvericin	Beauvericin	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Citrinin	Citrinin	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Enniatin A	Enniatins	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Enniatin A1	Enniatins	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Enniatin B	Enniatins	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Enniatin B1	Enniatins	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
(alpha + beta)-ergocryptine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
(alpha + beta)-ergocryptine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergocornine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergocorninine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergocristine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergocristinine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergometrine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergometrinine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergosine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergosinine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergotamine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Ergotaminine	Ergot alkaloids	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Alternariol	*Alternaria* toxins	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
Alternariol monomethyl ether	*Alternaria* toxins	Mycotoxins	LC-MS/MS	20	Deuterated	Commercial laboratory
HT-2 toxin	T-2 and HT-2	Mycotoxins	LC-MS/MS	19	13-C-labelled internal standards	Commercial laboratory
T-2 toxin	T-2 and HT-2	Mycotoxins	LC-MS/MS	19	13-C-labelled internal standards	Commercial laboratory
Diacetoxyscirpenol	Diacetoxyscirpenol	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Nivalenol	Nivalenol	Mycotoxins	LC-MS/MS	19	13-C-labelled internal standards	Commercial laboratory
3-acetyl-deoxynivalenol	3-acetyl-deoxynivalenol	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
15-acetyl-deoxynivalenol	15-acetyl-deoxynivalenol	Mycotoxins	LC-MS/MS	19	Deuterated	Commercial laboratory
Vitamin A (retinol)	Vitamin A	Nutrients	HPLC-FLD	13	/	Commercial laboratory
Vitamin A (β-carotene)	Vitamin A	Nutrients	HPLC-DAD	13	/	Commercial laboratory
Vitamin E (α-, β-, γ-, δ-Tocopherol)	Vitamin E	Nutrients	HPLC-FLD	13	/	Commercial laboratory
Vitamin K1	Vitamin K1	Nutrients	HPLC-FLD	11	/	Commercial laboratory
Vitamin K2 (menaquinone 4)	Vitamin K2	Nutrients	HPLC-MS/MS	12	Menaquinone 7/menadione (vitamin K3)	Commercial laboratory
Folic acid	Folic acid	Nutrients	Microbiological determination	11	/	Commercial laboratory
Calcium	Calcium	Nutrients	ICP-MS	16	Indium	Commercial laboratory
Magnesium	Magnesium	Nutrients	ICP-MS	16	Indium	Commercial laboratory
Chloride	Chloride	Nutrients	Titration, IC	17	/	Commercial laboratory
Potassium	Potassium	Nutrients	ICP-MS	16	Indium	Commercial laboratory
Sodium	Sodium	Nutrients	ICP-MS	16	Indium	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Fluoride	Fluoride	Nutrients	Potentiometric determination/ion-selective electrode	17	/	Commercial laboratory
Selenium	Selenium	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Chromium	Chromium	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Iodine	Iodine	Nutrients	ICP-MS	1	Tellurium	Commercial laboratory
Copper	Copper	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Manganese	Manganese	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Molybdenum	Molybdenum	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Phosphorous	Phosphorous	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Zinc	Zinc	Nutrients	ICP-MS	1	Niobium	Commercial laboratory
Glyphosate	Glyphosate/AMPA	Pesticide residues	LC-MS/MS	40	Glyphosate 1,2-13C2 15N	Commercial laboratory
