Chemical hazards in the fruiting vegetable supply chain in the Netherlands

R.G. Hobe, Y. Hoffmans, E.F. Hoek-van den Hil, E.D. van Asselt

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Summary

A literature study was performed to identify the chemical hazards that may be found in fruiting vegetables on the Dutch market. For this purpose, search terms were defined and used in Scopus and Web of Science for the period 2009-2019. Additionally, the advanced search feature of Google was used to retrieve relevant reports from EFSA, BfR, FAVV and Aecosan. Additional searches were performed on specific hazard groups in case limited number of hits were obtained or only experimental studies were retrieved. References were first evaluated on title, keywords and abstract. Those references that were seen as relevant were read in full and summarised in an Excel table that was submitted to NVWA-BuRO as additional file to this report.

Long list of chemical hazards in fruiting vegetables

The literature search in Scopus and Web of Science resulted in 350 hits of which 88 were seen as relevant. The Google search resulted in 17 relevant reports and the additional literature search resulted in 16 papers. The literature search showed that the most frequently mentioned fruiting vegetables were tomato, pepper and cucumber. Based on the information obtained, the following hazard groups were found to be present in fruiting vegetables: heavy metals and other elements, polycyclic aromatic hydrocarbons (PAHs), pharmaceuticals, dioxins and dl-PCBs, perfluorinated compounds, radionuclides, plant protection products (PPPs), mycotoxins, plant toxins, cleaning agents and disinfectants, and other chemical hazards such as phthalates, perchlorate and nitrate. These hazards were included in the so-called long list: chemical hazards that might be present in fruiting vegetables.

Intermediate list of chemical hazards in fruiting vegetables

Those chemical hazards that were found above legal limits, frequently encountered in fruiting vegetables or that led to an exceedance of a health-based guidance value (HBGV) were included on the so-called intermediate list. The heavy metals cadmium and lead were included on this list, since exceedances above the EU maximum limits (MLs) were found. A total of 54 PPPs were included on the list since these were either frequently found in fruiting vegetables or found at levels exceeding the EU maximum residue limits (MRLs). This list is solely identified based on the obtained literature. It is recommended to consult the Dutch monitoring data to confirm the relevance of the identified PPPs for the Netherlands. Total aflatoxins and aflatoxin B1 were included on the list since levels above the EU ML were found in pepper. The Alternaria toxins, tenuazonic acid and tentoxin were added since tomatoes were seen as the main contributors to the dietary intake of these toxins. The disinfectant didecyldimethylammonium chloride (DDAC) was added to the list since levels above the EU MRL were found in fruiting vegetables. Perchlorate levels in fruiting vegetables resulted in an exceedance of the provisional maximum tolerable daily intake (PMTDI) and thus this substance was also included on the list. Since high nitrate levels (up to 5665 mg/kg) were occasionally found in pumpkin, this substance was also added to the list. Several knowledge gaps were identified. PAH8 were seen as knowledge gap since high levels (>5 µg/kg) were found in fruiting vegetables but no information was found for fruiting vegetables on the Dutch market. Benzalkonium chloride (BAC) was identified as knowledge gap, since levels above the EU MRL were found in the group of Solanaceae. However, it is unclear whether these levels were found in potatoes or fruiting vegetables. Finally, chlorate was seen as knowledge gap, since the contribution of fruiting vegetables to the dietary intake of this substance was unknown.

Evaluation of trends in fruiting vegetables

In an earlier report, the general trends in vegetables were described (Banach et al., 2019). A Google search was done to collect information on future trends specifically related to fruiting vegetables. In general, a relevant trend for vegetable cultivation is the interest in the use of treated wastewater and sludge in open field cultivation, which may lead to the presence of e.g. pharmaceuticals in fruiting vegetables. Another relevant trend is the increased interest in the use of waste streams to produce new products or packaging materials. Chemical hazards present in these waste streams may end up in the final product.

Samenvatting

Er is een literatuuronderzoek uitgevoerd om de chemische gevaren te identificeren die kunnen voorkomen in vruchtgroenten op de Nederlandse markt. Hiervoor werden zoektermen gedefinieerd en in Scopus en Web of Science toegepast voor de periode 2009-2019. Verder is de geavanceerde zoekoptie binnen Google gebruikt om relevante rapporten te zoeken op de websites van EFSA, BfR, FAVV en Aecosan. Indien een beperkt aantal hits werd verkregen voor een bepaalde gevarengroep of alleen experimentele studies werden gevonden, werd aanvullende literatuur gezocht. Referenties werden in eerste instantie beoordeeld op titel, abstract en zoektermen. Referenties die relevant leken, werden volledig gelezen en samengevat in een Exceltabel die als aanvullend bestand is aangeleverd aan NVWA-BuRO.

Long list van chemische gevaren in vruchtgroenten
De literatuuropdracht in Scopus en Web of Science resulteerde in 350 hits, waarvan er 88 als relevant werden gezien. De zoektocht in Google leverde 17 relevante rapporten op en het additionele literatuur-onderzoek 16 artikelen. Uit het literatuuronderzoek bleek dat de meest bestudeerde vruchtgroenten tomaat, paprika en komkommer waren. De verkregen informatie liet zien dat de volgende gevaren-groepen gevonden werden in vruchtgroenten: zware metalen en andere elementen, polycyclische koolwaterstoffen (PAK's), geneesmiddelen, dioxinen en dl-PCB's, perfluorverbindingen, radionucliden, gewasbeschermingsmiddelen, mycotoxinen, planttoxinen, reinigings- en disinfectiemiddelen, en overige chemische gevaren zoals ftalaten, perchloraat en nitraat. Deze gevaren werden opgenomen op de zogenaamde long list: chemische gevaren die mogelijk kunnen voorkomen in vruchtgroenten.

Intermediate list van chemische gevaren in vruchtgroenten
Chemische gevaren die boven de wettelijke limiet werden gevonden, regelmatig werden aangetroffen in vruchtgroenten of die leidden tot een overschrijding van een gezondheidskundige richtwaarden werden opgenomen op de zogenaamde intermediate list. De zware metalen cadmium en lood werden op deze lijst opgenomen, aangezien er overschrijdingen van de EU maximale limiet (ML) werden gevonden. In totaal werden 54 gewasbeschermingsmiddelen op de lijst gezet, omdat ze ofwel regelmatig gevonden werden in vruchtgroenten ofwel werden aangetroffen in concentraties boven de EU-maximumwaarde voor residuen (MRL). Deze lijst is slechts gebaseerd op de verkregen literatuur. Er wordt daarom aanbevolen de Nederlandse monitoringsdata te raadplegen om de relevantie van de gewasbeschermingsmiddelen voor Nederland vast te stellen. Aflatoxinen en aflatoxine B1 werden op de lijst gezet, aangezien concentraties boven de EU ML werden gevonden in paprika. De *Alternaria* toxines tenuazonzuur en tentoxine werden toegevoegd, aangezien tomaten een belangrijke bijdrage bleken te hebben aan de dagelijkse inname van deze toxinen. Het desinfectiemiddel didecyldimethyl-ammoniumchloride (DDAC) werd toegevoegd aan de lijst, aangezien concentraties boven de EU MRL werden gevonden in vruchtgroenten. Perchloraatconcentraties in vruchtgroenten leidden tot een overschrijding van de voorlopige maximaal toegestane dagelijkse inname (PMTDI) en dus werd deze stof ook op de lijst gezet. Aangezien soms hoge concentraties nitraat (tot 5665 mg/kg) werden gevonden in pompoen, werd deze stof ook toegevoegd aan de lijst. Een aantal kennisleemtes werden geïdentificeerd. PAH8 werd als kennisleemte gezien, aangezien hoge concentraties (> 5 µg/kg) werden gevonden in vruchtgroenten, maar er was geen informatie over vruchtgroente op de Nederlandse markt. Benzalkoniumchloride (BAC) werd gezien als kennisleemte, aangezien concentraties boven de EU MRL werden gevonden in de groep *Solanaceae*. Het is echter onduidelijk of het hier aardappels of vruchtgroenten betrof. Tenslotte werd chloraat als kennisleemte aangemerkt, aangezien de bijdrage van vruchtgroenten aan de dagelijkse inname van deze stof onduidelijk is.

Evaluatie van trends

In een eerder rapport zijn de algemene trends in groente beschreven (Banach et al., 2019). Voor vruchtgroente is aanvullend nog gezocht naar toekomsttrends via een Google zoekopdracht. Een belangrijke trend, in het algemeen voor groente, is de interesse in het gebruik van behandeld afvalwater en slib bij de vollegrondsteelt. Dit kan leiden tot de aanwezigheid van bijvoorbeeld residuen van geneesmiddelen in vruchtgroenten. Een andere belangrijke trend is de toegenomen interesse in het gebruik van afvalstromen om nieuwe producten of verpakkingsmateriaal te maken. Chemische gevaren die in deze afvalstromen aanwezig zijn, kunnen uiteindelijk in het eindproduct terechtkomen.

1 Introduction

The main task of the Netherlands Food and Consumer Product Safety Authority (NVWA) is to protect human and animal health and as such the NVWA is responsible for the supervision of food business operations. 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.

The NVWA Office for Risk Assessment and Research (Bureau Risicobeoordeling & onderzoek; BuRO) advices on food safety hazards to include in the national monitoring programs based on risk assessments. Previously, the red meat chain, dairy chain, poultry chain, and egg chain have been assessed for the most relevant chemical hazards that may occur in these chains. Currently, the fruit and vegetable chain is being evaluated. This food supply chain is divided into seven 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 5, fruiting vegetables, is the focus of this research.

The aim of this study is to make an inventory of possible chemical hazards in the fruiting vegetables chain in the Netherlands. Based on scientific literature, chemical hazards that are frequently found in fruiting vegetables and/or found above legal limits are identified. The information can be used as input for the risk prioritization and assessment of chemical hazards in the fruiting vegetables chain.

As help for the Dutch reader of this report, the names of the vegetables used in this report have been translated in Annex 1. Furthermore, a list of abbreviations used is provided in Annex 2.

An overview of the literature review on the uptake and occurrence of chemical hazards in fruiting vegetables is given as well as the effects of processing on the presence of these hazards (section 3.3). These chemical hazards were placed on the so-called 'long list'. In case the literature review indicated that chemical hazards were frequently found, exceeded the (EU) legal limits or were reported to result in an exceedance of health-based guidance values (HBGV), these hazards were included on the so-called intermediate list (section 3.4). For the chemical hazards on the intermediate list and those identified as knowledge gap, toxicological information is provided (section 3.5). Finally, trends and developments identified for the supply chain of fruiting vegetables are reported and their possible effect on the occurrence of chemical hazards in these vegetables (section 3.6).

2 Methods

2.1 Project description and demarcation

A literature study was performed to identify chemical hazards that may occur in fruiting vegetables. The study focused on fresh products. Processed products of fruiting vegetables, like soup, juices, chips etc. were not part of this literature study. Furthermore, pepper was included in the study as it belongs to the fruiting vegetables, but dried pepper was excluded since this belongs to the food category of spices and herbs. The effect of processing, including drying, on the presence of chemical hazards in fruiting vegetables was included in this report, if encountered in literature, but no specific search was performed on the effects of processing.

Scientific literature and reports were screened for relevancy as described in 2.3.1. The relevant papers were retrieved, evaluated in detail (e.g., main message of study, concentrations, country of origin), and the information provided in the papers was summarized in an Excel file (that was provided to NVWA-BuRO as addition to this report). Furthermore, toxicological information was gathered for those chemical hazards that were frequently found, for which levels were found to exceed the legal limits, and/or that resulted in an exceedance of the HBGVs (see section 2.4). Next to the scientific literature review, an analysis of the trends in fruiting vegetables was performed using information from grey literature and the Innova database (see section 2.5). Each step of the study is outlined below.

2.2 Eurostat imports

Eurostat data on import to the Netherlands were used to prioritize references on heavy metals and pesticide residues, as these hazards resulted in many hits. Only articles from the main import countries (top 3-5 countries) were used in the report. The remaining articles are included in the accompanying Excel file, but not used further in this report. The EUROSTAT import data for the Netherlands for 2017 were extracted by NVWA-BuRO in September 2019. To obtain the import data of fruiting vegetables, the following harmonised system (HS) codes were included:

- Tomatoes, fresh or chilled (HS code: 70200);
- Cucumbers and gherkins, fresh or chilled (HS code: 70700);
- Fresh or chilled aubergines 'eggplants' (HS code: 70930);
- Fresh or chilled fruits of the genus capsicum or pimenta (HS code: 70960);
- Fresh or chilled pumpkins, squash and gourds 'cucurbita spp'. (HS code: 70993).

2.3 Literature study

2.3.1 Scientific literature

The focus of this study was on fruiting vegetables like tomato, aubergine, bell pepper, courgette and pumpkin. Since fruiting vegetables include a wide variety of product groups, the first step was to define the fruiting vegetable search terms to be used in the product commodity search string of the literature study. The EFSA classification and the Chain Classes for Fruits and Vegetables provided by the NVWA (Ketenklassen GF) were used. In the current study, spices made from fruiting vegetables, like dried pepper and chilli were excluded. In addition, gherkins (= pickled cucumbers) were excluded from this study, because gherkins belong to the fermented vegetables. Details on the product search terms (#1) used for the scientific literature study on fruiting vegetables can be found in Annex 3. The search string was supplemented with search terms for chemical hazards (#2) and public health (#3), analogous to previously performed chain studies (Banach et al., 2019; Hoffmans et al., 2020). Searches were further defined using exclusion terms to help obtain relevant papers.

The final search string used in the literature study was as follows:

#1 Product commodity - in Title:
"fruiting vegetable*" OR "fruit vegetable*" OR "fruity vegetable*" OR tomato* OR aubergine* OR pepper* OR courgette* OR zucchini* OR cucumber* OR cucurbit* OR gourd* OR pumpkin* OR squash* OR kabocha OR hokkaido OR tinda OR eggplant* OR egg*plant OR chilli* OR chili* OR oliv* OR okra

AND #2 Chemical hazards - in Title, abstract or keywords:
"food contamination" OR "chemical pollutant*" OR "chemical hazard*" OR contamina* OR toxin* OR "toxic substance*" OR "toxic compound*" OR pollutant* OR "agricultural chemical*" OR "chemical compound*" OR "chemical substance*" OR residu*

AND #3: Public Health - in Title, abstract or keywords:
"public health" OR "HACCP" OR "consumer protection" OR "food safety" OR "risk assessment*"
OR "risk analys*" OR "hazard analys*" OR "human health*" OR "health impact" OR "health risk*"

AND NOT #4 Exclusion terms - in Title:
pathogen* OR streptococcus OR listeria OR *virus* OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR fung* OR campylobacter OR "Escherichia coli" OR "E. coli" OR model* OR analytic* OR microbi* OR virol* OR nutri* OR method* OR environment* OR ecological* OR oil*

The search was limited to papers published in 2009-2019. The search was performed on the 27th of August 2019.

In the scientific literature study, two databases were used: Scopus and Web of Science. After removal of the duplicates, the remaining references were evaluated for relevancy.

To determine the relevancy of the references the following steps were performed:
1. Papers were screened based on title, abstract and keywords. Based on this screening, the papers were classified as 'relevant', 'maybe relevant' or 'not relevant'. Papers classified as 'maybe relevant' were, for instance, papers about MRL modifications, pre-harvest interval determination of pesticide residues, or papers written in another language than English. Examples of papers classified as 'not relevant' are papers focussing on method validation, microbiology-related topics, animals (e.g. olive flounder and sea cucumber juveniles) or specific places for which its name resembles a vegetable, but that do not discuss the presence of chemical hazards in vegetables (e.g. Hokkaido (island in Japan) and Chilika (lake in India)). For more details on choices made in the determination of the relevance of the scientific literature, see Annex 4.
2. Afterwards, a small part of the total references was peer reviewed by a second scientist to check for consistency of the grouping of references into relevant, maybe relevant and not relevant. Inconsistencies were discussed, and the evaluation was aligned (Annex 5).
3. After peer-review, the papers classified as relevant were downloaded and the information provided in the paper was summarized in the Excel table. This table includes, amongst others, the chemical hazards found, country of origin, concentrations and the main message of the paper.

2.3.2 Google search

In addition to the scientific literature search, an advanced Google search was performed. The websites of four food safety institutes were selected. EFSA was chosen as relevant institute related to food safety. In addition, BfR, FAVV and Aecosan were selected based on the countries important for the import of fruiting vegetables into the Netherlands (see Annex 6).

