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Summary

This report describes the results of a literature review on chemical hazards in cereals, seeds and nuts produced and/or brought on the market in the Netherlands. Based on the literature review, a so-called 'long list' of chemical hazards was established: substances that may occur in cereals, seeds and nuts. From this long list, an 'intermediate list' of chemical hazards was derived. This intermediate list includes substances that were either frequently found in cereals, seeds and nuts and/or found in concentrations above EU legal limits. The intermediate list will provide the Dutch Food and Consumer Product Safety Authority with input for prioritizing future monitoring activities. When this list is combined with consumption data and toxicological information, a 'short list' of substances can be established: substances that may cause human health risks and as such should be included in the national monitoring program. The established intermediate list in this study is solely based on literature review. It is recommended to evaluate the Dutch monitoring data to confirm or adapt the intermediate list. Toxicological information was provided for the substances on the intermediate list or for substances identified as knowledge gap. Furthermore, trends were evaluated that may influence the presence of chemical hazards in cereals, seeds and nuts.

Long list of chemical hazards that may occur in cereals, seeds and nuts
A literature review was performed separately for cereals, seeds and nuts using pre-defined search strings in Scopus and Web of Science for the years 2008-2018. After removing duplicate references, the papers were evaluated for their relevance for this study. Additionally, Google search was used to obtain relevant reports from international organisations such as WHO, FAO and the US FDA. Furthermore, additional searches were performed in Scopus on specific chemical hazards for which limited information was obtained in the initial literature search. The results obtained indicated the following hazard groups can be found in cereals, seeds and nuts: heavy metals, persistent organic pollutants (POPs), pesticides, mycotoxins, plant toxins, processing contaminants, polycyclic aromatic hydrocarbons (PAHs) and allergens. Additionally, radionuclides were mentioned for cereals and nuts, whereas processing aids and additives were only encountered in cereals. No information was found on residues of cleaning agents and disinfectants in cereals, seeds and nuts. Other chemical hazards such as melamine, mineral oils, perchlorate and plasticiser were found in cereals and fumigants in seeds.

Intermediate list of prioritised chemical hazards in cereals, seeds and nuts
In case chemical hazards were frequently reported to be present in cereals, seeds and nuts and/or in case EU legal limits were exceeded, they were included on the intermediate list. For cereals, the heavy metals (and elements) arsenic, cadmium and lead were frequently found and found in concentrations above EU maximum limits (MLs). Methylmercury was seen as an upcoming hazard in rice cultivated in polluted areas. Since there was limited information on this heavy metal, it was identified as knowledge gap. Another knowledge gap was identified for nickel as EFSA indicated that cereals and cereal-based products, oilseeds and nuts are main contributors to nickel dietary intake. However, occurrence data are currently limited.
A total of 43 pesticides were included on the intermediate list for cereals as these were detected above EU MRLs, found and not approved in the EU or recommended to be included in the monitoring. For seeds and nuts, pesticides were also included on the intermediate list as they were reported to be frequently used. However, in order to determine which pesticides should be included on the intermediate list, it is recommended to evaluate the Dutch monitoring data.
Mycotoxins were the most frequently studied hazard group for cereals and nuts. Within this group, aflatoxins were most relevant for cereals, seeds and nuts, since these were frequently found and found above EU MLs. Additionally, for cereals and seeds deoxynivalenol, ochratoxin A, T-2/HT-2 toxin and zearalenone were included on the intermediate list, since they were frequently found. Fumonisins were added to the intermediate list for cereals as EU ML exceedances were found. *Alternaria* toxins can be found in cereals, seeds and nuts, but information is limited. They were thus identified as knowledge gap. The limited information on enniatins indicates that high concentrations (up to 1100 μg/kg) may be found in cereal-based products. Therefore, these mycotoxins were also identified

as knowledge gap. Several plant toxins were added to the intermediate list: tropane alkaloids for cereals, opium alkaloids for poppy seeds and cyanogenic glycosides for flaxseed/linseed and almonds. PAHs were included on the intermediate list for cereals, since high concentrations may be found when cereals are grown in contaminated areas (e.g. high density of traffic or industrial activities). According to the literature, this may be a health risk since consumption of cereals is high. PAHs may also be formed when roasting seeds. However, limited information was available for PAHs in seeds; these substances were thus regarded as knowledge gap. Another knowledge gap was identified for acrylamide in nuts, which was reported to be found when roasting nuts. Literature study revealed that fumigants are used during the transport and storage of seeds in containers to protect the seeds from pests. Fumigants have been detected above EU legal limits and some of them have a long desorption time, which may result in elevated concentrations in seeds after transport and storage. Since no occurrence data were found for fumigants in seeds, these substances were identified as knowledge gaps.

Trends in cereals, seeds and nuts
Literature review and expert elicitation were used to identify upcoming trends that could influence the presence of chemical hazards in cereals, seeds and nuts. Results showed that there is an increased consumption of (raw) nuts and seeds due to their healthy image. This may lead to an increased exposure to the chemical hazards on the intermediate list, such as cyanogenic glycosides via increased consumption of linseed and almonds. Furthermore, due to more strict regulation regarding pesticide use and an increased awareness of sustainability, pesticide use is expected to decrease.

Samenvatting

Dit rapport beschrijft de chemische gevaren die voor kunnen komen in granen, zaden en noten die in Nederland zijn geproduceerd en/of op de markt gebracht. Op basis van het literatuuronderzoek is een zogenaamde 'long list' van chemische gevaren opgesteld: stoffen die mogelijk kunnen voorkomen in granen, zaden en noten. Stoffen die veel gevonden werden in granen, zaden en noten en/of boven Europese wettelijke limieten werden gevonden zijn opgenomen in de zogenaamde 'intermediate list'. Deze lijst kan bijdragen aan de prioritering van chemische monitoringsprogramma's in granen, noten en zaden door de NVWA. Door deze lijst te combineren met consumptiedata en toxicologische informatie kan een zogenaamde 'short list' opgesteld worden: chemische gevaren die een mogelijk risico kunnen vormen voor de mens en dus zouden moeten worden opgenomen in het nationale monitoringsprogramma. De intermediate list is uitsluitend gebaseerd op literatuuronderzoek. Het is daarom aan te bevelen de lijst aan te vullen met behulp van Nederlandse monitoringsdata. Voor de stoffen die op de intermediate list zijn aangegeven en voor stoffen die aangemerkt zijn als kennisleemte, is toxicologische informatie verstrekt. Daarnaast geeft dit rapport trends weer in granen, zaden en noten, die een invloed kunnen hebben op de aanwezigheid van chemische gevaren in deze voedselgewassen.

De long list van chemische gevaren die kunnen voorkomen in granen, zaden en noten
Er zijn aparte literatuuronderzoeken uitgevoerd voor granen, zaden en noten met vooraf gedefinieerde zoektermen in Scopus en Web of Science voor de periode 2008-2018. Nadat dubbele referenties waren verwijderd, zijn de artikelen geëvalueerd op hun relevantie voor deze studie. Daarnaast is met behulp van de zoekmachine van Google gezocht naar relevante rapporten van (inter)nationale organisaties zoals de WHO, FAO en de US FDA. Indien het initiële literatuuronderzoek weinig tot geen informatie opleverde voor bepaalde chemische gevaren, is nog een specifiek literatuuronderzoek uitgevoerd naar deze stoffen. De resultaten van het literatuuronderzoek laten zien dat de volgende gevarengroepen werden gevonden in granen, zaden en noten: zware metalen, persistente organische verontreinigende stoffen, pesticiden, mycotoxinen, planttoxinen, procescontaminanten, polycyclische aromatische koolwaterstoffen (PAK's) en allergenen. Radionucliden kwamen ook voor in granen en noten; technische hulpstoffen en additieven werden alleen in granen gevonden. Er is geen informatie gevonden voor reinigings- en desinfectiemiddelen in granen, zaden en noten. In granen werden verder nog andere chemische gevaren aangetroffen: melamine, minerale oliën, perchloraat en weekmakers. In zaden werden bovendien nog fumigatiemiddelen aangetroffen.

De intermediate list van geprioriteerde chemische gevaren in de fruitketen
Indien chemische gevaren regelmatig gevonden werden in granen, zaden en noten en/of indien er overschrijdingen van Europese limieten werden gevonden, werden ze opgenomen op de intermediate list. Voor granen werden de zware metalen (en elementen) arseen, cadmium en lood regelmatig gevonden en ook in concentraties boven de EU ML's. Methylkwik wordt gezien als opkomend gevaar in rijst dat verbouwd wordt in een besmet gebied. Aangezien er weinig informatie was over methylkwik, is deze stof aangemerkt als kennisleemte. Verder werd nikkel als kennisleemte geïdentificeerd aangezien granen en graanproducten, oliezaden en noten volgens EFSA een belangrijke bijdrage leveren aan de nikkelinname via voedsel. Momenteel zijn er echter weinig gegevens over het vóórkomen van nikkel in deze voedselgewassen. In totaal werden 43 pesticiden op de intermediate list voor granen gezet, omdat de concentraties van deze pesticiden boven de EU MRL's waren, deze pesticiden niet toegelaten zijn in de EU of omdat er aanbevelingen waren om de stoffen op te nemen in de monitoring. Voor zaden en noten zijn pesticiden als groep opgenomen op de intermediate list, aangezien het literatuuronderzoek aangaf dat ze veel gebruikt worden. Om vast te stellen welke pesticiden precies op de intermediate list opgenomen moeten worden, is het aan te bevelen de Nederlandse monitoringsdata te raadplegen. Voor granen en noten waren mycotoxinen het meest bestudeerd. Binnen deze groep zijn aflatoxinen het meest relevant voor granen, zaden en noten, aangezien deze vaak gevonden werden en ook boven de EU ML's zijn aangetroffen. Daarnaast zijn voor granen en zaden deoxynivalenol, ochratoxine A, T-2/HT-2 toxinen en zearalenon opgenomen op

de intermediate list, aangezien deze regelmatig werden gevonden. Fumonisinen werden opgenomen op de intermediate list voor granen aangezien overschrijdingen van de EU ML's werden gevonden. *Alternaria* toxinen kunnen voorkomen in granen, zaden en noten. Voor deze mycotoxinen werd echter weinig informatie gevonden; ze werden daarom aangemerkt als kennisleemte. Enniatines werden in hoge concentraties (tot 1100 µg/kg) gevonden, maar informatie was beperkt. Deze mycotoxinen werden dus ook geïdentificeerd als kennisleemte. Verder werden de volgende planttoxines op de intermediate list opgenomen: tropaanalkaloïden voor granen, opiumalkaloïden voor maanzaad en cyanogene glycosiden voor lijnzaad en amandelen. PAK's werden opgenomen op de intermediate list voor granen, aangezien hoge concentraties gevonden kunnen worden indien granen in besmet gebied geteeld zijn (bijvoorbeeld bij een drukke weg of bij industriële activiteiten). Door de hoge graanconsumptie kan dit resulteren in gezondheidsrisico's. PAK's kunnen ook gevormd worden tijdens het roosteren van zaden. Aangezien hier weinig informatie over gevonden is, werden PAK's als kennisleemte aangemerkt voor zaden. Acrylamide werd als kennisleemte gezien voor noten, aangezien dit gevormd kan worden tijdens het roosteren van noten. Het literatuuronderzoek liet verder zien dat fumigatiemiddelen gebruikt worden ter voorkoming van plagen tijdens opslag en transport van zaden in containers. Deze stoffen werden boven de Europese wettelijke limieten gevonden en sommige hebben een dermate lange desorptietijd dat ze in verhoogde concentraties in zaden gevonden kunnen worden na transport en opslag. Aangezien er geen monitoringsdata gevonden zijn over fumigatiemiddelen in zaden, werden deze stoffen ook aangemerkt als kennisleemte.

Trends in granen, zaden en noten
Er ia literatuuronderzoek uitgevoerd en experts zijn geraadpleegd om de trends in de keten van granen, zaden en noten te identificeren die een invloed zouden kunnen hebben op het vóórkomen van chemische gevaren. Hieruit bleek dat de consumptie van (onbewerkte) noten en zaden is toegenomen vanwege hun gezondheidsimago. Dat kan leiden tot een toegenomen blootstelling aan de gevaren op de intermediate list, zoals cyanogene glycosiden door een toename in consumptie van lijnzaad en amandelen. Verder is de verwachting dat het pesticidengebruik zal afnemen door striktere wetgeving en een toegenomen bewustwording omtrent duurzaamheid.

1 Introduction

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

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

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

Sub-chain 2, nuts, cereals and seeds, is the focus of this research.

The aim of the current study was to make an inventory of possible chemical hazards in the supply chains of cereals, seeds and nuts and to identify the most relevant chemical hazards, as based on scientific literature review. This information will be used by the NVWA as input to the risk prioritization of chemical hazards in these supply chains.

2 Methods

2.1 Project description and demarcation

The necessary information for this literature study was collected from scientific literature and reports from national and international institutes regarding chemical hazards in the supply chains of cereals, seeds and nuts. Annex I provides a list of terms and abbreviations used in this report.

For this report, we searched for information on chemical hazards in cereals, seeds and nuts produced and/or brought on the market in the Netherlands. Only raw materials, such as maize kernels, and first processing products such as flour and bran were taken into account and not the further processed products, such as corn flakes, fats and oils, bread, spaghetti etc. If encountered in literature, the effect of processing was included in this report, but no specific literature search was performed on the effects of processing on chemical hazards in cereals, seeds and nuts. Composite products in which cereals, seeds and nuts are used, e.g. muesli bars, were not part of this literature study.

2.2 Literature screening

The first step was to search for information from scientific literature. Two databases were used for the literature search: Scopus and Web of Science for the period 2008-2018. Within each literature search, keywords were combined for: #1 commodity, #2 chemical hazards and #3 public health. Searches were downsized with #4 exclusion terms in order to obtain the most relevant papers within available time and budget.

2.2.1 Cereals

2.2.1.1 Scientific literature

More detailed information on the reasoning on choosing the following search queries are outlined in Annex 2.

<u>Search-query 1 (option 6 of Annex 2):</u>

#1 In title:
Cereals or oat* or barley or rice or millet or rye or sorghum or wheat or maize or corn or poaceae or glycine or buckwheat or fonio or triticale

AND
#2 In title, abstract, 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 In title, abstract, 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*"

AND NOT
#4 In title, abstract, keywords
pathogen* OR streptococcus OR listeria OR virus OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR environment* OR ecological OR bioavailability OR "water management" OR soil OR nutritional*
AND NOT in title: fung* OR method* OR experiment* OR analytic* OR model*

Limited to publication years 2008-2018.

The exclusion terms were chosen, in order to downsize the number of hits and to retrieve a reasonable amount of hits that were relevant for this study. However, as this search string entails a lot of exclusion terms, relevant papers may be missed. Therefore, an additional search string for both databases was used, with a limited set of exclusion terms, but only focusing on the review papers:

<u>Search-query 2 (option 7 of Annex 2):</u>

#1 In title:
Cereals or oat* or barley or rice or millet or rye or sorghum or wheat or maize or corn or poaceae or glycine or buckwheat or fonio or triticale

AND
#2 In title, abstract, 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 In title, abstract, 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*"

AND NOT
#4 In title: pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "microb* contamin*" or "foodborne disease*" OR fung* or method* OR experiment* OR analytic* OR model* OR environment* or ecological)

Limited to publication years 2008-2018 and review papers.

By combining these options, the most relevant articles were retrieved and a good compromise between relevant articles and number of hits was met, which are feasible to study within the limited available time and budget. The literature search in Scopus and Web of Science was conducted on the 26th of July 2018.

All hits from Scopus and Web of Sciences were included in an Endnote file. First, the duplicate references, which were found in both databases, were removed. Subsequently, the following steps were applied to downsize the number of hits and to extract the relevant articles.

1. Relevance of the publication was determined based on the title and, if needed, the available abstract was read. Papers were then grouped in: relevant, maybe relevant and not relevant. Selection of relevant papers was checked by another scientist for a limited number of publications.
2. Papers that were evaluated in step 1 as relevant, were further screened based on abstract, material and methods, results and conclusion.
3. Relevant papers in step 2 were summarised in an Excel table that has been provided to NVWA-BuRo together with this report. Possible chemical hazards, region and country where these hazards were found, found concentrations, the type and size of the study and the main message of the publications were noted.