Aminomethyl-phosphonic acid (AMPA)	Glyphosate/AMPA	Pesticide residues	LC-MS/MS	40	Aminomethyl-phosphonic acid (13,C 99%; 15N, 98%)	Commercial laboratory
Chlorate	Chlorate/perchlorate	Pesticide residues	HPLC-MS/MS	41	-	State chemicals investigations office
Perchlorate	Chlorate/perchlorate	Pesticide residues	HPLC-MS/MS	41	-	State chemicals investigations office
1,2,4-triazole	Triazole	Pesticide residues	LC-DMS/MS/MS	39	1,2,4 triazole (3,5-13C; 1,2,4-15N)	Commercial laboratory
Triazole-alanine	Triazole	Pesticide residues	LC-DMS/MS/MS	39	Triazole-alanine (3,5-13C; 1,2,4-15N)	Commercial laboratory
Triazole acetic acid	Triazole	Pesticide residues	LC-DMS/MS/MS	39	Triazole-acetic acid (3,5-13C; 1,2,4-15N)	Commercial laboratory
Triazole-lactic acid´	Triazole	Pesticide residues	LC-DMS/MS/MS	39	Triazole-lactic acid (3,5-13C; 1,2,4-15N)	Commercial laboratory
Ethylene thiourea (ETU)	ETU/PTU/ Chlormequat	Pesticide residues	LC-MS/MS		D4-Ethylene thiourea	Internal
Propylenthiourea (PTU)	ETU/PTU/ Chlormequat	Pesticide residues	LC-MS/MS		D3-1,2-Propylene thiourea	Internal
Chlormequat	ETU/PTU/ Chlormequat	Pesticide residues	LC-MS/MS		D9-Chlormequat chloride	Internal
Boscalid (F) (R)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Captan	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Captan (total)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Chlorpyrifos (F)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Cyantraniliprole	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Cypermethrin (sum of isomers)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Cyprodinil (F) (R)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Deltamethrin (cis-Deltamethrin) (F)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Difenoconazole	Multimethod	Pesticide residues	GC-MS/MS, LC-MS/MS	42	*	Commercial laboratory
Dimethoate	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Fluopyram	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Hexachlorbenzene (F)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Hexythiazox	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Imazalil	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Indoxacarb (sum of S and R isomers) (F)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Iprodione (R)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Lambda-cyhalothrin (F) (R)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Myclobutanil (R)	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Omethoate	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Pirimicarb	Multimethod	Pesticide residues	GC-MS/MS, LC-MS/MS	42	*	Commercial laboratory
Pirimicarb, desmethyl-	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Pyraclostrobin (F)	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Pyrimethanil	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Spinosad (sum)	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Tetrahydrophthalimide	Multimethod	Pesticide residues	GC-MS/MS	42	*	Commercial laboratory
Tiabendazole (R)	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Thiacloprid (F)	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Triflumuron (F)	Multimethod	Pesticide residues	LC-MS/MS	42	*	Commercial laboratory
Perfluorooctanesulfonate (PFOS)	Perfluorooctanesulfonate (PFOS)	Perfluoroalkyl substances	LC-MS/MS	21	13C4-PFOS	Commercial laboratory
Perfluorooctanoic acid (PFOA)	Perfluorooctanoic acid (PFOA)	Perfluoroalkyl substances	LC-MS/MS	21	13C8-PFOA	Commercial laboratory
Perfluorobutanesulfonic acid (PFBS)	Perfluorobutanesulfonic acid (PFBS)	Perfluoroalkyl substances	LC-MS/MS	21	13C3-PFBS	Commercial laboratory
Perfluorobutanoic acid (PFBA)	Perfluorobutanoic acid (PFBA)	Perfluoroalkyl substances	LC-MS/MS	21	13C4-PFBA	Commercial laboratory
