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Summary

In order to establish a risk based monitoring program, the most relevant chemical hazards in the food supply chain need to be identified. This report gives an overview of all chemical hazards that may be encountered in the fruit supply chain based on literature review and monitoring data (the so-called long list of chemical hazards). Those hazards that were found above legal limits, unauthorised substances that were encountered and chemical hazards that were frequently found were included on the intermediate list of chemical hazards. The department for Risk Assessment & Research of the Netherlands Food and Consumer Product Safety Authority (NVWA-BuRO) will use this intermediate list as a starting point to derive a short list of chemical hazards in fruit products relevant for human health, which should be included in the Dutch monitoring program.

Long list of chemical hazards that might occur in the fruit supply chain
A literature review was performed using pre-set search strings for the years 2007-2018 to identify possible chemical hazards in the fruit supply chain. This information was combined with data from the Dutch monitoring program (2013-2017) to derive a long list of chemical hazards. The following groups of chemical hazards were encountered in fruits and fruit products and are described in this report: heavy metals and trace elements, persistent organic pollutants such as dioxins and perfluorinated compounds, polycyclic aromatic hydrocarbons, fertilizers, pesticides, mycotoxins, plant toxins, radionuclides, processing contaminants, substances added to fruits or products after harvesting or during processing, cleaning agents and disinfectants and allergens.

Intermediate list of prioritised chemical hazards in the fruit supply chain
The long list of chemical hazards was prioritised using information from literature and Dutch monitoring data resulting in an intermediate list of chemical hazards that are frequently detected in fruit, detected above the EU legal limits, unauthorised substances encountered or chemical hazards for which there were data gaps. Literature study indicated that heavy metals were frequently encountered in fruits, especially cadmium, lead and nickel, which were thus included on the intermediate list. Concentrations of these heavy metals were usually below maximum limits (MLs), but depending on the location, MLs were exceeded. These findings were confirmed by the Dutch monitoring data. For the heavy metals tested, cadmium and lead were sometimes above the ML for goji berries.

Perchlorate was indicated as the most relevant substance, which is used as fertilizer for fruits; imported fruits sometimes contained perchlorate concentrations above the EU reference level of 0.1 mg/kg. As this substance is currently not included in the Dutch monitoring program, it was added to the intermediate list.

Pesticides were frequently detected in many fruit species sometimes exceeding the EU MRLs. Fruits in which pesticide residues were most frequently detected were strawberries and table grapes. Since a range of pesticides were found, a structured approach was used to come to a set of pesticides to be included in the intermediate list. Those pesticides that are authorised for fruit in the Netherlands and were listed as toxic for humans according to the CLM report (Visser et al., 2016) were included in the intermediate list (n=17). Additionally, pesticides that are currently not included in the Dutch multi-method but for which more than 1% of the samples were positive in data obtained from the German monitoring program were also included (n=5). Furthermore, pesticides that were found above the MRL in more than 1% of the samples in the Dutch monitoring program were added (n=24) as well as pesticides that were unauthorised in the EU but found to be used according to literature (n=11). Six pesticides were found in more than one list. In total, 51 pesticides were added to the intermediate list.

Another relevant group of substances are the mycotoxins, which may be present in damaged fruits due to fungal growth. Patulin is predominantly found in apples and apple juices, and Ochratoxin A (OTA) in grapes and derived products. Furthermore, dried fruit can contain aflatoxins or OTA. Data analysis of Dutch monitoring data revealed that OTA and aflatoxins were sometimes found above the

MLs. A wide range of other mycotoxins were found in various fruit samples. Since these mycotoxins do not have legal limits, it is difficult to draw conclusions for these substances. For all mycotoxins tested, mycophenolic acid and tenuazonic acid were most frequently found in the Dutch monitoring program (17% and 26% of all samples respectively) at high concentrations (max 2500 and 83000 μg/kg, respectively). These were thus also added to the intermediate list.

The most relevant plant toxins for fruits are cyanogenic glycosides, which may be found in apricot kernels. Hydrocyanic acid (HCN) may be formed after hydrolysis of these cyanogenic glycosides. Levels of HCN in apricot kernels were found above the ML, which may pose a risk to human health.

Apart from environmental pollutants and natural contaminants, substances may also be added to fruit products after harvest. Postharvest malpractices could include the use of prohibited toxic ripening agents, such as calcium carbide or b the use of unauthorised colourants such as red dye to mislead consumers. Processing contaminants were not seen as relevant for fruit products, except for PAHs in banana chips. Currently, there is a lack of information for this substance in banana chips and for this reason, the substance was included on the intermediate list.

Trends in the fruit supply chain

In order to identify developments in the fruit supply chain that may influence the presence of chemical hazards in fruits and fruit products, trends were evaluated using Google search and expert elicitation. This revealed consumer trends, trends in the trade and organisation of the fruit supply chain, trends in sustainability demands, innovation and legal and policy aspects influencing the fruit supply chain. The most relevant consumer trend for chemical hazards is the increased demand for soft fruits and exotic fruits. This may lead to an increased detection of pesticide residues, since soft fruits are more vulnerable for fungal spoilage and as such are treated more frequently with pesticides than hard fruits. On the other hand, innovations in sustainability lead to less pesticide use and thus a decrease in pesticide residues. Reduced pesticide use may lead to increased fungal growth and mycotoxin levels. Overall, it is recommended to keep track of innovations in the fruit supply chain and evaluate their possible effects on the presence of food safety hazards in fruits and fruit products.

Samenvatting

Om een risicogebaseerd monitoringsprogramma op te kunnen stellen, moeten de belangrijkste chemische gevaren in de voedselketen geïdentificeerd worden. Dit rapport geeft een overzicht van alle chemische gevaren die kunnen voorkomen in de fruitketen, gebaseerd op literatuuronderzoek en monitoringsdata (de zogenaamde 'long list'). Chemische gevaren die boven wettelijke limieten werden gevonden, niet toegelaten stoffen en chemische gevaren die regelmatig gevonden werden, zijn opgenomen in de zogenaamde 'intermediate list'. Bureau Risicobeoordeling & onderzoek van de NVWA (NVWA-BuRO) zal deze intermediate list als startpunt gebruiken om een 'short list' op te stellen van chemische gevaren in fruitproducten die relevant zijn voor de humane gezondheid. De stoffen op deze lijst zullen worden opgenomen in het nationale monitoringsprogramma van de NVWA.

De long list van chemische gevaren die kunnen voorkomen in de fruitketen
Met behulp van vooraf vastgestelde zoektermen is een literatuuronderzoek uitgevoerd voor de jaren 2007-2018 om alle mogelijke chemische gevaren die zich kunnen voordoen in de fruitketen te identificeren. De informatie uit dit literatuuronderzoek werd gecombineerd met gegevens uit het Nederlandse monitoringsprogramma (2013-2017) om een long list met chemische gevaren te kunnen opstellen. De volgende groepen van chemische gevaren werden aangetroffen in fruit en fruitproducten: zware metalen en spoorelementen, persistente organische verontreinigende stoffen (POP's) zoals dioxines en perfluorverbindingen, polycyclische aromatische koolwaterstoffen (PAK's), meststoffen, pesticiden, mycotoxinen, planttoxinen, radionucliden, procescontaminanten, stoffen die aan fruit en fruitproducten worden toegevoegd na de oogst of tijdens de verdere verwerking, reinigings- en desinfectiemiddelen en allergenen. Deze stofgroepen zijn beschreven in dit rapport.

De intermediate list van geprioriteerde chemische gevaren in de fruitketen
Op basis van informatie uit de literatuur en nationale monitoringsgegevens werd de long list van chemische gevaren geprioriteerd wat resulteerde in een intermediate list van chemische gevaren die regelmatig gevonden werden, of aangetroffen boven EU-limieten of waarvoor kennisleemtes werden aangegeven. Uit het literatuuronderzoek bleek dat zware metalen regelmatig gevonden werden in fruit, met name cadmium, lood en nikkel. Deze werden dan ook opgenomen op de intermediate list. De concentraties van deze zware metalen waren over het algemeen beneden de maximumlimieten (ML's), maar afhankelijk van de locatie werd de ML soms overschreden. Deze resultaten werden bevestigd in de nationale monitoringsgegevens, waarin Cd en Pb soms boven de ML gevonden werden voor gojibessen.

Volgens de literatuur is perchloraat de belangrijkste meststof foor fruit. Geïmporteerd fruit bevat namelijk soms perchloraatconcentraties boven het EU-referentieniveau van 0,1 mg/kg. Aangezien deze stof momenteel niet in het nationale monitoringsprogramma is opgenomen, is deze toegevoegd aan de intermediate list.

Pesticiden worden regelmatig gevonden in verschillende fruitsoorten. In sommige gevallen worden de EU MRL's hierbij overschreden. Op aardbeien en tafeldruiven worden de meeste pesticideresiduen aangetroffen. Aangezien een breed scala aan pesticiden gevonden werd en de literatuur alleen een globaal overzicht gaf, is een gestructureerde aanpak gevolgd om een lijst met pesticiden op te stellen die opgenomen kon worden in de intermediate list. Pesticiden die in Nederland een toelating hebben op fruit en die volgens het CLM rapport aangemerkt werden als toxisch voor de mens (Visser et al., 2016) werden opgenomen in de intermediate list (n=17). Verder werden pesticiden opgenomen die momenteel niet in de Nederlandse multi-methode zitten, maar waarvan meer dan 1% van de monsters positief was in Duitse monitoringsgegevens (n=5). Daarnaast werden pesticiden opgenomen die in meer dan 1% van de monsters boven de MRL werden aangetroffen in het nationale monitoringsprogramma (n=24) evenals pesticiden die niet toegelaten zijn in de EU, maar die volgens de literatuur wel worden aangetroffen in fruit (n=11). Zes pesticiden werden in meer dan een lijst gevonden, wat resulteerde in totaal 51 pesticiden die werden opgenomen in de intermediate list.

Een andere relevante groep stoffen zijn de mycotoxinen, die op beschadigd fruit kunnen voorkomen door schimmelgroei. Patuline werd voornamelijk aangetroffen in appels en appelsap, ochratoxine A (OTA) in druiven en daarvan afgeleide producten. Verder kan gedroogd fruit nog OTA en aflatoxinen bevatten. De nationale monitoringsgegevens lieten zien dat OTA en aflatoxinen soms boven de ML's werden gevonden. Verder werd er nog een bereed scala aan andere mycotoxinen gevonden in diverse fruitmonsters. Van alle gemeten mycotoxinen werden mycofenolzuur en tenuazonzuur het meest gevonden (respectievelijk 17% en 26% van de monsters in het nationaal monitoringsprogramma) met soms hoge concentraties (respectievelijk maximaal 2500 en 83000 µg/kg). Deze twee mycotoxinen zijn dan ook opgenomen in de intermediate list.

De belangrijkste plantoxinen in fruit zijn de cyanogene glycosiden die kunnen voorkomen in abrikozenpitten. Door hydrolyse van deze cyanogene glycosiden kan blauwzuur (HCN) gevormd worden. Volgens de literatuur werden HCN-concentraties in abrikozenpitten boven de ML gevonden, wat gevolgen kan hebben voor de humane gezondheid.

Naast milieucontaminanten en stoffen die van nature voorkomen, kunnen stoffen ook na de oogst toegevoegd worden aan fruitproducten. Volgens de literatuur kunnen misstanden voorkomen na de oogst doordat bijvoorbeeld verboden toxische rijpingsstoffen zoals calciumcarbide gebruikt worden of niet-toegelaten kleurstoffen zoals rode kleurstof om de consument te misleiden. Procescontaminanten werden niet als relevant beoordeeld voor fruitproducten, behalve voor PAK's in bananenchips. Aangezien er momenteel weinig informatie is over de concentraties PAK's in bananenchips, is deze stofgroep ook opgenomen op de intermediate list.

Trends en ontwikkelingen in de fruitketen
Om ontwikkelingen in de fruitketen te kunnen identificeren die een effect kunnen hebben op het voorkomen van chemische gevaren in fruit en fruitproducten werden trends geëvalueerd met behulp van een Google search en de raadpleging van experts. Hieruit kwam naar voren dat consumententrends, trends in de handel en organisatie van de fruitketen, trends in duurzaamheidseisen, innovatie en wetgevings- en beleidsaspecten een invloed kunnen hebben op de fruitketen. De belangrijkste consumententrend is de toegenomen vraag naar zacht fruit en exotisch fruit. Dit kan leiden tot een toename in het aantreffen van pesticidenresiduen, aangezien zacht fruit gevoeliger is voor schimmelgroei en dus vaker behandeld wordt met pesticiden dan hard fruit. Aan de andere kant leiden innovaties op het gebied van duurzaamheid juist tot een afname in pesticidegebruik en dus een afname in het aantreffen van pesticidenresiduen in fruit. Indien minder pesticiden gebruikt worden, kunnen schimmelgroei en als gevolg daarvan de concentraties myctoxinen in fruit toenemen. In het algemeen wordt aanbevolen om innovaties in de fruitketen nauwlettend te volgen en mogelijke effecten hiervan op de aanwezigheid van voedselgevaren in fruit en fruitproducten in te schatten.

1 Introduction

The main task of the Netherlands Food and Consumer Product Safety Authority (NVWA) is to protect human and animal health. For this purpose, the NVWA monitors the possible presence of potential hazards for human and animal health in food and consumer products. As it is not possible to check all food and feed products in the Netherlands, the NVWA needs to prioritize its activities.

Risk based monitoring focuses on the most important food and feed safety hazards. Within risk based monitoring both the probability of a hazard occurring in the product and the effects of this hazard on human health are taken into account. The NVWA Office for Risk Assessment and Research (Bureau Risicobeoordeling & onderzoek; BuRO) gives advices for risk based monitoring in various food chains. Previously, the red meat chain, dairy chain, poultry chain, potato chain and egg chain have been assessed on the presence of food safety hazards. Currently, the fruits and vegetable chain is under investigation. This food supply chain is divided in 7 sub-chains:

1. Fruits
2. Nuts, cereals and seeds
3. Mushrooms
4. Leafy vegetables
5. Fruiting vegetables
6. Bulb, tuber (except potatoes) and root vegetables
7. Other vegetables

Sub-chain 1, the fruit chain, is the focus of this research.

The aim of the current study is to make an inventory of possible chemical hazards in the Dutch fruit chain, from farm-to-fork, and to identify the most relevant chemical hazards, as based on scientific literature review, monitoring data and expert input. This information will be used by the NVWA as input to the risk prioritization of chemical hazards in the fruit chain. Products included were whole fruits and processed fruits.

The project consisted of the following tasks:

- A literature study on chemical hazards that may occur in the fruit chain (section 3.1 and 3.2).
- An overview of health based guidance values of the most relevant chemical hazards (section 3.4) based on literature review (3.2) and data analysis (3.3).
- An evaluation of trends and developments within the fruit chain within the next 5 years that may influence the occurrence of chemical hazards (section 4).

2 Methods

2.1 Project description and demarcation

In this project, a literature study was performed to identify all possible chemical hazards that may occur in the fruit supply chain. Given time constraints, retrieved articles were not read in full, but only the abstract, material and methods and conclusion were read, and summarized.

For this study, we searched for information on products, semi-finished products and raw materials originating from the Netherlands or imported to the Netherlands. Only fresh and dried fruits, e.g. dried figs and raisins, were taken into account, as well as minimally processed fruits i.e. products that are the result of grinding, washing, cutting and drying of fruits. Composite products in which fruit is used, e.g. granola bars and fruit yoghurts, were not part of this literature study. Other processed products, such as fruit juices and jam, were also outside the scope of this research.

Apart from literature, information on the presence of chemical hazards was derived from monitoring data. Data analysis was performed by the RIVM, who summarised Dutch monitoring data from the KAP database. Combined with the information from the literature study, this information was used to prioritise the chemical hazards that may be present in the fruit supply chain.

Finally, an analysis into the trends in the fruit supply chain was performed using information from grey literature and results obtained through questionnaires and interviews.

Each of the steps performed in this study is outlined below.

2.2 Literature screening

The first step was to search for information on the presence of chemical hazards in scientific literature. Articles were collected from Web of Science and Pubmed using the following keywords: 'chemical hazard*' OR hazard analys* OR risk analys* AND fruit* for hits in keywords, title or abstract in the period 2007-2018.

Furthermore, via Google search, reports from international institutes and organisations e.g. the European Commission (EC), the European Food Safety Authority (EFSA), the US Food and Drug Administration (US FDA), the World Health Organisation (WHO), the Food and Agriculture Organisation (FAO), the National Institute for Public Health and the Environment (RIVM), United Kingdom Food Standards Agency (UK FSA), Food Standards Australia New Zealand (FSANZ), New Zealand Food Safety Authority (NZFSA) and the German Institute for Risk Assessment (BfR) were used to retrieve relevant information and data. Again, the following keywords were used: 'chemical hazard' OR hazard analysis OR risk analysis AND fruits combined with the institute name (for example site: nvwa.nl). For Google search no asterisk were used, so the search term used was 'fruits'. When Google results showed >100 hits, years were selected between 2007-2018. When still >100 hits were shown, only reports with .pdf (via Google settings, advanced search, file type: .pdf) were retrieved.

As search results showed that in some reports and papers the type of fruit is mentioned instead of the keyword fruit, extra searches were performed in Web of Science and Pubmed for additional (background) information and for potential hazards that were not found initially using the search terms specified above in the top 5 most consumed fruits during the day (i.e. strawberry, banana, apple, orange and kiwi) (Borgdorff-Rozeboom, 2013) and the top 5 most imported fruits (citrus fruits, grapes, mango, pineapple and avocado) (NVWA personal communication based on phytosanitary inspections). Again, the keywords 'chemical hazard*, 'hazard analys*', 'risk analys*' were combined with the specific fruit species in the period 2007-2018.

After this initial search, additional searches were performed to obtain more information on specific hazards. For this purpose, reports and papers were searched on PAH OR PFAS OR BFR OR dioxin*, OR 'cleaning agents' OR 'food supplement' OR 'edible oils' OR acrylamide OR 'postharvest preservation' OR 'edible coatings in combination with AND fruit in Web of Science and Google. In case many hits were obtained, additional keywords were used: hazard* OR risk* OR 'food safety' or only reviews were consulted.

All retrieved literature was saved in Endnote and screened for relevance based on title, keywords and abstract. Literature on dietary intake, microbiological hazards, pests, consumption, human health effect (e.g. relation fruit – cancer), composite products or analytic methods were not considered to be relevant for this study. Papers considered to be relevant included information on levels and/or occurrence of chemical hazards in fruit. Abstract, material and methods and conclusion of relevant literature references were read and possible chemical hazards were summarized (see chapter 3). Information regarding fruit species, place of origin and occurrence in the chain was also retrieved if possible.

2.3 Monitoring data

Monitoring data were obtained from the RIVM, who extracted all analytical results for chemical hazards that were monitored by the NVWA in the official control of fruits and stored in the KAP database (https://chemkap.rivm.nl) for the years 2013-2017. The monitoring data obtained originated from NVWA and RIKILT for: mycotoxins, acrylamide and heavy metals in fruits. For pesticides only the NVWA data were used. For each chemical hazard, the maximum concentration found, the average concentration of positive (= containing a concentration above the limit of quantitation of the analytical method used) samples and the percentage of positive samples were indicated per fruit species. For pesticides also the percentage of samples with concentrations above the MRL were indicated. Only 'objective' samples (meaning random samples, not selectively taken) were used for the analysis. Furthermore, German monitoring data on pesticides were retrieved for the year 2016 from the EFSA Knowledge Junction Zenodo (https://zenodo.org/communities/efsa-kj). These German data were used to assess which pesticides in the German monitoring data were found in more than 1% of the samples in which these pesticides were analysed and are currently not included in the Dutch monitoring systems.

2.4 Prioritization

The literature research gave indications on which chemical hazards may occur in fruits and fruit products. These chemical hazards were included in the so-called long list of possible hazards in the fruit supply chain. Each of these hazard groups is described in section 3.2. Based on information in the retrieved papers and reports regarding detected concentrations in fruits, the most relevant chemical hazards per group were identified, which is indicated in the conclusion of each section.