The "maybe relevant' group of references was checked in case a hazard group retrieved only a limited number of relevant papers. Two groups of chemical hazards (mycotoxins and heavy metals) showed too many relevant papers, which could not all be described in chapter 3. For these hazard categories, first, the review articles were summarized. Secondly, only the papers with a relatively high study sample (200 or more) were included. Furthermore, import data were used to select relevant regions to include in the report for these hazard groups.

2.2.1.2 Google search

Additional to the scientific literature, internet searches were conducted to retrieve reports and grey literature within specified websites using the Google search engine. The following institutions and organisations were consulted: the World Health Organization (WHO), the Food and Agriculture Organisation (FAO), the German Institute for Risk Assessment (BfR) and the Canadian Food Inspection Agency (CFIA). These four websites were chosen, based on a pre-screening of different institutions and organisations on their relevance for cereals (biggest cereal producing countries in the world, and presumed English publications) and according to relevant websites which were chosen in past chain analyses performed for the NVWA.

The following keywords were used:

- for cereal commodities: wheat, maize, barley, and cereals.
- for the hazard category: "food safety", contaminants, residue and "risk assessment" were used.

The four cereal commodities were used together, each time combined with one hazard and one website (via Google settings, advanced search, site or domain). Initially, all years were included, but when this resulted in more than 200 results, firstly the years were limited to 2008-2018 and secondly, if necessary, the results were limited to only the extension 'pdf' (via Google settings, advanced search, file type: .pdf). After this downsizing method, if the hits were still more than 200, only the first 200 most recent hits were screened.

2.2.1.3 Additional searches

As bulgur was not included in the search string, an additional search was conducted using the search term #1 bulgur and the search terms #2, #3 and #4 of search-query 2.

Moreover, the literature search in the scientific literature and google (sections 2.2.1.1 and 2.2.1.2) resulted in some cases only in a limited amount of information or in no information for some hazards. Therefore, an additional search was performed in Scopus for the following hazards: Persistent organic pollutants, radionuclides, progressing aids and additives, flour treatment agents, cleaning agents and disinfectants, plant toxins, melamine and plasticiser. Information on the specific hazards were searched in title, abstract or keywords and the cereal terms (#1 + bulgur) were searched in title.
The number of hits retrieved and the number of relevant articles is outlined in Annex 4.

2.2.2 Seeds

2.2.2.1 Scientific literature

More detailed information on choosing this search terms is outlined in Annex 2. Quinoa can be included in cereals as well. However, we chose to combine it with other pseudo-cereals such as chia under the seeds.

#1 In title:
"edible seed" OR flax* OR *linseed** OR *"hemp seed*"* OR *"safflower seed*"* OR *"marrow seed*"* OR *"pumpkin seed*"* OR *pepitas* OR *"ginkgo seed*"* OR *"sunflower seed*"* OR *"poppy seed*"* OR *"sesame seed*"* OR *camelina* OR hemp OR *carthamus* OR *cucurbita* OR *gingko* OR *helianthus* OR *linum* OR *papaver* OR *sesamum* OR *amaranth** OR *kaniwa* OR *quinoa* OR *chenopodium* OR *chia* OR *salvia*

AND
#2 In title, abstract, 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 In title, abstract, 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*"

AND NOT
#4 In title:
pathogen* OR streptococcus OR listeria OR virus OR bacillus OR salmonella OR clostridium OR staphylococcus OR outbreak OR "foodborne disease*" OR method* OR experiment* OR analytic* OR model* OR environment* or ecological) AND PUBYEAR >2007

Limited to publication years 2008-2018

The same procedure for evaluating papers was followed as described for cereals (Section 2.2.1). The literature search was conducted on the 13th of September 2018.

2.2.2.2 Google search

No information on the biggest seed producing countries in the world was found; therefore, the same initial institutions and organisations were chosen as for cereals. A pre-screening on these websites were conducted, after which the four most relevant websites were chosen: World Health Organisation (WHO), the French Agency for Food, Environmental and Occupational Health and Safety (Anses), the U.S. Food and Drug Administration (FDA) and the Food Safety Authority of Ireland (FSAI).

The following keywords were used:
- For the product category: seed, quinoa
- For the hazard category: "food safety", contaminants, residue and "risk assessment" were used.

The same procedure for evaluating the results was followed as described for cereals (Section 2.2.1)

2.2.2.3 Additional searches

The literature search in the scientific literature and google (sections 2.2.2.1 and 2.2.2.2) resulted in some cases in no or limited information for some hazards. Therefore, an additional search was performed in Scopus for the following hazards: Persistent organic pollutants, radionuclides, processing contaminants, processing aids and additives, cleaning agents and disinfectants. Information on the specific hazards were searched in title, abstract or keywords and the seed terms (#1) were searched in title.
The number of hits retrieved and the number of relevant articles is outlined in Annex 4.

2.2.3 Nuts

2.2.3.1 Scientific literature

An initial literature research on nuts, included in the fruit-chain, was already conducted in the past (van Asselt et al. (2018). Using the databases Web of Science and PubMed in combination with the search terms "chemical hazard*", "hazard analys*" and "risk analys*" resulted in very limited relevant hits (5 in Web of Science and 1 in PubMed), primarily describing aflatoxins in that study. In order to expand this search, an additional search in Scopus was conducted on the 12th of November 2018 using the following search query.

#1 In title:
Almond* OR "Brazil nut*" OR cashew OR chestnut* OR coconut* OR hazelnut* OR "macadamia nut*" OR peanut* OR pecan OR "pine nut*" OR pistachio OR walnut*

AND
#2 In title, abstract, 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 In title, abstract, 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*"

AND NOT
#4 In title:
pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" or method* OR experiment* OR analytic* OR model* OR environment* or ecological or oil*) AND PUBYEAR >2007

The majority of the relevant papers investigated the chemical hazard mycotoxins, which could not all be described in chapter 3. For this hazard category, review articles and papers with a relatively high study sample (200 or more) were included in the report. Papers from countries that currently do not export to the Netherlands, as based on Eurostat data, were not described in this report.

2.2.3.2 Additional searches

The literature search in the scientific literature resulted in some cases in limited information for some hazards. Therefore, an additional search was performed in Scopus for the following hazards: processing aids and additives, cleaning agents and disinfectants, and pesticides. Information on the specific hazards were searched in title, abstract or keywords and the seed terms (#1) were searched in title. The number of hits retrieved and the number of relevant articles is outlined in Annex 4.

2.2.4 Import data

To prioritize the references retrieved during the literature screening, the NVWA extracted EUROSTAT import data for cereals on 29 October 2018 for imports to the Netherlands for the year 2017. Several harmonised system (HS) codes were used to obtain all import data for cereals. These included the following cereals (excluding seed for sowing): Durum wheat (HS code: 100119), wheat and meslin (excluding durum wheat) (HS Code: 100199), Rye (HS Code: 100290), barley (HS Code: 100390), oats (HS Code: 100490), maize (HS Code: 100590), rice in the husk, "paddy", or rough (HS Code: 100610), husked or brown rice (HS Code: 100620), semi-milled or wholly milled rice, whether or not polished or glazed (HS Code: 100630), broken rice (HS Code: 100640), grain sorghum (HS Code: 100790), buckwheat (HS Code: 100810), millet (excluding grain sorghum0 (HS Code: 100829), triticale (HS Code: 100860) and other cereals (HS Code: 100890).

For nuts, the NVWA extracted EUROSTAT import data on 13 November 2018 for imports to the Netherlands for the year 2017. The following nuts were included (excluding seed for sowing): groundnuts in shell (roasted or otherwise cooked) (HS Code: 120241), groundnuts, shelled, whether or not broken (roasted or otherwise cooked) (HS Code: 120242) and groundnuts, prepared or preserved (excluding preserved with sugar) (HS Code: 200811).

Data was provided as the quantity in 100 kg. It has to be kept in mind that the Eurostat data do not distinguish between import for feed or for food purposes. In our study we used the total amounts imported from the various countries.

2.3 Prioritization

The literature search revealed which chemical hazards may occur in cereals, seeds and nuts; this is called the "long list". Each of these hazards is described in sections 3.2, 3.3 and 3.4 for cereals, seeds and nuts, respectively. Based on information in the retrieved papers and reports regarding concentrations detected in cereals, seeds and nuts, conclusions were drawn regarding their possible presence. Substances that were frequently found to be present in cereals, seeds or nuts as well as substances that exceeded legal limits were included on the " intermediate list". Furthermore, in case the literature revealed a possible human health risk, these hazards were also included on the intermediate list. In some cases, there were indications of a health risk, but information on occurrence of the hazard in cereals, seeds or nuts were limited or lacking. These hazards were identified as knowledge gap.

For the substances on the intermediate list and for substances identified as knowledge gap, health-based guidance values were indicated and EFSA opinions consulted to estimate the relevance of these substances for human health.

2.4 Evaluation of trends in the supply chain of cereals, seeds and nuts

Trends that might have an effect on chemical hazards in cereals, seeds and nuts were evaluated. This part of the project was performed in close collaboration with Wageningen Food & Biobased Research (WFBR). The following information sources were consulted:

- Expert reports from international institutions and organizations such as World Health Organisation (WHO), Food and Agricultural Organization (FAO), Rabobank and ABN-AMRO.
- A Google search to find information on future trends.
- A Google Scholar search to find scientific literature about future trends.
- Magazines and blogs on food and retail to find information on future trends.
- Innova database to find new product introductions. Innova Market Insights collects all new product introductions, collecting all information available on the package into the Innova Database (www.innovamarketinsights.com). Information about the product that is not mentioned on the package is consequently not in the database, nor is registered how long the product is, was, or has been available on the market. The overview the database provides shows the trend in products in the past years. In the database, products can be sorted based on the type of ingredients, packaging type, year, country, etc. Furthermore, the team from Innova makes regular updates on trends they note in several of the product categories. An Innova search was performed on introductions in the Netherlands between 2007 and 2017.
- Expert interviews or written responses of experts in the field to a questionnaire that was sent by email. In total, 12 experts were contacted using a pre-defined questionnaire (in Dutch, see Annex 5). The consulted experts occupied different positions in various organisations in the food supply chain. Participants were informed beforehand that the results would be used for a research project for NVWA-BuRO. Responses to the interview or written questionnaire were processed anonymously.

3 Results

3.1 Results literature search

3.1.1 Overview of relevant hits for cereals

3.1.1.1 Results for Scopus and Web of Science

The two combined search strings used in Scopus and Web of Science (see section 2.2.1.1) resulted initially in 1101 hits: 557 and 68 hits with Scopus (search queries 1 and 2) and 406 and 70 with Web of Science (Search query 1 and 2).

The references were saved in Endnote and duplicates were removed, after which 775 articles remained. Subsequently, these articles were screened upon relevance in the first step merely based on the title and, if needed, the available abstract was read. After this first screening phase, 298 references were considered as relevant, 387 as not relevant and 91 as maybe relevant. Relevant papers included information on concentrations and/or occurrence of chemical hazards in cereals. Literature on the following topics (examples) were considered to be not relevant:

- Health (e.g. Effect of contaminants on human health, GMO and public health)
- Nutrition (e.g. omega-3-fatty acids, healthy cereals, digestibility)
- Artificially contaminated cereals (inoculated, spiked)
- Waste reduction
- Modification of existing MRLs: EFSA opinions on specific pesticides
- Cereal growth, yield and inhibition
- Biodiversity
- Productivity systems/ sustainable systems
- EU legislation: MRL
- Development of a new detection method
- Mycotoxin-resistant genes in cereals
- Coeliac disease, prevalence of diabetes
- Toxicity studies: animal studies
- Microbiological topics
- Camera systems for detection of contaminants
- Bioethanol production
- Sensory characteristics
- Economic risk-analysis

The 298 potentially relevant articles were further screened. Abstract, material & methods and conclusion of the paper was read. In some cases, the full paper was checked for relevant information. After screening these 298 references, not all of these references remained relevant. Articles which the following topics (examples) were excluded:

- Articles containing no monitoring data in general
- Experimental studies/ cultured laboratory tests
- Testing/ Validation of new detection method
- Modelling and estimations, prediction models
- Spectral imaging
- Monitoring of fungi-species only, but not mycotoxins
- Breeding
- Management actions (prevention, control, decontamination, inactivation)
- Radiation effect
- Rice straw burning
- Toxicity tests of herbicides

In total, 194 references were evaluated as relevant. These references were included in an Excel file in which the details of the references were recorded, such as the chemical hazard, the country, exceedances of legal limits etc. The references in the 'maybe relevant' category were additionally screened for relevant articles regarding processing effects and, as a result, 17 references were added to the Excel file. The information obtained is summarised in the following sections.

The 194 references outlined various chemical hazards in various regions of the world. Most studies were conducted in Asia (80), followed by Europe (53), Africa (27), South America (12) and North America (8) and Worldwide (7). A few additional articles focused on two regions simultaneously in one study. The most frequently mentioned product groups in the articles were rice (60), cereals (46), maize (36), wheat (31), barley (6) and sorghum (4). The product group cereals can either consist of several cereal-grains, its processed products (e.g. flour, bran), cereal-based products (e.g. breakfast cereals, bread, biscuits) or a combination of these. Most of the references studied the occurrence of mycotoxins (142), followed by heavy metals (33), pesticides (10) and processing contaminants (4).

3.1.1.2 Results for Google

The Google search resulted in 45 relevant hits (WHO: 16; FAO: 5; BfR: 13; CFIA: 11). The total number of hits found in these websites is indicated in Annex 3.

References found on the websites included cereals (22), cereal products (7), cereals and cereal products (5), cereals and rice (4), maize (3), wheat (2) and rice (2). Hazards found via the websites are more diverse as compared to the results from the scientific databases and outline additional hazards. Hazards found in the references are the following:
Mycotoxins (16), Heavy metals (10), Processing contaminants (5), Plant toxins (3), Pesticides (2), Plasticiser, PCB, Processing aids, Allergen, Fertiliser, Mineral oil, PAH and Melamine (all 1).

The following topics (examples) were considered to be not relevant:
- HACCP standards
- Nutrition security plans
- Dietary guidelines
- Food security
- Global burden of foodborne diseases
- Microbiological topics
- Codex Alimentarius meeting on pesticide residues (MRL recommendations)
- Methods of analysis of pesticides/ evaluations of pesticides (trials)
- Indoor air pollution
- Drinking water
- Climate change
- Sustainable food systems
- Global food loses/ food waste
- Other food commodities (e.g. dairy, fish)

3.1.2 Overview of relevant hits for seeds

3.1.2.1 Results for Scopus and Web of Science

In total, 70 hits for Scopus and 51 hits for Web of Science were found. After de-duplication 85 remained. After screening the title (and abstract if necessary), 19 articles were evaluated as relevant, 7 as maybe relevant and 59 as not relevant. The following topics were evaluated as not relevant (examples):
- Alternative fertilizer urine
- Experimental studies (accumulation of antimicrobials in pumpkin)
- Herbs (Dalmatian sage)
- Supplements (ginkgo)
- Amaranth leaves flour for pasta production
- Effect of gamma radiation on fungus and alternariol toxins in sunflower seeds
- Insecticide seed treatment on foliar predator in sunflower
- Chitosan and modified atmosphere packaging to improve microbiological quality of amaranth

- Effect of seeds in the diet of animals on emissions and animal health
- EFSA: Modification of MRLs
- Detection method of sesame seeds in food
- Ginkgo extract in cardiovascular protection in Patients with Diabetes
- Meju – fermented soybean product
- Nutrition related
- Use of linseed – multipurpose plant

From the 19 relevant and 7 maybe relevant references, 8 references remained relevant after reading the articles. Articles with the following topics (examples) were considered not relevant:
- Field trials (spraying of pesticide and evaluation of residues)
- Effect nano-engineered + pesticide on zucchini
- Investigation in vegetable (leave parts) and not seeds
- Wheat bread enriched with sunflower seeds
- Bio fertiliser

3.1.2.2 Results for Google

The Google search resulted in 24 relevant hits (WHO: 7; Anses: 4; US FDA: 7; FSAI: 6). The total number of hits found in these websites is indicated in Annex 3.