Perfluoropentanoic acid (PFPeA)	Perfluoropentanoic acid (PFPeA)	Perfluoroalkyl substances	LC-MS/MS	21	13C5-PFPeA	Commercial laboratory
Perfluorohexanesulfonate (PFHxS)	Perfluorohexanesulfonate (PFHxS)	Perfluoroalkyl substances	LC-MS/MS	21	18O2-PFHxS	Commercial laboratory
Perfluorohexanoic acid (PFHxA)	Perfluorohexanoic acid (PFHxA)	Perfluoroalkyl substances	LC-MS/MS	21	13C2-PFHxA	Commercial laboratory
Perfluoroheptanesulfonic acid (PFHpS)	Perfluoroheptanesulfonic acid (PFHpS)	Perfluoroalkyl substances	LC-MS/MS	21	13C4-PFOS	Commercial laboratory
Perfluoroheptanoic acid (PFHpA)	Perfluoroheptanoic acid (PFHpA)	Perfluoroalkyl substances	LC-MS/MS	21	13C4-PFHpA	Commercial laboratory
Perfluorononanoic acid (PFNA)	Perfluorononanoic acid (PFNA)	Perfluoroalkyl substances	LC-MS/MS	21	13C5-PFNA	Commercial laboratory
Perfluorodecanesulfonate (PFDS)	Perfluorodecanesulfonate (PFDS)	Perfluoroalkyl substances	LC-MS/MS	21	13C4-PFOS	Commercial laboratory
Perfluorodecanoic acid (PFDeA)	Perfluorodecanoic acid (PFDeA)	Perfluoroalkyl substances	LC-MS/MS	21	13C2-PFDA	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Perfluoroundecanoic acid (PFUnA)	Perfluoroundecanoic acid (PFUnA)	Perfluoroalkyl substances	LC-MS/MS	21	13C2-PFUnA	Commercial laboratory
Perfluorododecanoic acid (PFDoA)	Perfluorododecanoic acid (PFDoA)	Perfluoroalkyl substances	LC-MS/MS	21	13C2-PFDoA	Commercial laboratory
Perfluorotridecanoic acid (PFTrA)	Perfluorotridecanoic acid (PFTrA)	Perfluoroalkyl substances	LC-MS/MS	21	13C2-PFDoA	Commercial laboratory
Perfluorotetradecanoic acid (PFTA)	Perfluorotetradecanoic acid (PFTA)	Perfluoroalkyl substances	LC-MS/MS	21	13C2-PFTeDA	Commercial laboratory
Florfenicol	Amphenicols	Pharmacologically active substances	LC-HR/MS	45	CAP-d5	Commercial laboratory
Danofloxacin	Quinolone	Pharmacologically active substances	LC-HR/MS	45	Enrofloxacin-d5	Commercial laboratory
Enrofloxacin	Quinolone	Pharmacologically active substances	LC-HR/MS	45	Enrofloxacin-d5	Commercial laboratory
Ciprofloxacin	Quinolone	Pharmacologically active substances	LC-HR/MS	45	Enrofloxacin-d5	Commercial laboratory
Marbofloxacin	Quinolone	Pharmacologically active substances	LC-HR/MS	45	Enrofloxacin-d5	Commercial laboratory
Trimethoprim	Diaminopyrimidine derivates	Pharmacologically active substances	LC-HR/MS	45	Sulfamethoxazole-d4	Commercial laboratory
Tylosin	Macrolide	Pharmacologically active substances	LC-HR/MS	45	Erythromycin-d3	Commercial laboratory
Tilmicosin	Macrolide	Pharmacologically active substances	LC-HR/MS	45	Erythromycin-d3	Commercial laboratory
Tulathromycin	Macrolide	Pharmacologically active substances	LC-HR/MS	45	Erythromycin-d3	Commercial laboratory
Tildipirosin	Macrolide	Pharmacologically active substances	LC-HR/MS	45	Erythromycin-d3	Commercial laboratory
Gamithromycin	Macrolide	Pharmacologically active substances	LC-HR/MS	45	Erythromycin-d3	Commercial laboratory
Erythromycin A	Macrolide	Pharmacologically active substances	LC-HR/MS	45	Erythromycin-d3	Commercial laboratory
Amoxicillin	Penicillin	Pharmacologically active substances	LC-HR/MS	45	Pen G-D7	Commercial laboratory
Benzylpenicillin	Penicillin	Pharmacologically active substances	LC-HR/MS	45	Pen G-D7	Commercial laboratory
Sulfathiazole	Sulfonamide	Pharmacologically active substances	LC-HR/MS	45	Sulfamethoxazole-d4	Commercial laboratory
Sulfadimidine (sulfamethazine)	Sulfonamide	Pharmacologically active substances	LC-HR/MS	45	Sulfamethoxazole-d4	Commercial laboratory
Sulfadiazine	Sulfonamide	Pharmacologically active substances	LC-HR/MS	45	Sulfamethoxazole-d4	Commercial laboratory
Sulfadoxine	Sulfonamide	Pharmacologically active substances	LC-HR/MS	45	Sulfamethoxazole-d4	Commercial laboratory
Sulfadimethoxine	Sulfonamide	Pharmacologically active substances	LC-HR/MS	45	Sulfamethoxazole-d4	Commercial laboratory
Chlortetracycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Tetracycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Oxytetracycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Epi-chlortetracycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Epi-tetracycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Epi-oxytetracycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Doxycycline	Tetracyclines	Pharmacologically active substances	LC-HR/MS	45	Demeclocycline	Commercial laboratory
Streptomycin	Aminoglycoside	Pharmacologically active substances	LC/MS/MS	46	-	Commercial laboratory
Dihydrostreptomycin	Aminoglycoside	Pharmacologically active substances	LC/MS/MS	46	-	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Spectinomycin	Aminoglycoside	Pharmacologically active substances	LC/MS/MS	46	-	Commercial laboratory
Gentamycin	Aminoglycoside	Pharmacologically active substances	LC/MS/MS	46	-	Commercial laboratory
Neomycin	Aminoglycoside	Pharmacologically active substances	LC/MS/MS	46	-	Commercial laboratory
Dinitrocarbanilide	Coccidiostats	Pharmacologically active substances	LC-MS/MS	47	DNC-D8	Commercial laboratory
Monensin	Coccidiostats	Pharmacologically active substances	LC-MS/MS	47	DNC-D8	Commercial laboratory
Lasalocid	Coccidiostats	Pharmacologically active substances	LC-MS/MS	47	DNC-D8	Commercial laboratory
Narasin	Coccidiostats	Pharmacologically active substances	LC-MS/MS	47	DNC-D8	Commercial laboratory
Maduramicin	Coccidiostats	Pharmacologically active substances	LC-MS/MS	47	DNC-D8	Commercial laboratory
Acrylamide	Acrylamide	Process contaminants	LC-MS/MS	43	Acrylamide-d3	Commercial laboratory
3-MCPD	2-/3-MCPD/-Ester	Process contaminants	GC-MS	44	d5-3-MCPD	Commercial laboratory
2-MCPD	2-/3-MCPD/-Ester	Process contaminants	GC-MS	44	d5-2-MCPD	Commercial laboratory
3-MCPD-Ester	2-/3-MCPD/-Ester	Process contaminants	GC-MS/MS	44	d5-3-MCPD-Ester	Commercial laboratory
2-MCPD-Ester	2-/3-MCPD/-Ester	Process contaminants	GC-MS/MS	44	d5-2-MCPD-Ester	Commercial laboratory
Glycidyl ester	Glycidol ester	Process contaminants	GC-MS/MS	44	d5-3-MCPD-Ester	Commercial laboratory
Benzo[c]fluorene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*a*]pyrene-D12	Commercial laboratory
Cyclopenta[c,d]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*a*]pyrene-D12	Commercial laboratory
Benzo[*a*]anthracene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*a*]anthracene D12	Commercial laboratory
Chrysene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Chrysene D12	Commercial laboratory
5-Methylchrysene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Chrysene D12	Commercial laboratory
Benzo[*b*]fluoranthene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*b*]fluoranthene D12	Commercial laboratory
Benzo[*k*]fluoranthene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*k*]fluoranthene D12	Commercial laboratory
Benzo[j]fluoranthene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*k*]fluoranthene D12	Commercial laboratory
Benzo[*a*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*a*]pyrene-D12	Commercial laboratory
Benzo[*e*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*a*]pyrene-D12	Commercial laboratory
Indeno[1,2,3-*cd*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Indeno[1,2,3-*cd*]pyrene D12	Commercial laboratory
Dibenz[*a,h*]anthracene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Dibenz[*a,h*]anthracene D14	Commercial laboratory
Benzo[*ghi*]perylene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*ghi*]perylene D12	Commercial laboratory
Dibenzo[*a,l*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*ghi*]perylene D12	Commercial laboratory
Dibenzo[*a,e*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*ghi*]perylene D12	Commercial laboratory