The four websites used:
1. European Food Safety Authority (EFSA) (efsa.europe.eu)
2. German Federal Institute for Risk Assessment (BfR) (bfr.bund.de)
3. Federal Agency for the Safety of the Food Chain (FAVV) (afsca.be)
4. Spanish Agency for Consumer Affairs, Food Safety and Nutrition (Aecosan) (aecosan.msssi.gob.es)

2.3.3 Additional searches

If no or only a limited amount of papers in the systematic literature search and the advanced Google search were obtained or only experimental studies, then an additional literature search in Scopus was done. The additional literature search was similar to the search terms described in 2.3.1, with the only exception that search terms #2 were replaced by the following terms:
- "flame retardant*"
- ("persistent organic pollutant*" OR POP* OR "perfluoroalkyl compound*" OR "perfluoroalkyl substanc*" OR pfas OR pfoa OR pfos OR polychlorinated biphenyl* OR pcb* OR dioxin*)
- ("plant toxin*" OR "pyrrolizidine alkaloid*" OR "tropane alkaloid*" OR solanidin* OR tomatidin* OR tomatin* OR soladulcidin* OR dulcamarin* OR solasonin* OR capsaicin* OR cucurbitacin*)
- acrylamide
- radionuclide*
- (polycyclic aromatic hydrocarbon* OR PAH*)
- (pharmaceutical* OR antibiotic* OR antimicrobial* OR steroid* OR endocrine*) AND NOT (resistance OR resistant OR antioxida*)
- (mycotoxin* OR aflatoxin* OR fumonisin* OR DON OR deoxynivalenol)
- (cleaning OR disinfect*)

2.4 Prioritization

Chemical hazards that may occur in fruiting vegetables according to the literature review, were included in a so-called long list of possible chemical hazards (see section 3.3). Hazards from this long list that were frequently mentioned in the literature to be present in fruiting vegetables and/or which resulted in exceedance of the (EU) legal limits or that resulted in an exceedance of HBGVs were selected for the intermediate list. If no monitoring data was available, but experimental studies indicated possible human health risks, then these substances were identified as knowledge gaps. For the substances on the intermediate list and the identified knowledge gaps, EFSA opinions and RIVM reports were consulted to establish information on the toxicity of the hazards. This information can be used by NVWA-BuRO to come to a short list of chemical hazards that may impact human health.

2.5 Evaluation of trends

In a previous report, the trends in the coming five years (2020-2024) were described for vegetables in general (Banach et al., 2019). The outcome was summarised in Hoffmans et al. (2020), see section 3.6. This information was used as a starting point to evaluate trends in fruiting vegetables. In addition, a Google search was done to collect information on future trends specifically related to fruiting vegetables. The search terms “trends” AND “vruchtgroente” OR “paprika” OR “tomaat” OR “komkommer” were used in the advanced search in Google. Due to the great number of hits, only the first two pages – i.e., the most relevant hits - were screened. Furthermore, these search terms were also applied in a search using the following websites:
- https://www.rabobank.com/;
- https://www.abnamro.nl/.

After this additional search, new products in scope of this research that are available in Dutch supermarkets were photographed. Furthermore, the Innova database was consulted by Wageningen Food & Biobased Research (WFBR) specifically for fruiting vegetables. Innova Market Insights collects all new product introductions and provides the information available on the package into the Innova

Database (www.innovamarketinsights.com). However, the duration of the product on the market is not registered in the database. The overview provided by the database was used to show the trend in products on the Dutch market in the past years. In addition, the team from Innova makes regular updates on trends they note in several of the categories. An Innova search was performed on introductions in the Netherlands between 2009 and 2018.

3 Results

3.1 Results Eurostat import data

In 2017, in total 229 million kg tomatoes, 122 million kg cucumbers, 110 million kg peppers and bell peppers, 45 million kg courgettes, 19 million kg pumpkins and 15 million kg aubergines were imported in the Netherlands. In total 50% of the fruiting vegetables imported in the Netherlands were from Spain (269.6 million kg). The import from Spain consisted of 33% tomatoes, followed by 25% cucumber and 25% pepper and bell pepper. Next to Spain, fruiting vegetables imported in the Netherlands mainly came from Belgium and Luxembourg, Germany, France and Morocco (Figure 1). The countries that provided ≤1% of the import into the Netherlands are summed together in 'Other'.

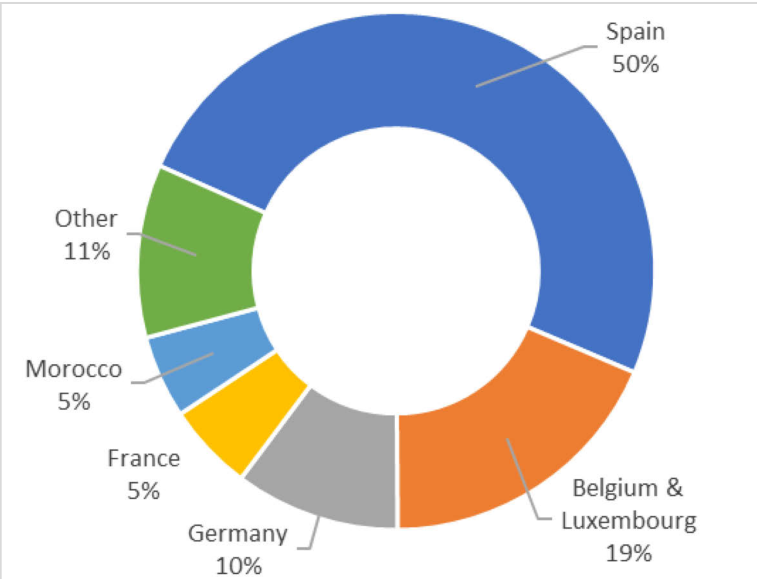

Figure 1 *Import of fruiting vegetables into the Netherlands in 2017, based on Eurostat data.*

3.2 Results literature study

3.2.1 Results from Scopus and Web of Science

The scientific literature search resulted in 288 hits in Scopus and 227 hits in Web of Science. Once uploaded into Endnote, 165 duplicate hits were removed, and the remaining 350 papers were evaluated for relevancy (section 2.3.1). Furthermore, 10% of the total references excluding duplicates were peer reviewed for their relevancy. This comparison of the evaluated references is presented in Annex 5, Table 3. The peer review showed an 86% agreement on the judged relevancy of the papers between the two scientists. Dissimilarities (5 references) were discussed to sharpen the relevance criteria and a final decision was taken on when to score the papers as relevant, maybe relevant or not relevant. The literature search resulted in 88 relevant papers, 66 papers were classified as maybe relevant and 196 as not relevant. After reading the full text, and depending on country of origin for heavy metals and pesticides, 33 of these were included in this report.

3.2.2 Results from Google search

The advanced Google search resulted in 17 relevant hits after screening the title (EFSA: 7, BfR: 6, FAVV: 3, Aecosan: 1). After reading the full text, 13 of these were included in this report. More information on the advanced Google search is available in Annex 6.

3.2.3 Results from the additional literature research

In the additional literature search, 16 relevant papers were found on polycyclic aromatic hydrocarbons (PAHs), POPs (more specific PCBs), pharmaceuticals, mycotoxins, nitrate, radionuclides and plant toxins. No relevant articles on flame retardants, processing contaminants, and cleaning agents and disinfectants. After reading the full text, 11 papers were included in this report.

3.2.4 Results per product

The relevant articles included in this report (57 in total) about each fruiting vegetable product were counted for the scientific literature search, advanced Google search, and additional literature research. Tomato was mentioned in 23 articles, different types of peppers were mentioned in 20 articles, cucumbers were mentioned in 14 articles. In 7 articles, olives, pumpkin, bell pepper and okra were mentioned. Aubergines, courgettes, and eggplants were mentioned in respectively 6, 4, and 2 articles.

3.3 Overview of chemical hazards in fruiting vegetables

3.3.1 Heavy metals and other elements

In total, 28 papers were found for heavy metals and other elements. Therefore, the papers containing occurrence data were downsized based on the country of origin. Papers on occurrence data were excluded if no fruiting vegetables were imported to the Netherlands in 2017 from the country of origin of the paper. As a result, 10 papers were excluded since we do not import fruiting vegetables from Nigeria, Pakistan, Jordan and Iran. Section 3.3.1.2 describes the results of the remaining papers. From the systematic literature study, 7 papers about the uptake of heavy metals by fruiting vegetables were included (section 3.3.1.1): 4 of these papers were based on experiments on the uptake of heavy metals via the soil and 3 about the uptake via water.

3.3.1.1 Uptake in fruiting vegetables

Heavy metals are present in the environment and the uptake of heavy metals can occur via the soil or (irrigation) water to the roots of the plant. No papers were found on the uptake of heavy metals from the air.

Uptake via the soil

The uptake of heavy metals from soil to tomato fruits was examined in Spain. The tomatoes were cultivated in an open field and the content of several heavy metals and elements in both tomato and the soil were monitored. No direct correlation between the heavy metal content in soil and the tomato fruits was found, except for manganese (Mn). If the Mn concentration was high in the soil (ranging from 240 to 1300 mg/kg dry weight (dw)) than high Mn levels were found in the tomato fruits (ranging from 5.8 to 23 mg/kg dw). Assuming a water content of 94% in tomato, the maximum Mn concentration found is 1.38 mg/kg fresh weight (fw) (Rodriguez-Iruretagoiena et al., 2015).

In Jordan, Al-Hwaiti and Al-Khashman (2015) determined the bioaccumulation factors in tomato and green pepper when grown in soil amended with phosphogypsum, which is waste from a phosphate fertilizer industry. A bioaccumulation factor is calculated by dividing the concentration in the crop by the concentration in the soil (both dw). A bioaccumulation factor below 1 means a higher concentration in the soil compared to the crop. Comparable amounts of heavy metals are taken up from the soil by tomatoes and green peppers. The bioaccumulation factors were all below 1 and decreased in the following order: zinc (Zn) > lead (Pb) > cadmium (Cd) > chromium (Cr). The authors also calculated a health risk index (HRI; local consumption of tomato and green pepper divided by the reference oral dose (RfD)). The intake was estimated assuming an average daily vegetable intake of 0.345 kg/person/day for adults. The RfD used was from the United States Environmental Protection Agency (US EPA). For adults, the HRI of tomatoes was 0.1 for Cd, 0.0 for Cr, between 0.4 and 0.7 for Pb, and 0.1 for Zn. The HRI of green peppers was 0.1 for Cd, 0.0 for Cr, between 0.3 and 0.7 for Pb, and 0.0 for Zn for adults. All HRIs were thus below 1, which means that heavy metal exposure via vegetable consumption was of no consequence for human health (Al-Hwaiti and Al-Khashman, 2015).

In Algeria, pepper was cultivated on two sites close to an industrial site, which was contaminated with heavy metals (Baba Ahmed and Bouhadjera, 2010). Information in this paper was given on the heavy metal uptake in stems, leaves and roots, but no information was provided on the uptake in the fruits. In pepper, Cd accumulation is higher in the roots (2.5 mg/kg dw) than in the stems and leaves (1.6 and 0.63 mg/kg dw, respectively). Copper (Cu) is accumulating primarily in the stems and leaves (26.6 and 23.3 mg/kg dw, respectively) in contrast to 1.1 mg/kg dw in the roots. For nickel (Ni), 22.3 mg/kg dw was found in the leaves of the pepper, 15.7 mg/kg dw in the stems and 11.0 mg/kg dw in the roots. Pb was primarily found in the leaves of the pepper (52.4 mg/kg dw), while Zn accumulated in the stems (726.5 mg/kg dw) (Baba Ahmed and Bouhadjera, 2010).

In Nigeria, the heavy metal content in okra grown in soil amended with sewage sludge was examined by Kuti et al. (2018). The concentration in the fruit was between 7.0-7.6 mg/kg for Cu, 31.9-51.6 mg/kg for iron (Fe), and 22.7-28.3 mg/kg for Zn. The FAO/WHO allowable limits for fruits and vegetables mentioned in the paper were 73.0 mg/kg for Cu, 425.0 mg/kg for Fe, and 99.4 mg/kg for Zn. This means that the concentrations of Cu, Fe and Zn in the fruits were lower than these maximum allowable limits. Furthermore, no bioaccumulation in okra was found as the bioaccumulation factors of Cu, Zn, and Fe were below one. The bioaccumulation order in okra was Zn > Cu > Fe (Kuti et al., 2018).

Uptake via water
Wastewater needs to be treated prior to irrigation in order to guarantee food safety. Sedimentation or sieving is used as first step to remove contaminants from wastewater. Secondary treated wastewater means that in addition to the first step, biofiltration, aeration or oxidation is used to degrade organic matter. To obtain tertiary treated wastewater, a final cleaning process is needed in which pathogens and inorganic compounds like phosphate and nitrate are removed. In several experimental studies, wastewater was treated differently to reduce heavy metal concentrations in tomato fruits after irrigation with this treated wastewater. Results are described below.

Battilani et al. (2009) studied the heavy metal concentration of tomato fruits in relation to irrigation in Italy. Two different treatments of secondary waste water were compared to tap water as control. The wastewater was treated using a membrane bioreactor (MBR) or a modular field treatment system (FTS). Tomatoes were cultivated in the open field and irrigated with tap water, FTS treated water or MBR treated water. Concentrations of heavy metals and elements in the different types of water were compared. The maximum arsenic (As) concentration in tap and MBR water was 0.05 mg/kg and 0.03 mg/kg in FTS water. The maximum Cr concentration was 0.10 mg/kg in FTS water and 0.06 mg/kg for both tap and MBR water. The maximum Cd concentration was 0.10, 0.04, and 0.03 mg/kg for FTS, MBR and tap water, respectively. The maximum values for Cu were 1.15, 1.11, and 1.07 mg/kg for MBR, FTS and tap water, respectively. The maximum Pb concentration was 0.29, 0.24, and 0.23 mg/kg for FTS, MBR and tap water, respectively. Zinc was most frequently found in the tomato fruits with a maximum concentration of 1.54 mg/kg when irrigated with MBR water, 1.32 mg/kg for FTS water and the lowest zinc concentration was in tap water (1.05 mg/kg). Since the heavy metals concentrations in the secondary waste water (either treated with MBR or FTS) were comparable to levels found in tap water, the authors concluded that this secondary treated water can safely be used for irrigation (Battilani et al., 2009)

In another irrigation experiment, wastewater was treated by sand filtration and chlorination (I) or by a membrane bioreactor and UV radiation (II) (tertiary treated wastewater) prior to irrigation of tomato fruits. Zn, Mn, Cu, Ni, and cobalt (Co) concentrations in tomato fruits irrigated with wastewater I were 43.4, 17.6, 19.6, 1.4, and 1.8 mg/kg dw, respectively, with wastewater II: 37.9, 14.5, 14.3, 1.0, and 2.1 mg/kg dw, respectively and in control tubewell water abstracted from a borehole: 47.8, 21.8, 1.4, 21.1 and 2.1 mg/kg dw, respectively. The results thus show that by treating the wastewater (either with treatment I or II) comparable levels of heavy metals and other elements in the tomato fruits were obtained as found when using the control tubewell water. The experiment also showed that bioaccumulation in the fruits was lower than in the leaves and that bioaccumulation factors for all elements were below 1 (Christou et al., 2014).

Instead of tomato, García-Delgado et al. (2012) studied the uptake of heavy metals in pepper when irrigated with tertiary treated wastewater in Spain. This was compared to ground water, as control. The waste water was first treated to remove the solids and to break down the fatty emulsions, then a secondary treatment with activated sludge was performed, and the tertiary treatment consisted of chlorination and ozonation. The bioaccumulation factor for Cd was 0.42 for groundwater and 0.35 for treated wastewater. For Cu the bioaccumulation factor was 0.39 for groundwater and 0.35 for treated wastewater. The bioaccumulation factor of Zn was 0.14 for groundwater and 0.12 for treated wastewater. The bioaccumulation factor for As and Pb was below 0.01 and for Mn it was 0.03, both wen using groundwater and treated wastewater. Since the heavy metal concentrations were not significantly different between tertiary treated wastewater and groundwater, the authors concluded that this tertiary treated wastewater can safely be used for irrigation of pepper(García-Delgado et al., 2012).

3.3.1.2 Occurrence data

The mean Pb, Cd, Ni, and Cr concentration was respectively 0.25, <LOD, 0.18, and 0.08 mg/kg in cucumbers and 0.6, 0.04, 0.08, and 0.13 mg/kg in bell pepper grown in greenhouses in Iran. Thus, the mean Pb, Cd, Ni and Cr concentrations in bell pepper in this study were higher than in cucumber. EU MLs for Pb and Cd for fruiting vegetables are both 0.05 mg/kg ((EU) regulation 1881/2006), implying that Pb in both cucumber and bell pepper exceeded this limit. The authors indicate that the measured Pb levels can possibly be explained by the application of fertilizers and pesticides in the greenhouse, or the use of Pb-enriched manure on the soil (Khoshgoftarmanesh et al., 2009).

Mansour et al. (2009) compared the heavy metal concentrations in cucumbers collected from the local markets in Egypt. The cucumbers were grown in different farming systems: conventional, greenhouse and organic. For conventional farming, these levels were 2.0, 0.91, 0.47, 5.4, 0.14, 1.0, and 0.38 mg/kg for Zn, Cu, Mn, Fe, Cd, Cr, and Pb, respectively. In cucumbers grown in the greenhouse, the highest concentrations found were 2.0, 0.60, 0.38, 3.1, 0.04, 0.61, and 0.34 mg/kg, respectively. For organic farming, the highest heavy metal concentrations measured were 2.5, 0.50, 0.99, 2.8, 0.06, 0.64, and 0.44 mg/kg, respectively. For Pb and Cd, exceedances of the MLs as established by FAO/WHO were noticed (Mansour et al., 2009).