The following topics (examples) were considered to be not relevant:
- GMO food
- Other commodities (dairy, fish)
- Dietary guidelines
- Food security
- Nutrition
- Microbiological topics
- Public health risk assessment and interventions (earthquake, typhoon, humanitarian crisis)
- Seed funding/ seedlings/ seed treatment/ seed fermentation
- Biodiversity and human health
- Drinking water
- Vaccination/ medicine
- Bee mortality
- Marketing authorisation of pesticides (France)
- Lupine seeds used in animal feed
- Haemolytic-uremic syndrome – fenugreek seeds and sprouts
- Food safety guidelines for production of potatoes
- US regulatory GRAS (generally recognised as safe) notifications
- Interstate Certified Shellfish Shippers list
- Swedish snus

3.1.3 Overview of relevant hits for nuts

Previous results described in Van Asselt et al. (2018) resulted in 5 relevant hits from Web of Science and PubMed as well as 43 relevant hits using Google.

The additional literature research in Scopus resulted in 188 hits, of which 50 references remained relevant after screening the title (and abstract if necessary). 13 Articles were considered as maybe relevant and 125 as not relevant. Literature on the following topics were evaluated as not relevant (examples):
- Economic
- Water quality
- Air quality
- Peanut allergen detector
- New detection methods (e.g. nuts in processed foodstuffs)
- Hygiene practices for minimising aflatoxin contamination in peanut-based products
- Impact of food contamination on brands

- Immunotherapy
- Studies on other commodities: yoghurt, fish
- Polyphenols tannin
- Microbiology
- Disease-resistant genes
- Nutrition
- Processed products
- Multispectral imaging detection methods
- Prediction
- Environmental pollution

From these 50 references, 33 remained relevant after screening the articles. Articles with the following topics (examples) were considered not relevant:
- Detection of fungi, not mycotoxins
- Aspects influencing quality and organoleptic properties during hazelnut production
- Trade developments of pistachio imports from Iran and the USA
- Experimental trials: Half-lives of fenaminstrobin and picoxystrobin in soil and peanut

3.1.4 Import data

Import data from Eurostat showed that most cereals are imported from Ukraine (around 26 million tons, primarily maize) followed by Brazil (around 6.5 million tons), Lithuania (2.8 million tons), Russia (2.6 million tons) and the US (2.1 million tons); see Figure 1.

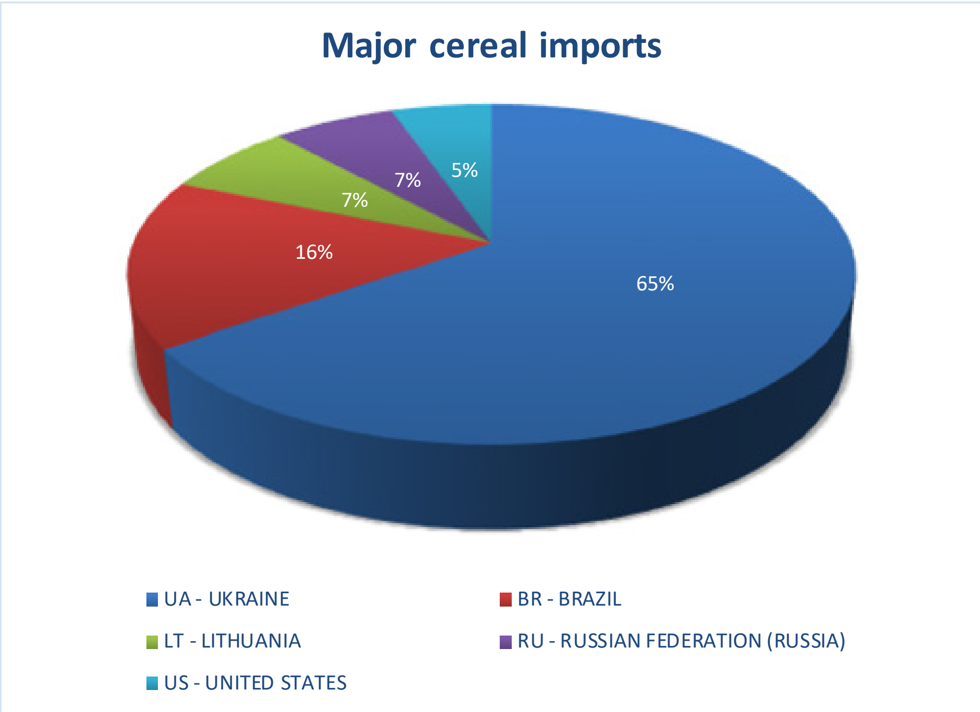

Figure 1 *Major countries exporting cereals to the Netherlands.*

When specified per cereal product, there were some differences between countries. The majority of the wheat imported in the Netherlands originated from Lithuania with around 2.2 million tons in 2017 (see Figure 2a), followed to a lesser extent by Russia, Ukraine, Moldavia, Estonia, Canada and Turkey. The most relevant country for maize imports was Ukraine from which we imported around 25 million tons of maize in 2017 (see Figure 2b). Other relevant countries for maize imports were Brazil, the US, Russia and Lithuania. Most of the rice we imported in 2017 came from India (around 860,000 tons) followed by Thailand, Cambodia, Guyana, Myanmar, Uruguay and Pakistan.

Figure 2 *Major countries exporting wheat (a), maize (b) or rice (c) to the Netherlands.*

Rye was only imported from Lithuania (around 30,000 tons) and Canada (around 6,000 tons). Barley was imported - in descending order - from Ukraine (around 109,000 tons), Russia, Austria, Argentina and Lithuania. Oats were imported from Estonia (around 36,000 tons), Lithuania (15,000 tons) and Ukraine (5,000 tons). Sorghum was imported from Russia (2800 tons) and buckwheat from Lithuania (around 23,000 tons). Negligible amounts were imported from other countries. Millet was imported from Ukraine (32,000 tons), India (8700 tons), Russia (7700 tons) and China (3900 tons). Finally, triticale was imported from Lithuania (15,000 tons).

The results from the import data were used to prioritize references in hazards groups in case too many hits were found to include in the report. All countries mentioned above were included for the references on cereals. For groundnuts, Argentina (around 2 million tons), the US (500,000 tons), China (320,000 tons) and Brazil (260,000 tons) were the most relevant countries exporting to the Netherlands in 2017. Eurostat data indicated we hardly imported groundnuts from African countries.

3.2 Overview of chemical hazards in cereals

The majority of the papers found in the literature research (around 74%) described mycotoxin presence in cereals. Around 18% of the papers described the presence of heavy metals in cereals. For the other hazard groups, limited information was found even after additional searches. The information obtained is summarised in the sections below. Information regarding the use of cleaning agents and disinfectants in cereal manufacturing factories or remaining residues in cereal and cereal-based products was not found in this study. An additional search specifically on cleaning agents and disinfectants used in cereals did not retrieve relevant papers. Cereals are stored as dry as possible to prevent fungal growth. As such, cleaning agents and disinfectants are usually not applied to clean storage or transport facilities.

3.2.1 Heavy metals and trace elements

Alldrick (2017) outlines in his overview about relevant chemical contaminants in cereals that for heavy metals in particular arsenic, cadmium and lead are of concern due to their toxic effect. Reviews conducted by EFSA pointed to the fact that cereals and cereal products are a major contributor to these metals via the human diet. Several papers reported exceedances of legal limits for heavy metals in cereals. Abtahi et al. (2017) reviewed 27 articles from 2008 – 2016 to investigate the presence of arsenic, chromium, lead, cadmium and nickel in rice in Iran. In several regions in Iran, exceedances of national legal limits (cadmium: 0.06 µg/g; lead: 0.15µg/g; arsenic: 0.15 µg/g; chromium: 1µg/g (WHO)) were found.
Al-Saleh and Abduljabbar (2017) reported regulatory exceedances for heavy metals in investigated rice samples from Saudi Arabia and imported rice from India, Thailand, USA, Italy, Indonesia, Iraq, Pakistan, Australia and Spain for heavy metals. Lead, methylmercury and arsenic concentrations were found above the legal limits (lead: 0.2 µg/g (Codex), methylmercury: 0.02 µg/g (China), arsenic: 0.2 mg/kg (Codex)) in rice grains not rinsed or soaked, indicating a potential health risk in particular from arsenic and for vulnerable groups. Additionally, also crops other than rice can be contaminated with heavy metals as exceedances of Codex limits were reported in Iran for lead and cadmium in rice, wheat and maize (Pirsaheb et al., 2016). Sofuoglu and Sofuoglu (2018) investigated the concentrations of heavy metals in bulgur and rice in Turkey and found that rice contained higher concentrations of cadmium, cobalt and lead whereas selenium, copper, manganese and zinc were found in higher concentrations in bulgur. Cadmium concentrations in rice exceeded the EU maximum limit, whereas no exceedance for lead maximum limit were found. Risk estimates indicated a potential health concern for cadmium, cobalt and lead in rice, whereas no health risk from bulgur consumption was found.

The vast majority of retrieved studies were conducted in Asia, in particular in China, of which the main reported chemical contaminant was arsenic.

Arsenic exposure is a well-recognised food safety related contaminant, which may have a carcinogenic effect on humans, even at low levels. Arsenic is a ubiquitous element that can pollute soil and water but also plants, which may lead to an arsenic ingestion via food crops. High concentrations of arsenic in crops are proportionally related to high arsenic contents in contaminated soil and/or groundwater/irrigation water. Gousul Azam et al. (2017) investigated in their review the arsenic contamination in cereal crops worldwide. Among food crops, rice accumulates arsenic more efficiently than any other cereals, which leads to higher arsenic concentrations (total or inorganic arsenic not indicated) in rice as compared to other cereals.
Arsenic concentrations in rice samples from China were found above the national maximum limit (As_i: 0.2 mg/kg) (Sun et al., 2008; Li et al., 2015). Also milled rice samples were found above the national maximum limit (Huang et al., 2015), although Lin et al. (2015) did not report any non-compliances. Li et al. (2015) indicated a potential health concern, whereas Lin et al. (2015) and Huang et al. (2015) did not conclude a potential adverse health effect. The high contamination levels found by Zhu et al. (2008) were reported to be a result from industrial pollution (mining and smelter districts, large-scale metal processing plants) in the regions where rice was grown.
Exceedances are not only occurring in Asian countries, but also in European rice producing countries such as Portugal and Spain, where reported levels were found above the maximum limit for arsenic (0.2 mg/kg) proposed by *Codex Alimentarius* (Tattibayeva et al., 2016) and the EU (Regulation (EC) No 1881/2006).
In regions where the diet is not based on rice, wheat is the main source of uptake of inorganic arsenic. Besides that, also maize can be one of the major contributors to dietary uptake of arsenic, in particular in regions of high maize consumption such as central America and Africa (Gousul Azam et al., 2017). The review from Rosas-Castor et al. (2014) on arsenic accumulation in maize confirms the general lack of information on arsenic levels in maize. In their evaluation of existing studies between 1976 and 2012, only seven studies were found to have reported arsenic concentrations in maize around the world (USA, Mexico, Chile and China). Reported concentrations of total arsenic in

maize grains and maize-based products ranged between 0.04 – 1.13 mg/kg and the inorganic arsenic constituted 50 – 73%. In contrast to that, the proportion of inorganic arsenic in rice and wheat is determined to be between 33 – 96%. Among these, seven studies focused on maize; the highest total arsenic content was found in processed maize products (tortilla) as compared to the grain (0.02 – 0.55 mg/kg). Thus, the concentrations in maize and maize-based products would exceed the limits established in China (see below).

Regarding arsenic accumulation in barley and sorghum, limited research has been performed. Within the last three decades, an increasing human exposure to arsenic has been observed on a global level, which raises a general concern and the need for further investigation about the adverse effect on human health as well as the need for intervention.
Worldwide, only a few countries have established regulatory limits for inorganic arsenic in foods. China has set limits in rice (0.15 mg/kg), flour (0.10 mg/kg) and other cereals (0.20 mg/kg), Australia and New Zealand in seafood products (1-2 mg/kg) and India in foods in general (1.1 mg/kg) (Gousul Azam et al., 2017). In the EU, the European Commission has established limits in 2015 for inorganic arsenic in 'rice destined for the production of food for infants and young children' at 0.1 mg/kg, at 0.2 mg/kg for 'non-parboiled milled rice (polished or white rice)', 0.25 mg/kg for 'parboiled rice and husked rice' and 0.3 mg/kg for certain rice products such as rice waffles (Regulation (EC) No 1881/2006).

The content of methylmercury (MeHg) in rice was reviewed in China by Li et al. (2010). Human exposure to MeHg mainly occurs via fish consumption; however, recently rice cultivated in Hg polluted area has been discovered as a new pathway for MeHg uptake via food consumption. Whereas the Hg content in food is generally below 20 ng/g, studies in China revealed that rice can contain high concentrations of MeHg, up to 144 ng/g in a mining area. Therefore, frequent consumption of rice from a Hg polluted area can lead to a MeHg accumulation of 100 ng/g in rice (edible portion), which constitutes a 10-100 times higher content compare to other food crops grown in a Hg polluted environment. The particular high bioaccumulation in rice may be explained by the ability of methylation in paddy soils. However, the exact process of MeHg accumulation in rice is not clear yet. According to EFSA, cooking and processing will have a limited effect on the mercury concentrations in food (EFSA, 2012c).

Studies conducted in polluted areas (industrial mining and smelting) led to high concentrations of cadmium above the national maximum limit found in rice samples in China by Ke et al. (2015). Mean concentrations of cadmium in different areas ranged from 0.149 – 0.189 mg/kg, which is below the Chinese and EU limit of 0.2 mg/kg. However, 18% of the samples exceeded these limits ranging from 0.29 – 1.17 mg/kg.

A recent survey performed by WFSR showed that nickel concentrations in cereals ranged between 0.089 and 4.9 mg/kg and cereal-based products from <0.05 to 0.73 mg/kg. One sample of rice cake showed a high concentration of 43 mg/kg. Consumption of this rice cake could give acute toxic effects for sensitive persons (Mol, 2019). EFSA concluded in 2015 that the chronic dietary intake of nickel is of concern for the general population. The 95th intake of nickel ranged from 3.6 to 20.1 µg/kg bw/day, which is above the TDI (2.8 µg/kg bw/day) for all age groups. For the young age groups, the TDI was also exceeded by the mean dietary intake. For acute dietary exposure, EFSA concluded that there was a concern for Ni-sensitized individuals. The main contributors to the dietary exposure to nickel were grain and grain-based products, non-alcoholic beverages, sugar and confectionery, legumes, nuts and oilseeds, and vegetables and vegetable product. The influence of grain and grain-based products was most probably due to the high consumption of these products (EFSA, 2015d).

3.2.1.1 Conclusion

Several papers indicated the presence of heavy metals in cereals. In case exceedances were detected, they were primarily found in rice. Heavy metals that most frequently exceeded EU and national limits were cadmium, lead and arsenic. Methylmercury might also be of concern if rice is cultivated in polluted areas due to industrial activities. Furthermore, a Dutch survey showed that high concentrations of nickel may be found in rice cakes and EFSA concluded that cereals and cereal-based products are a main contributor to nickel dietary intake.

3.2.2 Persistent organic pollutants

Limited information was found on persistent organic pollutants (POPs) in cereals. An additional literature search specifically on POPs resulted in a few hits, which are described below. No information was found on dioxins in cereals.