The information from literature and monitoring data from the KAP database (3.3) were used to come to a list of prioritised chemical hazards: the intermediate list. This list contains chemical hazards that are frequently found in fruits; i.e. hazards that were mentioned multiple times in the literature as being detected in fruit species or hazards or hazards that were detected in more than 5% of the samples in the Dutch monitoring data. Furthermore, hazards that were found at levels above legal limits were included in the intermediate list as well as unauthorised substances found or hazards for which there were data gaps. As many different pesticides were found in several fruit species, it was difficult to obtain a list of pesticides for the intermediate list. Therefore, a different approach was used for the group of pesticides. Although authorised pesticides have undergone a safety assessment prior to authorisation, we wanted to identify those authorised pesticides that potentially have the highest impact on human health. For this purpose, all authorised pesticides for fruit production in the Netherlands were downloaded from the website of the Dutch Board for the Authorisation of Plant protection products and Biocides (Ctgb July 2018) using 'gewasbeschermingsmiddel' as category and 'Fruitgewasssen' as field of application. This resulted in 303 authorised products in fruits with 118 separate active ingredients. These active ingredients were ranked based on the risk list prepared by CLM Onderzoek en Advies, in which they divided pesticides in three classes (green, orange and red) based on human health or environmental risks (Visser et al., 2016). Only pesticides authorised for use in fruit that were considered hazardous for human health (classified red) were put on the intermediate list. Pesticides that were authorised after 2016 are evaluated by EFSA and considered safe for use. These were therefore not included on the intermediate list. In the EU, approximately 480 active substances are authorised for use as plant protection product. Since not all fruit is produced in the Netherlands, and other pesticides may be used on fruits abroad (an estimate is that there about a 1000 pesticidal substances are used or were once used for plant protection), additionally pesticides were added to the list that are currently not included in the multi-method or for which no single residue method (SRM) is used in the Netherlands, but which may give residues in food. For this purpose, the German monitoring data on pesticides in fruit were consulted (https://zenodo.org/record/1322637). The German multi-method and SRMs for the analysis of residues of plant protection products in fruits are able to detect an additional 200 pesticides compared to the analytical methods currently used in the Dutch monitoring program (according to EFSA, 2018, the analytical scope of the Netherlands was 405 pesticides in 2016 and for Germany: 683 pesticides). One should keep in mind however that the scope (number of substances sought for) of a multi-method used is not always the same, even in one year. In the Netherlands for instance the NVWA uses a multimethod with a more limited scope for samples with short reporting times (import) except when time is not a limiting factor. In case pesticides were found in the German monitoring that were not included in the Dutch monitoring in concentrations above the LOQ in more than 1% of the samples in which this pesticide was analysed, they were included in the intermediate list.

2.5 Health based guidance values for prioritized hazards in the fruit chain

For the substances on the intermediate list, health-based guidance values were collected and EFSA opinions consulted to indicate the relevance of these substances for human health. Furthermore, the legal limits and the concentration range of the substances found in fruit species were included in section 3.4. MRLs and health-based guidance values of pesticides were obtained from the EU pesticide database (ec.europa.eu/food/plant/pesticides/eu-pesticides-database). Other health-based guidance values were obtained from reports of food safety authorities; EFSA, JECFA, WHO and US EPA.

2.6 Evaluation of trends

Trends that might have an effect on chemical hazards in the fruit chain were searched in Google using the following keywords:
- trends AND fruit
- 'consumer trends' AND fruit AND Europe
- trade and fruit and trend
- trend and fruit and innovations

Furthermore, trend reports from Dutch banks (e.g. Rabobank, ABN-AMRO) were searched. In case trends were mentioned in the literature search performed on chemical hazards in fruit (section 2.2), these were also added.

Moreover, internal and external experts in the field were consulted to identify trends in the fruit supply chain that can impact food safety. For this purpose, a pre-defined questionnaire (in Dutch) was drafted in cooperation with Wageningen Food & Biobased Research (WFBR) (Annex 2).

Fourteen experts working in the fruit chain were contacted via email to fill in the questionnaire specific on fruits or were invited to have an interview by phone. Furthermore, 12 experts working in the fruit and vegetable chain were contacted to fill in the general questionnaire or invited to have an interview by phone. These experts were involved in branch organisations, an interest group, processing industry, retail, primary production and whole trade and import.

Furthermore, in collaboration with WFBR the Innova Database (Innova) was used to determine trends in new product introductions. Innova Market Insights collects all new product introductions, collecting all information available on the product package into the Innova Database. Information about the product that is not mentioned on the package is consequently not in the database, nor is there a log on how long the product has stayed on the market. The overview the database shows the trend in products in the past years. In the database, products can be sorted on ingredients, packaging, year, country of origin etc. Furthermore, the team from Innova makes regular updates on trends they note in several of the categories they work in. The search in the database was performed using a free text search on the ingredients of the search terms used in the literature study as well (see section 2.2.1). The search was restricted to products introduced in the Netherlands between 2007 and 2017, while also relevant reports of the Innova team were studied.

3 Results

3.1 Results literature search

Previously, an initial screening on chemical hazards in the fruit supply chain was performed using the keywords chemical hazard, hazard analysis, risk analysis and risk assessment, combined with fruit and/or the top 5 consumed or produced fruit species. This resulted in 348 scientific papers that were retrieved using Web of Science (Table 1) and Pubmed (Table 2). These 348 papers were screened for relevance based on abstract, keywords and title, and 69 papers were considered relevant. Web of Science gave the most relevant papers, probably because Pubmed is more medically oriented. The results of this initial search are further described by van Asselt et al. (2018).

Table 1 *Relevant hits Web of Science*

Keywords	#hits 15-12-2017	# hits relevant based on keywords, abstract, title
'chemical hazard*' and fruit*	132	43
'hazard analys*' and fruit*	27	5
'risk analys*' and fruit*	53	5
'risk assessment*' and fruit*	729	NA[1]
'risk assessment' AND fruit* AND ('citrus fruit*' OR grape* OR mango* OR pineapple* OR avocado*)	63	6
'risk assessment' AND fruit* AND (strawberry* OR banana* OR apple* OR orange* OR kiwi*) Filter op Review	123 10	NA 0

[1] NA: Not analysed because there were more than 100 hits.

Table 2 *Relevant hits Pubmed*

Keywords	#hits 8-12-2017	# hits relevant based on keywords, abstract, title
'chemical hazard*' and fruit*	5	2
'hazard analys*' and fruit*	18	1
'risk analys*' and fruit*	40	7

Additionally, around 34 relevant articles and reports were retrieved from Google searches. There were initially 12,515 hits using the described search terms for all years (Table 3). Search terms with >100 hits were limited to the years 2007-2017 and to pdf files. After limiting 'hazard analys*' and fruits with years and pdf file on the FAO website, this still resulted in >100 hits. Therefore, search terms were combined: 'chemical hazard' AND fruits AND analysis, which resulted in 61 hits. Also, 'risk analysis' AND fruits resulted in >100 hits, which was refined to 'chemical risk analysis' AND fruits. For further details, see (van Asselt et al., 2018).

Table 3 *Relevant hits using Google*

Keywords	#hits (08-Dec-17)	# hits relevant based on keywords, abstract, title
'chemical hazard' and fruits Site: who.int	96	7
'chemical hazard' and fruits Site: fao.org	70	5
'chemical hazard' and fruits Site: efsa.europa.eu	28	0
'chemical hazard' and fruits Site: nvwa.nl	0	-
chemical hazard and fruits Site: nvwa.nl	15	3
'chemical hazard' and fruits Site:rivm.nl	3	0
'chemical hazard' and fruits Site: food.gov.uk	181	NA[1]
'chemical hazard' and fruits Site: food.gov.uk (2007-2017)	7	0
'chemical hazard' and fruits Site: fda.gov	57	4
'chemical hazard' and fruits Site: foodstandards.gov.au	8	1
'chemical hazard' and fruits Site: mpi.govt.nz	9	4
'chemical hazard' and fruits Site: bfr.bund.de	1	0
'hazard analysis' and fruits Site: who.int	513	NA
'hazard analysis' and fruits Site: who.int (2007-2017)	41	0
'hazard analysis' and fruits Site: fao.org	1500	NA
'hazard analysis' and fruits Site: fao.org (2007-2017)	179	NA
'hazard analysis' and fruits Site: fao.org (2007-2017) filetype:pdf	169	NA
'chemical hazard' and fruits and analysis Site: fao.org	61	0
'hazard analysis' and fruits Site: efsa.europa.eu	40	0
'hazard analysis' and fruits Site: nvwa.nl	9	0
'hazard analysis' and fruits Site: food.gov.uk	264	NA
'hazard analysis' and fruits Site: food.gov.uk (2007-2017)	57	1
'hazard analysis' and fruits Site: fda.gov	720	NA
'hazard analysis' and fruits Site: fda.gov (2007-2017)	209	NA
'hazard analysis' and fruits Site: fda.gov (2007-2017) filetype: pdf	98	2
'hazard analysis' and fruits Site: foodstandards.gov.au	95	2
'hazard analysis' and fruits Site: mpi.govt.nz	243	NA
'hazard analysis' and fruits Site: mpi.govt.nz (2007-2017)	133	NA
'hazard analysis' and fruits Site: mpi.govt.nz (2007-2017) filetype: pdf	24	0
'hazard analysis' and fruits Site: rivm.nl	23	1
'hazard analysis' and fruits Site: bfr.bund.de	27	0
'risk analysis' and fruits Site: who.int	815	NA
'risk analysis' and fruits Site: who.int (2007-2017)	44	0
'risk analysis' and fruits Site: fao.org	3.310	NA
'risk analysis' and fruits Site: fao.org (2007-2017)	352	NA
'risk analysis' and fruits Site: fao.org (2007-2017) filetype: pdf	317	NA
'chemical risk analysis' and fruits Site: fao.org (2007-2017) filetype: pdf	7	0
'risk analysis' and fruits Site: efsa.europa.eu	249	NA
'risk analysis' and fruits Site: efsa.europa.eu (2007-2017)	18	0
'risk analysis' and fruits Site: nvwa.nl	100	NA
'risk analysis' and fruits Site: nvwa.nl (2007-2017)	23	0
'risk analysis' and fruits Site: food.gov.uk	152	NA
'risk analysis' and fruits Site: food.gov.uk (2007-2017)	16	0
'risk analysis' and fruits Site: fda.gov	323	NA
'risk analysis' and fruits Site: fda.gov (2007-2017)	52	2
'risk analysis' and fruits Site: foodstandards.gov.au	2630	NA
'risk analysis' and fruits Site: foodstandards.gov.au (2007-2017)	219	NA
'risk analysis' and fruits Site: foodstandards.gov.au (2007-2017) filetype: pdf	42	0
'risk analysis' and fruits Site: mpi.govt.nz	469	NA
'risk analysis' and fruits Site: mpi.govt.nz (2007-2017)	133	NA
'risk analysis' and fruits Site: mpi.govt.nz (2007-2017) filetype: pdf	104	0
'risk analysis' and fruits Site: rivm.nl	513	NA
'risk analysis' and fruits Site: rivm.nl (2007-2017)	12	0
'risk analysis' and fruits Site: bfr.bund.de	52	2

[1] NA: Not analysed because there were more than 100 hits. The search was further refined limiting the time period (2007-2017) and/or focusing on pdf files.

The initial literature search resulted in information on a number of possible chemical hazards in fruit. In order to check whether information on certain chemical hazards was missed, an additional literature search was performed using specific keywords as indicated in Table 4.

Table 4 *Relevant hits additional searches Web of Science*

Keywords	#hits 13-07-2018	# hits relevant based on keywords, abstract, title
Dioxin and fruit*	54	3
(PAH OR PFAS OR BFR) and fruit*	77	2
'cleaning agent*' and fruit*	5	0
'food supplement*' and fruit*	240	
Review	39	0
'edible oil*' and fruit*	150	
Review	19	0
'processing contaminants OR acrylamide' and fruit*	102	4
'postharvest preservation' OR 'edible coatings' and fruit*	670	
((postharvest preservation OR edible coatings and fruit*) AND (hazard* OR risk* OR 'food safety'))	42	6

The literature searches performed did not always result in relevant hits. This is explained using the example of dioxin and fruit* for which 54 hits were obtained. Initial screening on title, keywords abstract showed that 47 papers were not relevant, 4 papers were maybe relevant and 3 papers were relevant. The rationale for including or excluding these papers is presented in Annex 3. The 3 relevant papers all included information on dioxin levels in fruit. The 4 papers that were maybe relevant and described dioxins concentrations in products from specific regions (Loutfy et al., 2008; Aslan et al., 2010) and/or gave a very general description of dioxins in food, not specifically on fruit (Miklos et al., 2008). The 47 non-relevant papers did not describe the occurrence of dioxins in fruit products. For example, papers described dioxins in non-fruit products. Fruit is then mentioned once in the abstract (see for example (Amakura et al., 2009) where dioxins are measured in tea materials such as rosa hip from rosa fruit). Or papers are about other chemical hazards in fruit, not on dioxins. For example, (Forouzan and Madadlou, 2014) describe patulin in apple juices and mentions food safety issues such as dioxins in the abstract. Furthermore, many papers were on human health effects of dioxins (see for example (Amakura et al., 2008; Connor et al., 2008; de Waard et al., 2008) or papers described analytical methods (see for example (Pitarch et al., 2007)). The 4 papers that might contain relevant information were read in full and added to the text in case they contained additional information not yet covered by the relevant papers.

Analogous to the procedure described for dioxin and fruit*, all other literature searches from Tables 1 to 4 were screened first on the title, keywords and abstracts to determine their relevance for this study. For relevant papers, the materials and methods and conclusion section were read. A summary of the relevant papers on chemical hazards that may occur in the fruit supply chain is given below.

3.2 Overview of chemical hazards in the fruit chain

Fruit may contain chemical hazards upon consumption when grown on contaminated soil (e.g. heavy metals, trace elements), or treated with contaminated water, fertilizers or pesticides. Furthermore, fruit can contain natural toxicants such as mycotoxins, which are formed in rotten or mouldy fruits. During further processing, products can also be contaminated with chemical hazards, i.e. through the use of cleaning agents or via production of processing contaminants. Hygiene code documents, e.g. HACCP (Hazard Analysis and Critical Control Points) identify various possible hazards during the processing steps. Most chemical hazards identified are residues of agricultural chemicals (pesticides, fungicides) and agricultural compound residues (fertilizers), cleaning chemicals and heavy metals (ANZFA, 2001; NZFSA and New Zealand Food Safety Authority, 2008; MPI and Ministry for primary industries, 2011). During a technical training for risk analysis, Bangladesh and Bhutan members reported that the most important chemical hazards in fruits are pesticide residues and ripening agents (FAO, 2013). The WHO collects data on chemical contamination in food. This WHO Food Contamination Monitoring and Assessment program (GEMS/Food) shows a decline in chemical contamination levels in fruit over time, due to increased restriction on the use of persistent toxic chemicals and pesticides and improved control of environmental pollution (WHO, 2018).

The following paragraphs summarize chemical hazards found in scientific literature and reports in different fruits worldwide.

3.2.1 Heavy metals and trace elements

Heavy metals are either naturally present in the environment, such as arsenic, or ended up in the environment through the use of fertilizers, contaminated sediment or through atmospheric deposition in industrial areas. Crops, such as fruits, grown in areas with elevated levels of heavy metals can take up these substances via the soil or the water. Characteristics of the soil (such as organic matter content and pH) and the crop cultivated on the land influence the uptake of heavy metals by the plants.

Heavy metals were reported in fruits all over the world, although few papers focused on Europe. Through contaminated soil and water, fruits can take up heavy metals in their flesh. EU maximum limit (ML) values in fruit are only set for lead (Pb) (0.1 resp. 0.2 mg/kg for all fruits resp. berries and small fruits) and cadmium (Cd) 0.050 mg/kg fruit) (Regulation (EC) 1881/2006). These limits are set for the edible parts of fruit. For copper (Cu) and mercury (Hg), maximum residue limits (MRL) have been set for fruit in Regulation (EC) 396/2005.

Some papers revealed exceedance of these MLs for Cd and Pb. Fruits (banana, water melon, orange and apple) purchased from local markets in South-West Nigeria contained manganese (Mn), iron (Fe), copper (Cu), chromium (Cr) and Cd. Cd concentrations in the analysed fruit species were found above the EU ML (Akinyele and Shokunbi, 2015). In 2006, Cd and Pb levels in apricot from Turkey were detected in concentrations above the EU maximum limits (Saracoglu et al., 2009). Radwan and Salama conducted a market basket study for Pb, Cd, Cu and Zn in Egyptian (Alexandria) fruits (e.g. apple, banana, melon, date, grapefruit, peach, orange, strawberries and watermelon). The highest mean concentrations of Pb were found in strawberries, peach, melon and date (0.87, 0.38, 0.33 and 0.22 mg/kg dw, respectively). The highest mean concentration of Cd was found in apples and oranges (0.05 and 0.04 mg/kg dw, respectively), Cu in dates (18.3 mg/kg dw) and Zn in melon and strawberries (10.5 and 7.49 mg/kg dw, respectively). The highest Cd levels were above the EU ML for both oranges as apples, Pb levels exceeded the EU MLs for multiple fruit species (Radwan and Salama, 2006). Lacatusu (Lacatusu and Lacatusu, 2008) collected soil and fruit (e.g. cherries, apples and pears) samples from vegetable gardens/orchards within strongly polluted areas in Romania and measured heavy metal content. There, data revealed that heavy metal accumulation in these fruits is low due to storage in other organs of the tree, especially in leaves. Nevertheless, the heavy metal concentration of Cd and Pb still exceeded maximum allowable limits. Nie et al (2016) analysed the heavy metals Pb, Cd, Cr and Ni in fruits, e.g. apple, pear, peach, grape and jujube from different regions in China. Jujube and peach contained the highest concentrations, and grape contained the lowest. Ni was found to be most likely to accumulate and in 2.2% of the total samples (up to 7.3% of peach samples) the levels of Ni exceeded the Chinese maximum permissible limit (0.3 mg/kg). Also, Pb concentrations were found higher than the EU limit (Nie et al., 2016). Raisin (Thompson Seedless raisins) samples from China (Xinjiang province) contained Cd, mercury (Hg) and Pb levels above the WHO provisional guidelines of 0.003, 0.001 and 0.01 mg/kg, respectively (Fang et al., 2010) although more elements (e.g. Arsenic (As), Cr, Cu, Mn, Ni, Fe and Vanadium (V)) were present.

Elbagermi (2012) analysed Pb, Cd, zinc (Zn), Cu, Cr and Ni in various types of fruit (banana, peach, orange, strawberries, watermelon, melon, apple, grape and mango) from market sites in Libya within the safe limits as prescribed by the WHO (Elbagermi et al., 2012). Dates from Saudi Arabia contained various trace elements at different concentrations depending on the location. Pb was not detected (Mohamed, 2000). Apple juice from the USA was contaminated with As (Carrington et al., 2013). FSANZ analysed domestic and imported shelf-stable peach, pear and apricot for As, Pb and tin.

They found no concentrations exceeding the Australian and New Zealand Food Standards Code (FSANZ, 2015).

Conclusion
Fruits may contain heavy metals and essential elements. Most frequently, Cd, Pb and Ni were detected in fruits, in most cases below legal limits. However, depending on the location, EU MLs for Cd and Pb were exceeded and Ni exceeded the Chinese MPLs. Therefore, these elements were included on the intermediate list.

3.2.2 Persistent organic pollutants

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation. As such they remain in the environment for a long time and may bio-accumulate resulting in potential adverse effects on human health. Fruits may become contaminated with POPs through uptake of these substances via the environment during cultivation.