Cadmium levels in tomato (n=10) were monitored in Belgium. Tomato is mentioned as a vegetable which has a high cadmium uptake from the soil. The mean cadmium concentration in the tomato samples was 0.008 mg/kg. Cadmium intake of 98% of the Belgium adults was estimated to be below the tolerable weekly intake (TWI) of 2.5 μg/kg bw based on the total diet. The main product groups that contributed to the Cd exposure were cereal products and potatoes, not fruiting vegetables (Vromman et al., 2010).

3.3.1.3 Conclusion

Experimental studies showed that heavy metals and other elements, such as Zn and Cr, can be taken up by fruiting vegetables from the soil or via the water. However, uptake is low, compared to the concentration in the soil. This results in bioaccumulation factors below 1. Nevertheless, occurrence data show that several heavy metals and elements were found in fruiting vegetables, primarily reported in tomatoes and peppers. Cadmium and lead were found at levels exceeding the EU and FAO/WHO MLs.

3.3.2 Polycyclic aromatic hydrocarbons (PAHs)

In the systematic literature search and in the advanced Google search no papers about the uptake or occurrence of polycyclic aromatic hydrocarbons (PAHs) in fruiting vegetables were obtained. In the additional search, 1 paper was found on the uptake of PAHs and 1 paper provided both occurrence data and information about the uptake.

3.3.2.1 Uptake in fruiting vegetables

Humans may be exposed to polycyclic aromatic hydrocarbons (PAHs) via smoking or via food. During the processing of food, PAHs can be formed during frying or smoking. Furthermore, PAHs can be taken up by vegetables via the (contaminated) environment. The information found in the scientific literature referred to this latter route of contamination.

In Spain, the uptake of polycyclic aromatic hydrocarbons (PAHs) was studied in peppers in an experimental setup by García-Delgado et al. (2012), as described in more detail in section 3.3.1.1 (uptake via water). No significant differences were found in the total PAH concentration in pepper fruits irrigated with groundwater or with treated wastewater during cultivation (García-Delgado et al., 2012). According to Paris et al. (2018), PAHs with more than four rings have a lower mobility in the soil and this results in a low uptake by the roots of the plant. The higher the mobility in the air and soil and the higher the water solubility of the PAHs, the easier the PAHs will be taken up by plants (Paris et al., 2018).

3.3.2.2 Occurrence data

In a review paper of Paris et al. (2018), global occurrence data of 16 PAHs are provided for raw chili, tomato, cucumber, and eggplant. The following 16 PAHs were included: naphthalene (NPH), acenaphthylene (ACY), acenaphthene (ACP), fluorene (FLR), anthracene (ANT), phenanthrene (PHE), fluoranthene (FA), pyrene (PYR), benz[*a*]anthracene (BaA), chrysene (CHR), BaP, benzo[*b*]fluoranthene (BbF), dibenz[*a,h*]anthracene (DBA), benzo[*k*]fluoranthene (BkF), benzo[*g,h,i*]perylene (BghiP) and indeno[*1,2,3,c,d*]pyrene (IP). In addition, PAH8 is given, which is the sum of the PAHs BaP, BaA, BbF, BkF, BghiP, CHR, DBA and IP. According to the author, PAH8 is an indicator of the presence of genotoxic and carcinogenic PAHs and this indicator can inform about the toxicity of the food product. All values in the review paper were recalculated to wet weight (Paris et al., 2018). In chili from India, the PAH8 level was 0.26 µg/kg ww and, out of the 16 PAHs, PHE had the highest concentration of 0.54 µg/kg ww. The highest PAH8 concentrations in tomato were 12.7 µg/kg ww for the tomato peels and 6.1 µg/kg ww for the tomato fruits in China. An argument given to explain the high concentration of PAHs (>10 µg/kg ww) in tomato products from Northern China is the use of coal for many applications in this area. The highest contributor to the PAH8 was FA in the tomato peels (9.4 µg/kg ww) and BaP in the tomato fruits (4.1 µg/kg ww). In cucumber, the highest PAH8 levels in peels and fruits from Pakistan were 9.8 µg/kg ww in peels and 7.3 µg/kg ww in fruits. BaP was mainly contributing to the PAH8 level with 2.9 µg/kg ww in the peels and 2.4 µg/kg ww in fruits. For eggplant, the occurrence of PAH8 was 6.5 µg/kg ww in fruits from Pakistan and Saudi Arabia. In general, for tomato and cucumber, the PAHs concentrations are higher in the peels, than in the fruits (Paris et al., 2018).

3.3.2.3 Conclusion

PAH8 levels up to 7.3 µg/kg have been found in raw fruiting vegetables. These high levels have been found in Asian countries, from which we currently do not import fruiting vegetables. Data for EU countries were not available.

3.3.3 Pharmaceuticals

Six experimental studies on the uptake of pharmaceuticals and personal care products in fruiting vegetables from the systematic literature review were included in the report. No papers were found in the advanced Google search, but in the additional search, 2 additional experimental studies were found and included.

3.3.3.1 Uptake in fruiting vegetables

Pharmaceuticals can end up in the environment by excretion via the urine or flushing medicines into the sewage. Even though wastewater is treated using several purification steps, residues of some pharmaceutical compounds can still be present in water and may result in uptake by crops when this water is used for irrigation. Antimicrobials, like triclocarban and triclosan, are used in personal care products. These compounds can enter the environment via reuse of wastewater from the domestic sewage (Aryal and Reinhold, 2013). This can lead to exposure of humans to pharmaceuticals and personal care products.

Antibiotics
In an experimental study, seedlings of cucumber and cherry tomato were cultivated in a greenhouse for 45 days. Irrigation water with six antibiotics from the groups tetracyclines and sulphonamides was used to spike the soil at concentrations of 5, 10 and 20 mg/kg soil. The uptake and accumulation of the antibiotics from the soil into the roots, leaves and fruits of cucumber and cherry tomatoes were quantified. The concentrations found did not result in an exceedance of the Acceptable Daily Intake (ADI) as established by JECFA, based on the consumption data of an adult in eastern countries (estimated by WHO as 233g fresh vegetables/day). Both tetracyclines and sulphonamides accumulated in the nonedible parts, i.e. leaves and roots rather than in fruits. Nevertheless, accumulation of sulphonamides in the plant was approximately 20 times higher as compared to tetracyclines. The higher accumulation of sulphonamides can be explained by the water-soluble characteristics of sulphonamides, which facilitates the uptake by the plant (Ahmed et al., 2015).

A long-term study of 12 weeks showed that triclosan was only detected in tomato fruits treated with the highest triclosan irrigation concentration of 1.5 µg/L. In this case, the detected level of triclosan in tomato fruits was 5±5 ng/g. As mentioned in the paper, triclosan levels in tomato fruits were not expected to be a concern for human health, based on the ADI in Canada (Health Canada and Environment Canada). However, the authors did not indicate which consumption data were used (Mendez et al., 2016).

To study the accumulation, distribution and metabolism of triclocarban in jalapeno pepper, an experiment on hydroponic media was performed. After uptake in jalapeno pepper, the triclocarban levels were 19.7, 0.26, 0.11, and 0.03 mg/kg dw respectively for root, stem, leaves, and fruits. The authors reported that metabolites should be taken into account to estimate human exposure to triclocarban (Huynh et al., 2018).

Pumpkin and zucchini shoots were cultivated in a hydroponic study and for two months the nutrient solution (280 mL) was weekly spiked with 0.32 µg/mL triclocarban and 0.29 µg/mL triclosan. The triclocarban and triclosan concentrations were higher in the roots of the pumpkin and zucchini compared to the concentrations in the shoots. No information on the edible part of the plant was provided. The concentrations of triclocarban and triclosan were comparable in pumpkin and zucchini (Aryal and Reinhold, 2013).

Other pharmaceuticals
Organic microcontaminants (OMCs) in tomato leaves and fruits were measured in four greenhouses in Spain. The tomatoes were irrigated with reclaimed water, which was reused. In general, the concentration of OMCs was 10 times lower in the tomato fruit compared to the leaves. In tomato fruits, the following 8 different substances were above the limit of quantification (LOQ) in one or more samples and the highest average concentration is provided: 4-AAA (4-acetyl-aminoantipyrine, a metabolite of dypirone) (0.4 ng/g fw), caffeine (1.0 ng/g fw), carbamazepine (0.2 ng/g fw), carbamazepine epoxide (0.07 ng/g fw), hydrochlorothiazide (0.2 ng/g fw), mepivacaine (0.1 ng/g fw), tramadol (0.7 ng/g fw), and venlafaxine (0.1 ng/g fw). According to the authors, no health risks for consumers were expected assuming a daily consumption of 130 g tomatoes on average per adult per day (Martínez-Piernas et al., 2019).

An experiment by Shenker et al. (2011) on the uptake of carbamazepine by cucumber plants showed that the bioaccumulation factor for leaves (17.1-20.0) was significantly higher than for fruits (0.8-1.1). The carbamazepine concentration was 1.2 µg/kg fw in the cucumber fruits cultivated with spiked water (Shenker et al., 2011).

3.3.3.2 Occurrence data
In the literature review, the advanced Google search and the additional search no papers were found on the occurrence of pharmaceuticals and personal care products in fruiting vegetables.

3.3.3.3 Conclusion

Several experimental studies showed that antibiotics and other pharmaceuticals can be taken up in plants via the water. No occurrence data were found, but the experimental studies indicated that pharmaceuticals primarily accumulate in the non-edible parts of the plants.

3.3.4 Persistent organic pollutants

Persistent organic pollutants (POPs) may be present in the environment and can subsequently be taken up by crops. The additional search revealed one report on dioxin concentrations in Dutch vegetables. Additionally, two more recent reports on dioxins were added. Furthermore, the most recent EFSA report on perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) was included.

3.3.4.1 Occurrence data

Dioxins (including polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and the dioxin-like non-ortho polychlorinated biphenyls (no-PCBs) were monitored in Dutch vegetables by RIVM in 2001 and 2002. The Lower Bound (LB) concentration of dioxins, furans and dl-PCBs was around 1.3 pg TEQ/kg ww whereas the Upper Bound (UB) concentration was around 4.5 pg TEQ/kg ww. UB means that results <LOD or LOQ are replaced with the numerical value of the LOD or LOQ; for LB these results are replaced by zero. The contribution of vegetables to human exposure via food consumption is estimated to be 2% of the mean daily intake of dioxins, furans and dl-PCBs. Within the group of vegetables and potatoes, tomato (including pepper and courgette) contributed only 3% to the dioxin dietary intake. This estimate is based on the consumption data of the Dutch National Food Consumption Survey (DNFCS) as established in 1998. The authors concluded that dioxin intake via vegetables is negligible compared to other food groups, like meat products, fish and dairy (Hoogerbrugge et al., 2004). A more recent dioxin intake assessment (Boon et al., 2014) used the dioxin concentrations in vegetables as analysed by Hoogerbrugge et al. (2004) and found that vegetables contributed less than 5% of the dioxin intake for the adult population (7-69 years) using DNFCS data of 2007-2010. The major contributors were milk, meat and vegetable oils and fats. For the intake assessment, a provisional TDI of 2 pg TEQ/kg bw/day was used. EFSA recently established a TWI of 2 pg TEQ/kg bw/week. They indicated that the mean concentration of dioxins and dl-PCBs (29 congeners) in vegetables was 0.05/0.08 LB/UB pg WHO_{2005}-TEQ/g, which is low compared to e.g. the mean concentration found in fish and seafood (4.35/4.45 LB/UB pg WHO_{2005}-TEQ/g). The main contributors for dioxins exposure via food consumed by adults were fatty fish, unspecified fish meat, cheese and livestock meat (EFSA, 2018d).

A recent EFSA report on the presence of PFOS and PFOA showed that the mean PFOS concentration in fruiting vegetables (n=140) was 0.002/0.138 µg/kg LB/UB and the mean PFOA concentration (n=122) 0.004/0.174 µg/kg LB/UB. According to EFSA, the main contributors to PFOS intake by the European population were fish and other seafood, meat and meat products and eggs and egg products. The main contributors for PFOA intake were milk and dairy products, drinking water and fish and other seafood (EFSA, 2018a).

3.3.4.2 Conclusion

Raw vegetables are not the main contributors to the dioxin dietary intake as they contribute with less than 5% to the overall intake. Furthermore, fruiting vegetables are not the main contributor to PFOS/PFOA dietary intake.

3.3.5 Radionuclides

Radionuclides are present in the environment, e.g. in the atmosphere, rock, soil, and water. Furthermore, nuclear incidents may result in an environmental contamination of radionuclides. No papers on the uptake or occurrence of radionuclides in fruiting vegetables were found in the systematic literature search, or advanced Google search. However, in the additional search, one paper was obtained on the occurrence of radionuclides in table olives. Additionally, the latest Dutch monitoring data reported by RIVM were added.

3.3.5.1 Occurrence data

The mean concentrations of the radionuclides ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs in table olives in Turkey were 37.9, 7.1, 274.6, and 7.2 Bq/kg dw, respectively. Using these concentrations and an average annual consumption of 4 kg, the effective radiation dose ranged from 3.4 to 22.7 µSv, with an average of 11 µSv. According to this study, no health hazards were expected for the intake of radionuclides via olives, as the mean effective radiation dose per year was below the recommended level of 1000 µSv (Karatasli, 2018).

A recent RIVM report indicated that in the group 'vegetables and mushrooms' three out of the 371 samples contained ^{137}Cs above the LOD. However, these samples concerned dried mushrooms. An overview of Dutch monitoring data for 2010-2013 also indicated that only 7 out of 585 vegetable samples contained ^{137}Cs > LOD. Again, all samples were mushrooms (Brandhoff et al., 2016).

3.3.5.2 Conclusion

Only one paper was found on the presence of radionuclides in olives. This study showed that levels found will not lead to an exceedance of the recommended yearly intake. Recent Dutch monitoring data published by RIVM indicated that ^{137}Cs in the group of vegetables is only found in mushrooms.

3.3.6 Plant Protection Products (PPPs)/Pesticides

In total, 40 papers were found about plant protection products. To downsize the number of papers on the occurrence of pesticides in fruiting vegetables, papers were excluded if no fruiting vegetables were imported in the Netherlands in 2017 from the country of origin of the paper. One paper was obtained on the uptake of pesticides by fruiting vegetables from the systematic literature review and the advanced Google search. Six papers from the systematic literature review and 6 papers from the advanced Google search were included on the occurrence of pesticide residues in fruiting vegetables. Amongst the 6 papers in the Google search, 5 of the papers were yearly EFSA reports. Seven papers were included from the systematic literature review, as they described the effect of processing (mainly on the effect of washing the fruiting vegetables on the removal of pesticide residues).

3.3.6.1 Uptake in fruiting vegetables

In agriculture, plant protection products are used in order to protect the crops. At the moment of harvesting, residues of these plant protection products may still be present in or on the crops.

Clostre et al. (2014) studied the uptake of chlordecone from the soil by three Cucurbitaceae species: cucumber, zucchini and pumpkin. Results showed that zucchini and pumpkin accumulate more chlordecone compared to cucumber. The distance between roots and fruits matters: the zucchini stem is shorter than the stems of cucumber and pumpkin. The shorter the stem, the higher the level of chlordecone concentration in the fruits. This experiment confirmed that chlordecone can be taken up from soil by the roots and translocated to the fruits. The authors reported that it implies a threshold is needed for soil contaminated with chlordecone in order to grow Cucurbitaceae species on this soil (Clostre et al., 2014).

3.3.6.2 Occurrence data

The occurrence of pesticide residues in fruiting vegetables was mainly obtained from EFSA reports of the last 5 years (published 2015-2019) and supplemented with papers found in the literature review. EFSA reports are based on monitoring data from EU member states, containing the results from both surveillance and enforcement samples. Results are published two years after collection of the data. Both unprocessed and processed samples are included in the EFSA reports. Unprocessed products with at least 50-60 samples and processed food products with at least 20-30 samples, depending on the EFSA report, are included in the EFSA reports.

The EFSA reports of the last five years indicate exceedances of the MRLs within the EU for the following unprocessed products: okra (15% of the samples in 2017, 11% in 2016, 12% in 2015, 10% in 2014, 17% in 2013), aubergines (4% in 2016, 6% in 2014, 5% in 2013), sweet pepper/bell pepper (6% in 2017, 4% in 2016, 4% in 2015), pumpkins (5% in 2016, 4% in 2014), table olives (35% in 2015), chilli peppers (26% in 2017), pumpkin seeds (7% in 2013) and peppers (3% in 2013) (EFSA, 2015a, 2016a, 2017a, 2018a, 2019). For processed products, the EFSA reports of the last five years indicate exceedances of the MRLs for: tomato (16% of the samples in 2017, 12% in 2016, 4% in 2015, 20% in 2014, 7% in 2013), sweet pepper/bell pepper (13% in 2017, 9% in 2016, 12% in 2015, 5% in 2014), table olives (2% in 2017, 3% in 2016, 5% in 2015), pumpkin seeds (5% in 2017, 1% in 2016), peppers (16% in 2013) and sweet peppers (9% in 2016) (EFSA, 2015a, 2016a, 2017a, 2018a, 2019). For the MRL exceedances mentioned above, the pesticides found were not indicated in the reports.