Polychlorinated biphenyls (PCBs) are classified as POPs that have been widely used in the past in the industry. Nowadays, manufacture has largely stopped with the aim to ban all production and use of PCBs by 2025. Most PCBs are biodegradable, but some persevere in the environment and accumulate in fat tissue. The general exposure for humans to PCB is via contaminated food, which makes up for more than 90% of the total uptake. Non-dioxin like PCBs constitute the majority of the food contamination in comparison to dioxin-like PCBs. PCBs also accumulate in the food chain, in particular in foods of animal origin, such as fish, dairy, eggs and meat. In comparison, cereals and cereal products as well as fruits and vegetables only contain low concentrations (WHO, 2016b).
Mahmood et al. (2014) investigated PCBs and dioxin-like PCBs (dl-PCBs) contamination in cereal crops in Pakistan. PCB concentrations ranged from 0.15-2.22 ng/g and 0.05 – 9.22 ng/g in wheat and rice, respectively. Samples from rural areas contained lower PCB levels as compared to peri-urban and urban areas. These higher levels in the urban areas were associated with irrigation of untreated wastewater, atmospheric contamination and traffic emissions. Mumtaz et al. (2016) found concentrations of PCBs ranging from 4.31 – 29.68 ng/g in Pakistani rice, with higher concentrations detected in the vicinity of industrial and urban areas.
Mehmood et al. (2017) also reviewed other POPs (polybrominated diphenyl ethers (PBDE), dechloran plus (DP), PCB and polychlorinated naphthalenes (PCNs), organochlorine pesticides (OCPs)) in wheat and rice in Pakistan. OCPs were the predominant contaminant, followed by PCNs, PCBs, PBDE and DB in wheat (OCP: 4.37-67.4 ng/g; PCN: 3.28-36.7 ng/g; PCB: 0.05-9.3 ng/g; PBDE: 0.30-1.43 ng/g; DP: 0.43 ng/g) and in rice (OCP: 2.60-27.3 ng/g; PCN: 2.36-109 ng/g; PCB: 0.15-2.30 ng/g; PBDE: 0.06-45 ng/g; DP: N.D.-12 ng/g). Compared with other parts of the world, the concentrations found in Pakistan were similar or lower. Higher contamination levels were found in urban areas as compared to peri-urban and rural areas, which is linked to industrial activities and mobilization.

3.2.2.1 Conclusion

When crops are cultivated in industrial areas or when untreated wastewater is used for irrigation, higher levels of POPs than the background levels may be expected. However, the limited information available on POPs in cereals indicate that, in general, concentrations found in cereals are low.

3.2.3 Polycyclic aromatic hydrocarbons (PAHs)

PAHs are chemical contaminants that are released into the environment upon incomplete combustion or organic matter during manmade (e.g. industrial processes, food preparation) and non-manmade actions (e.g. volcanic eruptions, forest fires). Food preparation methods (e.g. frying, smoking, drying, roasting, baking, barbecuing) may also result in PAH levels in food. Although higher concentrations of PAHs are found for instance in smoked fish and meat and barbecued products as compared to low concentrations in cereal and cereal products, the latter is a main contributor of PAHs intake via food. This is explained by the high consumption of these food types in comparison to smoked or barbecued products (FAO, 2009). High concentrations of PAHs were found in rice and rice hulls (40.8-138 ng/g and 67.7-412 ng/g, respectively) in a region in China, grown on highly contaminated soil in rice paddies in areas close to electronic waste recycling activities (combustion of plastic waste, wood and coal). Higher concentrations were found in the hulls than in the rice, which may be explained by the fact that the outside layers of the rice are more exposed to the PAHs released from the recycling activities (Liu et al., 2014). Chen et al. (2016) investigated the levels of 16 PAHs in maize from farmlands along roadsides in China. Concentrations ranged from 219.9-627 μg/kg with a mean value of 362 μ/kg. The source of PAH contamination was traced back to industrial activities and emissions, such as coal burning and vehicle emissions. Another study in China by Feng et al. (2017) found PAH concentrations in wheat tissue ranging from 13.9-50.9 ng/g. Levels decreased from root to straw to grain. Uptake of PAHs in maize was found to derive from the soils that were contaminated via industrial activities and traffic emissions. Results by Tian et al. (2018) came to the same result: PAH contaminated areas via cold combustion lead to PAH concentration in winter wheat (mean range 69.58 – 557 μg/kg).

EFSA estimated that general exposure to PAH was estimated to be of no concern (MOE around 17 000), however high consumption of cereals and seafood can be problematic (MOE around 9600) (EFSA, 2008). According to a review by Bansal and Kim (2015) cereals are a major route of PAH exposure to humans. Risk of high PAH contamination can be managed by controlling the temperature during drying and processing of cereals but also by choosing the right energy source for the heating process (Alldrick, 2017).

3.2.3.1 Conclusion

PAHs can end up in cereals if cultivated in polluted areas or due to processing techniques. Although PAH levels in general are low, due to the high consumption of cereals, these products could contribute to a human health risk.

3.2.4 Radionuclides

Radionuclides in cereals were investigated by Turtiainen et al. (2011) in Finland. Mean concentrations of ^{210}Pb/^{210}Po in wheat grains, wheat flour, rye flour, oat grains and barley grains were 0.29, 0.12, 0.29, 0.36 and 0.36 Bq/kg, respectively. Considering the consumption rate, the mean effective doses from these two radioactive isotopes for adults were assessed between 17 and 22 μSv per year. Milling seemed to have no reduction effect on ^{210}Pb.

Asaduzzaman et al. (2015) investigated the radioactivity in rice in Malaysia. ^{40}K was measured in higher quantities than ^{226}Ra and ^{232}Th. The average of ^{40}K activity ranged from 59.9 – 92.2 Bq/kg, ^{226}Ra from 1.4 – 2.7 Bq/kg and average concentrations of ^{232}Th were 3.3 – 7.2 Bq/kg. The total effective dose from ingestion of rice was estimated in the range of 153.4 – 294.3 μSv/y, which is in the same range as the world average value (290 μSv/y) established by UNSCEAR. The excess lifetime cancer risk (ELCR) was found to be below the acceptable ELCR limit (10^{-3}) for radiological risk. Therefore, no public health risk from consumption of rice was found. In Bangladesh, radioactivity was monitored in rice by Nahar et al. (2018). Average concentrations of ^{226}Ra, ^{228}Ra and ^{40}K were found to be 1.09, 0.17 and 4.70 36 Bq/kg. The total estimated effective dose was 43.7, 16.4 and 4.2 μSv/y for ^{226}Ra, ^{228}Ra and ^{40}K, respectively. These values are far below the world average (see above). The ELCR was lower than the acceptable ELCR, indicating no risk to public health. Investigations into ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in wheat and barley in Iraq revealed average concentrations of <1.46, <1.38, 180.54 ± 8.52 and <0.36 Bq/kg for ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in wheat and 1.92, 1.94, 242.22 ± 10.76 and 0.39 ± 0.03 Bq/kg in barley. The ELCR (0.005 10^{-3} – 0.015 10^{-3}) were calculated to be significantly lower than the acceptable ELCR limit (10^{-3}) (Pourimani and Shahroodi, 2018). Similar results were found in Iran. Natural radioactivity concentrations of ^{226}Ra, ^{232}Th, ^{137}Cs and ^{40}K in wheat and maize were below international standards (Changizi et al., 2013). In India, investigated cereal samples (wheat, rice, coarse grains) had radioactivity concentrations (^{238}U: 13.1 Bq/kg, ^{226}Ra: 20.1 Bq/kg, ^{232}Th: 41.5 Bq/kg, ^{40}K: 1639 Bq/kg) far below established safe limits of 1000 Bq/kg for ^{238}U, ^{226}Ra and ^{232}Th and 4000 Bq/kg for ^{40}K. However, due to the high consumption of cereals in India, the cancer risk was estimated to be 79.5 10^{-4} (Kumari et al., 2015).

3.2.4.1 Conclusion

Limited information on radionuclides in cereals was available. Additional literature research indicated that radionuclides in cereals in general are present at low levels and do not cause human health risks.

3.2.5 Pesticides

Pesticide residues in cereals may be a health concern if they exceed their established maximum residue limits (MRLs). No reviews or studies were found that investigated the global pesticide occurrence in cereals. Several studies were found describing pesticide residues in a number of countries. The summary below indicates results found for countries from which we currently import cereals (see section 3.1.4).

Chen et al. (2009) investigated organophosphorus pesticide residues (OPs) in 2520 milled rice samples obtained from local markets in 20 provinces in China from 2004 – 2006. In total, 235 (9.3%) samples contained pesticide residues, 165 samples (6.5%) exceeded the national MRL and all pesticides (chlorpyrifos, dichlorvos, methamidophos, omethoate, parathion, parathion-methyl and triazophos) were at least detected once above the national MRL. The detected residues above the LOQ ranged from 0.011 mg/kg for triazophos to 1.756 mg/kg for methamidophos. The most frequently detected pesticides were triazophos, methamidophos and chlorpyrifos (detection rate: 4.60%, 3.41%, 1.67%, respectively) and simultaneously these pesticides most often exceeded the national MRL (0.05 mg/kg, 0.1 mg/kg and 0.1 mg/kg, respectively). The range of these pesticides found were < LOQ – 0.21 mg/kg, < LOQ – 1.756 mg/kg and < LOQ 0 0.612 mg/kg, respectively, which is higher than the EU maximum established MRLs of 0.02 mg/kg, 0.01 mg/kg and 0.5 mg/kg, respectively.

Liu et al. (2014) similarly examined residues of 16 organochlorine pesticides (OCPs) in 33 rice and rice hull samples from rice paddies 2005 – 2007, which are in the area of recycling sites. The mean concentration was 122 ng/g (0.122 mg/kg) and concentrations ranged from 2.35 – 925 ng/g (0.00235 - 0.925 mg/kg), which was similar or higher to other polluted areas. In particular, residues of y-HCH (hexachlorocyclohexane), o,p′-DDD (dichlorodiphenyldichloroethane), p,p′- DDD, quintozene and dicofol were frequently detected (detection rate: 74%, 51%, 44%, 79%, 51%, respectively). The concentration range for these OCPs were 7.07–223 (mean: 41.4), 1.47–139 (21.2), 0.52–567 (51.0), 0.72–51.7 (6.32), 3.48–156 (36.7) ng/g, respectively. Levels were evaluated as moderate to high in comparison to other regions of China or other countries. Comparing these concentrations with the EU established MRLs showed that the mean HCH concentration (0.04 mg/kg) exceeded the EU MRL (0.01 mg/kg) and the mean concentration of DDT metabolites DDD (up to 0.051 mg/kg) exceeded the EU MRL of DDT (0.05 mg/kg). The mean quintozene concentration (0.00632 mg/kg) did not exceed the EU MRL (0.02 mg/kg); however, the maximum concentration found (0.0517 mg/kg) exceeded the limit. The mean dicofol concentration (0.0367 mg/kg) exceeded the EU MRL.

Yu et al. (2016) investigated residues of 12 OPs in 102 rice grains samples collected one week before harvest in 2014 in China. The most frequently detected OPs were diazinon, omethoate and parathion-methyl (detection rate: 39.2%, 31.4%, 25.5%). However, none of the pesticides exceeded the national maximum residue limit. Although the pesticides methamidophos, parathion-methyl, and parathion were prohibited for agricultural purposes since 2007 due to their toxicity to humans, their residues were still found in this study, which requires further monitoring of these banned pesticides. In a subsequent study, Yu et al. (2018) monitored the levels of 11 OPs in 55 maize samples in China, also collected one week before harvest in 2016. 67.3% Of the samples contained OP residues. However, none of the samples exceeded the national MRLs. Detected mean concentrations were the following: omethoate (0.8 mg/kg), quinalphos (0.8 mg/kg), phorate (0.7 mg/kg), dimethoate (0.7 mg/kg), parathion-methyl (0.6 mg/kg), isocarbophos (0.6 mg/kg), diazinon (0.5 mg/kg), fenitrothion (0.5 mg/kg), malathion (0.5 mg/kg), parathion (0.5 mg/kg) and fenthion (0.3 mg/kg). All levels were higher than the MRLs established in the EU (0.01; 0.01; 0.05; 0.01; 0.02; 0.01; 0.01; 0.05; 8.0; 0.05; 0.01 mg/kg, respectively), except for malathion. The prohibited pesticides parathion and parathion-methyl were also found in this study.

A study investigating the pesticide residues in inter alia polished rice in Brazil examined 73 samples in Sao Paulo. Pesticide residues were found in 3 samples with a mean concentration of 0.03 mg/kg for permethrin, 0.08 mg/kg for ametryn and 0.43 mg/kg for pirimiphos-methyl. None of the samples exceeded the national maximum limit. Pesticide residues of alachlor, ametryn and dimethenamid were detected in 1.3% of the rice samples although they are not permitted in Brazil (Ciscato et al., 2010). Comparing the detected mean concentrations with the EU MRL, permethrin and pirimiphos-methyl were below the maximum limit of 0.05 mg/kg and 0.5 mg/kg, whereas alachlor and ametryn are not allowed in the EU (MRL of 0.01 mg/kg).

In Canada, the Canadian Food Inspection Agency (CFIA) monitored in 2015-2016 inter alia 869 grain samples (barley, buckwheat, quinoa) from retail upon residues of the pesticide glyphosate. Residues of glyphosate were detected in 36.6% of the samples and 3.9% exceeded the national MRL (barley: 10 mg/kg; wheat: 5 mg/kg; quinoa: 0.1 mg/kg (default MRL)) (not specified which grain samples)(Canadian Food Inspection Agency, 2017). MRLs for glyphosate in the EU are 20.0 mg/kg, 10.0 mg/kg and 0.1 mg/kg for barley, wheat and quinoa, respectively. In an earlier investigation (2011-2012), 418 imported and domestic grain and grain products mostly from the US, Canada and unknown country of origin, were screened for 430 different pesticides by the CFIA. Cereal and cereal products consisted mainly of maize, oat, rice and wheat, but also of buckwheat, barley, millet, quinoa, rye and spelt. Only one sample of quinoa had higher residues of orthophenyl-phenol than the general national MRL of 0.1 mg/kg (Canadian Food Inspection Agency, 2018a).

In 2017, the European Commission published a recommendation on pesticides monitoring based on a Member States meeting in the Standing Committee on the Food Chain and Animal Health (SCoFCAH) in 2014. Pesticides were recommended to be voluntarily included in the national monitoring plan that are not yet included on the coordinated multiannual control programme of the EU (MACP). Their inclusion on the MACP will be considered after monitoring data were gathered via the national monitoring plans. The following pesticides were recommended in particular for cereals to be voluntarily monitored by the EU Member States: phosphane and phosphide salts, diquat, prochloraz, pyrethrins, guazatine and chlorpyrifos-methyl and its metabolite desmethyl-chlorpyrifos-methyl. (European Commission, 2017).

EFSA yearly reports on pesticide residues found in food. For 2012, 862 wheat samples were analysed for pesticides. In total, 39,7% of the samples contained one or more pesticides, 17.2% contained multiple residues (up to 5). 34 Different pesticides were found of which chlormequat, bromide ion, glyphosate and pirimiphos-methyl were most frequently detected (40%, 19%, 16% and 12% respectively). It should, however, be noted that bromide ion also occurs naturally in plants and as such is not an unambiguous maker for the use of the pesticide methyl bromide. MRL exceedances were found for 2,4-D, chlorpropham, chlorpyrifos and diflubenzuron (EFSA, 2014a). In 2013, 7 out of 126 rice samples contained carbendazim above the MRL (between 0.012-0.041 mg/kg). For oats, 232 samples were analysed of which 46% contained one or more pesticides. Chlormequat (62% of samples) and glyphosate (44%) were most frequently detected. MRL exceedances were found for chlormequat, dichlorvos and chlorpyrifos. In total, 424 samples of rye were analysed for pesticides, 41% of which contained one or more pesticides. Most frequently found were chlormequat, bromide ion and mepiquat (40%, 37% and 17% of the samples, respectively). None of the samples exceeded the MRL (EFSA, 2015a). In 2014, a total of 639 wheat flour samples were analysed for pesticides. 41% contained one or more pesticides. The most frequently detected pesticides were chlormequat (48% of the samples) and pirimiphos-methyl (18%). MRL exceedances were found for permethrin and cyfluthrin. It should however be noted that there are no MRLs for wheat flour. Processing factors were applied to determine exceedances of MRLs of the unprocessed wheat. For rice, 763 samples were analysed for pesticides; 27% of these contained one or more pesticides. The most frequently found pesticides were pirimiphos-methyl (8% of the samples), bromide ion (8%) and deltamethrin (7%). MRL exceedances were found for carbendazim, triazophos and methamidophos (EFSA, 2016a). In 2015, 851 wheat samples were analysed for pesticides; 38% contained one or more pesticides. Most frequently found were chlormequat (49% of the tested samples), pirimiphos-methyl (8.6%) and glyphosate (8.2%). MRL exceedances were found for dithiocarbamate, imidacloprid, clothianidin and dichlorvos (EFSA, 2017a). In total, 608 rye samples were analysed for pesticides in 2016. 35% contained one or more pesticides. The most frequently found pesticides were chlormequat (34% of the samples), mepiquat (14.2%) and pirimiphos-methyl (8%). The MRL was exceeded for: pirimiphos-methyl, permethrin, hexaconazole and dichlorvos (EFSA, 2018a).