Analyte	Substance group	Module	Method	Batch	Internal standard*	Laboratory
Dibenzo[*a,i*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*ghi*]perylene D12	Commercial laboratory
Dibenzo[*a,h*]pyrene	PAHs (15+1 and benzo(*e*)pyrene)	Process contaminants	LC-LC-GC-MS/MS	23	Benzo[*ghi*]perylene D12	Commercial laboratory

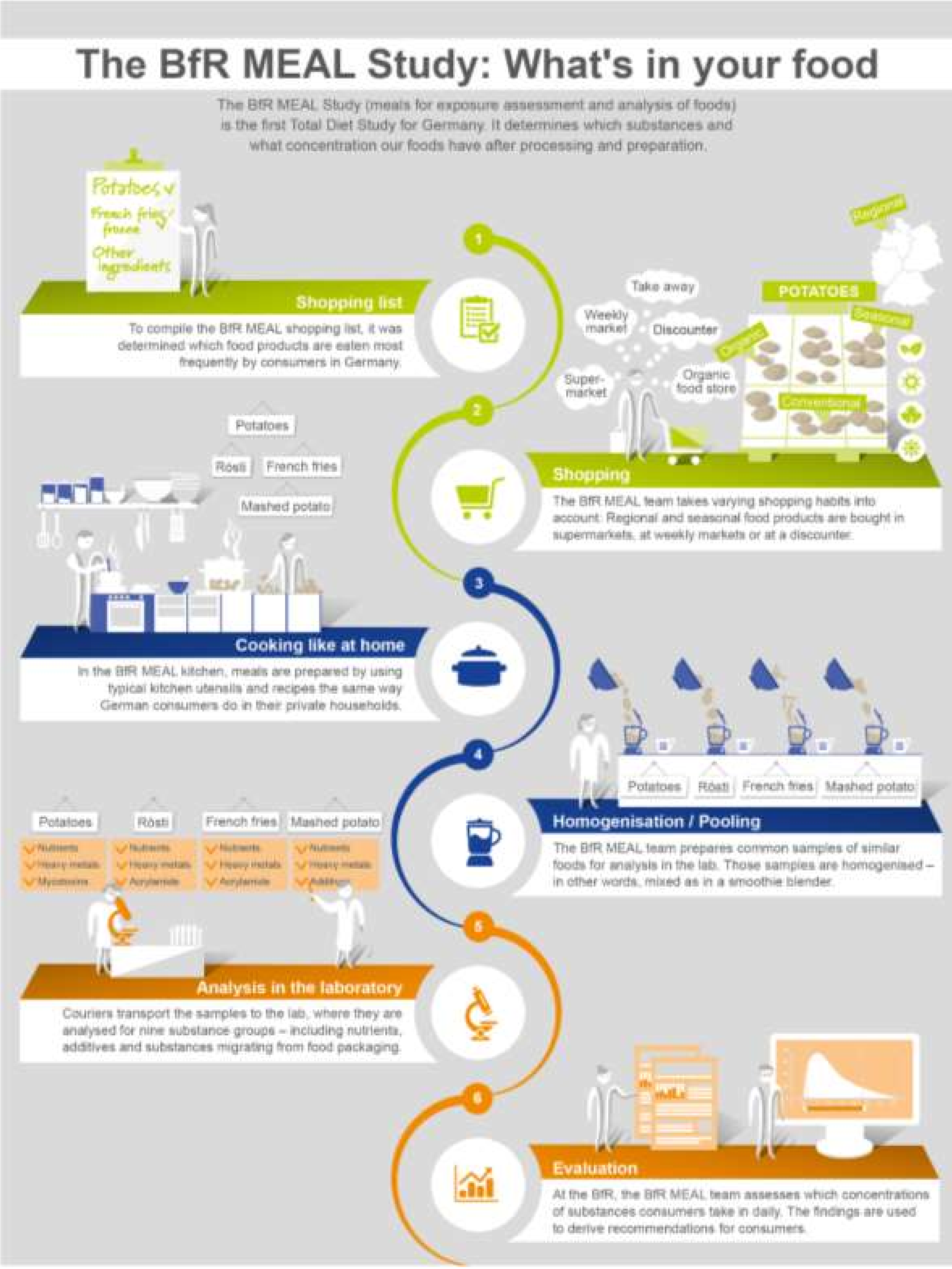
*No internal standards were used in the context of the multimethod pesticides. To check the sample processing, surrogate compounds/quality assurance standards ("procedural internal standards") were added to the samples during processing according to section 4.5 of the official method for the calibration and quantitative evaluation of chromatographic methods for determining pesticide residue and organic contaminants (ASU L 00.0013).