Tomato, aubergine and sweet pepper were the only fruiting vegetables described in more detail. Results are indicated below:

In <u>tomato</u> (n=1594), 91 different pesticides were at or above the level of quantification (≥LOQ) in 2016 (EFSA, 2018a). The most frequently quantified pesticides in at least 5% of the samples were bromide ion (31% ≥ LOQ), fluopyram (14% ≥ LOQ), dithiocarbamates (12% ≥ LOQ), spiromesifen (9.7% ≥ LOQ), chlorantraniliprole (8.9% ≥ LOQ), boscalid (7.4% ≥ LOQ) and acetamiprid (5.2% ≥ LOQ) (EFSA, 2018a). Bromide ion can originate from natural sources or past uses (EFSA, 2017a). Furthermore, 25 (2.6%) of the <u>tomato</u> samples exceeded the MRL in 2016 (EFSA, 2018a). The MRL was exceeded for 21 different pesticides (EFSA, 2018a). The pesticide dimethoate exceeded the MRL most frequently (n=19), followed by cypermethrin (n=4), chlorfenapyr (n=4), pirimiphos-methyl (n=3), acetamiprid (n=3), chlorpyrifos (n=2) and propargite (n=2) (EFSA, 2018a). Pesticides which exceeded the MRL only in one tomato sample in 2016 were carbaryl, carbendazim, chlormequat, chlorpyrifos-methyl, clothianidin, deltamethrin, dicofol, ethephon, fenpropathrin, fludioxonil, hexaconazole, lambda-cyhalothrin, procymidone and spiroxamine.

In aubergine samples (n=1074), 62 different pesticides were at or above the level of quantification in 2015 (EFSA, 2017a). Most frequently quantified (i.e., in more than 5% of the samples) were acetamiprid (10% ≥ LOQ), imidacloprid (6% ≥ LOQ) and cyprodinil (6% ≥ LOQ) (EFSA, 2017a). Acetamiprid, bitertanol, methomyl and dicloran exceeded the EU MRL in aubergine in 2015 (EFSA, 2017a).

<u>Sweet pepper</u> samples (n=1386) were analysed in 2015 and in total 71 different pesticides were quantified (EFSA, 2017a). Pesticides bromide ion (18% ≥ LOQ), flutriafol (15% ≥ LOQ), fludioxonil (7.1% ≥ LOQ), boscalid (5.9% ≥ LOQ) and azoxystrobin (5.4% ≥ LOQ) were found in more than 5% of the samples (EFSA, 2017a). Several pesticides exceeded the MRL: ethephon and lambda-cyhalothrin exceeded the MRL in two samples, and carbendazim, formetanate, diniconazole, propargite, quinoxyfen, azinphos-methyl, fenthion in one sample (EFSA, 2017a).

Ahmed et al. (2016) analysed pesticides in <u>tomato</u> samples in Egypt and found that 7 out of 16 tomato samples exceeded the MRL for one of the following pesticides: heptachlor-epoxide, P,P'-DDE, or gamma-HCH. The pesticides which were most frequently found in the tomato samples were heptachlor-epoxide (37.5%), P,P'-DDE (37.5%), profenofos (37.5%), gamma-HCH (25%), pirimiphos-methyl (6.25%), and P,P'-DDD (6.25%). For heptachlor-epoxide, the estimated daily intake was calculated to be higher than the accepted daily intake, based on Egyptian consumption data.

Another study in Egypt screened for pesticide residues in <u>cucumber</u> samples from conventional farming (C), greenhouse (G) and organic farming (O). The total pesticide residue concentration was highest in the samples from the greenhouse (1.0 mg/kg), and organic and conventional farming both contained 0.4 mg/g. Methamidophos and lindane were detected most frequently. Methamidophos was detected in 66.7%, 50.0% and 41.7% of the C, O, G samples, respectively. Lindane was detected in 50.0%, 33.3%, and 25.0% of the G, C, O samples, respectively (Mansour et al., 2009).

Green <u>pepper</u> samples (n=325) and <u>cucumber</u> samples (n=400) were used for monitoring of pesticide residues from 2014-2016 in Turkey. In 12.9% of the green pepper samples, pesticide residues were detected and in cucumber samples, this level was 13.5%. The pesticide residues that were detected most frequently were acetamiprid (6.2%), boscalid (3.4%), azoxystrobin (1.5%) and triadimenol (1.5%) in green pepper. And in cucumber, propamocarb (8.8%), acetamiprid (6.3%) and dimethomorph (2%) were detected most frequently. The pesticide residue concentrations found were all below the EU MRLs (Golge et al., 2018).

Tomato (n=85), cucumber (n=37) and pepper (n=16) from Poland were screened for pesticide residues. 46% Of the tomato samples contained pesticide residues, 25% of the pepper samples and 12% of the cucumber plants. Most frequently found in the fruiting vegetable samples were azoxystrobin (38%), boscalid (28%), and chlorothalonil (21%) (Słowik-Borowiec et al., 2016)

In total, 142 eggplant samples from Greece were measured and only 1 sample exceeded the EU MRL with dimethoate. In 58 eggplant samples, a single pesticide was detected, and 9 samples contained more than one pesticide. The following pesticide residues were detected in the eggplant samples: thiamethoxam (16.9%), cypermethrin (14.1%), deltamethrin (4.2%), thiacloprid (4.2%), acetamiprid (4.2%), azoxystrobin (2.8%), chlorpyrifos (2.8%), dimethoate (2.1%), propamocarb hydrochloride (1.4%) and chlorpyrifos methyl (0.7%). In 53% of the samples (n=75) no pesticide residues were detected at all (Prodhan et al., 2018).

Pesticide residues in fruiting vegetables in Belgium were analysed in 2014. In aubergine (n=30), both dimethoate and profenofos exceeded the MRLs once. In the 16 chilli pepper samples, acephate, carbendazim and benomyl, carbosulfan, and methamidophos exceeded the EU MRL once. For courgette (n=35), endosulfan and endosulfansulfate exceeded the MRLs twice, while dieldrin exceeded the MRL once. For pepper (n=37), EU MRL exceedances of chlormequat and procymidone were reported once. An exceedance of the MRL for dichlorvos, dimethoate, or ethephon was reported once for cucumber (n=29), okra (n=5) and tomato (n=75), respectively (FAVV, 2015).

In olive samples from 20 orchards in Turkey, chlorpyrifos, carbophenthion, chlorpyrifos methyl and azinphos ethyl were detected. In 17 samples, chlorpyrifos exceeded the MRL of the Turkish Food Codex for olives (Cansev et al., 2011).

3.3.6.3 Effects of processing

The effect of washing, cutting up, and blanching of zucchini was expressed in processing factors, which were calculated by dividing the pesticide residue in the processed fraction by the pesticide residue in the unprocessed fraction. The lowest processing factors belong to the washing procedure and were 0.62, <LOD, 0.76, 0.63, 0.27, and 0.73 for pyriproxyfen, deltamethrin, imidacloprid, trifloxystrobin, diethofencarb, and myclobutanil, respectively. Processing factors for cutting up were 0, 0, 0.96, 0.96, 1.00, 0.99 for pyriproxyfen, deltamethrin, imidacloprid, trifloxystrobin, diethofencarb, and myclobutanil, respectively. Processing factors for blanching were 0, 0, 0.79, 0.48, 0.76, 0.62 for pyriproxyfen, deltamethrin, imidacloprid, trifloxystrobin, diethofencarb, and myclobutanil, respectively. Processing factors for all steps combined (washing, cutting up, blanching, and freezing for 30 days) were 0, 0, 0.36, 0.29, 0.16, and 0.44 for pyriproxyfen, deltamethrin, imidacloprid, trifloxystrobin, diethofencarb, and myclobutanil, respectively (Oliva et al., 2017).

In the study of Ruiz-Medina and Llorent-Martínez (2012), the effect of washing of olives was compared between soil olives (n=50) and flight olives (n=20). Soil olives are picked from the soil, while flight olives are picked from the tree without touching the soil. The number of samples contaminated with pesticides residues in the soil olives were higher than in flight olives. For example, diuron was detected in 46 of the 50 soil olive samples and in 13 of the 20 flight olive samples. The effect of washing the olives was different for soil and flight olives. The pesticide residue level significantly reduced by washing the soil olives. The effect of washing was not clearly observed in flight olives (Ruiz-Medina and Llorent-Martínez, 2012).

Washing of cucumbers (n=180) led to 51% loss of ethion and 42.5% loss of imidacloprid residues. Peeling resulted in 93.4% loss of ethion and 63.7% loss of imidacloprid. The authors concluded that washing of cucumbers is less effective in removing ethion and imidacloprid than peeling (Leili et al., 2016). Mansour et al. (2009) mentioned thorough washing of the skin of the cucumber and peeling of the cucumber as methods to reduce the exposure to pesticides (Mansour et al., 2009).

Different organic acid solutions were studied for the removal of imidacloprid from cucumber and bell pepper. A 9% citric acid solution showed to give the best result in cucumber and bell pepper. For cucumber, the initial concentration of 1.92 mg/kg was reduced to 0.12 mg/kg and for bell pepper the initial concentration of 1.89 mg/kg was reduced to 0.52 mg/kg (Randhawa et al., 2014).

Lu et al. (2013) performed an experimental study in which various wash treatments were compared. This showed that washing green peppers with a low concentration of limonene for 5 minutes was the most optimal treatment considering removal of pesticide residues, time of the treatment and the costs. This treatment resulted in a 53.7% removal of chlorpyrifos methyl, chlorothalonil was below the limit of quantification (reduction >76%), chlorpyrifos was reduced by 64.3%, fenpropathrin by 68.7% and deltamethrin by 89.4%. In comparison, the removal after washing with tap water for 10 minutes was 25.2%, 37.8%, 21.8%, 20.5% and 13.9% for chlorpyrifos methyl, chlorothalonil, chlorpyrifos, fenpropathrin, and deltamethrin, respectively (Lu et al., 2013).

An experimental study investigated the removal of chlorpyrifos coating from cherry tomatoes skin with hydrostatic pressure with 10% ethanol solution. This method showed to be capable of removing chlorpyrifos coating without visual changes (in colour, size, and shape). After the hydrostatic pressure with 10% ethanol solution, the samples, treated with chlorpyrifos, were not significantly different from the control samples, not treated with chlorpyrifos (Iizuka and Shimizu, 2014).

3.3.6.4 Conclusion

Several PPPs were found to be present in fruiting vegetables. Most information was obtained for tomatoes, peppers and aubergine. A total of 54 PPPs were either frequently found or found at levels above the EU MRLs. Processing, such as peeling, washing (with or without organic compounds), cutting and blanching, results in a reduction of the pesticides levels present. The reduction levels found depend on the pesticide properties.

3.3.7 Mycotoxins

Mycotoxins can be produced by fungi and the production of mycotoxins is influenced by the local weather and agronomic conditions. From the systematic literature search, 4 papers on occurrence of mycotoxins were included, one from the advanced Google search and one from the additional search. No papers about production of mycotoxins by fungi in fruiting vegetables were available.

3.3.7.1 Occurrence data

In Turkey, packed and unpacked red peppers (n=48) were analysed for total aflatoxin levels. Of the 21 packed red peppers, 12 samples were above the limit of detection (LOD), but no exceedances above the ML of 10 µg/kg, which is the maximum level in Turkey and the EU, were found. For the unpacked samples, 15 of the 27 peppers were above the LOD and 2 unpacked samples exceeded the ML. The highest concentration measured in unpacked red pepper samples was 42.7 µg/kg (Acaroz, 2019). In another study in Turkey, 82 (78 unpacked and 4 packed) red peppers were monitored for aflatoxin B1 showing that 84.1% of the samples exceeded the EU ML and the concentrations were between 5.1-20.9 µg/kg. (Ergun et al., 2016). In 40 black and 36 red pepper samples from Iran, the aflatoxin (total of four aflatoxins, and each separately) content was measured. For total aflatoxins, five black pepper samples were above the LOD with a mean concentration of 2.0 µg/kg, and no samples exceeded the EU ML. All 36 red pepper samples were above the LOD for total aflatoxins and the concentration averaged 15.5 µg/kg. 69.4% Of the 36 red pepper samples exceeded the EU ML for total aflatoxins. For aflatoxin B1, the average concentration was 1.1 µg/kg for the black pepper samples and 15.5 µg/kg for the red pepper samples. 89% Of the red pepper samples exceeded the EU ML for aflatoxin B1. For aflatoxin B2, the average concentration was 0.2 µg/kg for black pepper and 1.2 µg/kg for red pepper. Aflatoxin G1 and G2 were not detected in the pepper samples. In conclusion, aflatoxin concentration in red pepper was significantly ($p<0.05$) higher than in black pepper (Barani et al., 2016). In chillies from Pakistan, aflatoxin B1 was measured and 16 out of the 22 samples (73%) contained levels above the EU ML. The aflatoxin B1 concentration ranged from 0 to 96.3 µg/kg and the mean concentration was 24.7 µg/kg (Iqbal et al., 2010).

The Spanish Agency for Food Safety and Nutrition (AESAN) reported the following mycotoxins in tomato and pepper: tenuazonic acid (TeA), alternariol (AOH) and alternariol monomethyl ether (AME). The mycotoxins found in olives were TeA and AME. Data were not provided, but the authors stated that the mycotoxin present in the highest concentration was TeA in tomato-based products and other foods products not belonging to the fruiting vegetables (Pascual et al., 2018). EFSA (2016b) also reported *Alternaria* toxins in tomato in EU samples. The mean AOH concentrations in tomato puree were 4.6 µg/kg LB and 17.1 µg/kg UB and the mean AME concentrations 0.6 µg/kg LB and 3.6 µg/kg UB. In sun-dried tomatoes, AOH concentrations were 2.5 µg/kg LB and 17.4 µg/kg UB and AME concentrations 0.7 µg/kg LB and 4.2 µg/kg UB. The most relevant contributor to the dietary AOH intake were fruits and fruit products. For AME, the main contributors to the dietary exposure were vegetable oils and pome fruits. The main contributor to the dietary exposure of TeA in adults was tomato with a maximum contribution of 45% LB. For tentoxin (TEN), tomato was the major contributor to the exposure in all age classes. For TEN, the maximum contribution was 93% of the total dietary exposure. The LB mean TEN concentration in tomato was 2.0 µg/kg (EFSA, 2016b).

3.3.7.2 Conclusion

Both aflatoxins and *Alternaria* toxins were detected in fruiting vegetables. For total aflatoxins and aflatoxin B1, concentrations above the EU MLs were reported in red pepper. Tomatoes were reported as the main contributor to the dietary exposure of the *Alternaria* toxins TeA and TEN in the EU.

3.3.8 Plant toxins

Plant toxins are secondary plant metabolites with toxicological properties, which can occur in foods including fruiting vegetables. No papers were found on plant toxins and fruiting vegetables in the literature search and the advanced Google search. In the additional literature search, 3 relevant papers on tomatine in tomato and solasonine in eggplants were obtained.

3.3.8.1 Occurrence data

One review article describes the harmful effects of glycoalkaloids such as tomatine present in tomatoes. Tomatine is mentioned to occur up to 500 mg/kg in unripe (green) tomato fruits, and in tomato stems and leaves. The main symptoms of tomatine poisoning are similar to solanine poisoning (Salehi et al., 2019). During ripening of the tomato, tomatine levels reduce. An overview by Friedman (2002) indicated a 100-fold reduction in ripe tomatoes (containing 0.4 mg/kg fw) as compared to green tomatoes (48 mg/kg fw).

In an experimental study in a greenhouse in Iran, solasonine (solanine-s) concentrations in physiologically ripe eggplant fruit, young fruit and mature fruit were 74.7, 61.3, and 21.6 µg/g, respectively, which were lower than the recommended food safety level of 200 µg/g. During maturation of the eggplant, the concentration of solasonine shows a decreasing trend. During ripening, glycoalkaloids, like solasonine, are converted into nitrogen-free compounds, which are not toxic (Bagheri et al., 2017). According to Milner et al. (2011), no adverse effects have been reported due to the presence of glycoalkaloids in tomatoes and eggplants. A recent EFSA opinion indicated that human health risks related to the presence of glycoalkaloids in tomatoes and aubergines could not be established due to a lack of data (EFSA, 2020).

3.3.8.2 Conclusion

Solanaceae are known to produce glycoalkaloids such as tomatine in tomatoes and solasonine in eggplants. However, during ripening of the plants, the levels gradually decrease. Solasonine levels found were below the recommended food safety level of 200 µg/g.

3.3.9 Cleaning agents and disinfectants

No relevant papers were obtained on cleaning agents and disinfectants in the literature search. The additional search also did not retrieve any relevant papers. From the papers obtained in the advanced Google search, 3 relevant ones were included in the report.