3.2.5.1 Effect of processing

Although not the focus of this study, the literature study on pesticides did retrieve some papers describing the effect of processing on pesticide residues in cereals. The results of those studies are summarised in this section.
With regard to reduction of pesticides residue levels, the following studies investigated the effect of processing on the pesticide levels. Uygun et al. (2008; 2009) investigated the degradation effect of organophosphorus pesticide levels in wheat during the production of pasta and cookies in a pilot-scale. Storage times of 5 and 8 month respectively were not sufficient to reduce the pesticide levels in wheat below the EU MRL in Turkey. However, the production process of spaghetti and cookies had a significant reduction effect on the levels of pesticides in general. Dobrinas et al. (2013) researched the distribution of pyrethroid, organochlorine and organophosphorus pesticides in processed wheat grain fractions (bran, semolina, flour). Highest pesticides concentrations were found in the bran, less in semolina and the least in flour. The effect of processing on pesticide residues (chlorpyrifos and its metabolite 3,5,6-trichloro-2-pyridinol) was also investigated in rice by Zhang et al. (2015). Different

processing steps were taken into account: sunlight exposure, hulling, polishing, washing, and cooking. Exposure to two hours sunlight did not reduce the residue levels in rice grains significantly; however, hulling reduced residues up to 50%. Cooking of rice led to the fact that residue levels were undetectable (below 0.01 mg/kg). While each of the mentioned processing steps had an effect on the reduction of chlorpyrifos residues, the most effective steps were cooking and hulling.

3.2.5.2 Conclusion

The literature study revealed that a range of pesticides was found. Several pesticides were frequently found, found above the legal limits, were banned in the respective countries and EU or combinations thereof. These pesticides were particularly reported in studies investigating rice, but also in maize.

3.2.6 Mycotoxins

This section provides an overview of papers found on mycotoxins in cereals. Occurrence of mycotoxins is widespread in cereals (e.g. wheat, maize, barley) in which a range of mycotoxins can be found (e.g. aflatoxins, ochratoxin, fusarium toxins). The section starts with papers summarising global prevalence of mycotoxins in cereals followed by papers from specific regions around the world. Since 142 papers were found describing mycotoxins in cereals, only regions relevant for the Netherlands were included based on import data from Eurostat, 2017. Therefore, papers on African countries and Iran were excluded in this summary. However, they were evaluated in the accompanying Excel file. Furthermore, only papers that included at least 200 samples are included in the summary below. Finally, the effect of processing on mycotoxins is indicated as this was described in some papers obtained in the literature review.

3.2.6.1 Global mycotoxin presence in cereals and cereal products

Mycotoxins are ubiquitously present in cereals with differences in the prevalence of the five main mycotoxins (aflatoxins, fumonisins, deoxinivalenol (DON), zearalenon (ZEA) and ochratoxin A (OTA). A review by Schatzmayr and Streit (2013) indicated that aflatoxins, fumonisins and OTA are primarily found in the warmer regions in the world as the fungi producing these toxins prefer humid and warm conditions (Paterson and Lima, 2010). Aflatoxins and OTA were primarily found in South Asia and fumonisins in South America. On the contrary, DON and ZEA are primarily found in cooler regions with highest prevalence in North Asia (Schatzmayr and Streit, 2013).

Lee and Ryu (2017) investigated the occurrence of aflatoxins, OTA, fumonisins, DON and ZEA in cereals and cereal-based products worldwide. In their literature review, consisting of 104 papers from 2006 – 2016, they indicated the prevalence and range of concentrations for raw maize, rice, wheat, barley, oat as well for processed grain products and showed that occurrence of mycotoxins is a ubiquitous issue around the world. The prevalence found in the studied papers for aflatoxins, OTA, fumonisins, DON and ZEA were on a global level 55%, 29%, 61%, 58% and 46% respectively, and the maximum concentrations (in µg/kg) found were 1642, 1164, 71121, 41157 and 3049, respectively. Aflatoxin contamination is of concern globally, but in particular in Africa where the highest concentration of 1642 µg/kg was found in rice. The highest concentrations in other regions were 850 µg/kg in maize in Asia, 1400 µg/kg in maize in South America and 33 µg/kg in rice in Europe. Processed products revealed lower prevalence and contamination levels as compared to the grains. With regard to OTA, the highest contamination was found in rice from Africa (1164 µg/kg), but oat and oat products more frequently contained OTA levels than other cereals and cereal products. Moreover, processed cereal products in all regions had similar or higher concentrations than the grains themselves, which may be explained by OTA contamination of other used ingredients than cereals. Fumonisins were most prevalent in America with a concentration up to 34700 µg/kg (maize). Maximum levels in Asia and Africa were found at concentrations reaching 71121 and 24225 µg/kg (both maize), whereas Europe had the lowest prevalence with a maximum content of 5400 µg/kg (wheat). DON contamination was found in a higher concentration in Europe and Asia (highest concentration 41157 µ/kg) and most commonly associated with wheat and wheat products. In processed food, concentrations of DON were significantly lower than the raw grains, which is explained by the fact that DON is located near the bran, which is removed in the milling process. Nevertheless, prevalence of DON in processed food is similarly high as in grains, showing that DON contamination may remain. ZEA mycotoxins were not as frequently found as DON. The highest ZEA concentration was found in wheat in Asia (3049 µg/kg). However, in general, higher concentrations of ZEA were found in maize and rice. Cereal-based products demonstrated significantly lower prevalence and concentrations. It was recommended to expand the monitoring of citrinin and trichothecenes other than DON, since there is currently limited information for these mycotoxins. The authors also indicated that most studies found co-occurrence of one or more mycotoxins in a sample indicating the need to further investigate this phenomenon. The literature review performed within this project confirmed the co-occurrence of several mycotoxins in cereal samples. This fact has to be taken into account, for instance for establishing maximum limits. Further studies are needed to investigate the risk arising from exposure to multiple mycotoxins (Ibanez-Vea et al., 2011; Vanheule et al., 2014; Lee and Ryu, 2017; Oliveira et al., 2017; Martins et al., 2018).

Andrade and Caldas (2015) investigated aflatoxins contamination in maize, rice, sorghum and wheat by reviewing literature worldwide (89 articles from 2000 – 2014 covering 18 097 samples) as well as monitoring data from the GEMS/Food database (Global Environment Monitoring System – Food Contamination Monitoring and Assessment Programme) from the WHO (4 536 samples). GEMS/ Food data indicated that higher mean aflatoxin concentrations were found in maize (13 µg/kg) than in rice (10.6 µg/kg), sorghum (8.6 µg/kg) and wheat (1 µg/kg), but the highest maximum concentrations were found in rice (272 µg/kg in America and 347 µg/kg in Africa) as compared to maize (93 µ/kg in America). Levels from evaluated literature, however, indicated the opposite effect: the highest mean aflatoxin concentration was in rice (46.6 µg/kg) as compared to maize (28.2 µg/kg), sorghum (38.7 µg/kg) and wheat (18.0 µg/kg). However, maize had a higher maximum concentration (48000 µ/kg) than rice (371.9 µg/kg). Overall, rice was more frequently contaminated with aflatoxins than maize and wheat, both in the literature data and the GEMS/Food data. Andrade and Caldas (2015) performed a risk assessment based on global GEMS/Food data, which indicated that rice, wheat and maize contribute the most to the dietary exposure to total aflatoxin (41.6%, 35.4% and 21.2% respectively). A JECFA meeting indicated that, based on the GEMS database, aflatoxin concentrations are generally higher in maize and groundnuts as compared to rice and wheat. However, high consumption of rice and wheat, as given in some countries, can lead to a high aflatoxin exposure accounting up to 80% of the total dietary exposure (FAO, 2016).

In 2016, the Joint FAO/WHO Expert Committee on Food additives (JECFA) indicated that the contamination of cereals with fumonisins is mainly associated with maize. Among all cereals and cereal-based products, maize and maize products have the highest occurrence and mean concentrations of fumonisins (FB1) and in particular higher concentrations are found in Africa, Central and South America and in the Western Pacific region. Moreover, maize is the product that contributes the most to fumonisin B1 (FB1) and total fumonisins uptake via the diet. Based on data from 2011-2016 in European countries, the mean exposure was usually below 250 ng/kg body weight per day for FB1 and total fumonisins, whereas in countries such as Guatemala, Zimbabwe and China high FB1 exposure were reported, up to 7700 ng/kg body weight per day. The highest exposure to total fumonisins on the other hand was reported in Malawi (3000 – 15 000 ng/kg body weight per day)(WHO, 2018).
Cendoya et al. (2018) reviewed the occurrence of fumonisins in wheat and wheat products. Although fumonisins are mainly associated with maize and maize products, natural occurrence in wheat and wheat products have been reported in the last 10 years around the world (South America, North America, Europe, Asia, South Africa). No regulatory limits have been established yet in wheat; however, JECFA highlighted the need to monitor fumonisins in order to obtain data to perform an exposure assessment for wheat. The review indicated that fumonisins in wheat and wheat products occur globally. However, the accumulation is not fully understood, as well as the possible effect from co-occurrence of fumonisins with other mycotoxins (DON, ZEA).

The mycotoxins ergot alkaloids are usually found in rye products; however, studies conducted in the European Union have also revealed that other cereal types can contain high concentrations (concentrations not indicated) (BfR, 2013a). The FAO published practices to prevent and reduce ergot and ergot alkaloids in cereal grains, which are recommended to crops most sensitive to this mycotoxin contamination, namely rye, triticale, sorghum and pearl millet (Codex Alimentarius Commission, 2017).

Less known mycotoxins are *Alternaria* toxins, which have a natural occurrence worldwide. These toxins are produced by the fungus *Alternaria* spp., a plant pathogen that causes spoilage of several crops after harvest. The fungus is commonly found in cereal grains around the world with a high prevalence of 90% reported. There are currently around 70 toxic metabolites known, but the most often found in food are alternariol (AOH), alternariol monomethyl ether (AME), tenuazonic acid (TA) and altertoxins (ATX). In 2011, EFSA published a report on the risk of *Alternaria* toxins on human and animal health. However, the risk of these toxins occurring from contaminated food and feed could not be assessed as sufficient data about occurrence and toxicity was lacking. Since then, regulation has been established by the Bavarian health and food safety authority in Germany for the toxin TA in infant foods based on sorghum and millet grains. Several studies were published in the last 10 years on the contamination of *Alternaria* toxins in cereals, mostly investigated maize and wheat and only a few focused on barley, soybeans and sorghum. With regard to the toxic metabolites, AOH, AME and TA were most frequently examined in cereals. Mean concentrations ranged from 0.13 μg/kg in maize to 320 μg/kg in soybeans (AME), 0.16 μg/kg in maize to 92.4 μg/kg in wheat (AOH) and 18.6 μg/kg to 289 μg/kg in wheat (TA). Prevalence for these toxins ranged for AME from 4% in maize to 100% in wheat, for AOH from 3.3% in maize to 66.6% in wheat and for TA from 5.9% in maize to 100% in wheat. In particular, toxin TA was found in four out of six studies above concentrations of 100 μg/kg indicating a potentially high contamination in cereals and cereal by-products. Thus, Tralamazza et al. (2018) concluded the need for further studies on the toxin TA as well as on the potential toxic effect of co-occurrence of several *Alternaria* toxins. Furthermore, considering the fact that more data is available after EFSA's report on *Alternaria* toxins in animal feed and food in 2011, the authors expect that besides the first establishment of TA limits in infants foods, further legislation regarding *Alternaria* toxins will emerge around the globe. EFSA (2016c) investigated the dietary exposure to *Alternaria* toxins (AME, AOH, TA, tentoxin (TEN)) in 2014, for which 15563 analytical results from 4249 food samples were used. Data were submitted by national food authorities, research institutes, academia and food businesses. Highest mean concentrations of AOH were reported in grains, such as buckwheat (Lower Bound (LB)-Upper Bound (UB): 27.9-33.1 μ/kg) and oats (LB-UB: 35.3-39.7 μg/kg), but also tomato based products. The highest mean concentrations of AME were measured in tree nuts (chestnuts LB-UB: 16.8-17.5 μg/kg) and oilseeds (sesame seeds LB-UB: 11.3-11.8 μ/kg). TA was found in much higher concentrations compared to other *Alternaria* toxins, with the highest concentrations in tomatoes and tomato based products (LB-UB up to 351.2 μg/kg) as well as "cereals with an added high protein food which are or have to be reconstituted with water or other protein-free liquid" (LB-UB: 496-497 μg/kg). Lowest concentrations of *Alternaria* toxins were reported for TEN with the highest concentrations found in sunflower seeds (LB-UB: 79-82 μg/kg). TA had by far the highest contribution to the dietary intake of *Alternaria* toxins, with toddlers and infants showing the highest mean dietary exposure with cereal-based food being the main source. Tomatoes and tomato based products was the food responsible for the highest dietary exposure to TA in other age groups (EFSA, 2016d).

Bauer et al. (2017) investigated another less known mycotoxin, the neurotoxic mycotoxin paxillin (PAX) in Germany in 2 rye and 1 barley samples taken shortly before harvest. Concentrations found were 620 and 160 μg/kg in rye and 130 μg/kg in barley ergot.

Other studies investigated the levels of beauvericin and enniatins in cereals. Yoshinari et al. (2016) frequently found enniatin B in imported and domestic wheat flour in Japan with the highest concentration of 633 μg/kg in domestic wheat flour, whereas maize grits only contained beauvericin with a maximum concentration of 26.1 μ/kg. A co-occurrence of enniatins and DON was also found in the wheat samples. Maximum limits for beauvericin and enniatins are not established, but the authors recommend conducting further research in these compounds, also in combination with the occurrence of DON. These mycotoxins can also occur in processed cereals as investigated by Juan et al. (2013). The authors found levels of beauvericin and enniatins in pasta and multi-cereal baby foods in the Italian market, with enniatins being the mycotoxins most frequently found with a maximum concentration of 106 and 1100 μg/kg in pasta and baby food, respectively. A conducted risk assessment indicated that the levels of enniatins found lead to a maximum EDI of 7.23 μg/kg bw/day for infants 8 month old. Since no TDIs have been established for enniatins, the relevance of this EDI cannot be established.

Keller et al. (2012) investigated the presence of gliotoxin in maize and sorghum intended for feed before and after fermentation in silo. Frequency of contaminated samples in pre- and post-fermented samples were similar in maize, but higher in post-fermented samples in sorghum. Gliotoxin levels were found in pre- and post-fermented samples in levels that are known to have immunosuppressive and apoptotic effects in cells. However, higher levels were found in post-fermented maize and sorghum as compared to pre-fermented samples. Furthermore, FAO identified mycotoxins in general as an emerging issue with regard to food safety. The emerging issue derives from the potential toxicity of mycotoxin mixtures and also from metabolic transformations in contaminated plants leading to modified mycotoxins. These modified chemical forms are also referred to as 'masked mycotoxins'. Little is known about the toxicity of these masked mycotoxins. Moreover, they may be easily overlooked by current analytical measurements, which can lead to the fact that the mycotoxin content is underestimated (Codex Alimentarius Commission, 2016).

3.2.6.2 Prevalence of mycotoxins in specific geographic regions

The following papers describe mycotoxin levels found in specific regions around the world that are relevant for cereals imported into the Netherlands. Eurostat data from 2017 indicates that from Asia we primarily import rice, whereas other cereals are imported from Europe, Russia, China and North and South America.