A3 Food list for the BfR MEAL Study's core module (last update 2022)

<table>
<tr><td>Grains and grain-based products</td><td>Puff pastry | Cornflakes | Cream cake | Spelt bread | Biscuits with cocoa filling | Pancake, Belgian waffle | Muesli with dried fruits | Sticks/pretzel sticks, salty | Multigrain bread with/without oilseeds (refined flour) | Rye-wheat bread (refined flour) | Wheat semolina porridge | Oat porridge | Oat flakes | Cheese cake | Crispbread | Pound cake, muffin | Yeast-leavened cake | Fruit cake | Lye pretzel, soft | Gingerbread and gingerbread products | Cereal cracker, puffed | Poppy seed cake and pastry | Biscuits | Rice | Rice cracker, puffed | Muesli with chocolate | Chocolate roll, milk roll | Bread dumpling, Bohemian dumpling | Muesli, mixed | Durum pasta | Egg pasta | Breakfast cereals | Wheat and rye bread and roll, wholemeal | Wheat bread and roll, white (refined flour) | Rusk | Chia seeds | Buckwheat | Quinoa | Amaranth | Millet</td></tr>
<tr><td>Vegetables, vegetable products and mushrooms</td><td>Algae | Aubergine | Lettuce and other leaf salads | Cauliflower | Green string beans | Broccoli | Green peas | Green peas and carrots, mixed | Fennel, bulb | Vegetables, mixed | Kale | Cucumber | Gherkin, pickled | Kohlrabi | Kitchen herbs, fresh | Pumpkin | Melon | Carrot | Sweet pepper | Leek | Radish | Red cabbage | Sauerkraut | Asparagus | Spinach | Tomato | White cabbage | Chanterelle mushroom | Courgette | Champignon mushroom | Sweet corn | Onions, bulb | Boletus/porcini mushroom | Vegetable crisps</td></tr>
<tr><td>Starchy roots or tubers and products thereof</td><td>Sweet potato | Potato puree/mashed potatoes | Potato crisps | Potato dumpling | Potatoes, pan-fried | Potatoes, peeled | Potatoes, unpeeled | Fries/chips</td></tr>
<tr><td>Legumes, nuts, oilseeds and spices</td><td>Broad beans, kidney beans (without pods) | Cashew nuts | Peanuts | Peanut butter | Spices | Hazelnuts | Hazelnut paste | Pulses, canned | Chickpeas (without pods) | Pumpkin seeds | Linseeds | Lentils | Macadamia nuts, brazil nuts, pecans | Almonds, sweet | Almond paste | Olives | Pistachio nuts | Sunflower seeds | Trail mix (tree nuts, oilseeds and raisins) | Walnuts</td></tr>
<tr><td>Fruit and fruit products</td><td>Apple | Apple puree | Avocado | Banana | Pear | Dates | Strawberries | Jam | Fruit puree from the squeeze bag | Cherries | Kiwi | Mango | Nectarine, peach | Fruits, mixed, canned | Fruit salad | Orange, tangerine, mandarin | Plum | Raspberries, blackberries, blueberries, gooseberries, currants | Dried fruits | Raisins | Grapes | Lemon</td></tr>
<tr><td>Meat and meat products</td><td>Blood sausage | Fine cooked sausage (e.g. Lyoner, Mortadella) | Mortadella (poultry) | Cooked sausage (pork, e.g. Wiener/frankfurter type) | Cooked sausage (poultry, e.g. Wiener/frankfurter type) | Bratwurst (pork) | Duck meat | Poultry liver | Cooked cured meat (pork, e.g. Kasseler, boiled ham) | Coarse cooked sausage (e.g. Bierwurst, Jagdwurst) | Minced meat (pork, beef) | Chicken meat | Cooked Mettwurst sausage | Liver sausage (poultry) | Liver sausage (pig, beef) | Kidney (Mammals) | Pate | Turkey meat | Bovine meat | Bovine liver (beef, veal) | Corned pork, smoked, uncooked | Ham, uncooked (pork) | Sheep meat | Sheep liver | Salami-type sausage (pork, beef) | Salami-type sausage (poultry) | Pork meat | Minced meat (pork) | Pig liver | Pork schnitzel, breaded | Edible offal (poultry) | Edible offal (pig, beef) | Cured unripened uncooked sausage (e.g. Mettwurst, Teewurst) | Deer meat | Wild boar meat</td></tr>
<tr><td>Fish, seafood and invertebrates</td><td>Eel | Eel, smoked | Spiny dogfish, smoked | Cod liver | Fish filet dish, gratinated | Fish fingers | Trout | Trout, smoked | Shrimps/prawns | Herring, fried herring | Halibut | Halibut, smoked | Herring, smoked| Herring, canned in sauce | Cod | Carp | Pollock, Alaska pollock | Salmon | Salmon, smoked | Plaice/sole | Herring, pickled, young salted herring, Bismarck herring | Herring, pickled (Roll mops) | Ocean perch | Tuna | Tuna, smoked | Tuna, canned in sauce or own juice | Tuna, canned in oil | Squid/octopus | Mussels | Striped catfish</td></tr>
<tr><td>Milk and dairy products</td><td>Buttermilk | Emmental cheese | Cream cheese | Cream cheese with herbs | Cream cheese product | Yoghurt, cow milk, plain | Yoghurt/yoghurt drink, cow milk, flavoured | Coffee cream | Condensed milk | Cow milk, plain | Flavoured milk | Ice cream, milk-based | Pudding | Quark | Quark with herbs | Quark dessert, flavoured | Cream, plain | Sheep cheese | Instant oat flakes in milk | Processed cheese | Firm/semi-hard cheese | Soft-ripened cheese | Goat cheese</td></tr>
<tr><td>Eggs and egg products</td><td>Hen egg | Hen egg, pan-fried</td></tr>
</table>