3.3.9.1 Occurrence data

In 2 out of 64 cucurbit samples, benzalkonium chloride (BAC) residues were found above the LOQ. The mean concentration in those two samples was 0.025 mg/kg (BfR, 2012a), which is below the current EU MRL of 0.1 mg/kg (Regulation (EC) 396/2005). In 2 out of 238 Solanaceae samples, the mean concentration was 0.71 mg/kg, which exceeds the EU MRL. However, the report does not specify the specific products (either potatoes or fruiting vegetables) within the group of Solanaceae samples. The Bundesinstitut für Risikobewertung (BfR, 2012a) performed a risk assessment using the concentrations found and concluded that both chronic and acute health risks are unlikely for the German and EU consumers. Furthermore, BfR performed a risk assessment on didecyldimethyl-ammonium chloride (DDAC). One cucurbit sample contained 0.22 mg/kg, which is above the EU MRL. Furthermore, 4 solanaceae samples contained levels above the LOQ, with a mean concentration of 0.113 mg/kg, which is also above the EU MRL. According to BfR, it is unlikely for German or other European consumer groups that this concentration poses an acute or chronic health risk. In the report, an ADI value of 0.1 mg/kg bw/day and an ARfD of 0.1 mg/kg bw/day is reported for DDAC (BfR, 2012b).

The use of chlorinated water during the processing of food and the disinfection of equipment can lead to the presence of chlorate in food. According to EFSA, mean UB chlorate concentration for 1654 fruiting vegetables samples (except peppers, chili pepper and aubergines) was 29 μg/kg. The mean UB concentration for chili pepper (n=27) was 169 μg/kg, for aubergines (n=73) it was 164 μg/kg and for (bell) peppers it was 70 μg/kg. Drinking water was found to be the main contributor to the chronic dietary intake. For acute dietary intake, drinking water was also the main contributor followed by broccoli and whey and whey products. A contribution of fruiting vegetables to chronic dietary intake was not indicated (EFSA, 2015b).

3.3.9.2 Conclusion

Residues of cleaning agents and disinfectants may end up in fruiting vegetables. BAC and DDAC were detected in levels above the EU MRL, although for BAC the exact product (either potatoes or fruiting vegetables) was unknown. According to EFSA, drinking water is the main contributor to the dietary chlorate intake; the contribution of fruiting vegetables to chronic dietary intake was not specified.

3.3.10 Other chemical hazards

The systematic literature study obtained two papers on the uptake of phthalates in fruiting vegetables. The advanced Google search resulted in 2 studies on perchlorate. In the additional search, two papers on nitrate were obtained.

3.3.10.1 Uptake in fruiting vegetables

Phthalates are endocrine disruptor compounds, which are used mainly as plasticizer. Phthalates may end up in the environment and can be taken up via the soil or water into the food crops. An experimental study aimed to investigate the potential transfer of phthalates from biosolids to tomato plants was performed by Sablayrolles et al. (2013). The phthalate di(ethyl)hexylphthalate (DEHP) was added as pure substance or via biosolids to the plant growth solution. DEHP was found for 99.5% in the roots, when applied as pure substance. If DEHP was applied as biosolids, then DEHP was traced in the roots, leaves and fruits. This could possibly be explained by the surfactant compounds which are present in the biosolids and enhance the uptake of DEHP by the roots. Two routes for uptake were identified: soil-to-root followed by root-to-shoot translocation and uptake from the surrounding air (Sablayrolles et al., 2013). Cucumber cultivated on a soil treated with 40 mg/kg di-n-butyl phthalate (DBP) resulted in a DBP residue concentration of 2.5 mg/kg dw in the cucumber fruit. Based on this result, the estimated daily intake was 2.49 μg/kg bw/day, given the consumption of cucumber in China (91.5 g/day). The target hazard quotient (HQ = EDI/RfD * 100%) was below 1, which implies that human health risks for cucumber consumption were not indicated. The RfD of 100 μg/kg bw/day, used in the health risk assessment, was based on the United States Environmental Protection Agency (USEPA) (Wang et al., 2016).

3.3.10.2 Occurrence data

Median nitrate concentration for total fruiting vegetables was 83 mg/kg. The highest median nitrate concentrations of 392 mg/kg, 303 mg/kg, and 297 mg/kg were measured in pumpkin, aubergine, and courgette. The maximum concentration of nitrate in pumpkin was 5665 mg/kg. In a few courgette samples, the nitrate concentration was above 1000 mg/kg (EFSA, 2008b). In a review paper of Colla et al. (2018), the nitrate content of the edible part of fruiting vegetables was classified. The nitrate content of gherkin, pepper, and tomato was below 200 mg/kg fw. Concentrations in cucumber, eggplant, gourd, marrow, pumpkin, and zucchini were between 200 and 500 mg/kg fw. The nitrate content in butternut squash was between 500 and 1000 mg/kg fw (Colla et al., 2018).

Perchlorate can end up in plants via fertilisers or contaminated irrigation (waste) water or soil (BfR, 2013; EFSA, 2014b). The mean UB perchlorate concentration was 23 μg/kg in fruiting vegetables (n=1745). Based on these data, no adverse effects were expected based on single day dietary exposure (EFSA, 2014). In a monitoring study of BfR, 522 fruiting vegetables samples were measured for perchlorate. In 59% of the samples, values above the LOQ were detected with a mean concentration of 51.9 μg/kg. Based on the highest concentration of 81.3 μg/kg in fruiting vegetables, the provisional maximum tolerable daily intake (PMTDI) exhaustion was 1233%. Taking into account 20.0 μg/kg, which is the 95th percentile, the PMTDI exhaustion is 303% for fruiting vegetables. The PMTDI is based on the consumer group with the highest exposure of the most frequently consumed product within the fruiting vegetables group. 11% Of the fruiting vegetable samples resulted in an exceedance of the ARfD. EU consumption data were used in the risk assessment (BfR, 2013).

3.3.10.3 Conclusion

Apart from the chemical hazards reported in sections 3.3.1 to 3.3.9, nitrate, perchlorate and phthalates were reported to be present in fruiting vegetables. The results described above indicate that nitrate levels in fruiting vegetables generally are low (median of 83 mg/kg), but high levels (up to 5665 mg/kg) have been found in pumpkin. Perchlorate levels were found in concentrations resulting in an exceedance of the ARfD. Furthermore, BfR performed a risk assessment using EU consumption data, which showed that the PMTDI was exceeded for the top 5% concentrations found in fruiting vegetables. Finally, the literature research showed that phthalates can be taken up from the soil or the water. Levels found in cucumber, however, did not result in human health issues as the estimated daily intake (assuming a consumption of 91.5 g/day) resulted in a HQ below 1.

3.4 Long list and intermediate list

Based on the information obtained in the literature and through the advanced Google search, substances were included on the long list of chemical hazards and prioritised into an intermediate list. Substances for which no conclusion could be drawn on its relevance were identified as knowledge gap. Results are indicated in Table 1.

Table 1 *Long list and intermediate list of chemical hazards in fruiting vegetables.*

Long list[a]	Intermediate list[b]	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list
Heavy metals and other elements (section 3.3.1)			
Arsenic (As)	-		One paper reported low As concentrations (30-50 µg/kg) in an experimental study. Furthermore, the bioaccumulation factor found was < 0.01.
Cadmium (Cd)	Cd		Exceedances above the EU ML were found.
Chromium (Cr)	-		Only 1 experimental study showed the possible presence of Cr in tomato and green pepper. No health issues were found with the concentrations found (Al-Hwaiti and Al-Khashman, 2015).
Cobalt (Co)	-		Only 1 experimental study reported the presence of Co in tomato after irrigation with treated wastewater at concentrations of 1.8 and 2.1 mg/kg dw. According to Barceloux and Barceloux (1999), a daily intake < 37 mg/day would not result in adverse human health effects.
Copper (Cu)	-		Only 1 experimental study showed the possible presence of Cu in the stems and leaves of pepper (no information on the fruits) cultivated in contaminated soil. Cu is an essential element. According to EFSA, tomatoes contribute 5% to the ADI (EFSA, 2018c).
Iron (Fe)	-		Fe concentrations were below the FAO/WHO legal limit in okra.
Lead (Pb)	Pb		Exceedances above the EU ML were found.
Manganese (Mn)	-		The highest Mn level in an experimental study was 1.38 mg/kg fw tomatoes. Mn is an essential element for which no UL is available. The adequate intake for adults is 3 mg/day (EFSA, 2013b).
Nickel (Ni)	-		Consuming fruiting vegetables with the levels found would not exceed the oral toxicity reference value (20 µg/kg bw/day) (Haber et al., 2017).
Zinc (Zn)	-		Consuming fruiting vegetables with the levels found would not exceed the UL of 25 mg/day (EFSA, 2006).
Polycyclic aromatic hydrocarbons (section 3.3.2)			
PAHs		PAH8	A review showed that levels may be high (> 5 µg/kg) in fruiting vegetables when grown in industrial areas. However, no data were found for countries from which fruiting vegetables are imported in the Netherlands.
Pharmaceuticals (section 3.3.3)			
Antibiotics (triclosan, triclocarban, tetracyclines, sulphonamides)	-		Experimental studies showed that antibiotics primarily accumulate in the non-edible parts of the plant. Furthermore, levels found in the fruiting vegetables did not result in an exceedance of the ADI based on Middle Eastern consumption data.
Other pharmaceuticals (4-AAA, caffeine, carbamazepine, carbamazepine epoxide, hydrochlorothiazide, mepivacaine, tramadol, and venlafaxine)	-		Experimental studies showed that other pharmaceuticals primarily accumulate in the non-edible parts of the plant. According to Martínez-Piernas et al. (2019), no human health risks are expected for the low levels found in the fruiting vegetables.

Long list[a]	Intermediate list[b]	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list
Persistent organic pollutants (section 3.3.4)			
Dioxins, furans and dl-PCBs	-		The food group vegetables in general contribute less than 5% to the total dietary intake of dioxins, furans and dl-PCBs.
PFOS, PFOA	-		According to EFSA, fruiting vegetables are not the main contributors to the PFOS/PFOA dietary intake.
Radionuclides (section 3.3.5)			
^{226}Ra	-		The concentrations found did not lead to an exceedance of the recommended level of 1 mSv/y.
^{232}Th	-		The concentrations found did not lead to an exceedance of the recommended level of 1 mSv/y.
^{40}K	-		The concentrations found did not lead to an exceedance of the recommended level of 1 mSv/y.
^{137}Cs	-		The concentrations found did not lead to an exceedance of the recommended level of 1 mSv/y.
PPPs (section 3.3.6)			
PPPs	Acephate		Exceedances above the EU MRL were found in pepper.
	Acetamiprid		Exceedances above the EU MRL in tomato and aubergine and frequently found in tomato, aubergine, pepper, and cucumber.
	Azinphos-methyl		Exceedances above the EU MRL were found in sweet pepper.
	Azoxystrobin		Frequently found in sweet pepper.
	Benomyl		Exceedances above the EU MRL in pepper.
	Bitertanol		Exceedances above the EU MRL in aubergine.
	Boscalid		Frequently found in tomato and sweet pepper.
	Bromide ion		Frequently found in tomato and sweet pepper.
	Carbaryl		Exceedances above the EU MRL in tomato.
	Carbendazim		Exceedances above the EU MRL in tomato, pepper, and sweet pepper.
	Carbosulfan		Exceedances above the EU MRL were found in pepper.
	Chlorantraniliprole		Frequently found in tomato.
	Chlorfenapyr		Exceedances above the EU MRL were found in tomato.
	Chlormequat		Exceedances above the EU MRL were found in tomato, and pepper.
	Chlorothalonil		Frequently found in tomato, cucumber, or pepper (not specified).
	Chlorpyrifos		Exceedances above the EU MRL were found in tomato and olive.
	Chlorpyrifos-methyl		Exceedances above the EU MRL were found in tomato.
	Clothianidin		Exceedances above the EU MRL were found in tomato.
	Cypermethrin		Exceedances above the EU MRL and frequently found in tomato and eggplant.
	Cyprodinil		Frequently found in aubergine.
	DDT and metabolites (P’P’-DDD, P’P’-DDE)		P’P’-DDE: Exceedances above the EU MRL and frequently found in tomato; P’P’-DDD: Frequently found in tomato.

Long list[a]	Intermediate list[b]	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list
	Deltamethrin		Exceedances above the EU MRL were found in tomato.
	Dichlorvos		Exceedances above the EU MRL were found in courgette.
	Dicloran		Exceedances above the EU MRL were found in aubergine.
	Dicofol		Exceedances above the EU MRL were found in tomato.
	Dieldrin		Exceedances above the EU MRL were found in courgette.
	Dimethoate		Exceedances above the EU MRL were found in tomato, eggplant, aubergine, and courgette.
	Diniconazole		Exceedances above the EU MRL were found in sweet pepper.
	Dithiocarbamates		Frequently found in tomato.
	Endosulfan		Exceedances above the EU MRL were found in courgette.
	Endosulfansulfate		Exceedances above the EU MRL were found in courgette.
	Ethephon		Exceedances above the EU MRL were found in tomato, sweet pepper, and cucumber.
	Fenpropathrin		Exceedances above the EU MRL were found in tomato.
	Fenthion		Exceedances above the EU MRL were found in sweet pepper.
	Fludioxonil		Exceedances above the EU MRL and frequently found in tomato, and sweet pepper.
	Fluopyram		Frequently found in tomato.
	Flutriafol		Frequently found in sweet pepper.
	Formetanate		Exceedances above the EU MRL were found in sweet pepper.
	Gamma-HCH (=lindane)		Exceedances above the EU MRL and frequently found in tomato and cucumber.
	Heptachlor-epoxide		Exceedances above the EU MRL and frequently found in tomato.
	Hexaconazole		Exceedances above the EU MRL were found in tomato.
	Imidacloprid		Frequently found in aubergine.
	Lambda-cyhalothrin		Exceedances above the EU MRL were found in tomato, and sweet pepper.
	Methamidophos		Exceedances above the EU MRL and frequently found in cucumber, and pepper.
	Methomyl		Exceedances above the EU MRL and frequently found in aubergine.
	Pirimiphos-methyl		Exceedances above the EU MRL and frequently found in tomato.
	Procymidone		Exceedances above the EU MRL were found in tomato, and pepper.
	Profenofos		Exceedances above the EU MRL and frequently found in tomato and aubergine.
	Propamocarb		Frequently found in cucumber.
	Propargite		Exceedances above the EU MRL were found in tomato and sweet pepper.
	Quinoxyfen		Exceedances above the EU MRL were found in sweet pepper.
	Spiromesifen		Frequently found in tomato.
	Spiroxamine		Exceedances above the EU MRL were found in tomato.
	Thiamethoxam		Frequently found in eggplant.

Long list[a]	Intermediate list[b]	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list
Mycotoxins (section 3.3.7)			
Aflatoxins	Aflatoxins (total aflatoxins an aflatoxin B1)		Levels above the EU ML were found in red peppers.
Alternariol (AOH)	-		Fruiting vegetables were not the main contributor to the AOH dietary intake.
Alternariol monomethyl ether (AME)	-		Fruiting vegetables were not the main contributor to the AME dietary intake.
Tenuazonic acid (TeA)	TeA		Tomato was the main contributor to the dietary TeA intake.
Tentoxin (TEN)	TEN		Tomato was the main contributor to the dietary TEN intake.
Plant toxins (section 3.3.8)			
Tomatine	-		Tomatine is primarily found in unripe tomatoes (Voedingscentrum, 2020).
Solasonine	-		Levels found were below the recommended food safety level.
Cleaning agents and disinfectants (section 3.3.9)			
Benzalkonium chloride (BAC)		BAC	Levels above the EU MRL were found in Solanaceae. However, whether these levels were found in potatoes or fruiting vegetables is unknown.
Didecyldimethylammonium chloride (DDAC)	DDAC		Levels above the EU MRL were found.
Chlorate	-	Chlorate	Drinking water is the main contributor to the dietary chlorate intake. For food products, the contribution of fruiting vegetables to the chronic dietary intake was not specified (EFSA, 2015b).
Other chemical hazards (section 3.3.10)			
Perchlorate	Perchlorate		Perchlorate levels in fruiting vegetables resulted in an exceedance of the PMTDI.
Nitrate	Nitrate		Levels in general are low (mean 149 mg/kg), but high levels (up to 5665 mg/kg) have been reported in pumpkin (EFSA, 2008b).
Phthalates (DEHP and DBP)	-		Phthalates primarily accumulate in the non-edible parts of the plants. Furthermore, no human health risks were found.

[a] Long list: Hazards that may occur in fruiting vegetables

[b] Intermediate list: Hazards that were frequently mentioned in the literature to be present in fruiting vegetables and/or which resulted in an exceedance of the (EU) legal limits or that resulted in an exceedance of HBGVs

3.5 Toxicological information

This section provides general toxicological information of the prioritised hazards on the intermediate list and on the hazards identified as knowledge gap. Information and the main contributors to the dietary intake of these hazards, except for the prioritized pesticides, are indicated in sections 3.5.1-3.5.8. The information has largely been obtained from previous reports (Banach et al., 2019; Hoffmans et al., 2020) and was collected from EFSA and RIVM reports. Information presented in Table 2 includes information on the MLs and HBGVs or other available reference points (BMDLs), except for the prioritized pesticides. For the prioritized pesticides, MRLs, ARfDs and ADIs, and approvals, were collected from the EU pesticides database; this information is summarized in Table 3.