3.2.2.1 Dioxins

Dioxins (polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)) are persistent, lipophilic compounds that accumulate in the environment and food chain, mainly in the fatty tissue of animals. Dioxins are found worldwide in the environment. Polychlorinated biphenyls (PCBs) cover a group of substances that can be divided into two groups: dioxin-like polychlorinated biphenyl (dl-PCBs, having toxicological properties similar to dioxins) and non-dioxin-like PCBs (ndl-PCBs). The main contribution to human total intake of dioxins and PCBs is from animal origin, e.g. eggs, milk, fish. For products of animal origin maximum levels are established by the EU as well as for vegetable oils and fats (Regulation (EC) 1881/2006).

Although fruits and vegetables may grow on polluted areas, information on the levels of dioxins and ndl-PCBs in fruits is scarce. One study analysed dioxin levels in fruits and vegetables from the area between Napoli and Caserta, Italy, which has been polluted in the past and high levels of dioxins were found in foods from this area. Levels of dioxins and ndl-PCBs in apricot were higher than in other fruits, but were still relatively low compared to animal products (Esposito et al., 2017). A Turkish study confirmed that fruits from a polluted area had low levels of dioxins; most of the congeners were < 0.25 pg TEQ/g (Aslan et al., 2010). In addition, other studies concluded that concentrations in fruits are low (Grassi et al., 2010). A Korean study showed that dioxin intake via fruit contributed only 1.6% of the WHO TDI of 4 pg-TEQ/kg body weight (b.w.)/day using a body weight of 60 kg and local consumption data (Choi et al., 2012).

3.2.2.2 Per- and polyfluoroalkyl substances (PFASs) and brominated flame retardants (BFRs)

PFASs are man-made chemicals that have been manufactured and used in different industries worldwide since the 1940s. BFRs are widely used, since the 1970s, in among others electronic household products, plastics and textile. These chemicals are very persistent in the environment and in the human body.

PFASs were not quantifiable in any fruit or fruit products analysed in a monitoring study on PFASs substances in food in the period of 2000-2009 (EFSA, 2011). An assessment performed by FSANZ also showed no detections of PFASs chemicals in any of the analysed fruits (FSANZ, 2017). The presence of the PFASs, perfluorooctane sulfonic acid (PFOS) and perfluorooctanicoic acid (PFOA) in food was recently discussed by EFSA (2018). PFOS were not detected in fruit or fruit products. PFOA was quantified in 30% of the fruit and fruit product samples (total 205 samples), mainly for apples and oranges. The mean PFOA concentration in this food category was 0.005 µg/kg LB/0.30 µg/kg UB. Fruits were not indicated as main contributors to PFOS or PFOA intake (EFSA, 2018c).

Fruits were not one of the main contributors to the dietary exposure to BFRs (contribution <2%) (RIVM, 2006). Both RIVM and Driffield et al. 2008, based on UK 2004 Total Diet study, concluded that BFRs as measured in foods were not of human health concern.

Conclusion POPs
Based on the characteristics of the POPs and the results found in literature, POPs are not expected to be present in fruit or fruit products at such levels that they will be of human health concern (no exceedances of heath based guidance values).Therefore, POPs are not included on the intermediate list.

3.2.3 Pesticides

Within the fruit chain, a wide range of pesticides c.q. plant protection products are used. According to Kushwaha et al. (2016) organophosphorus pesticides are the most widely used group of pesticides globally, of which profenofos is one of the most largely used organophosphate insecticides on fruit crops (Kushwaha et al., 2016). In the EU, profenofos is not approved for use since 2004 (EC, 2018).

According to the Dutch multi-annual national control plan (MANCP) in 2014, cactus fruit from Vietnam, cucumber-like fruit with an edible peel from Surinam, passion fruit from Colombia, pomegranate from India and Peru and lime from Brazil had high (up to 42.9% > MRL) non-compliance percentages for different pesticides, while in 2015 only lemons from Brazil had a high non-compliance percentage (NVWA, 2014, 2015). The most recent report of NVWA inspections on pesticide residues on fruit and vegetables (until December 2016) revealed pesticide residues above the MRL found in blueberries, cactus fruit, cherimoyas, grapefruits, grapes, lime, lychee, melons, papayas, passionfruit, mandarins, oranges, pomegranates, plums and strawberries (NVWA, 2017b). In 2016 important product/country combinations with the greatest MRL non-compliances were vine leaves from Turkey, rambutans from Vietnam, goji berries from China and oranges from Egypt. Also, strawberries from Egypt and cactus fruit from Vietnam had a high non-compliance percentage. Attention is given to products from South East Asia, the Dominican Republic, Surinam, Egypt, India (grapes) and China (NVWA, 2016b). Individual analyses at grocery stores in the Netherlands in 2016 revealed residues higher than MRL for dimethomorph in minneola's from Peru, chlorophenapryr, chlorantranililprole, flutriafol and thiabendazole in passionfruit from Colombia, propargite in plums from Spain and imazalil in oranges from Argentina. The highest number of different pesticide residues was found in strawberries, all below MRL (NVWA, 2016a).

EFSA annually publishes an overview of the EU-coordinated control programme (and results of national control programmes) on pesticide residues. In the EU-coordinated control programme the random (not risk based) monitoring on the selected fruits is repeated after three years. The most recent report provides an overview of the 2016 results of apples, peaches and strawberries. In 63.5% of the apple samples, 77.8% of the peaches and 77.4% of the strawberry samples one or several pesticides were found. The MRL exceedance rate for apples was 2.7% (11 different pesticides), for peaches 1.9% (10 different pesticides) and for strawberries 1.8%. For apples, up to 10 different pesticides were reported in one sample, for peaches 13 and for strawberries even up to 16 different pesticides were found in an individual sample. The most frequently quantified pesticides in apples were captan, boscalid and dithianon, while the MRL was exceeded most frequently for chlorpyrifos, diphenylamine, dimethoate and carbendazim. In peaches, the most frequently detected pesticides were tebuconazole, fludioxonil and dithiocarbamates, while the MRL was exceeded for 10 pesticides, of which 3 (propargite, carbendazim and procyidone) are not approved at the EU level. Most MRL exceedances were found in samples originating from Malta (8 samples with chlorpyrifos, 6 samples with deltamethrin, 4 samples containing dimethoate and 1 with etofenprox). In strawberries, cyprodinil, fludioxonil and boscalid were most frequently detected, while the MRL was exceeded most frequently for spinosad, tebuconazole, dimethoate and carbendazim. Repeatedly found non-approved substances in apples, strawberries and peaches were carbendazim, diphenylamine, propargite, hexaconazole, dicofol, and dichlorvos (EFSA, 2018a).

The report of 2015 results included only two fruits in the EU-coordinated programme, i.e. bananas and table grapes, and orange juice. The MRL exceedance rate for grapes was 1.7% and for bananas 0.3%. In 73.1% of the bananas, 77.3% of the grapes and 15.2% of the orange juice samples one or multiple residues were found. For bananas, up to 9 different pesticides in an individual sample were found, for orange juice up till 7 different pesticides and in table grapes even up till 19 different pesticides were reported in an individual sample. The most frequently found pesticides were imazalil, thiabendazole and carbendazim in orange juice, thiabendazole, imazalil and azoxystrobin in bananas, and different fungicides (boscalid, dimethomorph, dithiocarbamates, fenhaxamid) and ethephon in table grapes (EFSA, 2017a).

In 2014, mandarins, oranges and pears were part of the EU-coordinated monitoring programme. The MRL exceedance rate for mandarins was 2.6%, pears 1.6% and oranges 1.5%. In 79.1% of the mandarins, in 79.6% of the oranges and in 74.9% of the pears one or several pesticide residues were found. For mandarins and oranges up to 9 different pesticides in an individual sample were found; the most frequently detected pesticides were imazalil, chlorpyrifos and thiabendazole. In pears, even up till 14 different pesticides were reported in an individual sample. The most frequently found pesticides in pears were dithiocarbamates, captan and boscalid (EFSA, 2016a).

Apples, peaches/nectarines and strawberries were also analysed in the EU-coordinated monitoring programme of 2013. 2.5% of the strawberry samples exceeded the MRL, 1.1% of the peach/nectarine samples and 1.0% of the apple samples. In 76% of the strawberries, in 75% of the peaches/nectarines and in 67% of the apples multiple residues were found. In apples, up till 17 different pesticides were found in a single sample, the most frequently detected pesticides were captan/folpet, dithianon and dithiocarbamates. In peaches/nectarines and in strawberries up to 15 different pesticides were detected in individual samples. The most frequently detected pesticides in peaches/nectarines were tebuconazole and dithiocarbamates; in strawberries the most found pesticides were boscalid, cyprodinil, fludioxonil, fenhaxamid and pyraclostrobin (EFSA, 2015a).

In 2012, MRL exceedances were found in 1.8% of table grape samples, in 0.7% of banana samples, and no exceedances were found in orange juice. Highest percentages of MRL exceedances in fruits were found for fluazifop-P-butyl (1.1%), ethephon (1.0%) and folpet (0.8%) in table grapes (EFSA, 2014a).

In 2013-2015, between 30 and 38% of the MRL exceedances in the EU-coordinated programs were pesticides that are currently not approved in the EU (EFSA, 2015a, 2016a, 2017a).

The results of the EU and Dutch monitoring programmes correspond with data found in scientific literature. George and Aneesh (George and Aneesh, 2017) reported that among the fruits in the USA strawberries contain the largest number of different pesticides. One sample of strawberries even contained 17 different kinds of pesticides. Also, apples, nectarines, grapes and cherries frequently contained pesticide residues. The most frequently detected pesticides in strawberries, according to George and Aneesh (2017), were carbendazim, bifenthrin and malathion. In the EU, carbendazim is not approved for use since November 2014 while malathion is not approved in the Netherlands. In addition, in the Netherlands bifenthrin is only approved as wood preservative (website ctgb dd 6-6-2018). Lozowicka et al. (2016) indicated that fungicides have been used for many years to protect fruits in Poland and residue monitoring revealed that in currants, apples, cherries, strawberries and pears residues were found most frequently. Especially, dithiocarbamates and captan were frequently detected. Fungicide residues were detected in 52.0% of the 974 fruit samples tested between 2005-2014 of which 1.7% exceeded the MRLs. Gooseberries, strawberries, apples and currants had the highest number of samples with multiple residues (Lozowicka et al., 2016). One or more pesticide residues were detected in 59.6% of the table grapes tested in Turkey in 2016, of which 20.4% exceeded the MRL. The most frequently found pesticides were azoxystrobin, chlorpyrifos, boscalid and cyprodinil (Golge and Kabak, 2018).

Pesticide residues were also detected in 18% of the date fruit samples collected in large markets in Saudi Arabia, and 7.5% exceeded the EU MRL (Abdallah et al., 2018). Kishore et al (Kishore et al., 2015) published a review on the use of paclobutrazol in perennial fruit crops, which was detected in various fruits amongst others mango, pineapple, litchi, mandarin, grape, peach apricot, apple and strawberries, worldwide. The German BfR reported that they frequently find multiple residues in fruits, particularly in grapes, strawberries, pome fruit and citric fruits. The various active substances were applied between sowing and harvesting. The effect of the presence of multiple residues on human health is unknown (BfR, 2005).

In April 2018, nicotine, carbofuran and propargite was found in Belgium in goji berries, these berries were imported through the Netherlands and France and originated from China. Multiple samples exceeded the MRL. The concentration of nicotine was 550 µg/kg (MRL is 2 µg/kg). Carbofuran and propargiet were found at concentrations of 0.083 and 0.023 µg/kg goji berries. These compounds are not allowed in Europe, USA and Brazil (VMT, 2018).

In Spain (Madrid region) apples and orange juices were tested for a total of 100 pesticides. Residues were found in 87% of the apples analsyed and in 16% of the orange juice samples. Orange juices contained only residues from a single pesticide (two types of organophosphates chlorpyrifos and diazinon), while almost 75% of the apples contained residues of multiple (up to seven different) substances, i.e. organochlorines, organophosphates, carbamates, pyrethroids. The most abundant pesticides were captan, folpet, phosalone, diphenylamine and chlorpyrifos. Although pesticide concentrations found were all below the EU MRLs (Iñigo-Nuñez et al., 2010), diazinon (December 2007), phosalone (June 2007) and diphenylamine (June 2012) are no longer approved by the EU. In orange juice only diazinon and chlorpyrifos were found at levels lower than found in oranges.

A study by Keikotlhaile (2010) indicated that processing may influence the presence of pesticides in fruit products. The results from a meta-analysis showed that blanching, cooking, frying, peeling and washing reduced the pesticide residue levels in fruits. After baking, boiling, canning and juicing both an increase and a reduction was found, probably depending on the physio-chemical properties of the pesticide (Keikotlhaile et al., 2010).

Conclusion
The literature study revealed that many fruit species contain multiple residues of pesticides some of which exceeded the EU MRLs. The fruits with the most pesticide residues are strawberries and table grapes in numerous countries. A large percentage (30-38%) of non-conformaties in the EU-coordinated programmes between 2013 and 2015 were found for pesticides not authorized in the EU, i.e. carbendazim, carbofuran, diazinon, dichlorvos, dicofol, diphenylamine, hexaconazole, malathion, procymidone, profenofos and propargite. These pesticides were therefore included on the intermediate list. Other pesticides included on the intermediate list were pesticides frequently found in monitoring data and pesticides authorised in the Netherlands which are seen as human toxic (see section 3.4.2).

3.2.4 Mycotoxins

Mycotoxins are produced by fungi. Fruits can become contaminated with mycotoxins during cultivation if they are infested with fungi capable of producing mycotoxins. After harvest, proper storage is important to prevent mycotoxin contamination. Wet and warm environments stimulate fungal growth and toxin formation resulting in elevated levels of mycotoxins such as aflatoxins on fruit species.

Mouldy and rotten fruits can be a source of different mycotoxins. There are reports of patulin contamination in apples, pears and apple juice, ochratoxin A (OTA) in grapes, and *Alternaria* toxins in a variety of fruits including apples, grapes, dried vine fruits, oranges, lemons and mandarins (Paster and Barkai-Golan, 2008; Zhao et al., 2015). The US FDA published an overview of literature findings of food safety problems, including mycotoxin contamination in fruits and apple juice (US FDA, 2004).

Patulin was detected in Fuji apples collected from different markets in Brazil (Parana and São Paulo States). In 32 out of 35 apples patulin was detected at different levels in rotten as well as unaffected areas of the apples. Detection of patulin in unaffected parts of the apple confirmed that patulin could migrate through the apple tissue (Celli et al., 2009). Patulin is also detected in European apples and apple juices, including apples originating from the Netherlands and Belgium (De Clercq, 2016). Patulin can be produced by *Penicillium expansum* in apples that are damaged i.e. fallen, damaged, mouldy, rotten or improperly stored. As *P. expansum* can grow and produce patulin at low temperatures, patulin can also be produced post-harvest. When even one of these apples is used to make apple juice, the resulting patulin level could exceed the FDA action level of 50 µg/L (US FDA., 2004).

OTA contamination is found in grapes; its derived products (i.e. grape juices) are the second most contaminated after cereals (Akdeniz et al., 2013; Zhang et al., 2016). OTA can be produced by different fungi. *Aspergillus* spp. favours hot and wet climates, while in countries with a low temperature climate OTA is produced by species belonging to the *Penicillium* family (el Khoury and Atoui, 2010). Higher levels of OTA, compared to grapes, were found in 92% of the *pekme*z samples (boiled and concentrated grape juices) from Turkey (Akdeniz et al., 2013). Of these samples, 48% contained concentrations exceeding the EU maximum limits. Different *Aspergillus* spp were detected in grape products from the Mediterranean Basin of Southern Europe (i.e. Greece, Spain, France and Italy), North Africa and Australia. The resulting OTA concentrations were dependent on the grape species (Battilani et al., 2003).

Aflatoxins were found in dry fruits from Pakistan. In dried plums, dates, apricot, raisins, figs and (water)melon seeds without shells, aflatoxins (B_1 and total) were present with levels in the range of LOD up till levels exceeding the EU permissible level of AFB_1 and total AFs (except for raisins and (water)melon seeds without shells) (Masood et al., 2015). Dried figs from Turkey also were contaminated with aflatoxins (WHO and FAO, 2013). Dried tropical fruits were contaminated with AFB_1 and OTA (NVWA, 2016b). Most of the dried fruit available in New Zealand (2008-2009) contained low levels of aflatoxins and OTA. Aflatoxin was most frequently found in figs and OTA in dried vine fruits as raisins, sultanas and currants, with the exception of a high concentration of OTA detected in figs (MPI, 2009). In 2006, 57 RASFF notifications were reported regarding aflatoxin in dried figs and derived products primarily originating from Turkey (Paster and Barkai-Golan, 2008).

Conclusion
Mycotoxins may be present in damaged fruits due to growth of fungi. Patulin is found in apples and apple juices, and OTA in grapes and derived products. Furthermore, dried fruit can contain aflatoxins and/or OTA. For these mycotoxins exceedances of the EU MLs were found in literature. Therefore, patulin, OTA and aflatoxins are included on the intermediate list.

3.2.5 Plant toxins

Cyanogenic glycosides are present in a wide range of plant-based products such as elderberries, cassava and in kernels of stone fruits such as apricots, peaches and plums, and are degraded to cyanide (HCN) by chewing. Recently, EFSA published a scientific opinion on acute health risks related to cyanogenic glycosides in raw apricot kernels and derived products. They reported concentrations ranging from not detected up to 3.8 mg/g cyanide (based on a conversion from amygdalin to HCN (EFSA, 2016b). Regulation (EC) No 1334/2008 prescribes that HCN shall not be added to food as flavouring, however it may be naturally present in food ingredients. Therefore, a maximum level for HCN of 5 mg/kg is set in canned stone fruits. For non-canned apricot kernels (unprocessed whole, ground, milled, cracked, chopped) placed on the market for the final consumer a maximum level for HCN of 20 µg/kg is established (Regulation (EC) No 1881/2006). The reported maximum concentration exceeds the limit of 20 µg/kg by 190.000 times. Consumption of raw apricot kernels was linked to HCN poisoning in Australia (WHO and FAO, 2013) and also in the Netherlands (Omroep Brabant, 2017). (ANSES, 2018) warns consumers that an adult should not eat more than 2-3 apricot kernels per day (half a kernel for young children per day) of this claimed but not scientifically proven 'cancer-fighting food' to not exceed the safe limit established by EFSA. Higher consumption may lead to cyanide poisoning, since the kernels contain high levels of amygdalin which converts to the toxic compound cyanide during digestion.

In Australian and New Zealand, cyanide levels were found in a wide range of plant-based foods, e.g. apple juice, apricot kernels, apricot nectar, cassava roots, bamboo shoots and bread containing linseed in concentrations below the regulatory limit with the exception of raw apricot kernels. The FSANZ analysed different products (e.g. cassava, apple products, stone fruit products, passion fruit and derivate) on the presence of cyanogenic glycosides (measured as hydrocyanic acid (HCN)). These products all contained high HCN concentrations, with one cassava root and an apricot nectar sample exceeding the maximum limit of the Australian and New Zealand Food Standards Code of 50 mg HCN/kg sweet cassava and 5 mg HCN/kg stone fruit juices (FSANZ, 2014). Cyanogenic glycosides can also be determined based on amygdalin content. Bolarinwa et al. (2014) measured amygdalin in different fruit seeds and processed products and found that concentrations varied considerably between different fruits. Green plum contained the most amygdalin, followed by apricot, black plum, peach and cherry, while purple, yellow and red plums, apple, pear and nectarines had the lowest concentrations. The amygdalin concentrations of processed products were lower compared to the fruit seeds and kernels (Bolarinwa et al., 2014).

In liqueurs made from apricot pits considerable amounts of cyanogenic glycosides (measured as amygdalin and prunasin) were found ranging from 0.016 to 0.04 mg/g (Senica et al., 2016). The maximum limit for alcoholic beverages is 0.035 mg HCN/g (Regulation (EC) No 1334/2008).

A different plant toxin, hypoglycin, is found in ackee, the national fruit of Jamaica. Hypoglycin can be found when the fruit is picked too early and is not ripe (US FDA, 2014). Ackee fruit is not consumed frequently in the Netherlands.