Sugar, confectionery and water-based sweet desserts	Gums | Caramels, hard | Honey | Candied fruits | Chewing gums | Liquorice candies | Milk chocolate | Nut nougat cream, chocolate cream | Pralines | Chocolate-coated marshmallow treats | Filled chocolate | Chocolate bar | Water ice, sorbet | Dark chocolate | Sugar
Animal and vegetable fats and oils	Butter | Butter (low fat) | Corn oil/maize-germ oil | Margarine | Margarine (low fat) | Olive oil | Rapeseed oil | Sunflower seed oil
Fruit and vegetable juices and nectars	Fruit drink, fortified with vitamin A, C and E | Nectar, apple | Juice, apple | Nectar, others than orange and apple | Fruit juice, 100% pure fruit | Fruit nectar, fortified with vitamins | Fruit juice, fortified with vitamins | Nectar, orange | Juice, orange | Juice, grape
Water and water-based beverages	Ice tea | Energy drink | Fruit juice spritzer | Soft drink/lemonade | Mineral water | Drinking water (tap water)
Coffee, cocoa, tea and infusions	Fruit infusion, prepared with water | Coffee, prepared with water | Coffee substitute, prepared with water | Cocoa powder | Herbal infusion, prepared with water | Instant coffee, prepared with water | Rooibos tea, prepared with water | Fermented and non-fermented tea, prepared with water | Cocoa beverage-preparation, instant (powder)
Alcoholic beverages	Beer | Beer-based mixed drink | Malt beer | Red wine | Spirit | Mixed alcoholic drink (mixture of spirits with non-alcoholic drinks) | Wine-based drink | White wine, sparkling wine
Food products for infants and toddlers	Fruit and vegetable juice and nectar specific for infants and toddlers | Simple cereals for reconstitution with liquids, millet porridge (powder) | Mixed cereal porridge and infant formulae for reconstitution with liquids (powder) | Biscuits and rusks for infants and toddlers | Instant milk cereals for reconstitution with liquids (powder) | Ready-to-eat dairy-based meal for infants and toddlers | Ready-to-eat fruit-based meal for infants and toddlers | Ready-to-eat mixed meal for infants and toddlers | Ready-to-eat vegetable-based meal for infants and toddlers | Infant formulae, follow-on formulae for reconstitution with liquids (powder) | Infusion and hot beverage for infants and toddlers
Products for non-standard diets and food imitates	Rice drink | Soya yoghurt and dessert | Soya drink | Textured soy protein | Tofu | Vegetarian sandwich spread | Vegetarian sausage
Composite dishes	Omelette with potatoes and bacon | Veggie patty | Bread, gratinated | Burger | Doner kebab (bread, meat, salad and sauce) | Meat and vegetable meal | Meatball | Poultry-based dish (ragout, fricassee) | Poultry stew/soup | Vegetables, gratinated | Vegetable broth | Meat and vegetable soup | Vegetables, mixed, fried | Vegetable soup | Goulash (pork, beef) | Goulash soup | Gyros meat (pork) | Kaiserschmarn (pancake-like dessert) | Potato-vegetable-based meal for infants and toddlers (self-prepared) | Potato-vegetable-meat-based meal for infants and toddlers (self-prepared) | Potatoes, gratinated | Potato pancake/fritter | Prepared potato salad | Potato soup | Bouillon (soup) with pasta products | Bouillon (soup) with liver dumplings/spaetzle | Legume (beans, lentils, peas) soup | Rice pudding | Lasagna with meat sauce | Lasagna with vegetable-based sauce | Prepared pasta salad | Omelette/scrambled egg | Minced meat stuffed pepper | Mushroom soup | Pizza with fish/seafood topping | Pizza with meat | Pizza with vegetables | Creamed vegetable mix | Creamed spinach | Rice, vegetable and meat meal | Rice and vegetable meal | Beef roulade | Risotto | Salad with dressing, diverse | Bouillon (soup) with vegetables | Bouillon (soup) with cereals | Soup garnishes | Sushi | Pasta, filled with vegetable mix | Pasta, filled with meat mix | Tomato soup | Prepared meat salad
Seasoning, sauces and condiments	Stock cube (bouillon cube) | Brown sauce | Vegetable sauce | White/bright sauce, plain | White/bright sauce with bacon and Carbonara-like sauces | White/bright sauce, flavoured with herbs, mushrooms or garlic | Cheese sauce | Pesto | Salad dressing | Salt | Mustard | Soy sauce | Minced meat sauce | Tomato ketchup | Tomato sauce | Vanilla sauce