Asia

The main rice producing countries in the world are found in Asia. Ali (2018) reviewed studies conducted on the co-occurrence of citrinin (CIT) and OTA found in rice. Monitoring data in these countries revealed that CIT and OTA were detected in rice samples from Iran, Vietnam, India, Pakistan, China, Taiwan, Japan and Indonesia. Rice samples in Vietnam demonstrated a high percentage of co-occurrence of CIT and OTA. EU MLs on OTA were exceeded in rice samples from Pakistan and Iran, whereas rice from Malaysia exceeded the local limit for citrinin.

Sun et al. (2017) reviewed studies from 1999 onwards which focused on mycotoxin contamination in rice in China. Aflatoxins, OTA and fumonisins were the main mycotoxins found in these studies. Although a high prevalence of aflatoxins was identified, the concentrations varied among the various regions and only a few samples exceeded the national ML of 10 µg/kg for aflatoxin B1 (the EU ML is 5 µg/kg). Human health risk from consumption of mycotoxin contaminated rice was considered as generally low and higher concentrations of mycotoxins are usually found in the outer layer of rice (paddy rice/rough rice) as compared to hulled rice (e.g. brown rice).

Many studies on regulatory exceedances of mycotoxins were found from Asia. The following paragraph indicates in which countries mycotoxins concentrations exceeded legal limits in cereals. Samples from Pakistan showed that aflatoxin and OTA concentrations in rice, corn, corn flour and corn bread samples exceeded the EU limit (Majeed et al., 2013) as well as aflatoxin contents in rice samples (paddy, parboiled, brown, white and broken) in Pakistan (Iqbal et al., 2012). In Vietnam, EU established limits were exceeded for total aflatoxin in rice samples (Huong et al., 2016) In India, aflatoxin B1 was found above national legal limits (30 µg/kg) in rice paddy and rice grain samples (Reddy et al., 2009). Levels above the EU limits were also detected in brown and colour rice samples from Thailand for aflatoxin B1 (Panrapee et al., 2016).
In South Korea, no concentrations above legal limits were found in rice samples (brown, polished, and rice products) for DON, Nivalenol (NIV) and ZEA (Lee et al., 2011) and other studies investigating mycotoxins contents in cereals, including rice, indicated only very low non-compliances: 1 brown rice sample exceeded the national maximum limit of 200 µg/kg for ZEA.

Europe

Edwards (2009); (Edwards, 2011) investigated the content of trichothecenes in barley and ZEA in wheat, both grown in the UK, and found only 1 sample exceeding the DON limit in barley and ZEA non-compliances in wheat between 0.6% and 28.6%, depending on the seasons 2001-2010. In Germany, an investigation into trichothecenes in cereals (wheat/rye/oat kernels, flour, semolina, bran, flakes) showed only 1 wheat bran sample exceeding the European DON limit (Gottschalk et al., 2009), whereas a trichothecene examination in winter wheat in Slovakia revealed 2% of the samples exceeded the ML for DON (Lacko-Bartošová et al., 2017). In Switzerland, samples of wheat contained

concentrations higher than the EU DON and ZEA limit (Vogelgsang et al., 2017), and in Croatia regulatory limits were exceeded in several samples (unprocessed and processed) of maize and wheat regarding ZEA, maize and barley and rye regarding aflatoxin B1 and maize regarding DON (Pleadin et al., 2017). Another study investigated the content of the mycotoxins ergot alkaloids in cereal and cereal product samples (rye flour, wheat flour, multigrain flour and further processed products, e.g. bran, bread, biscuits) from several European countries. The highest prevalence of ergot alkaloids was found in rye (84%), followed by wheat (67%) and multigrain samples (48%). The most frequently occurring ergot alkaloids were ergosine, ergokryptine and ergocristine. There is no maximum limit set for ergot alkaloids on European level (Malysheva et al., 2014). The European Commission encouraged Member States and professional stakeholders' associations to monitor ergot alkaloids in cereals and cereal products and to report the findings to EFSA by the end of September 2016. By July 2017, the legislator planned to establish maximum limits for ergot alkaloids in cereal and cereal products. However, up to now this has not happened, yet (Regulation (EC) No 1881/2006).
T2- and HT2-Toxins are primarily found in small grain cereals and maize in Europe, where most research was performed in Northern European countries. Highest concentrations (up to 9990 µg/kg) were found in oats (Edwards et al., 2009).

South America
Studies from South America mainly focused on Brazil. Mycotoxins levels found above the EU maximum limit were detected in maize regarding fumonisins (Scussel et al., 2014) and above national legislative limits for both DON in barley (1250 µg/kg) and wheat (1250 µ/kg) and ZEA in barley (100 µ/kg) and wheat (200 µg/kg) (Mallmann et al., 2017) and DON exceedances in wheat grain, flour and bran (Machado et al., 2017).

North America
Exceedances of EU limits for mycotoxins in the USA and in Canada were found in breakfast cereals composed of several grains or grain mixes (Roscoe et al., 2008; Lee and Ryu, 2015), but not for cereal grains as such.

3.2.6.3 Effects of processing
Since mycotoxins are a globally recognised problem, various methodologies are used to control mycotoxins ranging from physical, chemical and microbiological methods. Physical methods include sorting, cleaning and sieving as well as flotation and density segregation to remove damaged grains susceptible to fungi from intact grains. Furthermore, milling is used to remove the outer layer of cereal grains, which has shown to be very effective in the reduction of DON levels. Furthermore, mycotoxin binders, such as aluminosilicitates and activated charcoal, have been studied that are capable of removing mycotoxins in foods. Although mycotoxins are heat stable, they can be reduced at high temperatures as applied during roasting, toasting, frying and extrusion cooking. Chemicals, such as the use of ammonia compounds, have been studied that are capable of detoxifying mycotoxins. Apart from physical and chemical methods, bacteria, such as *Flavobacterium* spp. and *Pseudomonas* spp. can also be used to degrade mycotoxins (James and Zikankuba, 2018).

Mycotoxin levels in processed cereals (e.g. after cleaning, sorting and milling) are generally lower than in the cereal grains (Lee and Ryu, 2017). Most studies investigating the effect of processing on the mycotoxin levels in processed cereals are available on wheat and less on maize and rice. The studies found on wheat primarily focused on DON. DON is mainly attached to the outer hull of the grain. Therefore, DON levels will increase in cereal-by products, such as bran, after cleaning, sorting or dehulling of grains (EFSA, 2017c). Furthermore, DON seemed to be stable during baking and cooking (EFSA, 2017c). Visconti and Pascale (2010) reviewed the effect on DON during pasta production and concluded that processing has a significant effect on the DON reduction. DON levels were consistently reduced during the processing steps with DON levels of 77% in the cleaned wheat (after milling and removing of bran), 37% in semolina, 33% in spaghetti and 20% in cooked spaghetti, as compared to the initial wheat grain. Cheli et al. (2013) confirms the findings and outlines that the mycotoxins concentrate in wheat fractions that are used for feed purposes (bran). Physical processes before milling, such as sorting, cleaning and debranning, also have a significant effect on the reduction of mycotoxins concentrations in grains. Wu et al. (2017) reviewed the effect of thermal processes on cereals, mainly wheat, with regard to the DON and DON-3-glucoside levels. Degradation of the DON

levels during baking depended on the applied temperature and time. While shorter baking times and lower temperature increased the content of DON-3-glucoside, higher temperature and longer exposure led to higher degradation. Boiling significantly reduces DON levels due to the fact that DON is water soluble. The effect of frying was not investigated as much as other thermal processing techniques. However, the studies conducted so far indicate that also this technique lowers the DON levels. With regard to steaming and extrusion cooking, these techniques led to inconclusive results, indicating the need for further studies.
Other studies focused on other mycotoxins: Pascale et al. (2011) investigated the distribution of T-2 and HT-2 toxins in the milling fractions of durum wheat (screenings, bran, red dog, fine middlings and semolina). The toxin concentration in screenings and brans increased up to 13- and 5- fold during the milling process as compared to the uncleaned wheat. However, T-2 and HT-2 concentrations significantly decreased in cleaned wheat and semolina (54% and 89%, respectively). Edwards et al. (2009) also found that cleaning and dehulling of oats reduced T-2 and HT-2 concentrations. With regard to OTA, Zebiri et al. (2018) examined the levels in durum and common wheat milling fractions. The milling process did not eliminate OTA levels, but OTA was just redistributed between semolina, flour, bran and middling's. Beauvericin and enniatins will reduce during processing, which generally happens for mycotoxins. In general, the milling process can influence the mycotoxin concentrations of the bran; for ZEA that has been demonstrated particularly. By-products, from cleaning cereal grains showed to have 3 to 30 fold higher ZEA concentrations than the cleaned cereals. ZEA is not affected by normal cooking (EFSA, 2011b). *Alternaria* toxins are also shown to be stable during food processing (EFSA, 2011a).
Other cereals were also studied: Maize and maize based feed were examined by Burger et al. (2013) for levels of fumonisin, DON and ZEA in milling fractions (whole maize, SPECIAL maize meal ("fine granulated product equivalent to maize flour", a maize-based food product), SUPER maize meal ("coarse granulated product equivalent to maize grits", a maize-based food product) and hominy feed (animal feed composed of dried maize with "fraction containing large pieces of pericarp and hull with some endosperm attached and clean medium sized pieces of bran and hull as well as the remnants of the tip cap")). Total hominy feed contained the highest levels of mycotoxins, whereas the SUPER maize meal contained the lowest levels. Milling was evaluated to be effective in reducing mycotoxins in maize and the majority of the three investigated mycotoxins generally accumulated in the outer layers of the kernel and were present in the bran/meal/germ fractions. The effect or processing on fumonisins is extensively studied in maize. A reduction after thermal processing is often observed by temperatures higher than 175 °C. Below 175 °C, processing like, baking or canning did not reduce fumonisins. Other processing methods like fermentation and milling can also reduce fumonisins (EFSA, 2018b). With regard to rice, Zhong et al. (2015) evaluated the effect of milling on aflatoxin levels in rough rice and its constituents. The aflatoxin concentration decreased with increase of the milling duration (30, 45 and 60 seconds). In brown rice, aflatoxin B1 was decreased 5-fold, whereas aflatoxin B2 was removed completely after 60 seconds of milling. Aflatoxin levels were mostly found in the bran with high concentrations in the outer bran layers. Aflatoxin G1 and G2 were not detected after the milling process. Processing, like heating, roasting and baking can also reduce aflatoxins, however they cannot be completely eliminated (EFSA, 2007, 2018c).

A review on the occurrence of mycotoxins in processed products worldwide was conducted by Mousavi Khaneghah et al. (2018). Aflatoxins, OTA, ZEA and DON were investigated in cereal-based products (bread, cornflakes, breakfast cereals, pasta) by analysing 38 articles with data from 9627 samples (mostly from Europe (47%) and Asia (29%), but also Africa (13%), North America (8%) and South America (3%)). As outcome of their meta-analysis, they outlined the rank order of the mycotoxins with regard to prevalence and concentrations. The overall rank order of mycotoxins in terms of concentrations were found to be DON > ZEA > 15-ADON > OTA > 3-ADON > TAF (total Aflatoxins). Furthermore, the rank order for these mycotoxins can be indicated for the specific cereal products. The following overview outlines the contamination ranks in a descending order:
DON: breakfast cereals > bread > biscuit > pasta > cornflakes;
ZEA: cornflakes > bread > breakfast > biscuit > pasta;
TAF: pasta > cornflakes > bread > biscuit > breakfast;
OTA: bread > cornflakes > breakfast > biscuit > pasta.
The highest mycotoxin contents in the cereal products were found in biscuits in Austria, cornflakes in Germany, breakfast cereals in Belgium, bread in Germany and pasta in Malaysia. Nevertheless, it has

to be taken into account that most of the analysed studies were conducted in Europe (18), followed by Asia (11), Africa (5) and North and South America (3 and 1).
Besides concentrations, the meta-analysis of this review also outlined the rank order of mycotoxins with regard to prevalence: OTA > DON > ZEA > TAF > 15-ADON > 3-ADON. TAF was most often found in biscuits, DON and ZEA in cornflakes and OTA was primarily found in pasta. With regard to the products, mycotoxins were most often found in pasta from Spain, cornflakes and breakfast cereals in Germany, bread from Canada and biscuits from Turkey.

3.2.6.4 Conclusion
Aflatoxins, DON, fumonisins, OTA and ZEA were most frequently mentioned mycotoxins in cereals (between 24 and 36% of the papers mentioned the presence of these mycotoxins in cereal crops). Crops imported from warmer regions such as South Asia, South America and Africa are more vulnerable for aflatoxins, OTA and fumonisins, whereas crops from cooler regions, such as Northern Europe, North America and North Asia are more vulnerable for DON and ZEA. Other mycotoxins that were investigated in literature were enniatins, *Alternaria* toxins, beauvericins, T-2 and HT-2 toxins and ergot alkaloids. Currently, there are no legal limits for these mycotoxins. They should be regarded as attention points, since these are also sometimes found in cereals and legislation of these mycotoxins is expected. High concentrations in cereal-based products were found for enniatins (up to 1100 µg/kg) and for one of the *Alternaria* toxins, tenuazonic acid (> 100 µg/kg).

3.2.7 Plant toxins

Plant toxins can be found in many plants and also in cereals. Plant toxins are toxic and can be divided into two groups. The first group are plant toxins inherently present in cereals, such as phytate and tannins and dhurrin in sorghum. The second group of plant toxins originate from plants that are harvested together with the grains and not removed during subsequent grain cleaning. Phytate and tannins are described as 'antinutrients' instead of being of toxicological concern and their anti-nutritional characteristics depend on the overall health status of the consumer. In the western diet, these compounds are generally considered to be of no concern. In contrast, the second group of plant toxins comprises pyrrolizidine alkaloids (PA) and tropane alkaloids (TA). PA are associated with hepatic venoocclusive diseases, which can have a high mortality rate. In 2015, 10 out of 72 RASFF notifications related to chemicals in cereals, reported plant toxins (tropane alkaloids) in millet- or maize-based products (Alldrick, 2017).

The Joint FAO/WHO Expert Committee on Food additives evaluated the content of 1,2 unsaturated PA and their N-oxides in foods from literature and data from Brazil, Germany, Hungary, Luxembourg and FoodDrinkEurope. In total, 1304 of 1368 samples contained PA concentrations below the limit of detection. Concentrations ranged between 0.12 – 98 000 µg/kg. The high number, as compared to other investigated commodities, is explained by the fact that the data included a survey from a veno-occlusive diseases outbreak due to elevated levels in cereals in Afghanistan and Iran (WHO, 2016a).

With regard to tropane alkaloids, Mulder et al. (2015) investigated the occurrence of TA in cereal-based products, i.e. breakfast cereals, biscuits, cookies, for infants and young children available in the Netherlands. Mean concentrations were 3.9, 2.4 and 0.4 µg/kg and maximum concentrations 80.8, 57.6 and 3.9 µg/kg in 2011, 2012 and 2014, respectively. EFSA established a group ARfD of 0.016 µg/kg body weight for (-)-scopolamine and (-)-hyoscyamine (EFSA, 2018d). Assuming a daily intake of 20 grams cereals per day and an average weight of 10 kg for young children, this would correspond to a maximum intake of 8 µg/kg. The authors concluded that examined products for young children were highly contaminated and monitoring should include multiple toxins. The lower concentrations found in 2014 were assigned to either variations in contamination levels in harvest or precautionary measures taken by the producers. TAs can be prevented in cereals by removing weeds in the field or, after harvest, through physical cleaning of cereals from weeds containing tropane alkaloids. However, cleaning does not always remove all weed plant parts and seeds and, thus, trace amounts of tropane alkaloids can remain in flour prepared from those cereals. Cirlini et al. (2018) investigated the content of tropane alkaloids in 26 buckwheat containing processed cereals products (flour, pasta, bakery products) in Italy. Tropane alkaloids were detected in three samples with concentrations of 13.9 – 83.9 µg/kg for atropine and 5.7 – 10.4 µg/kg for scopolamine. These levels are above the EU ML of 1,0 µg/kg in both processed cereal-based foods and baby foods for infants and young children, containing millet, sorghum, buckwheat (Regulation (EC) No 1881/2006). The highest concentration of 83.9 µg/kg of atropine was found in a buckwheat flour sample. The authors concluded that the overall prevalence was low. However, the high contaminated sample requires further precautionary measures. In Slovenia, a poisoning incident (symptoms: inter alia blurred visions, speech disturbance and hallucinations) occurred in 2003 involving 73 consumers who consumed products containing buckwheat flour. This buckwheat flour was contaminated with thorn-apple seeds, which contained the tropane alkaloids atropine and scopolamine (Perharic et al., 2013).