Conclusion
The most relevant plant toxin for fruits is cyanogenic glycosides that may be found in apricot kernels. HCN may be formed after the hydrolysis of cyanogenic glycosides that occurs during crushing of the plant material either during processing of the plant or during consumption (while chewing). Levels of HCN were found above the legal limits, which may pose human health problems. As a result, HCN is included on the intermediate list.

3.2.6 Radionuclides

Contamination of fruit with radionuclides can occur via airborne deposition directly on the fruit or via other aboveground parts of the plant, or via soil-to-fruit transfer in the plant. Soil-to-fruit transfer of radionuclides is nuclide and plant specific and also depends on the time of deposition, and soil characteristics such as pH, clay, silt and organic matter content (Carini et al., 2003; Hegazy et al., 2013).

In the EU, maximum permitted levels (MPLs) are set for food and feed following a nuclear incident. For food (including fruit), the MPL for ^{90}Sr is 750 Bq/kg) for ^{131}I 2000 Bq/kg) for ^{239}Pu and ^{241}Am 80 Bq/kg), and substances with a half-life greater than 10 days including ^{134}Cs and ^{137}Cs 1250 Bq/kg) (Council regulation (Euratom) 2016/52). For food products imported from countries following the Chernobyl accident, the accumulated MPL for ^{134}Cs and ^{137}Cs is 600 Bq/kg ((EC) 2008/733).

In the Spanish region Valenciana radioactivity levels were monitored in a range of foods between 1991-2013. In fruit, ^{40}potassium (K) was detected ranging from 18 Bq/kg of oranges to 133 Bq/kg of melon (no reference value available). Also, in unpeeled grapes and apricots, ^{7}beryllium (Be) was detected (Ballesteros et al., 2015).

^{226}Radium (Ra) and ^{228}Ra activity was found to be higher in berries than in fruits from trees (Renaud et al., 2015). In French berries ^{228}Ra activity between 0.1-0.73 Bq/kg ww was detected, which is above the reference value set by UNSCEAR of 0.02 Bq/kg ww. This reference value is used to assess to dose to which the population is exposed. In Germany, between 0.03-5.38 Bq/kg ww ^{226}Ra was measured in berries (UNSCEAR, 2000; Renaud et al., 2015).

An Italian diet study measured ^{210}Polonium (Po) activity in over 120 food products and found levels decreasing from leafy vegetables > flour > rice > fruits > pasta > other vegetables (i.e. onion, potato, fennel)> fruiting vegetables (e.g. courgette, tomato). Activity measured in fruits (0.034 Bq/Kg ww (0.006-0.069)) was in the range of the reference value given by UNSCEAR (0.04 Bq/kg ww) (Meli et al., 2014). ^{210}Po was also measured in mandarin, orange, pear and apple in the Catalan stretch of the Ebro River area in Spain. Concentrations for pear and apple were <0.1 Bq/kg and for mandarin and orange 0.22 ±0.11 and 0.36 ±0.23 respectively. In these same study, ^{210}lead (Pb) was measured in concentrations below the limit of detection, except for apples (0.37 ±0.07) thereby exceeding the reference value of 0.03 Bq/kg (UNSCEAR, 2000; Nadal et al., 2011).

In the Netherlands, radioactivity was analysed in food products (e.g. fruits) in 2015 for the presence of ^{134}Cs, ^{137}Cs and ^{90}Sr. Samples tested on fruit contained < 5 Bq/kg for both ^{137}Cs and ^{90}Sr (RIVM, 2016).

Processing steps can lead to a reduction in levels. The decrease in concentrations depends on the type of nuclide. For example, rinsing contaminated apples and grapes with tap water removed ^{85}Sr to a greater degree than ^{134}Cs. Turning grapes into wine reduces ^{134}Cs with 40%, while making olive oil leads to a reduction of 75% of ^{134}Cs and 90% of ^{85}Sr in olives (Carini et al., 2016).

Conclusion
Multiple radionuclides may be present in fruits depending on the location. Levels in fruit are lower than the legal limits in the EU and appear to be lower than levels found in vegetables. Therefore, radionuclides are not included on the intermediate list.

3.2.7 Fertilizers

Perchlorate is present in soil due to the use of fertilizers. Fertilizers may contain calcium carbonate, which can be obtained from areas with a natural occurrence of perchlorate. Chilean fertilizers contain between 0.1 and 0.3% perchlorate (Calderón et al., 2017). Plants grown on soil containing this perchlorate can take up this substance from the soil. There is no legal maximum limit for perchlorate, but the EC has set a reference value for intra-Union trade of 0.1 mg/kg fruits (EC., 2015). Furthermore, in an EU recommendation (Recommendation (EU) 2015/682) member states are encouraged to monitor the presence of perchlorate in foods using a method of analysis with a limit of quantification of 10 µg/kg. Calderon reviewed perchlorate occurrence in fruits produced and marketed worldwide. Focus was given to grapes from Chile, but levels of perchlorate have also been reported in fruits from Italy (kiwi, plums and Abate pears), Spain (pomegranates), Chile (apricot, raspberries), Guatemala (cantaloupe), Dominican republic (cantaloupe), Kuwait (grapes, orange, melon) (Calderón et al., 2017). Highest mean levels of perchlorate reported exceeded the reference value of 0.1 mg/kg fruits for apricots (Chile, 0.145 mg/kg) and cantaloupe (Guatemala 4.63 mg/kg, Costa Rica 0.15 mg/kg, Dominican Republic 0.713 mg/kg). Apart from the presence of perchlorate in fertilizers, they may also naturally be present in the soil or could be present due to the use of water disinfected with chlorinated substances that degrade to perchlorate (EFSA, 2014b). The NVWA analysed 64 samples of fruits and vegetables in 2015 and 66 in 2016. None of the samples exceeded the EU reference level (NVWA, 2017a).

The nitrate content of crops can be increased due to the use of nitrogen fertilizers. Nitrogen fertilization is the primary nitrate source for uptake in plants. A recent extensive literature review evaluated around hundred vegetable and fruit crops and concluded that fruits do not accumulate high levels of nitrate. The average nitrate content in fruit was very low (<15 mg/ kg fw), except for bananas, which may accumulate up to 100 mg/kg fw. Accumulation of nitrate in fruits was low compared to concentrations found in herbs (1000-5000 mg/kg fw) and leafy vegetables (200-5000 mg/kg fw) (Colla et al., 2018).

Conclusion
Perchlorate may be present in fruits from outside the EU at concentrations exceeding the reference value of 0.1 mg/kg. Therefore, this compound was included on the intermediate list.

Nitrate levels in fruits were observed to be low (<15-100 mg/kg fw), compared to nitrate levels found in herbs and leafy vegetables (up to 5000 mg/kg fw). As a result, nitrate was not included on the intermediate list.

3.2.8 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs comprise a large group of substances that are formed through incomplete combustion of organic matter such as fuels or forest fires and may lead to environmental contamination. A specific literature search was performed to find papers on PAHs in fruits. This yielded only one overview article regarding PAHs in raw fruits (Paris et al., 2018). Paris et al (2018) concluded that fruits and fruiting vegetables (e.g. tomato) generally have lower PAH contents than vegetables. PAH levels were related to PAH content in the environment of growing crops. Levels determined in fruits were low with concentrations between 0.01 and 0.5 µg/kg ww for 16 PAHs classified as priority pollutants by the US Environmental Protection Agency (EPA). Lighter PAHs (based on molecular weight such as napthalene) were predominant and preferentially accumulate in peels.

Apart from environmental contamination of fruits, PAHs may be formed during processing, when fruit is exposed to high temperatures. Benzo(a)pyrene (Bap) has been used as a marker of the group of PAHs, and the sum of benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene. There is no European maximum limit established for PAHs for fruit and vegetables, except for banana chips (Regulation (EC) 1881/2006), which has an ML for benzo(a)pyrene of 2 µg/kg and 20 µg/kg for the sum of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene. MLs for banana chips were set in 2015 because high levels of PAHs were found in banana chips due to the frying of these chips in coconut oil. Due to a lack of sufficient occurrence data in banana chips, the ML was set to the ML of coconut oil (Regulation (EU) 1933/2015).According to EFSA, cereals and cereal products together with seafood and seafood products have the highest contribution to consumer PAH exposure (median value of 67 and 36 ng BaP/day, respectively). Fruit consumption (assuming 4% dried fruits and 96% fresh fruits) resulted in a median exposure of 5 ng BaP/day (EFSA, 2008b).

Conclusion
The limited information available on PAHs in fruits indicate that these substances are generally found at low levels in raw fruits. However, PAHs may be found in banana chips due to frying. Since there is currently a lack of information on the PAH levels present in banana chips, this chemical hazard is included on the intermediate list.

3.2.9 Processing contaminants

Fruit can be processed in multiple ways i.e. to fruit juices, oils, cut fresh fruits, canned fruits, dehydrated or dried fruits and fried fruits. During heating steps, like frying and drying, processing contaminants, such as polycyclic aromatic hydrocarbons (PAHs), furan and acrylamide can be formed. PAHs have been discussed in section 3.2.8.

Furan is formed when a product is heated and contains ascorbic acid, amino acids, carbohydrates, unsaturated fatty acids and caretenoids (EFSA, 2017c). EFSA concluded that depending on the age of the consumer the main contributors to dietary intake are ready-to-eat meals, grain and grain-based products and coffee (EFSA, 2017c).

A risk assessment for furan contamination revealed that fruit consumption contribute for 9% to the total furan exposure of Belgian children (Scholl et al., 2012). Other relevant products contributing to furan exposure were soups (19%), milk and milk beverages (17%), pasta and rice (11%), and potatoes (9.4%). Calculated total estimated daily intakes of furan for children were rather low in this study. A small percentage (7%) of the population of children exceeded the oral chronic RfD.

Acrylamide can be formed when products are heated above 120 °C and contain asparagine and reducing sugars (EFSA, 2015b). EFSA concluded that highest levels of acrylamide are found in coffee and coffee substitutes, potato crisps and snacks and potato fried products (EFSA, 2015b).

Acrylamide is reported to be present in dried fruits, mainly in dried prunes and pears; for other dried fruits data is very scarce. Exposure to acrylamide from dried fruits is estimated to be lower than 0,3% of the total acrylamide exposure (Gökman, 2016). In dried fruit slices, dried prunes and dried pears, acrylamide levels (ranging from 15-332 mu g/kg) were relatively low compared to levels found in other products (Becalski et al., 2011; Gökman, 2016; De Paola et al., 2017). However, a large variation between species and brands was found, some incidental high acrylamide values were found in specific types of dried pears by Health Canada (Gökman, 2016).

Conclusion
Furan and acrylamide can be formed when fruits are heated for example to produce dried fruits or crisps. Fruit products are, however, not the main contributor to the dietary intake of these processing contaminants. As a result, furan and acrylamide are not included on the intermediate list.

3.2.10 Substances added to fruits and fruit products

Several substances may be added during fruit processing. These include processing aids, ripening agents, colourants and additives.

Processing aids may be added to improve the quality or shelf-life of fruit products. To enhance preservation, fruit can be processed into fruit juice powder by multiple techniques, e.g. freeze drying, foam mat drying and spray drying (Shishir and Chen, 2017). Foam mat drying implies that fruit juice is first turned into foam using air or other gases and then dried using hot air. Spray drying seems to be the most cost-efficient technique and the major dried fruit juices are mango, banana, orange, guava, bayberry, watermelon and pineapple. In spray drying, liquids are removed from the fruits by rapid evaporation on spray droplet under high temperature exposure. An atomizer or spray nozzle is used to disperse the liquid in a controlled drop size spray. Drying agents are added to the fruit juice, for example maltodextrin or liquid glucose, which results in moisture evaporation. The drying agents can form an outer layer on the drops to change the surface stickiness (Verma and Singh, 2015). Apart from approved drying agents, no chemicals are introduced during these drying methods and no additional chemical hazards are identified. In case processing aids are used resulting in residues on the final products, these residues should not result in human health risks (Regulation (EC) No 1333/2008).

Artificial ripening makes it possible to harvest prior to full ripening of the fruits, which facilitates transportation. Ripening agents will give the fruit sweetness, flavour, colour, softness and will speed up ripening. There are no international regulations for artificial ripening agents; many countries have their own legal framework regarding these substances (Islam et al., 2016). Ethylene is the major ripening agent naturally produced by fruits. Many artificial ripening agents are used to release ethylene and speed up the ripening process. Examples are ethanol, methanol, ethylene glycol, ethephon and calcium carbide (Mursalat et al., 2013). Calcium carbide is carcinogenic and prohibited in most countries and also by the Food Safety Standards Act of India (FSSA (2006)), but is reported to be still used by retailers in many regions of south Asia, including India, Bangladesh and Nepal (Mursalat et al., 2013; Panghal et al., 2018). India is an important exporting country for the Netherlands, mainly for berries and small fruits (NVWA, personal communication).

Edible coatings or films are thin edible layers on the surface of fruits to provide a barrier to moisture, oxygen and solute movement. Polysaccharide coatings are widely used, but coatings based on proteins or fats are also possible. In case proteins are used, edible coatings may contain gelatine, corn zein, wheat gluten, soy protein, casein, keratin, collagen or whey. These proteins can trigger an allergic reaction and presence thereof should be mentioned and emphasized in the ingredient list of the product. Nevertheless, fresh fruit is excluded from the obligation of providing an ingredient list, but the presence of these allergens should still be mentioned after the word "contains". (European Parliament and Council, 2011; European Parliament and Council, 2002; Dhall, 2013).

Plasticizers, surfactants, lipids and other polymers can be incorporated to improve the functional properties of the coatings. According to EU and US legislation edible coatings can be classified as food products, food ingredients, and food contact materials. Chemical substances added to coatings are regarded as food additives; however, each country has its own list of approved additives. New technologies, like nanotechnology or multilayer techniques, are under investigation for future use in edible coatings (Dhall, 2013).

Additives can also be used in the fruit supply chain. This is regulated in Regulation (EC) 1331/2008. In some cases, unauthorised colourants are used. Pangal et al., 2018 mentioned the adulteration of cut fruits from India in which colourants were used to attract consumers. Adulteration was also found in melons and watermelon in India where red dye and sweetener were injected into the melons.

Conclusion
The literature review did not indicate any human health problems related to processing aids and edible coatings used for fruits or fruit products. After harvest, illegal ripening agents, colourants and sweeteners may be used to mislead consumers. This may cause human health problems, as was shown for the prohibited ripening agent calcium carbide. As a result, prohibited ripening agents and unauthorised colourants are included on the intermediate list.

3.2.11 Cleaning agents and disinfectants

Throughout the fruit supply chain cleaning and disinfection is performed and the fruit can come into contact with residues of cleaning agents and disinfectants. Disinfectants may leave residues on fruit when rinsing is not performed adequately by the producer or the consumer. Biocides are used in the food industry for the disinfection of the processing sites, equipment, transport or storage containers for example. Biocides that are regularly used in general are quaternary ammonium compounds, peracetic acid (PAA), and sodium hypochlorite, which all have MRLs (Ctgb 2018). Biocides can also be used as food preservatives. In that case, they are considered as food additives and authorised for use by the EU. Biocides are used in the food industry for the disinfection of the processing sites, equipment, transport or storage containers for example.

Conclusion
The literature study did not indicate any possible chemical hazards in fruit related to the use of cleaning agents and disinfectants in the fruit supply chain. Therefore, cleaning agents and disinfectants are not included on the intermediate list.

3.2.12 Allergens

Allergy to fruits have been described for some commonly consumed fruits e.g. apple, musk melon, kiwi, peach, grape, banana, custard apple, strawberry, mango, pomegranate and cherry, but also tropical fruits such as pineapple and berries cause allergic reactions. The most frequent allergic reactions to fruits can be divided in two types of allergies, pollen-food cross-reactions and lipid transfer protein (LTP) reactions. Pollen-food reactions mainly evoke oral allergic reactions triggered by eating fresh fruits, caused by the presence of cross-reactive IgE to certain (mostly birch) pollens. Birch pollen allergens share common epitopes with allergens in some fruits and berries. Following a primary sensitization to birch pollen allergen, a subsequent IgE cross-reaction with homologous proteins in the consumed fruit occurs, a so called type II food allergy (Hassan and Venkatesh, 2015).

LTP reactions result from a primary sensitization to LTPs, stable plant food allergens, and lead to systemic reactions and even anaphylaxis. These allergens can resist heat treatment and enzymatic digestion. LTPs can induce sensitisation and eliciting reactions and are type I food allergies induced by both fresh and processed fruits (Fernandez-Rivas, 2015).

Conclusion
Some people are allergic to some fruit species. However, fruits do not belong to the allergens that need to be labelled as an allergen. As a result, allergens are not included on the intermediate list.

3.3 Data analysis

The KAP database included a total number of 465.350 samples tested on pesticides and 12.909 samples tested on other substances for the period 2013-2017. For the pesticides, 1293 samples (0.28% of all samples tested) contained residues of pesticides in concentrations above the MRL. For 24 pesticides, the percentage of samples that exceeded the MRL was larger than 1%. These 24 pesticides and corresponding MRLs can be found in Table 6. This table also contains other pesticides such as those found in the German monitoring (see 3.4.2.)

Apart from pesticides, fruit samples were tested on heavy metals (cadmium, copper, lead and nickel), mycotoxins (DON, aflatoxins, alternariol, zearalenon, beauvericin, enniatins, citrinine, fumonisins, T2/HT2-toxins, mevonolin, mycophenolic acid, fusarenon X, ochratoxin A, tenuazonic acid) and acrylamide. Only 5 samples on apple crisps and banana crisps were tested on acrylamide of which 4 contained levels above the LOD. However, there is no legal limit for acrylamide in these products. 8.2% of all samples tested on aflatoxin B1 were tested positive and 6.7% of all samples tested on total aflatoxins. Melon, mulberry, fig and raisin samples contained levels above the ML. 18.7% of all samples tested on ochratoxin A were positive, of which currant and raisin samples contained levels above the ML. These MLs are indicated in Table 7. The other mycotoxins tested have no MLs. Results showed that more than 5% of figs were positive for alternariol, beauvericins and fumonisins. More than 5% of the apple puree samples contained enniatins. T2 and HT2-toxins were found in more than 5% of the cranberry samples and one third of the goji samples contained T2-toxin. Tunuazonic acid was found in a range of fruit samples. More than 5% of all berries tested were positive for cadmium, lead and nickel. The legal limit for cadmium was exceeded for goji berries. For lead, the legal limit was exceeded for goji berries and mulberries. A summary of the maximum levels, the percentage of positive levels found and the average levels of the positives is indicated in Annex 4 in case more than 5% of the samples in which these substances were analysed were positive.

3.4 Prioritisation of chemical hazards in fruit

3.4.1 Long list of chemical hazards in fruits

All chemical hazards that may be found in fruits are included in the long list. This list thus includes all chemical hazards mentioned in literature (section 3.2) and the chemical hazards found in the Dutch monitoring data (section 3.3). The outcome is indicated in Table 5. The following groups of chemicals are included in this table: heavy metals and trace elements, POPs, fertilizers, pesticides, mycotoxins, plant toxins, radionuclides, processing contaminants, substances added to fruit, cleaning agents and disinfectants and allergens. The specific substances found within each group are indicated as well as the reasons for inclusion on the long list: a. based on literature or b. based on the Dutch monitoring data. Since numerous pesticides were detected in fruits these could not be listed individually.

3.4.2 Intermediate list of chemical hazards in fruits

Based on the literature review as described in section 3.2 and monitoring data as described in section 3.3, the most relevant chemical hazards for fruit were identified; the intermediate list (see Table 5). This list includes chemical hazards that are frequently found in fruits, chemical hazards that are found above the EU legal limits or reference values as well as unauthorised substances encountered in fruits and substances for which occurrence data is lacking. A rationale for including chemical hazards in this list is indicated below and in Table 5.

Literature study indicated that heavy metals were frequently encountered in fruits, especially Cd, Pb and Ni. Concentrations of these heavy metals were usually below MLs, but depending on the location EU MLs were exceeded. These findings were confirmed in the Dutch monitoring data. For the heavy metals tested, cadmium and lead were sometimes above the EU limit for goji berries.