A4 Communication media



A5 Overview of publications by substance

Substance	Published			References
	Occurrence data	Exposure	Risk assessment	
Arsenic & arsenic species (5 substances)	x	x		**Hackethal, C.** et al. (2023): Chronic dietary exposure to total arsenic, inorganic arsenic and water-soluble organic arsenic species based on results of the first German total diet study. Science of the Total Environment 859 160261. **Hackethal, C**. et al. (2021): Total arsenic and water-soluble arsenic species in foods of the first German total diet study (BfR MEAL Study). Food Chemistry 346.
Lead	x			**Fechner, C**. et al. (2022): Results of the BfR MEAL Study: In Germany, mercury is mostly contained in fish and seafood while cadmium, lead, and nickel are present in a broad spectrum of foods. Food Chemistry X 14, 100326. **Ptok, S.** et al. (2020): Cadmium und Blei in Lebensmitteln expositionsrelevanter Lebensmittelgruppen – Ergebnisse der BfR-MEAL-Studie (Cadmium and lead in foods of exposure-relevant food groups – results of the BfR MEAL Study). *14. DGE-Ernährungsbericht*, 142-179.
Cadmium	x			**Fechner, C.** et al. (2022): Results of the BfR MEAL Study: In Germany, mercury is mostly contained in fish and seafood while cadmium, lead, and nickel are present in a broad spectrum of foods. Food Chemistry X 14, 100326. **Ptok, S.** et al. (2020): Cadmium und Blei in Lebensmitteln expositionsrelevanter Lebensmittelgruppen – Ergebnisse der BfR-MEAL-Studie (Cadmium and lead in foods of exposure-relevant food groups – results of the BfR MEAL Study). *14. DGE-Ernährungsbericht*, 142-179.
Calcium	x			**Schwerbel, K.** et al. (2022): Results of the BfR MEAL Study: The food type has a stronger impact on calcium, potassium and phosphorus levels than factors such as seasonality, regionality and type of production. Food Chemistry X 13, 100221.
Dioxines & dl-PCBs (29 substances)	x	x		**Stadion, M.** et al. (2022): The first German total diet study (BfR MEAL Study) confirms highest levels of dioxins and dioxin-like polychlorinated biphenyls in foods of animal origin. Food Chemistry X 16, 100459. **BfR** (2022): Exposition gegenüber ndl-PCB und dl-PCB über Lebensmittel aus der BfR-MEAL-Studie. Erlass des Bundesministeriums für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV) (Exposure to ndl-PCB and dl-PCB via food from the BfR MEAL study. Decree of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)).
Iodine	x	x	x	**BfR** (2022): Declining iodine intake in the population: model scenarios to improve iodine intake in children and adolescents. BfR opinion no. 026/2022 of 17 Ocotber 2022. **BfR** (2021): Declining iodine intake in the population: model scenarios to improve iodine intake. BfR opinion no. 005/2021 issued 9 February 2021.
Potassium	x			**Schwerbel, K.** et al. (2022): Results of the BfR MEAL Study: The food type has a stronger impact on calcium, potassium and phosphorus levels than factors such as seasonality, regionality and type of production. Food Chemistry X 13, 100221.
Copper	x	x		**Kolbaum, A. E.** et al. (2023). Long-term dietary exposure to copper in the population in Germany – Results from the BfR MEAL study. Food and Chemical Toxicology, 176: 113759.
Methyl mercury	x	x		**Sarvan, I.** et al. (2021): Exposure Assessment of methylmercury in samples of the BfR MEAL Study. Food and Chemical Toxicology 149.

Substance	Published			References
	Occurrence data	**Exposure**	**Risk assessment**	
ndl-PCBs (6 substances)	x	x		**BfR** (2022): Exposition gegenüber ndl-PCB und dl-PCB über Lebensmittel aus der BfR-MEAL-Studie. Erlass des Bundesministeriums für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV) (Exposure to ndl-PCB and dl-PCB via food from the BfR MEAL study. Decree of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)). **BfR** (2018): Non-dioxin-like PCBs are undesirable in food and feed. BfR communication no. 037/2018 issued 3 December 2018.
Nickel	x	x	x	**Fechner, C.** et al. (2022): Results of the BfR MEAL Study: In Germany, mercury is mostly contained in fish and seafood while cadmium, lead, and nickel are present in a broad spectrum of foods. Food Chemistry: X 14, 100326. **BfR** (2022): Nickel: estimate of long-term intake via food based on the BfR MEAL Study. BfR communication no. 033/2022 issued 22 November 2022.
Phosphorous	x			**Schwerbel, K.** et al. (2022): Results of the BfR MEAL Study: The food type has a stronger impact on calcium, potassium and phosphorus levels than factors such as seasonality, regionality and type of production. Food Chemistry X 13, 100221.
Mercury	x			**Fechner, C.** et al. (2022): Results of the BfR MEAL Study: In Germany, mercury is mostly contained in fish and seafood while cadmium, lead, and nickel are present in a broad spectrum of foods. Food Chemistry X 14, 100326.
ß-Carotene*	x			**Schendel, S**. et al. (2022): Results of the BfR MEAL Study: Highest levels of retinol found in animal livers and of β-carotene in yellow-orange and green leafy vegetables. Food Chemistry X 16, 100458.
Sweeteners (10 substances)	x			**BfR** (2023): Sugar alternatives: how much sweetener is there in soft drinks? BfR opinion no. 006/2023 issued 07 February 2023
Vitamin A	x			**Schendel, S**. et al. (2022): Results of the BfR MEAL Study: Highest levels of retinol found in animal livers and of β-carotene in yellow-orange and green leafy vegetables. Food Chemistry X 16, 100458.

About the BfR

The German Federal Institute for Risk Assessment (BfR) is a scientifically independent institution within the portfolio of the Federal Ministry of Agriculture, Food and Regional Identity (BMLEH). It protects people's health preventively in the fields of public health and veterinary public health. The BfR provides advice to the Federal Government as well as the Federal States ('Laender') on questions related to food, feed, chemical and product safety. The BfR conducts its own research on topics closely related to its assessment tasks.

BfR MEAL Study

In what quantities do we ingest desirable and undesirable substances on average through our food? Are certain foods more contaminated than others? And what health effects does the preparation method have on the food? The BfR MEAL Study helps to answer these and other questions

With support from

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