Table 2 *MLs and HBGVs or other available reference points (BMDLs) for the prioritised hazards and hazards identified as knowledge gaps.*

Prioritised hazards	EU ML[a] (mg/kg FW)	Chronic effect (µg/kg bw/day)	Acute effect (µg/kg bw)
Heavy metals and other elements (section 3.3.1)			
Cadmium (Cd)	0.05	TWI: 2.5 (EFSA, 2009a)	NA
Lead (Pb)	0.1 (sweet corn), 0.05 (other fruiting vegetables)	$BMDL_{01}$: 0.5 (for young children) $BMDL_{01}$: 1.5 (for cardiovascular effects in adults) $BMDL_{10}$: 0.63 (for and nephrotoxicity in adults) (EFSA, 2012b)	NA
Polycyclic Aromatic Hydrocarbons (section 3.3.2)			
PAH8	NE	$BMDL_{10}$: 490 (EFSA, 2008d)	NA
Mycotoxins (section 3.3.7)			
Total aflatoxins	NE	NA, genotoxic carcinogens	NA
Aflatoxin B1	NE	NA, genotoxic carcinogen	NA
Tenuazonic acid (TeA)	NE	NA	NA
Tentoxin (TEN)	NE	NA	NA
Cleaning agents and disinfectants (section 3.3.9)			
Benzoalkonium chloride (BAC)	0.1[b]	ADI: 100 (EFSA, 2014a)	ARfD: 100 (EFSA, 2014a)
Didecyldimethylammonium chloride (DDAC)	0.1[b]	ADI: 100 (EFSA, 2014a)	ARfD: 100 (EFSA, 2014a)
Chlorate	0.01[b]	TDI: 3	ArfD: 36
Other chemical hazards (section 3.3.10)			
Perchlorate	NE	TDI 0.3 (EFSA, 2014b)	NA
Nitrate	NE	ADI: 3700 (EFSA, 2008a).	NA

[a] Legal limits from Regulation (EC) No 1881/2006

[b] Legal limits from Regulation (EC) No 396/2005

NA; not applicable; NE: not established

Table 3 *MRLs, ADIs, ARfDs, and EU approval for the prioritised pesticides based on the* *EU pesticides database.*

Pesticides	EU MRLs (mg/kg) for most relevant fruiting vegetables[a]	ADI (mg/kg bw/day)	ARfD (mg/kg bw)	EU approval
Acephate	0.01 (sweet pepper)	0.03	0.1	Not approved
Acetamiprid	0.05 (tomato), 0.02 (aubergine), 0.3 (cucumber, sweet pepper)	0.025	0.025	Approved
Azinphos-methyl	0.05 (sweet pepper)	0.005	0.01	Not approved
Azoxystrobin	3 (sweet pepper)	0.2	NA	Approved
Benomyl	0.1 (sweet pepper, sum of carbendazim and benomyl)	NA	NA	Not approved
Bitertanol	0.01 (aubergine)	0.003	0.01	Not approved
Boscalid	3 (sweet pepper)	0.04	NA	Approved
Methyl bromide (bromide ion)	30 (sweet pepper)	0.001	0.003	Not approved
Carbaryl	0.01 (tomato)	0.0075	0.01	Not approved
Carbendazim	0.3 (tomato), 0.1 (sweet pepper)	0.02	0.02	Not approved
Carbosulfan	0.002 (sweet pepper)(expressed as carbofuran)	0.005	0.005	Not approved
Chlorantraniliprole	0.6 (tomato)	1.56	NA	Approved
Chlorfenapyr	0.01 (tomato)	0.015	0.015	Not approved
Chlormequat	0.01 (tomato, sweet pepper)	0.04	0.09	Approved
Chlorothalonil	6 (tomato), 5 (cucumber), 0.01 (sweet pepper)	0.015	0.05	Not approved
Chlorpyrifos	0.1 (tomato), 0.01 (olive)	0.001	0.005	Not approved
Chlorpyrifos-methyl	1 (tomato)	0.01	0.1	Not approved
Clothianidin		0.097	0.1	Not approved
Cypermethrin	0.5 (tomato, aubergine)	0.05	0.2	Approved
Cyprodinil	1.5 (aubergine)	0.03	NA	Approved
DDT and metabolites (P'P'-DDD, P'P'-DDE)	0.05 (tomato)	0.01	NA	Not approved
Deltamethrin	0.07 (tomato)	0.01	0.01	Approved
Dichlorvos	0.01 (courgette)	0.00008	0.002	Not approved
Dicloran	0.01 (aubergine)	0.005	0.025	Not approved
Dicofol	0.02 (tomato)	0.002	0.15	Not approved
Dieldrin	0.05 (courgette)	0.0001	0.003	Not approved
Dimethoate	0.01 (tomato, aubergine, courgette)	Not specified	Not specified	Not approved
Diniconazole	0.01 (sweet pepper)	Not specified	Not specified	Not approved (diniconazole-M)
Dithiocarbamates[b]	3 (tomato)	Not specified	Not specified	Not approved (Sodium dimethyl-dithiocarbamate)
Endosulfan	0.05 (courgette, sum of alpha- and beta-isomers and endosulfan-sulphate expresses as endosulfan)	0.006	0.02	Not approved
Endosulfansulfate	0.05 (courgette, sum of alpha- and beta-isomers and endosulfan-sulphate expresses as endosulfan)			
Ethephon	2 (tomato), 0.05 (cucumber, sweet pepper)	0.03	0.05	Approved
Fenpropathrin	0.01 (tomato)	0.03	0.03	Not approved
Fenthion	0.01 (sweet pepper)	0.007	0.01	Not approved
Fludioxonil	3 (tomato), 1 (sweet pepper)	0.37	NA	Approved
Fluopyram	0.9 (tomato)	0.012	0.5	Approved
Flutriafol	1 (sweet pepper)	0.01	0.05	Approved
Formetanate	0.01 (sweet pepper)	0.004	0.005	Approved
Gamma-HCH (=lindane)	0.01 (tomato, cucumber)	0.005	0.06	Not approved
Heptachlor-epoxide	0.01 (tomato)	0.0001	NA	Not approved
Hexaconazole	0.01 (tomato)	0.005	NA	Not approved

Pesticides	EU MRLs (mg/kg) for most relevant fruiting vegetables[a]	ADI (mg/kg bw/day)	ARfD (mg/kg bw)	EU approval
Imidacloprid	0.5 (aubergine)	0.06	0.08	Approved
Lambda-cyhalothrin	0.07 (tomato), 0.1 (sweet pepper)	0.0025	0.005	Approved
Methamidophos	0.01 (cucumber, sweet pepper)	0.001	0.003	Not approved
Methomyl	0.01 (aubergine)	0.0025	0.0025	Not approved
Pirimiphos-methyl	0.01 (tomato)	0.004	0.15	Approved
Procymidone	0.01 (tomato, sweet pepper)	0.0028	0.012	Not approved
Profenofos	10 (tomato), 0.01 (aubergine)	0.03	1	Not approved
Propamocarb	5 (cucumber)	0.29	1	Approved
Propargite	0.01 (tomato, sweet pepper)	0.03	0.06	Not approved
Quinoxyfen	0.02 (sweet pepper)	0.2	NA	Not approved
Spiromesifen	1 (tomato)	0.03	2	Approved
Spiroxamine	0.01 (tomato)	0.025	0.1	Approved
Thiamethoxam	0.2 (aubergine)	0.026	0.5	Not approved

[a] Most relevant fruiting vegetables are those vegetables in which the pesticides were frequently found and/or in which MRL exceedances were found (see Table 1)

[b] Dithiocarbamates comprises a group of substances including maneb, mancozeb, metiram, propineb, thiram and ziram

NA: not applicable

3.5.1 Cadmium

EFSA concluded that the main source of Cd exposure for the non-smoking general population is food. Cd is toxic to the kidney, especially to the proximal tubular cells, where Cd accumulates (half-life: 10-30 years) and may cause renal dysfunction. This can progress after prolonged or high exposure to renal failure. Cd is also classified as human carcinogen Group 1 IARC. The TWI of Cd was set at 2.5 µg/kg bw/week, which corresponds to a TDI of 0.357 µg/kg bw/day (EFSA, 2009b).

Based on detailed individual food consumption data, EFSA made a better estimation of the dietary intake of Cd in 2012 (EFSA, 2012a). An average weekly dietary exposure of Cd was estimated at 2.04 µg/kg bw per week and a high exposure (P95) was estimated at 3.66 µg/kg bw per week. This review confirmed that the 95th percentile exposure could exceed the TWI. There is a small 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. Foods that are consumed in larger quantities have the greatest impact on the dietary Cd exposure. This was the case for the broad food categories of grains and grain products (26.9%), vegetable and vegetable products (16%) and starch roots and tubers (13.2%). From the vegetables category, fruiting vegetables were not the main contributors to the total exposure as this was <3% for fruiting vegetables for all age categories (EFSA, 2012a).

RIVM concluded in 2015 that the median daily intake in the Netherlands exceeded the TDI (0.357 µg/kg bw/day) up to the age of about 10. However, the life-long Cd exposure estimates were lower (0.25 µg/kg bw/day) than the TDI, because of a much lower intake at later ages. Therefore, the risk of developing kidney failure due to life-long exposure was regarded as negligible for the general population. Cereals and potatoes were important contributors to the exposure of Cd due to the high consumption of these food products. Vegetables and fruits were also important contributors, in which spinach and pineapple had the highest contribution, fruiting vegetables were not mentioned as main contributors within the vegetable category. The refined model used in this RIVM study showed that the long-term intake was lower than calculated by EFSA in 2012 (Spong and Boon, 2015).

3.5.2 Lead

The major exposure route to Pb is via food. Pb can accumulate in the skeleton of the human body; the half-life in bones is 10-30 years. In blood, the half-life of Pb is approximately 30 days. The main target organ of Pb toxicity is the central nervous system. Neurotoxicity associated with Pb can affect the short-term verbal memory, fine motor skills, information processing and can cause psychiatric symptoms. In 2010, EFSA established a new HBGV as the previously established PTWI was concluded to be no longer appropriate. A 95th 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 estimated mean exposure for young children was higher than the $BMDL_{01}$ of 0.5 µg/ kg bw /day. For adults, the respective BMDLs for cardiovascular effects ($BMDL_{01}$ of 1.5 µg/ kg bw /day) and nephrotoxicity ($BMDL_{10}$ of 0.63 µg/ kg bw /day) were not exceeded by the estimated mean exposure for adults (EFSA, 2012b).The broad food categories contributing the most to Pb 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 main contributors within the vegetables and vegetable product category were leafy vegetables (2.0%), fruiting vegetables (1.8%), and root vegetables (0.9%). In the category of vegetables, root and fruiting vegetables were more important in very young children while leafy vegetables were more important and fruiting vegetables were less important with increasing age.

RIVM concluded that because of the dietary intake of Pb in the Netherlands detrimental health effects cannot be excluded for children up to 7 years of age, pregnant women and adults. The food groups contributing the most to the dietary intake of Pb were the same as the groups mentioned by EFSA. Grains and grain-based products, non-alcoholic beverages, vegetables and vegetable products and milk and dairy products, were the main food groups contributing to the exposure of lead (in total 61%) for persons aged 7-69. In children (2-6 years), the main contributors were grains and grain-based products, fruits and fruit products, milk and dairy products, sugar and confectionary and vegetables and vegetables products (total 74%). Fruiting vegetables were not indicated as main contributors within the vegetables category. Data of Pb concentrations in food products from other countries were also used because of limited Dutch data for some food products (Boon et al., 2017).

3.5.3 Polycyclic aromatic hydrocarbons (PAH)

PAHs can be considered mutagenic, genotoxic, and carcinogenic to humans (EFSA, 2008c; 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 the carcinogenic PAHs in food, a $BMDL_{10}$ of 0.49 mg/kg bw/day was selected for PAH8 as a marker. 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, 2008d).

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). Fruiting vegetables were not indicated as main contributors to the dietary PAH intake (EFSA, 2008d).

3.5.4 Aflatoxins

Aflatoxins are genotoxic and carcinogenic; they cause hepatocellular carcinomas in humans. Aflatoxin B1 is the most potent genotoxic and carcinogenic aflatoxin and the most common aflatoxin (out of the four aflatoxins) 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. In the evaluations, EFSA uses the cancer potencies as estimated by JECFA. These cancer potencies are estimated for an AFB1 exposure of 1 ng/kg bw per day in 100,000 person years, 0.017 ng/kg bw per day for hepatitis B surface antigen negative (HBsAg-) individuals and 0.269 ng/kg bw per day for HBsAg+ individuals (these cancer potencies are mean estimates) (EFSA, 2007, 2018b). No specific information was thus found on the contribution of fruiting vegetables to the aflatoxin dietary exposure.

3.5.5 Tenuazonic acid (TeA) and Tentoxin (TEN)

In 2011, EFSA used a threshold of toxicological concern (TTC) approach to assess the possible concern of the *Alternaria* toxins alternariol (AOH), alternariol monomethyl ether (AME), tenuazonic acid (TeA) and tentoxin (TEN). For the genotoxic *Alternaria* toxins, AOH and AME, it was concluded that chronic dietary exposures could exceed the TTC value and compound specific toxicity data was needed. For the non-genotoxic TeA and TEN, it was concluded that the exposure was unlikely to be of human health concern. Tomatoes were reported as the main contributor to the dietary exposure of the TeA and TEN, which is also indicated in section 3.3.7 (EFSA, 2016c).

3.5.6 Quaternary ammonium compounds (quats)

EFSA evaluated monitoring data on residues of the quaternary ammonium compounds DDAC and BAC in food. Overall, the highest mean values were found in animal products and fruits and nuts. Around 2% of the vegetable samples analysed were positive. The compounds found were mostly detected in leafy vegetables and fresh herbs, legumes and *Solanaceae* (tomatoes and peppers) (EFSA, 2013a).

Furthermore, EFSA concluded based on dietary risk assessments for DDAC and BAC that the proposed temporary MRL of 0.1 mg/kg for all food commodities is expected to be sufficiently protective for the general population in Europe (EFSA, 2014a). The Netherlands currently applies an MRL of 0.5 mg/kg expressed for cetryltrimethylammoniumchloride (Warenwetregeling residuen van bestrijdings-middelen). EFSA used ADI and ARfD values for their dietary risk assessment that were derived by the BfR: ADI for both DDAC and BAC: 0.1 mg/kg bw per day, ARfD for both compounds: 0.1 mg/kg bw (EFSA, 2014a).

3.5.7 Chlorate

Chlorate can occur in food due to the use of chlorinated water during processing or due to disinfection of processing equipment. The critical effect for chronic exposure is inhibition of iodine uptake. A TDI of 3 µg/kg bw was established by EFSA, and the ARfD was established at 36 µg/kg bw. Chronic exposure of adolescent and adult age classes did not exceed the TDI. However, the TDI was exceeded at the P95 intake in infants and toddlers. Chronic exposures are thus of concern for the human health of the younger age groups. The ARfD was not exceeded by the estimated acute exposures for all age groups. Overall, the main contributor to dietary exposure was drinking water for all age categories. From the different food groups, the highest concentrations were found in vegetable and vegetable products. Highest mean concentrations were found for chilli pepper (UB: 169 µg/kg) and aubergines (UB: 164 µg/kg) (EFSA, 2015b).

3.5.8 Perchlorate

EFSA established a TDI of 0.3 µg/kg bw/day for perchlorate. They concluded that dietary intakes are far too low to cause acute toxicity. Therefore, an ARfD was not warranted. The chronic exposure to perchlorate is of potential concern. High exposure to perchlorate can lead to inhibition of thyroid iodine uptake, which could lead to multinodular toxic goitre, in particular in 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. Fruiting vegetables were not indicated as main contributors in the vegetable category (EFSA, 2017b).

3.5.9 Nitrate

Vegetables are the main contributors to human exogenous exposure to nitrate; to a lesser extent, exposure also occurs via other food products and water. Nitrate is also endogenously formed. Nitrate itself is relatively non-toxic. However, metabolites and reaction products, such as nitrite, nitric oxide and N-nitroso compounds have been shown to give adverse health effects. The adverse effects are among others methaemoglobinaemia and some evidence for carcinogenic effects.

The type of vegetables consumed and the corresponding nitrate levels have a high impact on the dietary exposure, more than the total amount of vegetables consumed. The highest nitrate values were found for leafy vegetables. The nitrate concentrations found in fruiting vegetables were disparate. However, fruiting vegetables had the third lowest median concentration. Some high concentrations were found in a few pumpkin samples (max: 5,665 mg/kg) and in a few courgette samples (>1000 mg/kg).

An ADI of 3.7 mg/kg bw/day has been derived by EFSA and was also confirmed by JECFA. EFSA estimated that the ADI was not exceeded in a conservative case of consumption of 400 grams mixed vegetables per day. Overall, the EFSA concluded that the estimated exposures are unlikely to pose a risk for human health (EFSA, 2008a).