POPs were not seen as relevant hazards for fruit as these substances are not regularly found in fruits and/or not at levels that may result in exceedances of HBGV. There were no monitoring data available on POPs in the KAP database. Perchlorate was indicated as the most relevant substance used as fertilizer for fruits; fruits from outside the EU sometimes contained perchlorate concentrations above the EU reference level of 0.1 mg/kg. This substance was not included in the Dutch monitoring program. Therefore, perchlorate was added to the intermediate list.

Pesticides were frequently detected in many fruit species, sometimes exceeding the EU MRLs. Fruits with the most pesticide residues are strawberries and table grapes. These soft fruit species, as well as berries, are more vulnerable for bruising, which enhances the outgrowth of spoilage microbes (Barth et al., 2009). Pesticides are used to prevent such spoilage. Since a range of pesticides were found and the literature only gave a broad overview, it was decided to use a structured approach to come to a set of pesticides to be included on the intermediate list. Those pesticides that are authorised for fruit in the Netherlands and were listed as toxic for humans according to the CLM report (Visser et al., 2016) were included in the intermediate list (n=16). After 2016, additional pesticides were authorised for use in the Netherlands: flupyradifurone, isoxaben, penthiopyrad and propaquizafob. According to EFSA opinions on these pesticides, consumer health risks related to residues of these pesticides are not expected. Therefore, these additional pesticides were not included on the intermediate list. Additionally, pesticides that are currently not included in the Dutch analytical scope but for which more than 1% of the samples in which these pesticides were analysed were positive (> LOQ) in the German monitoring data were also included (n=5). It should be noted that the 1% threshold was chosen arbitrarily for all fruit species. Some pesticides are only authorised for a limited number of fruit species, which may not be identified using this approach. Furthermore, pesticides that were reported in the KAP database for 2013-2017 to be present in concentrations above the MRL in more than 1% of the samples they were analysed in were also added (n=24). Also pesticides that were unauthorised in EU but frequently found as described in section 3.2.5 (n=11) were included. Six pesticides (gluphosinate-ammonium, oxamyl, carbendazim, carbofuran, procymidone and propargite) were found in more than one list. In total, 51 pesticides were included in the intermediate list.

Another relevant group of substances are the mycotoxins, which may be present in damaged fruits due to growth of fungi. Patulin is found in apples and apple juices, and OTA in grapes and derived products. Furthermore, dried fruit can contain aflatoxins or OTA. Data analysis of Dutch monitoring data revealed that ochratoxin A and aflatoxins were sometimes found above the MLs. A wide range of other mycotoxins were found in various fruit samples. Since these mycotoxins do not have legal limits, it is difficult to draw conclusions for these substances. For all mycotoxins tested, mycophenolic acid and tenuazonic acid were most frequently found (17.3% and 26.9% respectively) at high concentrations (max 2500 and 83000 μg/kg, respectively). These were therefore added to the intermediate list.

The most relevant plant toxin for fruits is cyanogenic glycosides that may be found in apricot kernels. HCN may be formed after hydrolysis of these cyanogenic glycosides. Levels of HCN were found above the legal limits, which may pose human health problems. Radionuclides may be present in fruits depending on the location. Levels in fruit were usually lower than the legal limits and appear to be lower than levels found in vegetables. Therefore, radionuclides were not added to the intermediate list.

Apart from environmental pollutants and natural contaminants, substances may also be added to fruit products. Postharvest malpractices could occur by the use of prohibited toxic ripening agents, such as calcium carbide or by the use of colourants and sweeteners to mislead consumers. Calcium carbide and red dye were thus added to the intermediate list. Processing contaminants, cleaning agents and disinfectants and allergens were not identified as relevant chemical hazards in fruit according to the literature. Since there is limited information on PAH levels in banana chips, this chemical hazard was included on the intermediate list.

Table 5 *Prioritizaton of chemical hazards in fruits*

Long list (hazards that might be present in fruit)	**Intermediate list (hazards that are frequently found and/or above EU legal limits in fruit)**	**Rationale**
Heavy metals and trace elements[a] Cd Pb Mn Ni Fe Cr Cu Zn	Heavy metals and trace elements Cd[a,b] Pb[a,b] Ni[a]	According to literature (section 3.2.1), Cd, Pb and Ni were frequently encountered in fruits, in some cases above the MLs. Furthermore, the Dutch monitoring data showed that between 16-22% of berries tested contained Cd, Pb and Ni, some exceeding the EU legal limit.

Long list (hazards that might be present in fruit)	Intermediate list (hazards that are frequently found and/or above EU legal limits in fruit)	Rationale
<u>POPs</u>[a] Dioxins PFASs BFRs	<u>POPs</u> -	
<u>Fertilizers</u>[a] Perchlorate Nitrate	Fertilizers Perchlorate[a]	According to literature (section 3.2.3), perchlorate may be present in fruits at levels exceeding the reference value of 0.1 mg/kg fruit
<u>Pesticides</u>[a,b] Many different pesticides are found in various fruit species (see 3.2.4)	<u>Pesticides</u> *Pesticides > 1% above LOQ in German analytical scope:* • Bromide ion • Chlorates • Copper compounds • Dithianon • Glufosinate-ammonium *Pesticides > 1% above MRL in KAP:* • 3-Chloraniline[c] (chlorpropham) • 3-Hydoxy-carbofuran[c] • Aminopyralide[c] • Amitraz[c] • Anthrachinon[c] (anthroquinone) • Carbendazim[c] • Carbofuran[c] • Carbosulfan[c] • Cinerin I (pyrethrins) [c] • Diethyltoluamide (DEET)[c] • Esfenvaleraat[c] • Fipronil[c] • Hepa (ethephon) [c] • Isocarbofos[c] • Mecarbam[c] • Mepronil[c] • Methidathion[c] • Mehtoprene[c] • Monocrotophos[c] • Oxamyl[c] • Procymidone[c] • Propargite[c] • Rotenon[c] • Triazefos[c] Pesticides authorised in NL but human toxic (categorized ‘red’) according to the CLM report *(Visser et al., 2016):* • 1-methylcyclopropeen • Cyprodinil[c] • Difenoconazol[c] • Diquatdibromide[d], expressed as diquat • Fludioxonil[c] • Flumioxazin • Gluphosinate-ammonium[d] • Lambda-cyhalothrin[c] • Mancozeb (dithiocarbamate) • Metalaxyl-M[c] • Metam-natrium[d] • Oxamyl[c] • Pendimethalin[c] • Pirimicarb[c] • Quizalofop-P-ethyl[c] • Tebuconazol[c] • Thiacloprid[c]	Pesticides were included in the intermediate list if they were found in >1% of the German monitoring data and currently not in the Dutch monitoring program, if more than 1% of the samples in the Dutch monitoring system were above the MRL, if pesticides are authorised in the Netherlands but seen as human toxic or if pesticides are not authorised in the EU but nevertheless found in fruits.

Long list (hazards that might be present in fruit)	Intermediate list (hazards that are frequently found and/or above EU legal limits in fruit)	Rationale
	Unauthorized pesticides in the EU reported in literature as present in fruit: • Carbendazim[c] • Carbofuran (sum) [c] • Diazinon[c] • Dichlorvos[c] • Dicofol[c] • Diphenylamine[c] • Hexaconazole[c] • Malathion[c] • Procymidone[c] • Profenofos[c] • Propargite[c]	
Mycotoxins Alternaria toxins (such as tenuazonic acid and alternariol)[a] OTA [a] Aflatoxins [a] Patulin [a] Mycophenolic acid[b] Beauvericin[b] Enniatins[b] T2/HT2-toxins[b] Citrinin[b] Fumonisins[b] Mevinolin[b] Deoxynivalenol[b] Zearalenone[b]	Mycotoxins Tenuazonic acid[b] OTA[a,b] Aflatoxins[a,b] Patulin[a] Mycophenolic acid[b]	According to literature (section 3.2.5), patulin is frequently found in apples and apple juices. Both literature and Dutch monitoring data indicate that OTA and aflatoxins are frequently found in fruits, especially dried fruits, mulberry and raisins. Furthermore, the Dutch monitoring data indicate that tenuazonic acid and mycophenolic acid are frequently found in fruits (resp. 26% and 17% of the samples) and sometimes in high concentrations (resp. 83000 and 2500 μg/kg)
Plant toxins[a] Cyanogenic glycosides	Plant toxins Cyanogenic glycosides[a]	According to literature (section 3.2.6), HCN can be formed after hydrolysis of cyanogenic glycosides. Levels of HCN were found above the legal limits, which may pose human health problems
Radionuclides ^{40}K ^{226}Ra ^{228}Ra ^{210}Po ^{210}Pb ^{134}Cs ^{137}Cs ^{90}Sr	Radionuclides -	
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs	PAHs may occur in banana chips. However, data is currently lacking (section 3.2.8).
Processing contaminants[a] Acrylamide Furan	Processing contaminants	
Added substances[a] Processing aids Ripening agents Edible coatings Colourants sweeteners	Added substances Prohibited ripening agents (calcium carbide)[a] Unauthorised colourants (red dye)[a]	According to literature (section 3.2.9), prohibited ripening agents such as calcium carbide are sometimes found in fruits. Furthermore, sometimes unauthorised colourants such as red dye are encountered in fruits.
Cleaning agents and disinfectants[a]	Cleaning agents and disinfectants -	
Allergens[a]	Allergens -	

[a] Based on the literature review
[b] Based on the Dutch monitoring data
[c] Currently in the NVWA multi-methods
[d] Requires a single method

3.5 Information on concentrations and toxicity of the prioritized hazards

For the chemical hazards that were identified on the intermediate list additional information was sought and summarised in Table 6 for the pesticides and Table 7 for the non-pesticides. These tables include the concentrations found in the various fruit species (from literature and or monitoring data), the legal limits and the health based guidance values. The concentrations as stored in the KAP data base were used to calculate the average concentrations for all products tested positive (> LOQ) for the substance. For specific concentrations in a certain food product, we refer to the KAP database itself (see also Annex 4 for non-pesticides). Table 6 also indicates whether pesticides are approved for use or not. In some cases, pesticides are no longer approved but may be used until the product is out of stock. An example is glufosinate-ammonium.

Additional relevant information from EFSA reports on the hazards of the intermediate list are described in the paragraphs below. EFSA opinions were available for cadmium, lead, nickel, perchlorate, aflatoxins, tenuazonic acid and OTA. EFSA has also published a report on cyanogenic glycosides in raw apricot kernels, which is already described in section 3.2.6. Since the number of pesticides on the intermediate list was too high (n= 51) to evaluate all the separate EFSA opinions, only the ARFDs and ADI's for the prioritised pesticides are included in Table 6. No additional information on toxicity of the pesticides was provided in this section.

Table 6 *Concentrations, legal limits and health based guidance values of the pesticides from the intermediate list*

Pesticides	highest found level (mg/kg)	average of positive measurements(mg/kg)	Total number of measurements	> LOQ (%)[d]	>MRL (%)	Fruits (top 3) [b]	MRLs [c] (mg/kg)	ADI[c] (mg/kg bw/day)	ARfD[c] (mg/kg bw)	EU approval[c]
Bromide ion	40.8[d]	2.68 [d]	672 [d]	13.5%		pineapples, pomegranates, lemons	N	0.4 (EMEA)		not in database
Chlorates	0.68[d]	0.05 [d]	851 [d]	4.8%		apple juice, cherries	0.01, 0.01	N	N	not approved
Copper compounds	15.5 [d]	0.87 [d]	342 [d]	55.8%		pineapples, apples, apple juice	N	0.15	na	approved
Dithianon	0.7[d]	0.11[d]	573[d]	1.9%		currants (red, black and white), apricots, table grapes	3.0, 0.5, 3.0	0.01	0.12	approved
Glufosinate-ammonium (sum of glufosinate, its salts, mpp and nag expressed as glufosinate	0.18	0.04	598	2.2%		currants (red, black and white), apricots, raspberries	1.0, 0.15, 0.1	0.021	0.021	not approved
3-Chlooraniline	1.90[a]	1.90 [a]	20 [a]		5.0%	litchi	0.01			not in database
3-Hydroxy-carbofuran	0.22 [a]	0.03 [a]	592 [a]		5.7%	goji berry, pitahaya	0.002, 0.01	carbofuran: 0.00015	carbofuran: 0.00015	carbofuran not approved
Aminopyralid	0.02 [a]	0.01 [a]	84 [a]		2.4%	goji berry	0.01	0.26	0.26	approved
Amitraz	1.60 [a]	0.31 [a]	84 [a]		17.9%	goji berry	0.05	0.003	0.01	not approved
Anthrachinon (anhraquinone)	0.05 [a]	0.05 [a]	94 [a]		2.1%	longan, goji berry	N	N	N	not approved
Carbendazim (som)	3.10 [a]	0.09 [a]	7926 [a]		1.5%	rambutan, goji berry, longan	0.1, 0.3, 0.1	0.02	0.02	not approved
Carbosulfan	2.10 [a]	0.35 [a]	216 [a]		7.4%	goji berry, lime	0.002, 0.01	0.005	0.005	not approved
Cinerine i	0.02 [a]	0.02 [a]	84 [a]		1.2%	gojibes				not in database
Diethyltoluamide (deet)	0.02 [a]	0.02 [a]	93 [a]		4.3%	mangistan, goji berry				not in database
Esfenvalerate	0.38 [a]	0.07 [a]	621 [a]		1.8%	cherry, goji berry, raisin	0.02, 0.1, 0.3	0.0175	0.0175	approved
Fipronil (som)	0.01 [a]	0.01 [a]	92 [a]		2.2%	soursop, goji berry	0.005, 0.005	0.002	0.009	not approved
Hepa (metabolite of ethephon)	0.16 [a]	0.05 [a]	1121 [a]		5.0%	table grape	1 (ethephon)	0.03 (ethephon)	0.05 (ethephon)	ethephon approved
Isocarbophos	0.09 [a]	0.06 [a]	205 [a]		3.4%	goji berry, pomelo	0.01, 0.01	N	N	not approved

Pesticides	highest found level (mg/kg)	average of positive measurements(mg/kg)	Total number of measurements	> LOQ (%)[d]	>MRL (%)	Fruits (top 3) [b]	MRLs [c] (mg/kg)	ADI[c] (mg/kg bw/day)	ARfD[c] (mg/kg bw)	EU approval[c]
Mecarbam	0.03 [a]	0.02 [a]	84 [a]		1.2%	tangelo (excl. minneola) / ugli	0.01	0.002	N	not approved
Mepronil	0.04 [a]	0.04 [a]	33 [a]		3.0%	raisin	0.01	N	N	not approved
Methidathion	0.24 [a]	0.03 [a]	2381 [a]		1.6%	pomelo, lime, orange	0.02, 0.02, 0.02	0.001	0.01	not approved
Methoprene	0.28 [a]	0.28 [a]	33 [a]		3.0%	raisin	0.02	N	N	not approved
Monocrotophos	0.76 [a]	0.41 [a]	107 [a]		1.9%	passion fruit	0.01	0.0006	0.002	not approved
Oxamyl	0.21 [a]	0.04 [a]	243 [a]		2.1%	strawberry	0.01	0.001	0.001	approved
Procymidone	0.06 [a]	0.03 [a]	8 [a]		25.0%	durians, sweet passion fruit	0.01, 0.01	0.0028	0.012	not approved
Propargite	0.92 [a]	0.08 [a]	3508 [a]		1.5%	goji berry, pomegranate, strawberry	0.01, 0.01, 0.05	0.03	0.06	not approved
Rotenone	0.04 [a]	0.04 [a]	84 [a]		1.2%	goji berry	0.01	N	N	not approved
Triazophos	0.03 [a]	0.02 [a]	915 [a]		1.3%	litchi, goji berry, pomelo	0.01, 0.01, 0.01	0.001	0.001	not approved
1-Methylcyclopropene		No data in KAP						0.0009	0.07	approved
Cyprodinil	5.70 [a]	0.22 [a]	3628 [a]		0.1%	granate apple	0.02	0.03	na	approved
Difenoconazole	11.00 [a]	0.05 [a]	6594 [a]		0.2%	lychee, passion fruit, goji berry	0.1, 0.1	0.01	0.16	approved
Diquatdibromide (diquat)		No data in KAP						0.002	na	approved
Fludioxonil	3.40 [a]	0.27 [a]	6700 [a]		0.0%	kiwi berry	5	0.37	na	approved
Flumioxazin		No data in KAP						0.009	0.05	approved
Lambda-cyhalothrin	0.28 [a]	0.02 [a]	7342 [a]		0.3%	lychee, guava, goji berry	0.02, 0.02, 0.1	0.0025	0.005	approved
Mancozeb		No data in KAP						0.05	0.6	approved
Metalaxyl-m	0.90 [a]	0.03 [a]	4197 [a]		0.0%	pitihaya	0.05	0.08	0.5	approved
Metam-natrium		No data in KAP						0.01	1	approved
Pendimethalin	0.01 [a]	0.01 [a]	1488 [a]		0.0%			0.125	0.3	approved
Pirimicarb	2.20 [a]	0.32 [a]	1109 [a]		0.1%	raspberry	4	0.035	0.1	approved
Quizalofop-p-ethyl		No data in KAP						0.013	0.1	approved
Tebuconazole	3.40 [a]	0.07 [a]	7339 [a]		0.1%	guava, mango, strawberry	0.02, 0.1, 0.02	0.03	0.03	approved

Pesticides	highest found level (mg/kg)	average of positive measurements(mg/kg)	Total number of measurements	> LOQ (%)[d]	>MRL (%)	Fruits (top 3) [b]	MRLs [c] (mg/kg)	ADI[c] (mg/kg bw/day)	ARfD[c] (mg/kg bw)	EU approval[c]
Thiacloprid	0.75 [a]	0.04 [a]	4884 [a]		0.1%	passion fruit, pomegranate, orange	0.01, 0.01, 0.01	0.01	0.03	approved
Flupyradifurone		No data in KAP						0.064	0.15	approved
Isoxaben		No data in KAP						0.05	Not applicable	approved
Penthiopyrad		No data in KAP						0.1	0.75	approved
Propaquizafop		No data in KAP						0.015	Not applicable	approved
Carbofuran (som)	0.17 [a]	0.04 [a]	1645 [a]		2.4%	goji berry, lime, pitahaya	0.01, 0.01, 0.01	0.00015	0.00015	not approved
Diazinon	0.13 [a]	0.02 [a]	2156 [a]		0.5%	orange, strawberry, pomelo	0.01, 0.05, 0.01	0.0002	0.025	not approved
Dichlorvos		No data in KAP				N	N	0.00008	0.002	not approved
Dicofol	0.02 [a]	0.02 [a]	10 [a]		0.0%		0.02 (citrus fruits, pome fruit, berries)	0.002	0.15	not approved
Diphenylamine	1.80 [a]	0.31 [a]	623 [a]		0.0%		N	0.075	not applicable	not approved
Hexaconazole	0.36 [a]	0.04 [a]	2803 [a]		0.6%	goji berry, lychee, lemon	0.01, 0.01, 0.01	0.005	N	not approved
Malathion	0.05 [a]	0.02 [a]	1689 [a]		0.5%	blackberry, blueberry, mandarin	0.02, 0.02, 2	0.03	0.3	approved, not in NL
Profenofos	0.67 [a]	0.10 [a]	3030 [a]		0.5%	strawberry, passion fruit, mandarin	0.01, 0.01, 0.01	0.03	1	not approved

[a] Data is from the KAP database (https://chemkap.rivm.nl) for the years 2013-2017

[b] Top 3 is based on the first three fruits with the highest number > MRL or > LOQ/ total measurements. When only 1 fruit is mentioned; all measurements > MRL or > LOQ were in this fruit. In case of < 10 measurements per fruit, these were excluded in case of more than 3 fruits with numbers > MRL or > LOQ. If needed, the top 3 is also based on the highest average of positive measurements. The category from KAP data 'ov. fruit, noten' is excluded from the top 3 fruits.