In 2014, EFSA published a call to investigate tropane alkaloids levels in food products to remedy the limited available occurrence data in Europe. Subsequently, 1709 samples from retail stores from nine countries (Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain and the United Kingdom) were investigated, including flours (buckwheat, millet, corn), cereal-based products for young children (breakfast cereals, biscuits and other products), breakfast cereals, biscuits and pastry, bread and pasta. Tropane alkaloids were detected in all food products with different prevalence, but not in pasta. The highest mean concentration of tropane alkaloids was found in cereal-based products for young children (130.7 µg/kg), the highest maximum concentration in dry herbal tea (4357.6 µ/kg). Among all investigated tropane alkaloids, atropine and scopolamine were most frequently detected with the highest concentration found in (dry) herbal tea (mean concentration: 13.4 µg/kg; maximum concentration: 428.5 µg/kg). Samples consisting of single flours and cereal-based products without any vegetables mostly contained atropine and scopolamine (Mulder et al., 2016).

3.2.7.1 Conclusion

Plant toxins of concern may be present in cereals when they are co-harvested with plants producing these toxins and may end up in cereal-based products if not removed with physical cleaning post-harvest. Only a limited number of references on the occurrence of plant toxins in cereals were found, despite an additional search. The described references, however, indicate that despite physical cleaning of cereals, traces of tropane alkaloids may remain in cereals, which are further processed into cereal-based products, inter alia intended for infants and young children. The literature indicated that tropane alkaloids concentrations above the EU ML were found and a Dutch survey showed that reported maximum concentrations would result in exceedances of the ARfD. Most frequently detected tropane alkaloids in cereal-based products were atropine and scopolamine.

3.2.8 Processing contaminants

Processing contaminants are toxic compounds that can be formed during the processing of food. During the manufacturing of cereals, the interaction between ingredients may lead to the formation of chloropropanols and acrylamide. Chloropropanols (3-monochloropropane-1,2-diol (3-MCPD)) have been detected in low concentrations in bread. According to the authors, these concentrations do not pose a risk to the consumer (Alldrick, 2017).
Results from the literature and google study showed acrylamide to be present in maize products (Boroushaki et al., 2010), in cereal breakfast and biscuits (Capei et al., 2015) and in barley-based Japanese tea (Mizukami et al., 2014). Acrylamide is formed in food as a by-product of the browning-reaction (Maillard reaction) of carbohydrates and amino acid rich foods upon heating such as baking, grilling, frying and roasting (BfR, 2011b). Acrylamide can also be converted into glycidamide in the human body. However, besides being a metabolite of acrylamide, glycidamide can also be formed directly upon heating of food due to a reaction between acrylamide and hydroperoxides in unsaturated fatty acids. The contaminant glycidamide can be found in foodstuffs that are rich in carbohydrates, such as potatoes and cereals; however, levels are relatively low (BfR, 2009). Other compounds formed during the Maillard reaction are furan derivatives, volatile cyclic compounds, which were found in rye bread in Latvia (Ozolina et al., 2011).

The EC has published maximum limits for 3-MCPD for hydrolysed vegetable protein and soy sauce, but not for cereal products (Regulation (EC) No 1881/2006). Besides that, Commission Recommendation (2013/647/EC) outlines indicative values on acrylamide levels in food (inter alia several cereal-based products). These indicative levels do not constitute a safety threshold, but merely express that an investigation may be needed, which has to be evaluated case by case.

3.2.8.1 Conclusion
Processing contaminants are, as the name implies, contaminants that may be formed during processing of foodstuff. Cereal grains as such, and its milled forms flour and bran, do not undergo a heat treatment, unless they are further processed. Therefore, processing contaminants are not of concern for cereals, but have to be taken into account in the further processing of cereals (e.g. into bread).

3.2.9 Processing aids and additives

The literature research resulted in one generic paper on chemical hazards in food, among other food additives. The google search also resulted in only 1 report on food additives and the additional search on additives, processing aids, flour treatment agents and dough conditioners did not result in further information.

Food additives may be added during processing of cereals. Certain additives that have been used in the past are now prohibited or restricted in use, due to new toxicological data over time. These additives are for instance flour-treatment agents such as chlorine and chlorine dioxide, dough conditioners such as ascorbic acid, azodicarbonamide and potassium bromate and pH regulators such as aluminium phosphates (Alldrick, 2017).

The Joint FAO/WHO Expert Committee on Food Additives evaluated certain food additives, inter alia aluminium containing food additives that can be used in cereals. The estimated exposure to aluminium via food additives in cereal and cereal-based products was estimated to be 2-124 mg/person per week for the adult population (Europe: 2-46), whereas the overall exposure from the diet was estimated to be 11-136 mg/person per week (Europe: 11-91). The overall exposure includes the diet, natural sources, water consumption, food contact materials and food additives. Cereal and cereal-based products constitute around 20 – 90% to the overall aluminium exposure, depending on the country and region. In particular, sodium aluminosilicate (INS 554) and sodium aluminium phosphate acidic (INS 541 (i)) were reported to have a high usage in cereal and cereal-based products. The Committee concluded that aluminium uptake via cereals and cereal-based products was most probably due to the presence of food additives (WHO, 2011a). With regard to aluminium additives, EFSA evaluated aluminium phosphate and aluminium sulphates and concluded that these food additives are of no safety concern, due to their low bioavailability and low acute toxicity and limited exposure, since these additives have only a limited authorised usage in for example cereals and cereal products (EFSA, 2018e).

3.2.9.1 Conclusion
The limited information on processing aids and additives indicated that aluminium uptake via food additives in cereals is a potential exposure route. However, EFSA evaluated that the use of these food additives in cereals are not a safety concern.

3.2.10 Allergens

The Food Information to Consumers Regulation (Regulation (EU) No 1169/2011) outlines in Annex II 14 substances and products that have the potential to cause allergies or intolerances. The protein gluten, which is commonly found in cereals, is recognised as an intolerance and as such may have consequences for susceptible consumers. The literature research indicated one paper in which the authors describe allergenic reactions to buckwheat. Buckwheat is increasingly used as ingredient in food products and is also used as a substitute for gluten-sensitive people. Allergic reactions to buckwheat have been reported in Asia, but also in Europe (Panda et al., 2010).

3.2.10.1 Conclusion
Gluten are commonly found in cereals; susceptible consumers can be intolerant for gluten. Furthermore, allergic reactions towards buckwheat have been reported.

3.2.11 Other chemical hazards

Besides the above mentioned hazards, further contaminants were found that do not fit within one of the above outlined categories.

Melamine
In 2007, wheat bran was diluted with melamine in animal feed to increase the nitrogen content to pretend a higher protein content. This led to a number of pet deaths and 150 withdrawn pet food products from the US market. Besides economically motivated adulteration, sabotage motivated by employee grievance, terrorism or blackmailing, can be a second pathway of illegal contaminants in food and feed (Alldrick, 2017). An investigation into adulterated cereals and bakery products in Poland revealed one incident in 2008, where melamine (3.5 ppm) was found in wheat-based snacks (salty sticks), which was suspected to originate from tainted wheat flour, which is above the EU ML of 2.5 mg/kg (Regulation (EC) No 1881/2006). However, the majority of adulterated cases was due to mislabelled products (Kowalska et al., 2018).

Perchlorate
Perchlorate occurs naturally in the environment and in nitrate and potash deposits and can dissolve in soil and groundwater. It is also a fabricated contaminant occurring in the environment due to the use of nitrate fertilisers and the manufacture and use of several industrial products. With regard to food contamination, soil, water and fertiliser are regarded as potential contamination pathways (European Commission, n.d.).
In 2013-2014, the Canadian Food Safety Agency (CFIA) investigated the perchlorate content in various food products (fresh vegetables, processed fruit and vegetables, dairy products, grain products, infant formula) available on the retail market. In 30% of the grain products, levels of perchlorate could be detected. Of all investigated commodities, grain products contained the lowest average concentrations of perchlorate (5 ppb) in comparison to the highest concentration found in fresh vegetables (130 ppb). With regard to levels found in literature, they were comparable with reported contaminant levels by US FDA and EFSA. A risk assessment indicated no health concern arising from the contaminant levels in the investigated food samples (Canadian Food Inspection Agency, 2018b). The European Commission published a recommendation (Recommendation (EU) 2015/682) outlining that more data on the presence of perchlorate in food is needed in order to evaluate the risk. A Risk assessment conducted by EFSA provided a scientific opinion indicating that perchlorate in food can be of potential concern for young people with mild to moderate iodine deficiency in case of a high consumption. In order to obtain more data, Member States in cooperation with food businesses should monitor food samples on the presence of perchlorate as well as investigate the potential pathway of perchlorate, such as fertiliser, soil and irrigation and processing water (European Commission, 2015).

Mineral oils
In Germany, mineral oils (MOSH: mineral oil saturated hydrocarbons; MOAH: mineral oil aromatic hydrocarbons) have been found in dry foods like breakfast cereal and noodles. The mineral entered the food via printing inks in recycled cardboard packaging, which transferred to the food product during storage (BfR, 2011a). Mineral oils can be found in all food commodities for which package consist of recycled cardboard from newspaper. Levels found and possible human health risks related to mineral oils are currently unknown.

Plasticiser
Packaging may also contain the plasticiser di(2-ethylhexyl) phthalate (DEHP). It is used in plastic packaging to make it more flexible. DEHP can be found in all staple foods, such as cereals. Higher concentrations are, however, found in fatty products (e.g. mayonnaise and oily products, such as vegetable and fish in jars). Its use in packaging of fatty food is forbidden since 2007 and banned in the manufacturing of consumer goods since 2015. However, imported products may contain the plasticiser and it also may end up in the food via the environment (BfR, 2013b). A study investigating the content of phthalate esters (PAE) in rice from the Serbian and Chinese market found six PAE of which DEHP had the highest concentrations, 947 and 562 µg/kg (average: 621 and 392 µg/kg), respectively in the two countries (Škrbić et al., 2017).

3.2.11.1 Conclusion

Melamine in cereals (and food) is not an environmental contaminant, but requires a manmade, deliberate addition driven by economically motivated adulteration. Under normal circumstances melamine is not found in cereals. Mineral oils are chemical hazards that can concern all food products that are packaged in recycled cardboard containing residues of printing inks. Residues are therefore not specifically linked to cereal products. Not much information was found for plasticisers even though an additional literature search was performed. The use of plasticiser in practice is limited and higher levels are usually found in fatty food as compared to cereals. The European Commission advised to monitor the perchlorate levels in food in order for EFSA to conduct a risk assessment and to close the knowledge gap. Perchlorate concentrations in grain products are, however, low compared to other products.

An overview of chemical hazards included on the intermediate list, and legal limits is indicated in section 3.5.

3.3 Overview of chemical hazards in seeds

The literature study resulted in only 19 relevant papers describing heavy metals, POPs, pesticides, mycotoxins, plant toxins and additives. Additional searches were performed to obtain information on persistent organic pollutants, radionuclides, processing contaminants, processing aids and additives, and cleaning agents and disinfectants. This resulted in 1 additional paper on processing contaminants, 1 paper on PAHs, 1 paper on POPs and 2 papers on plant toxins. Information regarding radionuclides and the use of cleaning agents and disinfectants in seeds were not found in this study. An additional search did not retrieve relevant papers.

3.3.1 Heavy metals and trace elements

Chen et al. (2010) investigated the content of heavy metals in sunflower seeds grown on soils irrigated with sewage from industrial and domestic effluent in China. Sunflower seeds showed higher concentrations compared to cotton seeds and maize seeds. Sunflower seeds had the highest concentrations of lead, cadmium, copper, zinc, chromium and nickel (0.75 mg/kg, around 0.14 mg/kg, 28 mg/kg, 90 mg/kg, 5 mg/kg and around 4 mg/kg, respectively). The estimated dietary intake of lead and cadmium was below the TWI and TDI of the FAO/WHO. Also, the dietary intake of copper and zinc was below the recommended values.
In an experimental study conducted by Memoli et al. (2017) in Italy, uptake of heavy metals (cadmium, chromium, copper, nickel and lead) was investigated in several parts of the sunflower plant, including seeds. Sunflowers were grown on a field close to a busy road and in short distance of a previous lead pipe factory. In comparison with sorghum, sunflower plants showed higher metal accumulation, in particular high concentrations of cadmium and copper were found in the seeds (around 0.1 and 15 mg/kg, respectively). Chromium, nickel and lead were not detected in the seeds. The roots showed higher concentrations of all the investigated metals as compared to stems, leaves or seeds.

The WHO Committee on Food Additives evaluated the presence of cadmium and lead in food commodities, inter alia nuts and oilseeds, using data submitted by EFSA, and several European and non-European countries. National mean cadmium concentrations in 350 nuts and oilseeds samples ranged between 0.02-0.1 mg/kg and mean lead concentrations in 184 samples ranged between < LOD- 0.024 mg/kg and a maximum concentration of 0.3 mg/kg. Nuts and oilseeds types were not further specified (WHO, 2011b). Maximum EU limits for cadmium and lead in seeds have not been established.

In 2009, EFSA evaluated the safety of chia seeds upon earlier application of chia seeds as a novel food ingredient. The applicant provided analytical information on heavy metals in chia seeds samples from 2005-2008 harvest originating from Bolivia, Peru and Australia. Mean concentrations for arsenic and mercury were 0.102 mg/kg and < 0.01 mg/kg, respectively. Cadmium and lead concentrations in these chia seeds samples complied to the established EU limit for cereals (0.1 mg/kg for cadmium and

0.2 mg/kg for lead). EFSA concluded that, while toxicological studies are limited, no evidence of an adverse effect of chia seeds was found also with regard to the current and earlier use in non-EU countries (EFSA, 2009c). Subsequently, the European Commission allowed chia seeds to be used in certain percentages in bread products, baked products, breakfast cereals, fruits, nuts and seed mixes and as pre-packaged chia seeds (Commission Decision 2009/827/EC and Commission Implementing Decision 2013/50/EU).
In 2015, EFSA conducted a risk assessment on nickel in food. High mean nickel concentrations were reported for legumes, nuts and oilseeds (2 mg/kg), certain type of chocolate products (3.8 mg/kg) and cocoa beans and cocoa products (9.5 mg/kg). The intake assessment revealed that the 95th intake of nickel ranged from 3.6 to 20.1 µg/kg bw/day, which is above the TDI (2.8 µg/kg bw/day) for all age groups. EFSA concluded that the chronic dietary intake of nickel is of concern for the general population. For the young age groups, the TDI was also exceeded by the mean dietary intake. For acute dietary exposure, EFSA concluded that there was a concern for Ni-sensitized individuals. Overall, the main contributors to the dietary exposure to nickel were grain and grain-based products, non-alcoholic beverages, sugar and confectionery, legumes, nuts and oilseeds, and vegetables and vegetable product (EFSA, 2015d).

3.3.1.1 Conclusion

The literature study revealed that limited information was available on heavy metals in seeds. EFSA indicated that the group 'nuts and oilseeds' is a main contributor to nickel dietary intake. The information on specific seeds (sunflower seed and chia seed) did not indicate a human health concern.