3.6 Trends in fruiting vegetables

Previously, trends were evaluated for the vegetable chain in general. Results of this analysis are described in the report on leafy vegetables (Banach et al., 2019). These trends were summarised in (Hoffmans et al., 2020), as: "In short, consumer trends were identified such as increased demand for convenience products and increased attention for human health aspects resulting in an expected increase in (fresh) vegetable consumption. Furthermore, consumer behaviour is changing because of increased importance of sustainability and circularity. As a result, food waste is being diminished, for example, by offering ready-to-prepare packages in which rest products can be processed. Another development related to sustainability is the increased use of biodegradable packaging. The analysis also showed that there is an increased interest in the use of effluent and sludge products in open field cultivation due to the movement towards a more circular economy. With respect to production and trade of vegetables, a relevant trend is the increased production of organic vegetables. Furthermore, production is influenced by climate change. The expected increased temperatures may lead to the introduction of other chemical hazards or the increase of known food safety hazards. The evaluation of trends also showed that vegetable trade is a global market allowing for product diversity in retail. As a result, the supply chain is complex. However, labelling is improving and the increase in intelligent packaging allows for an increased transparency of the vegetable supply chain. Analysis of legal and policy aspects showed that pesticide regulation is becoming stricter, which is expected to decrease pesticide residues in vegetable products."

Additional to the general trends summarised above, WFBR evaluated the trends specific for fruiting vegetables by consulting the Innova database. The results are indicated below.

3.6.1 New product introductions

"An Innova database search was performed with search terms specific for fruiting vegetables. In the fruiting vegetables category, paprika and chili were excluded as they are mainly used as spices and obscure the trends for the fruiting vegetables. In the past ten years, the number of product introductions for fruiting vegetables clearly increased. Most introductions were in the following categories:

- 'Ready Meals and Side Dishes', including do-it-yourself vegetable packs to make soup or other dishes, pizza, lasagne and frozen meals;
- 'Sauces and Seasonings', with both cooking sauces and table sauces as well as seasonings;
- 'Meat, Fish & Eggs', where tomato puree is used in hamburgers or marinade, tomato powder is used universally in spice mixes, but also vegetarian burgers based on i.e. pumpkin;
- 'Snacks', where tomato powder is often used in the herb mixes for chips or nuts.

Some of the categories are obscured by the presence of pumpkin seeds. Especially the 'Snacks', 'Bakery' and 'Cereals' categories have a large number of these products.

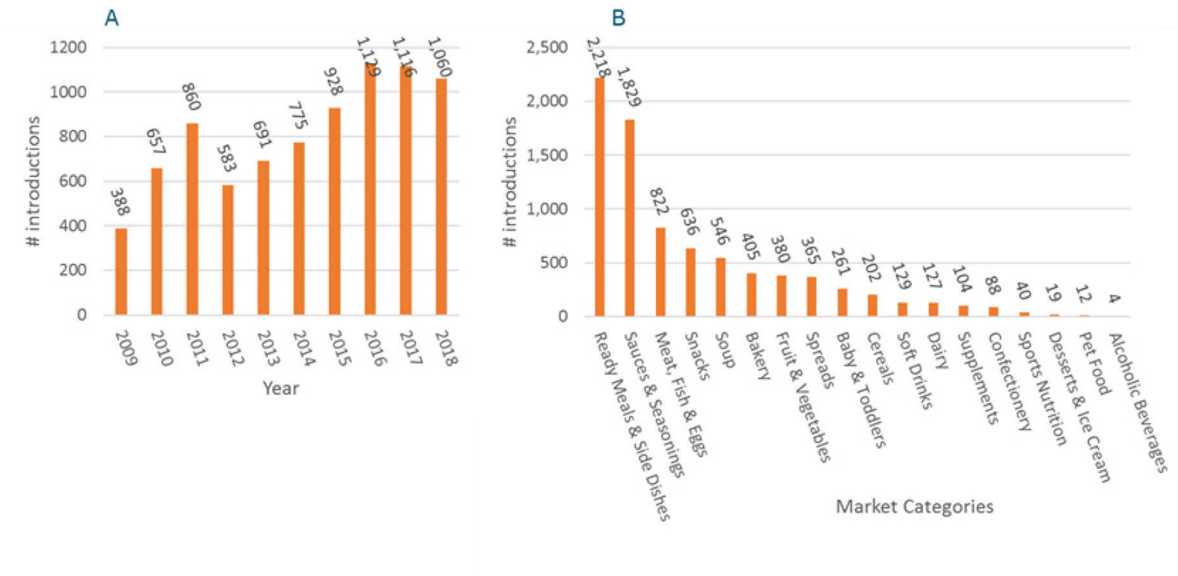

Figure 2 *a) Annual and b) Category of market introductions for fruiting vegetables.*

For all products, the main positioning categories are: 'convenience', 'ethical' and 'healthy'. Positioning categories that grow in the convenience category are 'time saving', 'ready-prepared' and 'easy to prepare'. In the ethical category, 'vegetarian', 'organic', 'vegan', 'good for animal, fish and birds' and 'environment' are growing. The important categories within the healthy category are 'gluten free', 'source of fibre', 'source of protein' and 'no added sugar'. Low sodium and low fat claims remain the same on packages of new products" (Hayrapetyan et al., 2019).

3.6.2 Specific trends for fruiting vegetables

An upcoming trend is to seek diversity in the diet. Alternatives with vegetables are developed to several conventional products, such as cereal-based products. A couple of examples of the latter product group that are available on the Dutch market are hamburger buns with tomato or paprika-chili (Batenburg, 2019), buns with paprika (Figure 3) and wraps with paprika-chili (Figure 4). Inclusion of vegetables in breakfast is also reported, like bread of courgette, and hummus with squash (Figure 5) (Batenburg, 2018). Instead of using only potato to manufacture crisps, other varieties of crisps are available on the Dutch market (Figure 6).

Figure 3 *Bun with bell pepper.*

Figure 4 *Wrap with bell pepper-chili.*

Figure 5 *Hummus with pumpkin.*

Figure 6 *Crisps prepared from bell pepper.*

Not only diversity in diets and replacement of carbohydrate-rich ingredients are a trend, but consumers are also experimenting more with replacing meat by vegetables. For example, tomatoes on the barbecue (Kleyn, 2019) and pâté made of sundried tomatoes (Berg, 2017). Besides, new products are introduced that are manufactured from rest streams and surplus of tomato cultivation. Where normally the stems and the leaves of the tomato plant becomes waste, new initiatives are set-up to upcycle these rest streams into packaging material for packing the tomatoes. Cardboard is made of the stems and foil is made of the leaves of the tomato plant. Furthermore, the surplus of tomato cultivation is processed into oven dried tomatoes, tapenades (van Adrichem, ND) and soups (Rabobank, 2019).

3.6.3 Conclusion

In general, a relevant trend for vegetable cultivation is the interest in the use of treated wastewater and sludge in open field cultivation. This may lead to the presence of e.g. pharmaceuticals in vegetables as residues of these compounds may be present in wastewater and sludge and are shown to be taken up by fruiting vegetables (Aryal and Reinhold, 2013). Although in the Netherlands, fruiting vegetables are primarily cultivated in greenhouses (only courgettes may be cultivated in open field), in other countries open field cultivation is used more frequently. Imported fruiting vegetables may thus contain chemical residues when treated wastewater or sludge is used during cultivation.

Another relevant trend is the increased interest in the use of waste streams to produce new products or packaging materials. Chemical hazards present in these waste streams may end up in the final product.

4 Conclusions

A literature review was performed to identify the chemical hazards that may be found in fruiting vegetables. Both scientific papers and reports from established research organisations (EFSA, BfR, FAVV and Aecosan) were included. A so-called long list of chemical hazards that might be present in fruiting vegetables was established based on the obtained information. This list contained:

- Heavy metals and other elements
- Polycyclic aromatic hydrocarbons (PAHs)
- Pharmaceuticals
- Dioxins
- Perfluorinated compounds
- Radionuclides
- Plant protection products (PPPs)
- Mycotoxins
- Plant toxins
- Cleaning agents and disinfectants
- Other chemical hazards: perchlorate, nitrate, phthalates

Those chemical hazards that were frequently found, found at levels exceeding (EU) legal limits or resulting in exceedances of health-based guidance values (HBGVs) were included in the so-called intermediate list. This list contained:

- Cadmium
- Lead
- 54 PPPs. These PPPs were solely identified based on the obtained literature. It is recommended to consult the Dutch monitoring data to confirm the relevance of the identified PPPs for the Netherlands
- Total aflatoxins and aflatoxin B1
- Tenuazonic acid
- Tentoxin
- Didecyldimethylammonium chloride (DDAC)
- Perchlorate
- Nitrate

For PAH8, levels up to 7.3 µg/kg were detected in fruiting vegetables from Asia. However, we primarily import these vegetables from other EU countries, not from Asia. For these countries, no information was found on the occurrence of PAH8 in fruiting vegetables. Therefore, this group of substances was identified as knowledge gap. Furthermore, benzalkonium chloride was detected in Solanaceae samples above the EU MRL. Since it is unknown whether these samples were potatoes or fruiting vegetables, this substance was identified as knowledge gap. Finally, chlorate was identified as knowledge gap since the contribution of fruiting vegetables to the dietary intake of this substance was unknown.

For the chemical hazards on the intermediate list and those identified as knowledge gap, toxicological information was summarised such as HBGVs, adverse effects related to the chemicals, and the contribution of the fruiting vegetables to the dietary intake of the chemical hazard. NVWA-BuRO can use this information to come to a so-called short list of chemical hazards that should be included in the monitoring.

Apart from identifying relevant chemical hazards in fruiting vegetables, trends in the vegetable supply chain were evaluated. This trend evaluation showed that the most relevant trend is the increased interest in circularity, which may result in the use of treated wastewater and sludge in open field cultivation. Fruiting vegetables imported from countries who use these practices may contain elevated levels of chemical hazards present in the water, such as heavy metals or residues of pharmaceutical compounds. Furthermore, the use of waste streams to produce new products may lead to the presence of chemical hazards depending on the origin of the waste stream.

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Annex 1 English-Dutch crop names

English	Dutch
Aubergine (=eggplant)	Aubergine
Bell pepper (=sweet pepper)	Paprika
Chilli / Chili	Chilipeper
Courgette	Courgette
Cucumber	Komkommer
Cucurbits/Cucurbitaceae	Komkommerfamilie (waartoe ook pompoen en courgette behoren)
Eggplant (=aubergine)	Aubergine
Fruiting vegetables	Vruchtgroenten
Gourd	Pompoen/ Kalebas
Hokkaido	Hokkaido
Kabocha	Kabocha
Marrow	Pompoen
Muscat	Muskaatpompoen
Okra	Okra
Olive	Olijf
Pepper	Peper
Pumpkin	Pompoen
Red pepper	Chilipeper
Solanaceae	Nachtschadefamilie (aardappel, aubergine, paprika, tomaat)
Sweet pepper (=bell pepper)	Paprika
Squash	Pompoen

Annex 2 List of abbreviations

Abbreviation	English	Dutch
4-AAA	4-acetyl-aminoantipyrine	N-acetyl-4-aminoantipyrine
ACP	Acenaphthene	Acenafteen
ACY	Acenaphthylene	Acenaftyleen
ADI	Acceptable daily intake, a HBGV for the chronic effects of compounds in food and drinking water	Aanvaardbare dagelijkse inname
AESAN	The Spanish Agency for Food Safety and Nutrition	Spaans agentschap voor voedselveiligheid en voeding
AME	Alternariol monomethyl ether	Alternariol monomethylether
ANT	Anthracene	Antraceen
AOH	Alternariol	Alternariol
ARfD	Acute reference dose, a HBGV for the acute effects of compounds in food and drinking water	Acute referentie dosis
As	Arsenic	Arseen
BaA	Benz[*a*]anthracene	Benz[*a*]antraceen
BAC	Benzalkonium chloride	Benzalkoniumchloride
BaP	Benzo[*a*]pyrene	Benzo[*a*]pyreen
BbF	Benzo[*b*]fluoranthene	Benzo[*b*]fluoranteen
BfR	Bundesinstitut für Risikobewertung (German Federal Institute for Risk Assessment)	Duits federale instituut voor risicobeoordeling
BghiP	benzo[*g,h,i*]perylene	benzo[*g,h,i*]peryleen
BkF	Benzo[*k*]fluoranthene	Benzo[*k*]fluoranteen
$BMDL_{01}$/$BMDL_{10}$	Benchmark Dose Lower confidence limit (lower limit of the 95% confidence interval of the dose that results in a low (1 or 10%) health response)	De ondergrens van het 95%-betrouwbaarheidsinterval van de 'Benchmark' dosis
BuRO	Office for Risk Assessment and Research	Bureau Risicobeoordeling & onderzoek
bw	Body weight	Lichaamsgewicht
Cd	Cadmium	Cadmium
CHR	Chrysene	Chryseen
Co	Cobalt	Kobalt
Cr	Chromium	Chroom
Cu	Copper	Koper
DBA	Dibenzo[*a,h*]anthracene	Dibenzo[*a,h*]antraceen
DDAC	Didecyldimethylammonium chloride	Didecyldimethylammoniumchloride
DDT	Dichlorodiphenyltrichloroethane	Dichloordifenyltrichloorethaan
DEHP	Bis(2-ethylhexyl)phthalate	Bis(2-ethylhexyl)ftalaat
dw	Dry weight	Drooggewicht
EDI	Estimated daily intake	Geschatte dagelijkse inname
EFSA	European Food Safety Authority	Europese Voedselautoriteit
EU	European Union	Europese Unie
EUROSTAT	European Statistical Office	Europees Bureau voor de Statistiek
FA	Fluoranthene	Fluoranteen
FAO	Food and Agricultural Organization of the United Nations	Voedsel- en Landbouworganisatie van de Verenigde Naties
FAVV	Federal Agency for the Safety of the Food Chain (Belgium)	Federaal Agentschap voor de veiligheid van de voedselketen (België)
Fe	Iron	IJzer
FLR	Fluorene	Fluoreen
FTS	Field treatment system	Veldbehandelingssysteem
fw	Fresh weight	Versgewicht
HBGVs	Health based guidance values	Gezondheidskundige richtwaarden
HQ	Hazard quotient (= EDI/ADI * 100%)	Risicoquotiënt
HRI	Health Risk Index (consumption divided by the reference oral dose (RfD))	Risico-index

Abbreviation	English	Dutch
HS	Harmonised system	Geharmoniseerd systeem
IP	indeno[*1,2,3,c,d*]pyrene	indeno[*1,2,3,c,d*]pyreen
LB	Lower bound (levels < LOD or LOQ are replaced by zeros)	Ondergrens
LOD	Limit of detection	Detectielimiet
LOQ	Limit of quantification	Bepaalbaarheidsgrens
MBR	Membrane bioreactor	Membraan bioreactor
ML	Maximum level; the maximum concentrations of contaminants allowed in the edible part of a food product ((EU) 1881/2006)	Maximumgehalte
Mn	Manganese	Mangaan
MOE	Margin of Exposure (Ratio between a point on the dose response curve (e.g. NOAEL or BMD) and the exposure)	Blootstellingsmarge
MRL	Maximum residue limit; the highest level of a pesticide/veterinary drug residue that is legally tolerated in or on food or feed when applied correctly ((EU) 37/2010 and (EC) 396/2005)	Maximumwaarde voor residuen
Ni	Nickel	Nikkel
NOAEL	No observed adverse effect level	Dosis waarbij geen negatieve effecten zijn geobserveerd
NPH	Naphthalene	Naftaleen
NVWA	Netherlands Food and Consumer Product Safety Authority	Nederlandse Voedsel- en Warenautoriteit
OMC	Organic microcontaminants	Organische microcontaminanten
PAH8	Sum of 8 PAHs: BaP, BaA, BbF, BkF, BghiP, CHR, DBA and IP	Som van 8 PAK's: BaP, BaA, BbF, BkF, BghiP, CHR, DBA en IP
PAHs	Polycyclic Aromatic Hydrocarbons	Polycyclische aromatische koolwaterstoffen (PAK's)
Pb	Lead	Lood
PCBs	Polychlorinated biphenyl	Polychloorbifenylen
PCDD/F	Polychlorinated dibenzo-p-dioxins	Gechloreerde dibenzo-p-dioxines
PCDF	Polychlorinated dibenzofurans	Gechloreerde dibenzofuranen
PHE	Phenanthrene	Fenantreen
PMTDI	Provisional maximum tolerable daily intake	Voorlopige maximaal toelaatbare dagelijkse inname
POPs	Persistent organic pollutants	Persistente organische verontreinigende stoffen
PPP	Plant protection product	Gewasbeschermingsmiddel
PYR	Pyrene	Pyreen
TDI	Tolerable daily intake	Toelaatbare dagelijkse inname
TeA	Tenuazonic acid	Tenuazonzuur
TEN	Tentoxin	Tentoxine
TTC	Threshold of toxicological concern	Toxicologische gevarendrempel
TWI	Tolerable weekly intake	Toelaatbare wekelijkse inname
UB	Upper bound (levels < LOD or LOQ are replaced by the numerical value of the LOD or LOQ)	Bovengrens
UL	Tolerable Upper Intake Level; the maximum level of total chronic intake of a nutrient to be unlikely to pose a risk of adverse human health effects (EFSA)	Maximumwaarde
WFBR	Wageningen Food & Biobased Research	
WFSR	Wageningen Food Safety Research	
WHO	World Health Organization	Wereld Gezondheidsorganisatie
ww	Wet weight	Nat gewicht
Zn	Zinc	Zink

Annex 3 Search terms fruiting vegetables

To classify vegetables as fruiting vegetables, the EFSA categorisation and the list 'Ketenklassen GF' of the NVWA were considered.