[c] ADIs, ARfD, and information about the approval in the EU are extracted from the EU pesticide database http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN

[d] data are levels >LOQ from German monitoring data on pesticides for the year 2016 from the EFSA Knowledge Junction Zenodo (https://zenodo.org/communities/efsa-kj)N, no information available

Table 7 *Concentrations, legal limits and health based guidance values of the non-pesticides from the intermediate list*

Chemical hazards	Main products[a]	Monitoring data (Dutch monitoring)[b]				Literature	EU legal limit	Health based guidance values[c]	
		Average of positive measurements (mg/kg)	Maximum level (mg/kg)	Total number of measurements	Percentage positive measurements / total (%)	Max level (mg/kg)	(mg/kg)	Chronic (ug/kg bw/day)	Acute (ug/kg bw/day)
Heavy metals									
Cadmium	Goji berry	0.06	0.11	48	20.8%	some exceedances found (Radwan and Salama, 2006; Lacatusu and Lacatusu, 2008; Saracoglu et al., 2009; Fang et al., 2010)	0.05	2.5 ug/kg bw (TWI, (EFSA, 2009)	
Lead	Goji berry, mulberry	0.05	0.23	126	15.9%	some exceedances found (Lacatusu and Lacatusu, 2008; Nie et al., 2016)	0.1 (all fruits), 0.2 (cranberries, currants, elderberries and strawberry tree fruit)	0.5 (dietary intake value corresponding to BMDL01 (developmental neurotoxicity, (EFSA, 2012b))	N
Nickel	Acai berry	1.37	2.5	9	22.2%	some exceedances of Chinese limit (0.3 mg/kg)found (Nie et al., 2016)	N	2.8 (EFSA, 2015c)	1.1 (acute RP for hypersensitivity reactions, (EFSA, 2015c)
Fertilizers									
Perchlorate	imported fruit	N	N	N	N	4.63 (cantaloupe, Guatemala) (Calderón et al., 2017)	0.1 (EC ref value for trade)	0.3 (TDI, (EFSA, 2014b))	N
Mycotoxins									
Tenuazonic acid	Goji berry, mulberry, figs	1.43	83	1163	26.1%	N	N	N	N
OTA	Mulberry, currants, raisins, figs	0.066	0.34	962	12.2%	Detected (Battilani et al., 2003; Paster and Barkai-Golan, 2008; MPI, 2009; Akdeniz et al., 2013; Zhang et al., 2016)	10 (dried)	0.12 (TWI, (EFSA, 2006))	N

Chemical hazards	Main products[a]	Monitoring data (Dutch monitoring)[b]				Literature	EU legal limit	Health based guidance values[c]	
		Average of positive measurements (mg/kg)	Maximum level (mg/kg)	Total number of measurements	Percentage positive measurements / total (%)	Max level (mg/kg)	(mg/kg)	Chronic (ug/kg bw/day)	Acute (ug/kg bw/day)
AflatoxinB$_1$	Mulberry, figs and other fruits	0.024	0. 83	300	7.0%	Detected (Masood et al., 2015; NVWA, 2016a)	2 (dried fruit), 6 (dried figs)	N, genotoxic carcinogen	N
Total aflatoxins	Mulberry, figs and other fruits	0.037	1.1	300	6.7%	Detected (Paster and Barkai-Golan, 2008; WHO and FAO, 2013; Masood et al., 2015; NVWA, 2016a)	4 (dried fruits), 10 (dried figs)	N, genotoxic carcinogen	N
Patulin	apple	N	N	N	N	Detected (US FDA., 2004; Paster and Barkai-Golan, 2008; Celli et al., 2009; De Clercq, 2016)	50 (fruit juices), 25 (solid apple products), 10 (apple juice etc for infants and young children)	0.4 (PMTDI, (JECFA, 1995))	N
Mycophenolic acid	Currants, raisins	0.15	2.5	713	17.3%	N	N	N	N
Plant toxins									
Cyanogenic glycosides	apricot kernels	N	N	N	N	3.8 mg/g cyanide (EFSA, 2016b)	20 µg/kg (EC 1881/2006), 5 mg/kg (flavoroungs, EC1334/2008)	20 (PMTDI, (JECFA, 2011))	90 (ARfD, (JECFA, 2011))
PAHs									
PAHs	Banana chips	N	N	N	N	N	Benzo(a)pyrene of 2 µg/kg and 20 µg/kg for the sum of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene (Regulation (EC) 1881/2006)	Benzoapyrene: 0.07 (BMDL10) PAH2: 0.17 (BMDL10) PAH4: 0.34 (BMDL10) PAH8: 0.49 (BMDL10) (EFSA, 2008b)	N
Added substances									
Ripening agents (calcium carbide)		N	N	N	N	N	N	N	N
Red dye		N	N	N	N	N	N	N	N

[a] Main products are those products with the highest percentage of positive samples

[b] Data is from the KAP database (https://chemkap.rivm.nl) for the years 2013-2017. Only objective, i.e. random samples were used for the analysis.

[c] Health based guidance values (HBGVs) are indicated in µg/kg bw/day unless otherwise indicated.

N, no information available

3.5.1 Cadmium

EFSA has concluded that the main source of cadmium exposure for the non-smoking general population is food. Cadmium is toxic to the kidney, especially to the proximal tubular cells, where cadmium accumulates (half-life: 10-30 years) and may cause renal dysfunction. This can progress after prolonged or high exposure to renal failure. Cadmium is also classified as human carcinogen Group 1 IARC (EFSA, 2009).

Based on detailed individual food consumption data a better estimation of dietary intake of cadmium has been made by EFSA in 2012 (EFSA, 2012a). Across age groups, potatoes (13.2%), bread and rolls 11.7%) and fine bakery wares (5.1%), chocolate products (4.3%), leafy vegetables (3.9%) and water molluscs (3.2%) contributed the most to the dietary exposure of cadmium. The contribution of fruit and fruit products to the exposure was small (<2%) compared to the high contributors. An average weekly dietary exposure was estimated at 2.04 ug/kg bw per week and high exposure (P95) was estimated at 3.66 ug/kg bw per week. This review confirmed that 95^{th} percentile exposure could exceed the TWI. There is a limited margin between the dietary exposure and the TWI. Although the risk for adverse effects on kidney function is low, EFSA concluded that the current exposure to Cd should be reduced at population level (EFSA, 2012a).

3.5.2 Lead

The major exposure route to lead is via food. Lead can accumulate in the skeleton of the human body, the half-life time in bone is 10-30 years. In blood the half-life of lead is approximately 30 days. The main target organ of lead toxicity is the central nervous system. Neurotoxicity associated with lead can affect the short-term verbal memory, fine motor skills, information processing and can cause psychiatric symptoms. In 2010, EFSA has established a new health based guidance value, the previous established PTWI was concluded to be no longer appropriate. Therefore, a 95^{th} percentile lower confidence limit of the benchmark dose of 1% extra risk ($BMDL_{01}$) of 0.5 µg/kg bw/day for developmental neurotoxicity in young children was identified. The broad food categories contributing the most to lead exposure are: grains and grain products (16.1%), milk and dairy products (10.4%), non-alcoholic beverages (10.2%) and vegetables and vegetable products (8.4%). The contribution of fruit was < 6% to the total lead exposure.

The $BMDL_{01}$ of 0.5 ug/ kg bw /day is lower that the estimated mean exposure for young children. For adults the respective BMDLs for cardiovascular effects and nephrotoxicity were not exceeded by the estimated mean exposure for adults (EFSA, 2012b).

3.5.3 Nickel

The diet is the most important route for nickel exposure for the general population. The IARC has classified nickel as human carcinogen causing lung and nasal cavity cancer. However, EFSA considered it unlikely that dietary exposure will result in cancer in humans because of no consistency in epidemiological data and no confirmation in animal studies. Non-carcinogenic acute effects in humans after dietary exposure are gastrointestinal, haematological, neurological effects and effect on the immune system. Reproductive and developmental toxicity are critical effects for chronic exposure to nickel.

The TDI of nickel is 2.8 µg/kg bw/day. There are no maximum levels for nickel in food, only for drinking water (20 µg/L). High mean levels of nickel were reported for legumes, nuts and oilseeds (2 mg/kg), certain type of chocolate products (3.8 mg/kg) and cocoa beans and cocoa products (9.5 mg/kg). Overall, the main contributors to the dietary exposure to nickel are grain and grain-based products, non-alcoholic beverages, sugar and confectionery, legumes, nuts and oilseeds, and vegetables and vegetable products (including fungi). Fruits are not mentioned as important contributors to dietary nickel exposure (EFSA, 2015c).

3.5.4 Perchlorate

A TDI of 0.3 µg/kg bw/day was established by EFSA. EFSA concluded that dietary intakes are far too low to cause acute toxicity, therefore an ARfD was not warranted. Chronic exposure to perchlorate can lead to inhibition of thyroid iodine uptake, which could lead to multinodular toxic goitre, in particular the population with iodine deficiency (EFSA, 2014b).

Important contributors to the dietary exposure of perchlorate were vegetable and vegetable products, dairy products and fruit and fruit products (EFSA, 2017b).

3.5.5 Aflatoxins

Aflatoxins are genotoxic and carcinogenic. Aflatoxin B1 is the most potent genotoxic and carcinogenic aflatoxin and the most common aflatoxin in food. Exposure to aflatoxins through food should be kept as low as possible. Aflatoxins have been primarily detected in imported foods, like peanuts, tree nuts, dried fruit, spices and crude oil, cocoa beans, maize and rice. EFSA opinions specifically focus on nuts, because these contribute the most to the total dietary exposure of aflatoxins (EFSA, 2007, 2018b).

3.5.6 Tenuazonic acid

In 2011 the EFSA has used a threshold of toxicological concern (TTC) approach to assess the possible concern of among other the mycotoxin tenuazonic acid. For the non-genotoxic tenuazonic acid it was concluded that the exposure was unlikely to be of human health concern. The highest mean values of tenuazonic acid were found in paprika powder (8.8 mg/kg) and in four samples of mulberries 5.7 mg/kg). For infants the main contributor to the dietary exposure of tenuazonic acid was cereals-based food for infants and young children. In the adult population were fruiting vegetables (mainly tomatoes and tomato-based products) the main contributors to the exposure (EFSA, 2016c).

3.5.7 Ochratoxin A (OTA)

A TWI of 120 ng/kg bw/ was derived for OTA, based on early markers of renal toxicity. EFSA concluded that the most sensitive effects of OTA are on the kidneys. The exposure to OTA is estimated to be between 15-20 ng/kg bw/ per week and 40-60 ng/kg bw per week for low and high consumers respectively. These exposures are below the TWI, however infants and children were not included in the consumption data. Foods frequently contaminated with OTA are cereals, pulses, coffee, wine, grape juice, dried fruits and spices (EFSA, 2006).

3.5.8 PAHs

PAHs can be considered mutagenic, genotoxic, and carcinogenic to humans (EFSA, 2008a; International Agency for Research on Cancer (IARC), 2018). For non-smokers the major route of exposure is via food.

EFSA used the margin of exposure (MOE) approach considering $BMDL_{10}$ values, to evaluate potential concerns for human health. For high end consumers (P97.5) only, the margin of exposure (MOE) was around 10,000, which indicates a potential concern for human health (EFSA, 2008a). As already indicated in paragraph 3.2.8, according to EFSA, cereals and cereal products together with seafood and seafood products have the highest contribution to consumer PAH exposure (median value of 67 and 36 ng BaP/day, respectively). Fruit consumption (assuming 4% dried fruits and 96% fresh fruits) resulted in a median exposure of 5 ng BaP/day (EFSA, 2008b).

4 Trends in the fruit chain

This chapter evaluates the trends in the fruit chain that may influence the presence of food safety hazards related to the chemical hazards. The information was obtained from consulting experts and from grey and scientific literature. In total 7 experts working in the fruit (and vegetable) supply chain were interviewed or filled in the questionnaire. These experts were involved in two branch organisations (one consulted three members to answer the questions), an interest organisation and companies working in processing, retail, and whole trade and import.

4.1 Consumer trends

The general decrease in fruit consumption over the last years has stagnated. Especially, there is an increased fruit consumption by children (RIVM, 2018). In the period 2012-2016, the most consumed fruits in the Netherlands are apples, banana, pears and citrus fruits (van Rossum et al., 2016). Soft fruits are more popular than hard fruits (expert opinion). Although there is an increasing interest in locally grown products, exotic products with claimed health benefits such as avocado, pomegranates, berries and papaya are also emerging at the expense of apple and pear consumption (Borgdorff-Rozeboom, 2013; CBI, 2018; Rabobank, 2018). Furthermore, the sale of organic fruit in the EU is still rising (CBI, 2018). This was confirmed by the experts interviewed. Currently, 5% of the fruit market share in the Netherlands is for organic fruits (van Rijswick, 2018). The general consumer trend of health and sustainability, which is connected to these changes in fruit consumption, were also mentioned during the expert interviews.

In the past ten years, the number of new products on the market that contained fruit increased until 2011, then fluctuated and was uncharacteristically low in 2017 (Figure 1). This information is obtained from the Innova database, which collects all product introductions (WFBR, personal communication). This database showed that most introductions in the last five years were based on pineapple, while also strawberry and blueberry were favourite in new introductions (WFBR, personal communication).

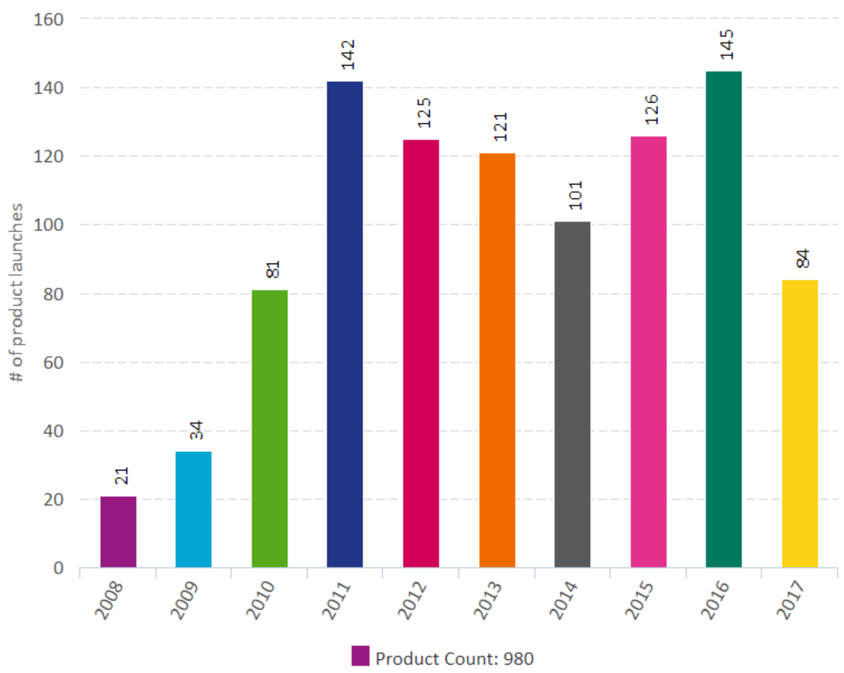

Figure 1 *Amount of product introductions containing fruit in the Netherlands from 2008-2017*

Apart from a change in fruit species demands, there is an increasing trend towards convenient fruit, e.g. ready-to-eat products, ripened fruit, fresh-cut fruit and seedless fruit (Hemker et al., 2018).

Instead of juices and canned fruit, consumers increasingly prefer natural and fresh fruits, including frozen fruits. As a result, global demand for frozen fruit has increased with 5% per year (van Rijswick, 2018). This trend is confirmed in the Innova database, which showed that frozen introductions increase steadily while introductions containing fruit at room temperature or in the fridge fluctuated (Figure 2). Furthermore, in the snacks category, fruits grow faster than other snacks, because of their better health image (Innova, 2018). A natural and healthy image is important. Freeze dried fruits are ticking the boxes of natural, no added sugar and high in fibre (Innova, 2018).

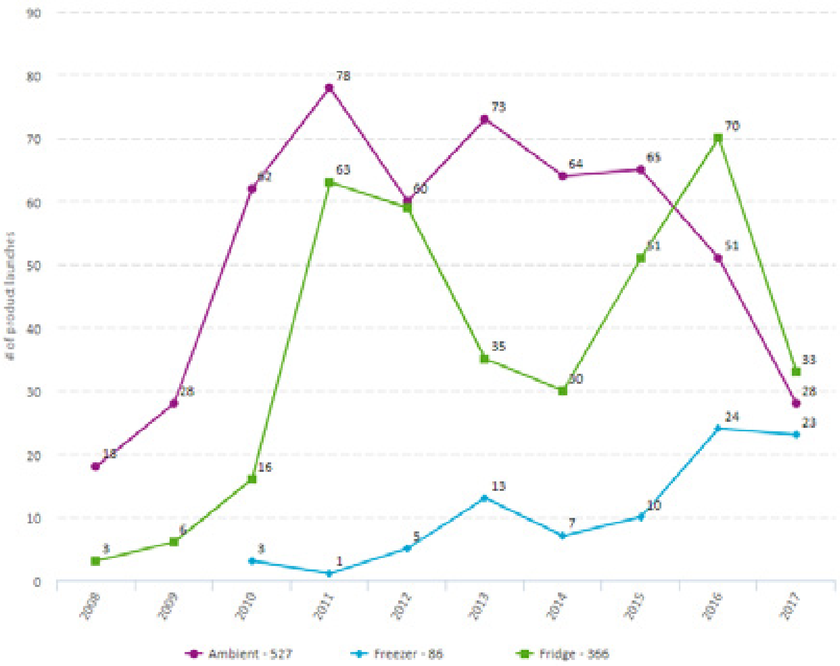

Figure 2 *Amount of fruit product introductions in the Netherlands from 2008-2017 split to shelving (room temperature, fridge and frozen)*

Also, the markets for easy peelers and individually sized fruits like mini-watermelons are growing. Another consumer trend is the increased demand for fruits with a prolonged shelf life. In combination with the demand for ready-to-eat products, consumers buy their fruits more and more out-of-home (Hemker et al., 2018). The trend for more convenience fruit products is confirmed in the Innova database (WFBR, personal communication) and in the expert interviews. In the Netherlands, a large number of new introductions is frozen fruit or fruit mixtures, while in the fresh category convenience is an important topic leading to products such as ready-to-eat or pre-cut fruits. The 'indulgent' trend is met with fruit mixtures, exotic fruits and fruit sold with a dipping sauce. Furthermore, smoothie mixes or mixes for wine make fruits a less day-to-day product. For the smaller households, smaller portion sizes are offered (i.e. a part of a melon). A large amount of the introductions is tinned.

Along this line is the current trend of the so-called food festivals where food trucks are used that sell a range of ready-to-eat products, such as fruit smoothies, which are produced on-site (Romero Cabrera, 2017).

The consumer trends mentioned in this section primarily influence the microbiological quality of fruits and fruit products. The increase in exotic products imported from outside the EU may also influence the presence of chemical hazards as food safety standards in non-EU countries may differ.

4.2 Fruit trade

The fruit market is more international than the vegetable market (van Rijswick, 2018). Therefore, it is relevant to follow trends in fruit trade. Brexit will have its consequences on trade with Europe (CBI, 2018). However, the Netherlands currently does not import fruit from Great-Britain (NVWA, personal communication), so the effect on the fruit trade is expected to be minimal.

The top 3 of fruit producing countries in 2017 were China (32% of the market), India (11% of the market) and Brazil (4% of the market). The last 10 years, China showed the largest increase in production share in the global market from 26% in 2007 to 32% in 2017. The main exporting countries for frozen fruit in 2016 were Poland (350,000 tonnes), Mexico (around 180,000 tonnes), Serbia and China (both around 170,000 tonnes). Between 2006 and 2016, Chile showed the largest increase in export from hardly any export in 2006 to around 125,000 tonnes in 2016 (van Rijswick, 2018).

Experts of the fruit chain expected that the import of soft fruits will stagnate, because soft fruits will be more cultivated with assimilation light in the Netherlands (expert opinion). Overall, many fruits are available throughout the year, due to import. Retailers and consumers do not pay much attention to regional products (expert opinion).

The country of origin of new product introductions in the Netherlands confirms the increase of exotic products in the Innova database (WFBR, personal communication). Although this information was not available for all products, it still gives an idea of the international trade. The Netherlands is clearly the number 1 country with fruit innovations in the home market, but Spain, South Africa, Italy and Thailand also contribute heavily to the new introductions. Countries with a long travelling distance (China, Chile) primarily export tinned produce to the Netherlands, but also fresh produce is shipped from e.g. South Africa (WFBR, personal communication).

As a result of the superfood trend, import of avocados, blueberries and cranberries has increased tremendously over the last 10 years (van Rijswick, 2018).

Changes in trade may have its consequences on food safety since food standards in non-EU countries might differ from the EU standards.

4.3 Trends in the fruit supply chain

There are four key developments that will play a significant role in driving the fruit supply chain, i.e. more rapid supply, more flexible supply, more precise supply and more transparent supply (CBI, 2018; Hemker et al., 2018; Wyman, 2018). An example is that producers now automatically collect data on fertiliser use to enhance transparency. Also, weather data is collected, making it possible to forecast the risk on fungi outbreak. Furthermore, innovations are foreseen in chain logistics and technology that will result in more flexible and transparent supply chains. One of the trends is the increase in on-line sale, which is expected to grow on a global scale to 7% by 2030 (Hemker et al., 2018).

Traceability has become more and more important in the fruit supply chain, which increases the transparency of the supply chain (CBI, 2018; Hemker et al., 2018). This was confirmed by the experts consulted. Certification and the use of GLOBALG.A.P. stimulates this (CBI, 2018) and the use of blockchain technology facilitates the transfer of information from one step to the next (CBI, 2018; Hemker et al., 2018). Furthermore, companies increasingly use QR codes to provide product information to the consumer (CBI, 2018).

In case of shortage of some fruits due to for example a natural disaster, the retail pushes to deliver. This could result in a switch to other unknown suppliers, which could probably affect the quality and safety of the products (expert opinion).

A more transparent fruit supply chain and increased use of certification might have a positive effect on food safety within the fruit supply chain as a more transparent supply chain is easier to control.

4.4 Sustainability demands

Lately, consumers are more interested in sustainability issues, such as working conditions in the country of origin and environmental problems related to fruit cultivation (CBI, 2018). Certification organisations such as Fairtrade and the Rainforest Alliance impose requirements on working conditions, but also on the use of water, the soil quality, biodiversity and the use of pesticides. They also help to develop different cultivation methods and less and more efficient use of pesticides in non-EU countries. Within Europe, retailers and traders are currently working together in the Sustainability Initiative Fruits and Vegetables (SIFAV), which aims to make all non-EU import sustainable by 2020 (CBI, 2018). Not only the working conditions outside the EU are a point of consumer interest, but also the working conditions of seasonal workers within the Netherlands (Rabobank, 2018).

There is a decrease in pesticides use due to pressure from the government, retailers, and consumers. This results in an increase in organic cultivation of fruits (expert opinion). Pesticides use is more restricted, which also puts pressure on the processing industry of for example canned fruits. These products have a long shelf-life. Therefore, they could contain pesticides that were previously allowed to be used but are not approved anymore and could therefore not be sold (expert opinion).

Due to changing weather conditions and reduced pesticides use, other measures are needed in the primary production of fruits. The quality of fruits can be less optimal for the processing industry, which means that more parts need to be removed. The automatic processing of fruits needs to be further optimized in the processing industry (expert opinion).

As a result of the sustainability demands, Dutch growers invest in other cultivation methods. For example, since January 2018, drain water from greenhouses needs to be purified before it can be discharged. As a result, closed water circuits are used in horticulture where processed water is purified and re-used. They aim is to achieve a 100% recycling of drain water in 2027. Another innovation is the cultivation of apples in trenches instead of in open soil. This cultivation method requires less pesticides use while maintaining a good yield (van der Maas, 2017)

Initiatives on sustainability may lead to a reduced pesticide use. The probability of detecting residues in fruit products will then decrease. On the other hand, reduced pesticide use may lead to increased fungal growth and subsequent mycotoxin formation. Furthermore, the trend of closing nutrient cycles and reusing water may pose food safety issues as chemical hazards present may accumulate.

4.5 Innovation

The Innova database contains around a hundred new fruit products that are introduced yearly on the Dutch market (WFBR, personal communication). These new products may comprise a range of different innovations. Due to changing consumer demands, suppliers need to diversify and innovate CBI (2018). One of these innovations is the use of nanotechnology or multilayer techniques in edible coatings. This technology is not yet on the market, but is under research so could be applied in the future (Dhall, 2013). Another innovation is the use of fruit as natural sweetener. Monk fruit is such a high-intensity natural sweetener, which like stevia is designated as GRAS (generally recognized as safe) in the USA. Monk fruit is between 100-250 sweeter than table sugar (Mooradian et al., 2017). Monk fruit extract has recently been accepted as additive by the EU according to the EU additives database (https://ec.europa.eu/food/safety/food_improvement_agents/additives/database_en) although it does not have an E number yet.

Innovation is needed to maintain the current competitive position of the Netherlands in comparison to low-wage countries such as Poland. As a result, growers invest in new fruit species such as new Elstar mutants or other cultivars with better taste and product quality. Compared to the soft fruit sector, the hard fruit sector is more conservative and thus less innovative. A general trend in both sectors is the use of big data to optimise cultivation and the supply chain. Both chains will become more automated for example by using harvesting robots (Rabobank, 2018). This was confirmed by the experts consulted. Furthermore, storage conditions will be optimised to increase the shelf-life of fruits (expert opinion).

A recent study on consumer preferences showed that innovations related to food safety are perceived better than convenience oriented innovations (Baselice et al., 2017). For example, the pre-harvest applications of microbial antagonists to control OTA-producing fungi in grape berries seem to be promising (Zhang et al., 2016). Another example is innovation in smart packaging that provides information on the freshness of the product (Baselice et al., 2017). Packaging can also contribute to the traceability of fruit products by the use of radio-frequency identification (RFID) technology, which can identify individual items along the whole chain from farm to fork. Developments within packaging can also contribute to reduce food waste by increasing the product's shelf-life (Baselice et al., 2017).

Innovations are also driven by climate change, which brings along different pests and diseases as well as environmental challenges, such as salinity, high temperatures and water availability and quality. As a result, new varieties and species are being developed that can cope with these circumstances (AREFLH et al., 2016).

Innovations may relate to new fruit products, other packaging materials, labelling or new processing techniques. As each innovation may have consequences for food safety, it is important to keep track of new developments in the market.

4.6 Legal and policy aspects

Changes in EU legislation may have its consequences on the fruit supply chain and possible food safety hazards. For example, when EU subsidy for farmers changes or when phytosanitary restrictions are implied on non-EU fruit species (CBI, 2018). In order to adjust quickly to changes, EU regulation (EC) No 669/2009 regarding increased level of control on imports of non-animal products is reviewed on a quarterly basis. If necessary, Annex I of this regulation is updated to include those products and substances that need an increased level of official control. At EU level, compounds may also be forbidden due to new insights into the toxicity of compounds. This may lead to the use of alternatives, which may pose new food safety issues.

Apart from EU legislation, Dutch policy will have its effect on the fruit sector. Recently, the Dutch minister of Agriculture, Nature and Food Quality indicated that the Netherlands should move towards a circular agriculture meaning that resources should be recycled and/or used more efficiently (Ministery of Agriculture, 2018). Recycling, for example by reusing water, may lead to an accumulation of residues. These developments should thus be followed carefully to prevent food safety problems. Furthermore, the Dutch Scientific Committee for Government Policy (WRR) wrote a document on food policy aiming for healthy, safe, secure and sustainable food production in the Netherlands (Knottnerus et al., 2014).

Overall, changes in regulations and policies will have its effect on the fruit sector. Its consequences on food safety depend on the changes made.

5 Conclusions

This report gives an overview of chemical hazards that may occur in the fruit supply chain. A literature review was performed resulting in a range of chemical hazards: heavy metals and trace elements, POPs, fertilizers, pesticides, mycotoxins, plant toxins, radionuclides, processing contaminants, substances added to fruit such as colourants, cleaning agents and disinfectants and allergens. All chemical hazards mentioned in literature or found in the Dutch monitoring data were included in the long list of chemical hazards in fruits. This list thus includes all chemical hazards that might occur in fruits. Based on levels reported in literature and monitoring data from the Dutch monitoring system (KAP) and German monitoring data on pesticides, an intermediate list was established of substances that were frequently found and/or frequently above the legal limits. This intermediate included the heavy metals Cd, Pb and Ni as these were frequently found in a range of fruits. Levels found were usually below legal limits but depending on the location MLs were exceeded. Perchlorate was indicated as the most relevant substance used as fertilizer for fruits; imported fruits sometimes contained high concentrations of perchlorate. Pesticides were frequently detected in many fruit species. Fruits with the most pesticide residues are strawberries and grapes. Soft fruits are more vulnerable for fungal spoilage and as such are treated more frequently with pesticides. In total 51 pesticides were identified as relevant for fruits based on literature data and monitoring data. Most of these pesticides are currently in the NVWA multi-method. However, some require a single method due to their characteristics or are currently not included in the multi-methods. These pesticides need further evaluation to determine their relevance for monitoring. Another relevant group of substances are the mycotoxins, which may be present in damaged fruits due to growth of fungi. Patulin is found in apples and apple juices, and OTA in grapes and derived products. Furthermore, dried fruit can contain aflatoxins or OTA. The monitoring data revealed that mycophenilic acid was frequently found in currants and raisins and tenuazonic acid in a range of fruits. These latter mycotoxins do not have legal limits, so further research is needed into their relevance for human health. The most relevant plant toxins for fruits are cyanogenic glycosides that may be found in apricot kernels, which are transferred to HCN when chewing. Levels of HCN were found above the legal limits, which may pose human health problems. Apart from environmental pollutants and natural contaminants, substances may also be added to fruit products. Postharvest malpractices could occur by the use of prohibited toxic ripening agents, such as calcium carbide or by the use of colourants and sweeteners to mislead consumers. Calcium carbide and red dye were thus added to the intermediate list of substances. Processing contaminants were not seen as relevant for fruit products, except for PAHs in banana chips. Currently, there is a lack of information for this substance in banana chips and for this reason, the substance was included on the intermediate list.

All substances on the intermediate list should be evaluated further to determine their possible risk for human health by combining concentrations found and consumption data. Substances with a possible health risk should be included in the short list; the list that should be included in risk-based monitoring programs for fruit and fruit products.

Apart from identifying chemical hazards in the fruit supply chain, this study also looked at possible trends that may affect the presence of these chemical hazards in fruit. Consumer trends were observed as well as trends in trade and the supply chain. Sustainability demands and legal aspects influence the fruit supply chain. Together with consumer demands, these lead to new products on the market. The identified trends may have consequences for food safety. For example. Increased import of exotic fruits from outside the EU may impact the presence of chemical hazards as food safety standards in non-EU countries may differ. As each innovation may have consequences for food safety, it is important to keep track of new developments in the market.

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Annex 1 English-Dutch term list

English	Abbreviations	Dutch
Ackee		Ackee
Action level	AL	Actielimiet
Aflatoxin	AF	Aflatoxine
Allergen		Allergeen
Analytical method		Analyse methode
Apple (juice/puree)		Appel(sap/moes)
Apricot (kernels)		Abrikoos (Abrikozenpitten)
Bamboo shoots		Bamboesheuten
Banana		Banaan
Biocides		Biociden
Blueberry		Blauwe
Brominated flame retardants	BFRs	Broomhoudende vlamvertragers
Bulb vegetables		Bolgewasssen
Cactus fruit		Cactusvrucht
Cantaloupe melon		Cantaloupe meloen
Cereals		Granen
Chemical substances/hazards		Chemische stoffen/gevaren
Cherimoya		Cherimoya
Cherry		Kers
Cleaning agent		Schoonmaakmiddel
Components		Componenten
Contaminants		Contaminanten
Currant		Krent
Cranberry		Veenbes
Date		Dadel
Detection limit		Dectectielimiet
Disinfectant		Desinfectiemiddel
Dioxins		Dioxines
Dried vine fruit		Gedroogde druiven
Elderberry		Vlierbes
European Food Safety Authority	EFSA	Europese Voedselautoriteit
European Union	EU	Europese Unie
Exposure		Blootstelling
Fertilizer		Meststof
Fig		Vijg
Food and Agricultural Organization of the United Nations	FAO	Voedsel- en Landbouworganisatie van de Verenigde Naties
Food contact materials		Materialen bestemd om met levensmiddelen in aanraking te komen
Food Standards Australia New Zealand	FSANZ	Voedselautoriteit van Australië en Nieuw-Zeeland
Fruiting vegetables		Vruchtgroente
Fruits		Vruchten
German Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung)	BfR	Duitse federale instituut voor risicobeoordeling
Goji berry		Gojibes
Grape		Druif
Grapefruit		Grapefruit
Group of substances		Stofgroep
Guavas		Guaves
Hazard analysis		Gevarenanalyse
Hazard Analysis and Critical Control Points	HACCP	Gevarenanalyse en kritische controlepunten
Heavy metals		Zware metalen
Hydrogen Cyanide	HCN	Waterstofcyanide
Jujube		Jujube
Kiwi		Kiwi

English	Abbreviations	Dutch
Leafy vegetables		Bladgroente
Lemon		Citroen
Lime		Limoen
Lychee		Lychee
Mandarin		Mandarijn
Mango		Mango
Maximum residue level		MRL
Maximum limit		ML
Melon (seeds)		Meloen(pitten)
Minneola		Minneola
Mulberry		Moerbei
Mushrooms		Paddenstoelen
Mycotoxins		Mycotoxinen
National Institute for Public Health and the Environment	RIVM	Rijksinstituut voor Volksgezondheid en Milieu
Nectarine		Nectarine
Netherlands Food and Consumer Product Safety Authority	NVWA	Nederlandse Voedsel- en Warenautoriteit
New Zealand Food Safety Authority	NZFSA	Nieuw-Zeelandse autoriteit voor voedselveiligheid
Non-compliant		Niet-conform
Non-dioxin-like pcb	Ndl-pcb	Niet-dioxineachtige pcb
Nuts		noten
Ochratoxin A	OTA	Ochratoxine A
Orange (juice)		Sinaasappel(sap)
Papaya		Papaja
Passion fruit		Passievrucht
Peach		Perzik
Pear		Peer
Per- and polyfluoroalkyl subtances	PFAS	Per- en polyfluoralkylverbindingen
Persimmon		Kaki/dadelpruim
Persistent Organic Pollutants	POPs	Persistente organische verontreinigende stoffen
Pesticides		Pesticiden
Pineapple		Ananas
Plant toxins		Planttoxinen
Plum		Pruim
Polycyclic Aromatic Hydrocarbons	PAHs	Polycyclische aromatische koolwaterstoffen
Pomegranate		Granaatappel
Processing aid		Technische hulpstof
Processing contaminant		Procescontaminant
Production chain		Productieketen
Radionuclide		Radionuclide
Raisin		Rozijn
Rambutan		Ramboetan
Raspberry		Framboos
Risk analysis		Risicoanalyse
Risk based		Risicogebaseerd
Risks		Risico's
Root vegetables		Wortelgewassen
Scientific Committee for Government Policy	WRR	Wetenschappelijke Raad voor het Regeringsbeleid
Seeds		Zaden
Strawberry		Aardbei
Table grapes		Tafeldruiven
Tuber vegetables		Knolgewassen
United Kingdom Food Standards Agency	UK FSA	Brits agentschap voor de voedselveiligheid
United States Food and Drug Administration	US FDA	Voedsel- en drugsinstituut (FDA) van de Verenigde Staten van Amerika
Vine leaves		Wijnrankbladeren
Water melon		watermeloen
World Health Organisation	WHO	Wereld Gezondheidsorganisatie

Annex 2 Questionnaire on trends in the fruit supply chain (in Dutch)

Vragen toekomstvisie experts:

1. Welke veranderingen ziet u de komende 10 jaar in de fruitsector (bv groei biologische markt oid?)?
2. Verwacht u een verandering door de Brexit?
3. Verwacht u veranderingen in import? (meer/minder? andere fruitsoorten?)
4. Wat verwacht u van de superfood trend in de komende 10 jaar?
5. Verwacht u verschillende ontwikkelingen voor verschillende fruitsoorten (boomfruit vs bessen etc)?
6. Welke trends verwacht u in de primaire sector (andere oogstmethodes?).
7. Welke trends verwacht u in de verwerkende industrie? (andere technologieën?)
8. Zijn er bepaalde consumententrends die relevant zijn voor de fruitsector? Of voor bepaalde onderdelen (meer kant-en-klaar? minder suiker? Minder processing?)
9. Welke microbiologische gevaren vindt u het belangrijkst in fruit en fruitproducten (zoals gemengde fruitsalade, fruitsap, etc), voor welke fruitsoorten en waarom?
10. Welke chemische gevaren vindt u het belangrijkst in fruit en fruitproducten, voor welke fruitsoorten en waarom?