In 'Ketenklassen GF', based on the EFSA categorisation, the following commodities for fruiting vegetables were provided:
- Tomato
- Aubergine
- Pepper
- Gourd
- Squash

Based on the examples of commodities provided in the EFSA categorisation were added:
- Courgette
- Cucumber
- Pumpkin
- Kabocha
- Hokkaido
- Tinda
- Chilli / chili
- Marrow
- Muscat

Additionally, the following names were added to the search string for fruiting vegetables:
- Zucchini
- Eggplant

In Scopus the search string provided below was tested and adjusted as described in Table A3.1.

> #1: Fruiting vegetables
> tomato* OR aubergine* OR pepper* OR courgette* OR zucchini* OR cucumber* OR gourd* OR pumpkin* OR squash* OR kabocha OR marrow* OR muscat* OR hokkaido OR tinda OR eggplant* OR egg*plant OR chilli* OR chili*
>
> AND #2: Chemical hazards
> In title, abstract or keywords:
> "Food contamination" OR "Chemical pollutant*" OR "chemical hazard*" OR contamina* OR toxin* OR "toxic substance*" OR "toxic compound*" OR pollutant* OR "agricultural chemical*" OR "chemical compound*" OR "chemical substance*" OR residu*
>
> AND #3: Public health
> In title, abstract or keywords:
> "Public health" OR "HACCP" OR "Consumer protection" OR Consumer* OR "Food safety" OR "risk assessment*" OR "risk analys*" OR "hazard analys*" OR "Human health*" OR "Health impact" OR "health risk*"

Table A3.1 *Overview of results for the various search options.*

Search nr.	Search	Details	Number of hits (Scopus)	
1	#1 and #2	Title-abs key	27367	
2	idem	#1 title #2 title abs key	7704	
3	#1 and #2 and #3	Title-abs-key	2414	
4	idem	Title abs key Limited to 2009-2019	1727	
5	Idem	#1 Including *"fruiting vegetable*"* OR *"fruit vegetable*"* OR *"fruity vegetable*"*	1859	
6	#2 and #3	And only #1 only *"fruiting vegetable*"* OR *"fruit vegetable*"* OR *"fruity vegetable*"*	164	
7	#1 and #2 and #3	#1 + fruiting vegetables (in title) #2 and #3 in title-abs-key	470	
8	idem	#1 in title + NOT in title: (pathogen* OR streptococcus OR listeria OR *virus* OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR fung* OR campylobacter OR "Escherichia coli" OR "E. coli" OR model* OR analytic* OR microbi* OR virol* OR nutri*)	350	
9	as search nr. 8	And NOT in title (method* OR environment* OR ecological*)	312	
10	as search nr. 9	Removed from #1: marrow* and muscat*	292	Based on contact with WFBR
11	as search nr. 10	Added to #1: oliv* Added to exclusion terms: oil*	323	Based on contact with WFBR
12	as search nr. 11	Added to #1: cucurbit*	331	Based on contact with WFBR
13	as search nr. 12	Added to #1: okra	344	
14	as search nr. 13	Removed from #3: consumer*	288	

Search nr. 14 is chosen as final search string:

#1: Fruiting vegetables – In title:
"fruiting vegetable*" OR "fruit vegetable*" OR "fruity vegetable*" OR tomato* OR aubergine* OR pepper* OR courgette* OR zucchini* OR cucumber* OR cucurbit* OR gourd* OR pumpkin* OR squash* OR kabocha OR hokkaido OR tinda OR eggplant* OR egg*plant OR chilli* OR chili* OR oliv* OR okra

AND #2: Chemical hazards - In title, abstract or keywords:
"Food contamination" OR "Chemical pollutant*" OR "chemical hazard*" OR contamina* OR toxin* OR "toxic substance*" OR "toxic compound*" OR pollutant* OR "agricultural chemical*" OR "chemical compound*" OR "chemical substance*" OR residu*)

AND #3: Public health - In title, abstract or keywords:
“Public health" OR "HACCP" OR "Consumer protection" OR "Food safety" OR "risk assessment*" OR "risk analys*" OR "hazard analys*" OR "Human health*" OR "Health impact" OR "health risk*"

AND NOT #4: Exclusion terms – In title:
pathogen* OR streptococcus OR listeria OR *virus* OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR fung* OR campylobacter OR "Escherichia coli" OR "E. coli" OR model* OR analytic* OR microbi* OR virol* OR nutri* OR method* OR environment* OR ecological* OR oil*

The final search string resulted in 288 hits in Scopus and 227 hits in Web of Science. After the removal of 156 duplicates, a total of 359 scientific papers were found. The exact search string in Scopus and Web of Science are provided below.

Search string in Scopus
(TITLE("fruiting vegetable*" OR "fruit vegetable*" OR "fruity vegetable*" OR tomato* OR aubergine* OR pepper* OR courgette* OR zucchini* OR cucumber* OR cucurbit* OR gourd* OR pumpkin* OR squash* OR kabocha OR hokkaido OR tinda OR eggplant* OR egg*plant OR chilli* OR chili* OR oliv* OR okra) AND TITLE-ABS-KEY("Food contamination" OR "Chemical pollutant*" OR "chemical hazard*" OR contamina* OR toxin* OR "toxic substance*" OR "toxic compound*" OR pollutant* OR "agricultural chemical*" OR "chemical compound*" OR "chemical substance*" OR residu*)AND TITLE-ABS-KEY("Public health" OR "HACCP" OR "Consumer protection" OR "Food safety" OR "risk assessment*" OR "risk analys*" OR "hazard analys*" OR "Human health*" OR "Health impact" OR "health risk*") AND NOT TITLE (pathogen* OR streptococcus OR listeria OR *virus* OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR fung* OR campylobacter OR "Escherichia coli" OR "E. coli" OR model* OR analytic* OR microbi* OR virol* OR nutri* OR method* OR environment* OR ecological* OR oil*)) AND (LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012) OR LIMIT-TO (PUBYEAR,2011) OR LIMIT-TO (PUBYEAR,2010) OR LIMIT-TO (PUBYEAR,2009))

Search string in Web of Science
TI=("fruiting vegetable*" OR "fruit vegetable*" OR "fruity vegetable*" OR tomato* OR aubergine* OR pepper* OR courgette* OR zucchini* OR cucumber* OR cucurbit* OR gourd* OR pumpkin* OR squash* OR kabocha OR hokkaido OR tinda OR eggplant* OR egg*plant OR chilli* OR chili* OR oliv* OR okra) AND **TS**=("Food contamination" OR "Chemical pollutant*" OR "chemical hazard*" OR contamina* OR toxin* OR "toxic substance*" OR "toxic compound*" OR pollutant* OR "agricultural chemical*" OR "chemical compound*" OR "chemical substance*" OR residu*) AND **TS**=("Public health" OR "HACCP" OR "Consumer protection" OR "Food safety" OR "risk assessment*" OR "risk analys*" OR "hazard analys*" OR "Human health*" OR "Health impact" OR "health risk*") **NOT TI**= (pathogen* OR streptococcus OR listeria OR *virus* OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR fung* OR campylobacter OR "Escherichia coli" OR "E. coli" OR model* OR analytic* OR microbi* OR virol* OR nutri* OR method* OR environment* OR ecological* OR oil*)

Timespan: 2009-2019. Indexes: SCI-EXPANDED, SSCI, A&HCI, ESCI.

Annex 4 Relevancy of scientific literature

Not relevant:

- Sea cucumber juveniles
- Detection of contamination by multispectral imaging
- Peppermint
- Tomato dip / Tomato paste
- Biorefinery / industrial by-products
- Dried red pepper flakes / red pepper powder (belong to spices)
- Olive waterways of river in Morocco
- Olive flounder
- Improvement of drought tolerance
- Tomato peels used in biotechnology
- Tomato leaf miner
- Thrips
- Hokkaido (island in Japan)
- Chilika (lake in India)
- Impact of eggplants on Arthropods
- Sea turtle Lepidochelys olivacea
- Microbiology related (Salmonella, yeast)
- Method validation
- Silicon supplementation
- Binders (biochar or zeolite)

Maybe relevant:

- Dissipation behaviour / pre-harvest interval determination of pesticide residues
- MRL modification for pesticide residues
- Papers written in other languages than English

Annex 5 Peer review of scientific literature

Table A5.1 References reviewed and judgement of peer review.

Nr	Reference	Scientist 1	Scientist 2	Remarks	Final decision
1	(Al-Hwaiti and Al-Khashman, 2015)	Relevant	Relevant	Risk assessment of heavy metals in tomato and paprika	Relevant
2	(Cantín Galindo et al., 2016)	Relevant	Maybe relevant	Pesticides residues in fruits, vegetables and cereals in aragon: broad paper (which fruiting vegetables are included and do we import from Aragon?)	**Maybe relevant**
3	(Chan et al., 2019)	Not relevant	Not relevant	Effect of pesticides on bees	Not relevant
4	(Brancato et al., 2018b)	Maybe relevant	Maybe relevant	MRL modifications	Maybe relevant
5	(Yang et al., 2014)	Not relevant	Not relevant	Paper on analytical method	Not relevant
6	(Ahmed et al., 2015)	Relevant	Relevant	Uptake of antibiotics in fruiting vegetables	Relevant
7	(Bolat and Abaci, 2018)	Not relevant	Not relevant	Paper on analytical method to detect pesticides	Not relevant
8	(Ataş et al., 2012)	Not relevant	Not relevant	Paper on analytical method to detect aflatoxins	Not relevant
9	(Chawla et al., 2018)	Maybe relevant	Relevant	Experimental study on uptake and risk assessment of a pesticide in cucumber	**Maybe relevant**
10	(Christou et al., 2014)	Relevant	Relevant	Use of treated wastewater on irrigation of tomato crops	Relevant
11	(Brancato et al., 2018a)	Maybe relevant	Maybe relevant	Modification of an existing MRL	Maybe relevant
12	(Denyes et al., 2012)	Not relevant	Not relevant	Effect of the use of biochar on the bioavailability of PCBs in the soil	Not relevant
13	(Efsa, 2016d)	Maybe relevant	Maybe relevant	Evaluation of import tolerance of flurtiafol in cucurbits	Maybe relevant
14	(Galal, 2016)	Relevant	Relevant	Heavy metals in pumpkins	Relevant
15	(Hou et al., 2018)	Not relevant	Not relevant	Study on gene expressions in the plant	Not relevant
16	(Johnson, 2013)	Not relevant	Not relevant	Study on specialty crops (subsidies, requirements)	Not relevant
17	(Li et al., 2019)	Maybe relevant	Maybe relevant	Experiment on imidacloprid degradation in tomatoes	Maybe relevant
18	(Lu, 2012)	Relevant	Relevant	Pesticide residues in eggplant	Relevant
19	(Mohammed et al., 2014)	Not relevant	Not relevant	Effect of fungi on anti-oxidants etc. in organic tomatoes	Not relevant
20	(Mozaffarinejad and Giri, 2015)	Not relevant	Not relevant	Aflatoxins in spices	Not relevant
21	(Okada et al., 2013)	Not relevant	Not relevant	PFAS in human plasma	Not relevant
22	(Ozilgen et al., 2013)	Relevant	Relevant	Food safety hazards in red pepper	Relevant
23	(Qu et al., 2012)	Not relevant	Not relevant	Traceability system for cucumbers	Not relevant
24	(Ross et al., 2016)	Not relevant	Not relevant	Heavy metals in turtle eggs	Not relevant
25	(Sánchez et al., 2010)	Not relevant	Not relevant	Paper on analytical methods	Not relevant
26	(Shokrzadeh and Saeedi Saravi, 2009)	Relevant	Relevant	Pesticide residues in cucumbers	Relevant
27	(Stazi et al., 2018)	Relevant	Relevant	Effect of organic farming on As uptake in tomatoes	Relevant
28	(Van de Perre et al., 2015)	Not relevant	Relevant	Effect of climate change on Alternaria toxins in tomatoes	**Relevant**
29	(Xie et al., 2019)	Maybe relevant	Maybe relevant	Experimental study + model on a new insecticide in cucumber	Maybe relevant

Nr	Reference	Scientist 1	Scientist 2	Remarks	Final decision
30	(Ye et al., 2016)	Not relevant	Relevant	Effect of eggshell waste on uptake of As, heavy metals etc. in bell peppers	**Relevant**
31	(Zinno et al., 2017)	Not relevant	Not relevant	Effect of NaCl on fermentation of olives	Not relevant
32	(Ruiz-Medina and Llorent-Martínez, 2012)	Maybe relevant	Relevant	Pesticide residues in olives	**Relevant**
33	(Nanyunja et al., 2015)	Not relevant	Not relevant	FSMS in Africa (focus on beans and spices)	Not relevant
34	(Li et al., 2016)	Maybe relevant	Maybe relevant	Experiment on carbendazim and diethofencarb in tomatoes in China	Maybe relevant
35	(Chen et al., 2016)	Not relevant	Not relevant	Effect of growth-promoting substance on uptake of heavy metals in spices (hot pepper)	Not relevant

((30/35) *100)) = **86% agreement**

Annex 6 Results advanced Google search

To determine the websites for the advanced Google search, the top 5 countries exporting to the Netherlands were taken into account. Fruiting vegetables are imported in the Netherlands from Spain, Belgium, Germany, France and Morocco mainly, based on the Eurostat data. In a preliminary search, EFSA, BfR (Germany) and FAVV (Belgium) resulted in relevant hits, which were available in English. For the fourth website, it was decided to focus on Europe and choose between France (Anses) and Spain (AECOSAN). In addition to the import data, production data was used for this decision. Based on the production data of FAOSTAT, Spain is not only trading, but also producing fruiting vegetables. For this reason, AECOSAN was chosen as fourth website for the Advanced Google Search.

It was noticed that fruiting vegetables is not a common term. In the preliminary search, tomato resulted in more hits than fruiting vegetables, while fruiting vegetables is broader than tomato only. For this reason, it was decided to use the following search strategy:

a. Search for vegetables and screen in the results for fruiting vegetables afterwards.
b. Additional search in last 10 year and pdf files for specific fruiting vegetables: tomato, cucumber, courgette, pumpkin. These specific fruiting vegetables are based on the consumption data obtained from RIVM, 15-10-2019. Sweet pepper or bell pepper was tried as well, but in the advanced Google search it turned out to be too difficult to have another exact phrase next “food safety” or “risk assessment”.

For vegetables the number of hits is provided in 4 for the 3 search strings and the 4 websites: EFSA, BfR, FAVV and Aecosan. In Table A6.1 an overview of the number of hits for tomato, cucumber, courgette and pumpkin.

Table A6.1 *Number of hits in advanced Google Search (A).*

Searches	EFSA[a]	BfR[b]	FAVV[c]	Aecosan[d]
1. Vegetable AND “food safety”	865	**163**	**165**	**172**
Id., 2010-03/12/2019	211			
Id., only PDF	**83**			
2. Vegetable AND (contaminant OR residue)	280	**100**	**120**	**42**
Id., 2010-03/12/2019	**84**			
3. Vegetable AND “risk assessment”	1330	472	**182**	**114**
Id., 2010-03/12/2019	259	**139**		
Id., only PDF	**114**			
Total hits	**281**	**402**	**467**	**328**

[a] efsa.europa.eu [b] bfr.bund.de [c] afsca.be [d] aecosan.msssi.gob.es

Table A6.2 *Number of hits in advanced Google search (B) (2010-03/12/2019 & PDF).*

Searches	EFSA[a]	BfR[b]	FAVV[c]	Aecosan[d]
1. Tomato AND “food safety”	**37**	**17**	**28**	**18**
1. Cucumber AND “food safety”	**5**	**6**	**5**	**2**
1. Courgette AND “food safety”	**3**	**2**	**36**	**2**
1. Pumpkin AND “food safety”	**8**	**2**	**2**	**3**
2. Tomato AND (contaminant OR residue)	**10**	**5**	**35**	**4**
2. Cucumber AND (contaminant OR residue)	**3**	**1**	**1**	**-**
2. Courgette AND (contaminant OR residue)	**3**	**2**	**37**	**1**
2. Pumpkin AND (contaminant OR residue)	**4**	**1**	**1**	**1**
3. Tomato AND “risk assessment”	**47**	**119**	**38**	**10**
3. Cucumber AND “risk assessment”	**7**	**6**	**1**	**2**
3. Courgette AND “risk assessment”	**3**	**2**	**6**	**2**
3. Pumpkin AND “risk assessment”	**5**	**1**	**1**	**3**
Total hits	**140**	**165**	**193**	**48**

[a] efsa.europa.eu [b] bfr.bund.de [c] afsca.be [d] aecosan.msssi.gob.es

In Table A6.3, the total relevant number of hits per website is specified, based on the search for fruiting vegetables and the additional search for specific fruiting vegetables. Only English papers are considered.

Table A6.3 *Number of relevant hits in advanced Google search (search A & B combined).*

Searches	EFSA[a]	BfR[b]	FAVV[c]	Aecosan[d]
Total relevant hits	**7**	**6**	**3**	**1**

[a] efsa.europa.eu [b] bfr.bund.de [c] afsca.be [d] aecosan.msssi.gob.es

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