Annex 3 Example of literature screening for dioxin and fruit*

Nr	Author	Relevance	Rationale
1	Amakura, Y., T. Tsutsumi, K. Sasaki, M. Nakamura, T. Yoshida and T. Maitani (2008). 'Influence of food polyphenols on aryl hydrocarbon receptor-signaling pathway estimated by in vitro bioassay.' Phytochemistry **69**(18): 3117-3130.	Not relevant	Paper is on human health effects
2	Amakura, Y., T. Tsutsumi, K. Tanno, K. Nomura, T. Yanagi, Y. Kono, M. Yoshimura, T. Maitani, R. Matsuda and T. Yoshida (2009). 'Dioxin Concentrations in Commercial Health Tea Materials in Japan.' Journal of Health Science **55**(2): 290-293.	Not relevant	Paper is not on fruit
3	Arisawa, K., H. Uemura, M. Hiyoshi, A. Kitayama, H. Takami, F. Sawachika, Y. Nishioka, M. Hasegawa, M. Tanto, H. Satoh, M. Shima, Y. Sumiyoshi, K. Morinaga, K. Kodama, T. Suzuki and M. Nagai (2011). 'Dietary patterns and blood levels of PCDDs, PCDFs, and dioxin-like PCBs in 1656 Japanese individuals.' Chemosphere **82**(5): 656-662.	Not relevant	Paper is on dietary intake
4	Augusto, S., F. Catarino and C. Branquinho (2007). 'Interpreting the dioxin and furan profiles in the lichen Ramalina canariensis Steiner for monitoring air pollution.' Science of the Total Environment **377**(1): 114-123.	Not relevant	Paper is not on fruit
5	Banerjee, K., S. Utture, S. Dasgupta, C. Kandaswamy, S. Pradhan, S. Kulkarni and P. Adsule (2012). 'Multiresidue determination of 375 organic contaminants including pesticides, polychlorinated biphenyls and polyaromatic hydrocarbons in fruits and vegetables by gas chromatography-triple quadrupole mass spectrometry with introduction of semi-quantification approach.' Journal of Chromatography A **1270**: 283-295.	Not relevant	Paper is on an analytical method
6	Barr, N. B. and B. M. Wiegmann (2009). 'Phylogenetic relationships of Ceratitis fruit flies inferred from nuclear CAD and tango/ARNT gene fragments: Testing monophyly of the subgenera Ceratitis (Ceratitis) and C. (Pterandrus).' Molecular Phylogenetics and Evolution **53**(2): 412-424.	Not relevant	Paper is not on dioxins or on fruit
7	Barre, T., F. Vieux, M. Perignon, J. P. Cravedi, M. J. Amiot, V. Micard and N. Darmon (2016). 'Reaching Nutritional Adequacy Does Not Necessarily Increase Exposure to Food Contaminants: Evidence from a Whole-Diet Modeling Approach.' Journal of Nutrition **146**(10): 2149-2157.	Not relevant	General paper on modelling dietary intake
8	Connor, K. T., M. A. Harris, M. R. Edwards, R. A. Budinsky, G. C. Clark, A. C. Chu, B. L. Finley and J. C. Rowlands (2008). 'AH receptor agonist activity in human blood measured with a cell-based bioassay: Evidence for naturally occurring AH receptor ligands in vivo.' Journal of Exposure Science and Environmental Epidemiology **18**(4): 369-380.	Not relevant	Paper is on human health effects
9	De Coster, S., G. Koppen, M. Bracke, C. Schroijen, E. Den Hond, V. Nelen, E. V. de Mieroop, L. Bruckers, M. Bilau, W. Baeyens, G. Schoeters and N. van Larebeke (2008). 'Pollutant effects on genotoxic parameters and tumor-associated protein levels in adults: a cross sectional study.' Environmental Health **7**.	Not relevant	Paper is on human health effects
10	de Waard, P. W. J., T. de Kok, M. Maas, A. Peijnenburg, R. Hoogenboom, J. Aarts and F. J. van Schooten (2008). 'Influence of TCDD and natural Ah receptor agonists on benzo a pyrene-DNA adduct formation in the Caco-2 human colon cell line.' Mutagenesis **23**(1): 67-73.	Not relevant	Paper is on human health effects

Nr	Author	Relevance	Rationale
11	de Waard, P. W. J., A. Peijnenburg, H. Baykus, J. Aarts, R. Hoogenboom, F. J. van Schooten and T. de Kok (2008). 'A human intervention study with foods containing natural Ah-receptor agonists does not significantly show AhR-mediated effects as measured in blood cells and urine.' Chemico-Biological Interactions **176**(1): 19-29.	Not relevant	Paper is on human health effects
12	de Waard, W. J., J. Aarts, A. Peijnenburg, H. Baykus, E. Talsma, A. Punt, T. de Kok, F. J. van Schooten and L. A. P. Hoogenboom (2008). 'Gene expression profiling in Caco-2 human colon cells exposed to TCDD, benzo a pyrene, and natural Ah receptor agonists from cruciferous vegetables and citrus fruits.' Toxicology in Vitro **22**(2): 396-410.	Not relevant	Paper is on human health effects
13	Ding, H. Y. (2011). 'Extracts and Constituents of Rubus chingii with 1,1-Diphenyl-2-picrylhydrazyl (DPPH) Free Radical Scavenging Activity.' International Journal of Molecular Sciences **12**(6): 3941-3949.	Not relevant	Paper is not on dioxins
14	Domingo, J. L., G. Perello, M. Nadal and M. Schuhmacher (2012). 'Dietary intake of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) by a population living in the vicinity of a hazardous waste incinerator. Assessment of the temporal trend.' Environment International **50**: 22-30.	Not relevant	Paper is on dietary intake
15	Dymkowska-Malesa, M., A. Szparaga and E. Czerwinska (2014). 'Evaluation of Polichlorinated Biphenyls Content in Chosen Vegetables from Warmia and Mazury Region.' Rocznik Ochrona Srodowiska **16**: 290-299.	Not relevant	Paper is not on fruit
16	El Gendy, M. A. M., V. Somayaji and A. O. S. El-Kadi (2010). 'Peganum harmala L. is a Candidate Herbal Plant for Preventing Dioxin Mediated Effects.' Planta Medica **76**(7): 671-677.	Not relevant	Paper is on human health effects
17	Fang, C. C., F. Y. Chen, C. R. Chen, C. C. Li, L. C. Wong, Y. W. Liu and J. G. J. Su (2013). 'Cyprodinil as an activator of aryl hydrocarbon receptor.' Toxicology **304**: 32-40.	Not relevant	Paper is on human health effects
18	Fernandes, A., D. Mortimer, M. Gem, F. Smith, M. Rose, S. Penton and M. Carr (2010). 'Polychlorinated Naphthalenes (PCNs): Congener Specific Analysis, Occurrence in Food, and Dietary Exposure in the UK.' Environmental Science & Technology **44**(9): 3533-3538.	Not relevant	Paper is not on dioxins
19	Forouzan, S. and A. Madadlou (2014). 'Incidence of Patulin in Apple Juices Produced in West Azerbayjan Province, Iran.' Journal of Agricultural Science and Technology **16**: 1613-1622.	Not relevant	Paper is not on dioxins
20	Garvie, L. A. J., B. Wilkens, T. L. Groy and J. A. Glaeser (2015). 'Substantial production of drosophilin A methyl ether (tetrachloro-1,4-dimethoxybenzene) by the lignicolous basidiomycete Phellinus badius in the heartwood of mesquite (Prosopis juliflora) trees.' Science of Nature **102**(3-4).	Not relevant	Paper is not on dioxins or on fruit
21	Hennig, B., E. Oesterling and M. Toborek (2007). 'Environmental toxicity, nutrition, and gene interactions in the development of atherosclerosis.' Nutrition Metabolism and Cardiovascular Diseases **17**(2): 162-169.	Not relevant	Paper is not on dioxins or on fruit
22	Hilden, K. S., R. Bortfeldt, M. Hofrichter, A. Hatakka and T. K. Lundell (2008). 'Molecular characterization of the basidiomycete isolate Nematoloma frowardii b19 and its manganese peroxidase places the fungus in the corticoid genus Phlebia.' Microbiology-Sgm **154**: 2371-2379.	Not relevant	Paper is not on dioxins or on fruit
23	Hofe, C. R., L. M. Feng, D. Zephyr, A. J. Stromberg, B. Hennig and L. M. Gaetke (2014). 'Fruit and vegetable intake, as reflected by serum carotenoid concentrations, predicts reduced probability of polychlorinated biphenyl-associated risk for type 2 diabetes: National Health and Nutrition Examination Survey 2003-2004.' Nutrition Research **34**(4): 285-293.	Not relevant	Paper is on human health effects

Nr	Author	Relevance	Rationale
24	Hu, G. F., M. Hernandez, H. H. Zhu and S. Q. Shao (2013). 'An efficient method for the determination of furan derivatives in apple cider and wine by solid phase extraction and high performance liquid chromatography-Diode array detector.' Journal of Chromatography A **1284**: 100-106.	Not relevant	Paper is on an analytical method and not on dioxins
25	Hulin, M., N. Bemrah, A. Nougadere, J. L. Volatier, V. Sirot and J. C. Leblanc (2014). 'Assessment of infant exposure to food chemicals: the French Total Diet Study design.' Food Additives and Contaminants Part a-Chemistry Analysis Control Exposure & Risk Assessment **31**(7): 1226-1239.	Not relevant	Paper is on human health effects
26	Inui, H., M. Sawada, J. Goto, K. Yamazaki, N. Kodama, H. Tsuruta and H. Eun (2013). 'A Major Latex-Like Protein Is a Key Factor in Crop Contamination by Persistent Organic Pollutants.' Plant Physiology **161**(4): 2128-2135.	Not relevant	Paper is on human health effects
27	Leake, J. R., A. Adam-Bradford and J. E. Rigby (2009). 'Health benefits of 'grow your own' food in urban areas: implications for contaminated land risk assessment and risk management?' Environmental Health **8**.	Not relevant	Paper is on human health effects
28	Leung, A. O. W., J. K. Y. Chan, G. H. Xing, Y. Xu, S. C. Wu, C. K. C. Wong, C. K. M. Leung and M. H. Wong (2010). 'Body burdens of polybrominated diphenyl ethers in childbearing-aged women at an intensive electronic-waste recycling site in China.' Environmental Science and Pollution Research **17**(7): 1300-1313.	Not relevant	Paper is on human health effects
29	Li, K., J. Q. Wu, L. L. Jiang, L. Z. Shen, J. Y. Li, Z. H. He, P. Wei, Z. Lv and M. F. He (2017). 'Developmental toxicity of 2,4-dichlorophenoxyacetic acid in zebrafish embryos.' Chemosphere **171**: 40-48.	Not relevant	Paper is on human health effects
30	Llobet, J. M., R. Marti-Cid, V. Castell and J. L. Domingo (2008). 'Significant decreasing trend in human dietary exposure to PCDD/PCDFs and PCBs in Catalonia, Spain.' Toxicology Letters **178**(2): 117-126.	Not relevant	Paper is on dietary intake
31	Marti-Cid, R., A. Bocio and J. L. Domingo (2008). 'Dietary exposure to PCDD/PCDFs by individuals living near a hazardous waste incinerator in Catalonia, Spain: Temporal trend.' Chemosphere **70**(9): 1588-1595.	Not relevant	Paper is on dietary intake
32	Peijnenburg, A., J. Riethof-Poortman, H. Baykus, L. Portier, T. Bovee and R. Hoogenboom (2010). 'AhR-agonistic, anti-androgenic, and anti-estrogenic potencies of 2-isopropylthioxanthone (ITX) as determined by in vitro bioassays and gene expression profiling.' Toxicology in Vitro **24**(6): 1619-1628.	Not relevant	Paper is on human health effects
33	Perello, G., J. Gomez-Catalan, V. Castell, J. M. Llobet and J. L. Domingo (2012). 'Assessment of the temporal trend of the dietary exposure to PCDD/Fs and PCBs in Catalonia, over Spain: Health risks.' Food and Chemical Toxicology **50**(2): 399-408.	Not relevant	Paper is on dietary intake
34	Pitarch, E., C. Medina, T. Portoles, F. J. Lopez and F. Hernandez (2007). 'Determination of priority organic micro-pollutants in water by gas chromatography coupled to triple quadrupole mass spectrometry.' Analytica Chimica Acta **583**(2): 246-258.	Not relevant	Paper is on an analytical method
35	Porrini, C., E. Caprio, D. Tesoriero and G. Di Prisco (2014). 'Using honey bee as bioindicator of chemicals in Campanian agroecosystems (South Italy).' Bulletin of Insectology **67**(1): 137-146.	Not relevant	Paper is not on dioxins
36	Saito, K., A. Ohmura and M. Takekuma (2008). 'Assessment of dioxin intake from commercial baby food in infant.' Bulletin of Environmental Contamination and Toxicology **80**(3): 185-187.	Not relevant	Paper is on dietary intake and not on fruit

Nr	Author	Relevance	Rationale
37	Sapozhnikova, Y. and S. J. Lehotay (2013). 'Multi-class, multi-residue analysis of pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, polybrominated diphenyl ethers and novel flame retardants in fish using fast, low-pressure gas chromatography-tandem mass spectrometry.' Analytica Chimica Acta **758**: 80-92.	Not relevant	Paper is on an analytical method
38	Tan, Y. Q., L. C. Chiu-Leung, S. M. Lin and L. K. Leung (2018). 'The citrus flavonone hesperetin attenuates the nuclear translocation of aryl hydrocarbon receptor.' Comparative Biochemistry and Physiology C-Toxicology & Pharmacology **210**: 57-64.	Not relevant	Paper is on human health effects
39	Traore, T., C. Bechaux, V. Sirot and A. Crepet (2016). 'To which chemical mixtures is the French population exposed? Mixture identification from the second French Total Diet Study.' Food and Chemical Toxicology **98**: 179-188.	Not relevant	Paper is on dietary intake
40	Tuyet-Hanh, T. T., N. H. Minh, L. Vu-Anh, M. Dunne, L. M. Toms, T. Tenkate, M. H. N. Thi and F. Harden (2015). 'Environmental health risk assessment of dioxin in foods at the two most severe dioxin hot spots in Vietnam.' International Journal of Hygiene and Environmental Health **218**(5): 471-478.	Not relevant	Paper is on human health effects
41	Uddin, G., A. Latif, M. Arfan, M. Ali, S. H. Hussain, T. J. Simpson, R. J. Cox and M. I. Choudhary (2013). 'Phytochemicals from the stem wood of Sorbus lanata (D. Don.) Schauer.' Phytochemistry Letters **6**(1): 84-89.	Not relevant	Paper is not on dioxins or on fruit
42	van der Lee, M. K., G. Van der Weg, W. A. Traag and H. G. J. Mol (2008). 'Qualitative screening and quantitative determination of pesticides and contaminants in animal feed using comprehensive two-dimensional gas chromatography with time-of-flight mass spectrometry.' Journal of Chromatography A **1186**(1-2): 325-339.	Not relevant	Paper is on an analytical method
43	van Ede, K., A. Li, E. Antunes-Fernandes, P. Mulder, A. Peijnenburg and R. Hoogenboom (2008). 'Bioassay directed identification of natural aryl hydrocarbon-receptor agonists in marmalade.' Analytica Chimica Acta **617**(1-2): 238-245.	Not relevant	Paper is on human health effects
44	Vogt, R., D. Bennett, D. Cassady, J. Frost, B. Ritz and I. Hertz-Picciotto (2012). 'Cancer and non-cancer health effects from food contaminant exposures for children and adults in California: a risk assessment.' Environmental Health **11**.	Not relevant	Paper is on human health effects
45	Wang, W. D., G. T. Chen, H. J. Hsu and C. Y. Wu (2015). 'Aryl hydrocarbon receptor 2 mediates the toxicity of Paclobutrazol on the digestive system of zebrafish embryos.' Aquatic Toxicology **159**: 13-22.	Not relevant	Paper is on human health effects
46	Xing, G. H., S. C. Wu and M. H. Wong (2010). 'Dietary exposure to PCBs based on food consumption survey and food basket analysis at Taizhou, China - The World's major site for recycling transformers.' Chemosphere **81**(10): 1239-1244.	Not relevant	Paper is on dietary exposure
47	Zhang, D. B., G. Y. Li and Y. Wang (2017). 'A genome-wide identification and analysis of basic helix-loop-helix transcription factors in cattle.' Gene **626**: 241-250.	Not relevant	Paper is not on dioxins or fruit
48	Aslan, S., M. K. Korucu, A. Karademir and E. Durmusoglu (2010). 'Levels of PCDD/Fs in local and non-local food samples collected from a highly polluted area in Turkey.' Chemosphere **80**(10): 1213-1219.	Maybe relevant	Paper is on dioxin levels in specific region and general on food
49	Lee, C. C., H. T. Lin, Y. M. Kao, M. H. Chang and H. L. Chen (2016). 'Temporal trend of polychlorinated dibenzo-p-dioxin/polychlorinated dibenzofuran and dioxin like-polychlorinated biphenyl concentrations in food from Taiwan markets during 2004-2012.' Journal of Food and Drug Analysis **24**(3): 644-652.	Maybe relevant	Paper is on dioxins in food in general (not specific for fruit)

Nr	Author	Relevance	Rationale
50	Loutfy, N., M. Fuerhacker, C. Lesueur, M. Gartner, M. T. Ahmed and A. Mentler (2008). 'Pesticide and non-dioxin-like polychlorinated biphenyls (NDL-PCBs) residues in foodstuffs from Ismailia city, Egypt.' Food Additives & Contaminants Part B-Surveillance **1**(1): 32-40.	Maybe relevant	Paper is on dioxin levels in specific region and general on food
51	Miklos, K., B. Ildiko and L. Attila (2008). 'Dioxins in the foods. Part 2. Dioxin contamination in 2007. Case report.' Magyar Allatorvosok Lapja **130**(6): 374-379.	Maybe relevant	Paper is on dioxins in food in general (not specific for fruit)
52	Choi, G. H., D. S. Choi, S. M. Hong, O. K. Kwon, H. S. Eun, J. H. Kim and J. H. Kim (2012). 'Investigation on Polychlorinated Dibenzo-p-dioxins, Polychlorinated Dibenzofurans and Dioxin-like Polychlorinated Biphenyls in Korean Fruits and Dietary Intake Estimation.' Journal of the Korean Society for Applied Biological Chemistry **55**(3): 423-427.	Relevant	Paper is on dioxin levels in fruit
53	Esposito, M., A. De Roma, S. Cavallo, G. Diletti, L. Baldi and G. Scortichini (2017). 'Occurrence of Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans and Polychlorinated Biphenyls in Fruit and Vegetables from the 'Land of Fires' Area of Southern Italy.' Toxics **5**(4).	Relevant	Paper is on dioxin levels in fruit
54	Grassi, P., E. Fattore, C. Generoso, R. Fanelli, M. Arvati and E. Zuccato (2010). 'Polychlorobiphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) in fruit and vegetables from an industrial area in northern Italy.' Chemosphere **79**(3): 292-298.	Relevant	Paper is on dioxin levels in fruit

Annex 4 KAP data on non-pesticides – substances with more than 5% positive samples (in Dutch)

Stof	Maximum (µg/kg; zware metalen mg/kg)	Gemiddelde van de positieven	Aantal monsters	Percentage positieve monsters
ACRYLAMIDE	276.0	111.2	5	80.0%
APPELCHIPS	14.0	14.0	2	50.0%
BANANENCHIPS	276.0	208.3	3	100.0%
AFLATOXINE B1	830	23.9	300	7.0%
MOERBEI	13.0	3.4	43	16.3%
OV. FRUIT, NOTEN	4.6	2.9	8	25.0%
VIJG	830.0	88.0	122	9.0%
AFLATOXINE B12G12	1100.0	36.8	300	6.7%
MOERBEI	15.0	3.7	43	16.3%
OV. FRUIT, NOTEN	4.6	2.9	8	25.0%
VIJG	1100.0	139.5	122	8.2%
AFLATOXINE B2	85.0	7.8	165	4.8%
VIJG	85.0	14.0	122	5.7%
BEAUVERICINE	460.0	36.6	392	17.3%
OV. FRUIT, NOTEN	1.5	1.5	8	12.5%
VIJG	460.0	141.7	122	53.3%
CADMIUM	0.1	0.1	48	20.8%
GOJI BES	0.1	0.1	48	20.8%
ENNIATINE A1	2.9	1.9	464	0.9%
APPELMOES	2.9	2.2	29	10.3%
ENNIATINE B	13.0	5.1	29	37.9%
APPELMOES	13.0	5.1	29	37.9%
ENNIATINE B1	7.3	1.9	37	29.7%
APPELMOES	7.3	2.8	29	34.5%
OV. FRUIT, NOTEN	1.0	1.0	8	12.5%
FUMONISINE B1	420.0	115.6	122	11.5%
VIJG	420.0	115.6	122	11.5%
Fumonisine B1 en B2 (som)	420.0	112.9	122	10.7%
VIJG	420.0	112.9	122	10.7%
HT-2 TOXINE	170.0	165.0	35	5.7%
VEENBES	170.0	165.0	35	5.7%
LOOD	0.23	0.05	126	15.9%
GOJI BES	0.23	0.06	48	18.8%
MOERBEI	0.11	0.07	43	20.9%
VEENBES	0.03	0.03	35	5.7%
MYCOFENOLZUUR	2500.0	150.4	713	17.3%
KRENT	740.0	120.6	73	52.1%
ROZIJN	2500.0	355.9	435	18.9%
NIKKEL	2.5	1.4	9	22.2%
ACAIBES	2.5	1.4	9	22.2%
OCHRATOXINE A	340.0	65.6	962	12.2%
KRENT	22.0	7.1	73	21.9%
MOERBEI	11.0	6.0	43	14.0%
ROZIJN	25.0	6.0	435	16.3%
VIJG	120.0	28.0	122	17.2%
T-2 TOXINE	130.0	125.0	35	5.7%
VEENBES	130.0	125.0	35	5.7%
TENUAZONZUUR	83000.0	1433.5	1163	26.1%
ABRIKOOS	790.0	114.6	162	32.7%

Stof	Maximum (µg/kg; zware metalen mg/kg)	Gemiddelde van de positieven	Aantal monsters	Percentage positieve monsters
CHINESE JUJUBES/RODE DADELS/CHINESE DADELS	310.0	310.0	3	33.3%
DADEL	170.0	68.3	127	7.1%
GEMENGDE VRUCHTEN	40.0	40.0	4	25.0%
GOJI BES	2500.0	751.6	48	75.0%
KRENT	400.0	114.7	73	21.9%
MOERBEI	83000.0	13737.4	43	79.1%
PRUIM, INCL KWETS	120.0	55.0	100	6.0%
ROZIJN	3400.0	173.9	435	17.7%
TUTTIFRUTTI	26.0	26.0	11	9.1%
VEENBES	120.0	120.0	35	2.9%
VIJG	7800.0	1690.4	122	55.7%

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