3.3.2 Persistent organic pollutants

Non-dioxin like PCB levels in foods were reported by different countries to the WHO in order to evaluate dietary exposure. Reported mean concentrations for PCB congeners in the category of 'nuts and oilseeds (in ng/kg ww) were: PCB 28: 10.7; PCB 52: 6.66; PCB 101: not reported; PCB 138: 5.35; PCB 153: 5.37; PCB 180: 3.62 in Canada; PCB 28: 0.5; PCB 52: not detected; PCB 101: 0.046; PCB 138: 0.092; PCB 153: 0.094; PCB 180: 0.089 in Czech Republic; PCB 28: 4.63; PCB 52: not detected; PCB 101: not detected; PCB 138: 87.9; PCB 153: 78.0; PCB 180: 58.0 in Slovenia and PCB 28: 26.6; PCB 52: 11.6; PCB 101: not detected; PCB 138: not detected; PCB 153: 9.97; PCB 180: 8.31 in the United Kingdom. Other countries in and outside the EU did not report PCB levels in seeds. In general, non-dioxin like PCBs were found in higher levels in fish, milk, meat, eggs and their products, as well as fats and oils, as compared to nuts and seeds (WHO, 2016b).

In the Netherlands, dietary exposure to polybrominated diphenyl ethers (PBDE) were investigated in several food commodities. The five congeners (-47, -99, -153, -100 and -183) showed low levels in the category 'nuts and seeds' as compared to food of animal origin (milk, fish, meat and eggs). Calculations showed that the intake of three PBDEs (-47, -99 and -153) is so low that the risk to health is negligible. Due to the absence of guidance values for the two congeners -100 and – 183, a health effect could not be assessed (RIVM, 2016).

In an experimental study in Nicaragua, toxaphene and other POPs uptake from soil to three amaranth cultivars was investigated. The study area was characterised by a heavy application of pesticides until 1993. Toxaphene congeners (Parlar 11, 12, 15,25, 31, 32, 39, 40, 44, 42, 50 and 59) and 8 other chlorinated pesticides (α-HCH, ß-HCH, ɣ-HCH, aldrin, dieldrin, cis-heptachlor epoxide, trans-heptachlor epoxide, ß-endosulfane) were examined. The concentration of toxaphene and other POPs in the edible parts of amaranth (leaves and seeds) exceeded the EU MRL in most cases. Bioaccumulation factors for the substances varied, but concentrations in amaranth were more than 10 times higher than in the soil (Haller et al., 2018).

3.3.2.1 Conclusion

Despite an additional literature search, limited information was found on POPs. Dioxins, PCBs and PBDEs are generally more associated with food of animal origin. In general, oilseeds are less prone to accumulate these substances. One study was found on pesticide uptake from polluted soil in amaranth. However, this was an experimental study for a specific contaminated region in Nicaragua.

3.3.3 Pesticides

France investigated pesticide residues (283 active substances) in 194 food products in their total diet study in 2011. Only a few active substances were found with a detection frequency higher than 1%. However, these were mostly found in other food groups than seeds (e.g. fruits and vegetables). Moreover, no MRL exceedances were observed in seeds (ANSES, 2011). In comparison, the FDA in the United States reported pesticide concentrations in seeds in their pesticide residue monitoring program. While no violations with US MRLs were found for domestic produced seeds, the product category 'Other' of imported products, consisting inter alia of nuts, seeds, oils, honey, candy, beverages and spices, contained samples exceeding the MRLs. However, the reports do not outline which particular foods of this product group were exceeding legal limits and for which pesticide. Nevertheless, it outlines a list of products that may warrant special attention due to a violation rate above 10%. Among these products were quinoa seeds from Peru with a violation rate of 33% out of 18 analysed samples in 2014 (FDA, 2014) and 12.1% out of 33 samples in 2015 and chia seeds with a violation rate of 15.4% out of 26 in 2015. In total, 9 samples out of 114 imported 'seeds, edible and seed products' (7.9%) had residue levels above the US legal limits (FDA, 2015a). In 2016, 38 samples of quinoa were tested and a violation rate of 13.2% was found. In total, 10 out of 93 samples from the category 'seeds, edible and seed products' were found with pesticide concentrations above the US legal limits (FDA, 2016). The FDA also conducted a qualitative risk assessment for food that is manufactured and prepared at the farms. Their evaluation showed that pesticides residues in seeds are likely to occur (FDA, 2015b).
In Canada, the CFIA screened 418 imported and domestic grain and grain products for 430 different pesticides in 2011-2012 mostly from the US, Canada and unknown country of origin. Cereal and cereal products consisted mainly of maize, oat, rice and wheat, but also of buckwheat, barley, millet, quinoa, rye and spelt. Only one sample of quinoa had higher residues of orthophenyl-phenol than the general national MRL of 0.1 mg/kg (Canadian Food Inspection Agency, 2018a).

The literature search resulted in three EFSA papers on MRL modifications of prothioconazole in sunflower seeds, trinexapac in poppy seed and fluazifop-P in pumpkin seeds. These papers indicated that a health risk as a result of the presence of residues of these pesticides is not likely (EFSA, 2015b, 2016e; European Food Safety, 2016).

3.3.3.1 Conclusion

Only a few studies were found describing pesticide residues in seeds. The limited information available indicates that pesticide residues were found above the US legal limits for quinoa and chia seeds.

3.3.4 Mycotoxins

The FDA conducted a risk assessment for the manufacturing and preparation of food at the farm. Their evaluation showed that chemical hazards in form of mycotoxins, such as aflatoxin and DON, are reasonably likely to occur in grains, but also on amaranth, buckwheat, quinoa and oilseeds that are processed and stored at the farm (FDA, 2015b). Several institutions (ANSES, 2006; WHO, n.d.) indicate that oilseeds are susceptible to aflatoxin (B1) contamination. Among seeds, in particular pumpkin seeds and watermelon seeds are more prone to be contaminated than other seeds (FDA, 2013). Seeds are considered to be similar to nuts due to their composition and production processes. In Ireland, ready-to-eat dried seeds and nuts were investigated in 2012 on microbiological and chemical safety. 18 Out of 891 samples were examined for aflatoxin B1 and total aflatoxin levels and none of the samples exceeded the regulatory limits established by the EU (FSAI, 2012). The EU MLs for aflatoxin B1 and total aflatoxins in oilseeds for direct consumption are 2 and 4 µg/kg, respectively ((EU) Regulation 1881/2006).

Bhat and Reddy (2017) was the first to review available data from the last decade (2000 – 2010) on the presence of fungi and mycotoxins in oilseeds and edible oils. It is a recognised fact that seeds and the oils during pre- or postharvest, as well as the by-products of the seeds (oil cake/meal) can be contaminated by fungi and their mycotoxins. However, up to now, there is limited information on fungi and mycotoxins in oilseeds and vegetable oils. The following information outlines the conducted studies on mycotoxin occurrence in edible seeds: with regard to sunflower seeds, several fungi were

found that might produce the mycotoxins citrinin, aflatoxins, alternariol (AOH), alternariol monomethyl ether (AME) and tenuazonic acid (TA). Studies in Brazil revealed the presence of AOH and AME in sunflower seeds, as well as aflatoxin B1 (16 ppb) and OTA (800 ppb) in poultry feed based on sunflower seeds. In safflower seeds, DON, T-2 toxin and other trichothecenes can often be found. A wide range of mycotoxins was found in different linseed (flaxseed) cultivars. Positive samples with DON were found and after several months of storage also aflatoxins and OTA were found (2.5 μg/kg and 1.2 μg/kg, respectively). Other studies found high concentrations of aflatoxin B1 (range: 120 – 810 μg/kg), AOH (104 μg/kg), AME (30 μg/kg) and altenuene in linseeds. In rapeseeds, mycotoxins concentrations of 164 – 183 μg/kg for DON and 1.0 – 3.1 μg/kg for aflatoxins were detected. In China, concentrations of aflatoxin B1 in sesame paste were found up to 20.5 μg/kg. However, in artificially inoculated sesame plants, no aflatoxins were found in the sesame seeds. Several studies investigated the mycotoxin concentrations in sesame seed: in Nigeria, mycotoxin contamination in sesame seed were reported by Ezekiel et al. (2012). While aflatoxins and fumonisins were not detected in sesame seed (n= 17), DON and ZEA mean concentrations of 28 and 7 μg/kg, respectively, were found with a range of 8 – 76 and 0.7 – 38 μg/kg, respectively. Both mycotoxins were detected in 15 out of the 17 samples (88%). While Ezekiel et al. (2012) did not detect any aflatoxin concentrations, Hosseininia et al. (2014) found aflatoxin B1 and total aflatoxin concentrations in sesame samples in Iran imported from Afghanistan. Mean concentrations were 1.25 ± 3.7 and 1.43 ± 4.38 μg/kg, respectively and 5 out of 269 samples exceeded the national Iranian standard (5 and 15 μg/kg, respectively) with a maximum total aflatoxin concentration of 48 μg/kg. While total aflatoxins concentrations above 1 μg/kg were found in 49.4% of all samples, Kollia et al. (2016) found aflatoxin B1 concentrations in 77.6% of the sesame seed samples (n=30) in Greece. 8 Of these samples exceeded the EU maximum limit of 2 μg/kg established for oilseed for direct human consumption. The authors concluded that sesame seed may contribute to the dietary uptake of aflatoxin B1 as the seeds are popular for consumers with particular diets, such as healthy diets, diets for athletes, veganism and raw foodism.
Chia seeds were monitored in an evaluation for a novel food ingredient in 2009 by EFSA (EFSA, 2009c). The provided analytical information on mycotoxins by the applicant did not show any mycotoxin concentrations above the detection limit for aflatoxin B1, B2, G1, G2, OTA, DON, ZEA and T-2 toxins in samples from Peru and Bolivia (EFSA, 2009c). In a substantial equivalence opinion, FSAI authorised the marketing of chia seeds from Uganda and did not find human health concerns for mycotoxins, pesticides and other contaminants from the environment (FSAI, 2017).

Fumonisin levels in seeds do not seem to be a concern. Data from reported fumonisin concentrations (FB1, FB2, FB3) in several seed types and categories (sunflower seed, linseed, other seeds, oilseeds) in 2003-2009 were collected by the WHO, mainly reported by the Netherlands but also by Hungary. Results showed that all of these samples had fumonisin concentrations below the LOD (WHO, 2012).

EFSA published a dietary exposure assessment on *Alternaria* toxins (AME, AOH, TA, tentoxin (TEN)) showing that these toxins are frequently found in oilseeds. Highest concentrations were found for sunflower seeds. AOH was found at mean concentrations of 22.4 μg/kg LB and 29.1 μg/kg UB, AME at mean concentrations of 5.6 μg/kg LB and 9.4 μg/kg UB, TA at mean concentrations of 563.2 μg/kg LB and 569.6 μg/kg UB and TEN at mean concentrations of 79.4 μg/kg LB and 82.1 μg/kg UB. *Alternaria* toxins were also reported in linseed, sesame seed and pumpkin seed (EFSA, 2016c).

3.3.4.1 Conclusion

Limited information (also in reviews) is available on the presence of mycotoxins in seeds. Different types of seeds may be a source of different kinds of mycotoxins. Sesame seeds were the most investigated seed for mycotoxins. Seeds in general can contain a wide range of mycotoxins, but aflatoxins (B1) are most commonly reported in seeds and were sometimes found to exceed the EU MLs.

3.3.5 Plant toxins

Fejér and Salamon (2014) assessed the content of opium-alkaloids (morphine) in poppy seeds in Slovakia. Poppy seeds do not contain significant amounts of alkaloids, but low concentrations may be found in the seeds due to contamination during harvest with alkaloid-containing poppy straws.

Cultivars in Slovakia were found to have low to moderate concentrations of morphine and it was concluded that consumption does not cause human health effects. Besides contamination during harvest, also pest damage can lead to seed contamination with opium-alkaloids. The latex (milky sap) of the poppy plant can contain up to 80 alkaloids, inter alia morphine and codeine. EFSA has updated its risk assessment on opium alkaloids in poppy seeds and confirmed the earlier established safe level (ARfD – acute reference dose) of 10 µg morphine/kg body weight, which now also includes the codeine content (EFSA, 2018g).
The European Commission published a recommendation outlining good agricultural and processing practices in order to prevent opium alkaloids as well as processing methods to reduce the content of alkaloids in poppy seeds and poppy products (Commission Recommendation 2014/662/EU).
In a Federal State in Germany (Baden-Würtemberg), opium alkaloids (morphine) were monitored in food since 2005 as part of the official surveillance. Concentrations of opium alkaloids were investigated in poppy seeds and foods made thereof (ready-made poppy seed mixtures, poppy seeds from bakeries and poppy seeds dedicated directly for consumption). In 2005, a homemade milk drink, prepared with poppy seeds, led to hospitalization of an infant. Investigations revealed a content of about 1,000 mg/kg morphine in the used poppy seeds. In 2006, the concentrations in the foods in the monitoring study were considerably lower. However, 76% of the 111 samples still exceeded the guidance value of 4 mg/kg poppy seed set by the German BfR. In 28% of these samples, the morphine content exceeded 20 mg/kg, which according to BfR is tolerable if warning notices are given (Perz et al., 2007). Processing of poppy seeds, like washing, soaking, heat treatment and grinding could decrease the alkaloid content of raw poppy seeds by 25 to 100% (EFSA, 2018g). However, for poppy seeds samples dedicated for direct consumption, concentrations exceeding 20 mg/kg are not satisfactory (Perz et al., 2007). In 2015, (López et al., 2018) determined the opium alkaloids concentrations (morphine, codeine, thebaine, noscapine, papaverine, narceine) in 41 samples of poppy seeds and bakery products containing poppy seeds from the Netherlands and Germany. Morphine, codeine and thebaine were detected in 100%, 78% and 78% of the samples. Morphine concentrations ranged from 0.2 – 240 mg/kg with 60% of the samples exceeding the German guidance value of 4 mg/kg. Compared with the established limits of opium alkaloids in poppy seeds in Hungary, 25% of the samples did not comply with maximum established national limits in Hungary of morphine (30 mg/kg), codeine (20 mg/kg), theabine (20 mg/kg) and sum of morphine and noscapine (40 mg/kg).

Another product that may contain plant toxins are hemp seeds, which are used for human consumption for their source of protein, carbohydrates, oil and other nutrients. They are added to several foods, such as beverages, soups, sauces and snacks. Hemp seeds are derived from the hemp plant *Cannabis sativa* that is specifically used for food and fibre production. This species has no or trace amounts of the psychoactive component tetrahydrocannabinol (THC), as compared to from the plant species used to derive cannabis. However, hemp seed may contain trace amounts of THC and cannabidiol (CBD) when they come into contact with other parts of the plants during harvesting or processing. Trace amounts have, however, no psychoactive effect (FDA, 2018a).

Another category of plant toxins are cyanogenic glycosides producing plants that may contain compounds such as amygdalin or dhurrin, which can generate the toxin hydrocyanic acid (HCN – hydrogen cyanide). Several studies found HCN contents in cyanogenic glycoside containing foods, such as flaxseed/linseed, bitter almonds, bitter apricot kernel, peach kernel, plum kernel and nectarine kernel. Flaxseed samples from Canada, Australia and New Zealand (years not specified) contained mean concentrations of 2-590 mg/kg HCN equivalent with a range up to 6500 mg/kg (WHO, 2012). EFSA has set an acute reference dose of 20 µg/kg bw for cyanide (EFSA, 2016b).

3.3.5.1 Conclusion

Cyanogenic glycosides can be present in flaxseed/linseed and the formation of HCN is regarded as highly toxic. Furthermore, opium alkaloids were found in poppy seeds in the Netherlands and Germany. A recent survey showed that 60% of the samples exceeded the German guidance value of 4 mg/kg for morphine (López et al., 2018).

3.3.6 Processing contaminants

The literature search and Google search did not result in any papers on processing contaminants in seeds. In the additional search, only two study were found.

Mesías et al. (2016) investigated the risk concerning the addition of chia flour to wheat based biscuits. While it enhanced the nutritional value of the biscuits, it also increased the levels of the processing contaminants acrylamide, hydroxymethylfurfural (HMF) and furfural. Concentrations of contaminants were 151 μg/kg, 22.8 mg/kg and 1.3 mg/kg for acrylamide, hydroxymethylfurfural and furfural, respectively when no chia flour was added and increased to a maximum of 1188 μg/kg, 71.4 mg/kg and 5.6 mg/kg, respectively in the biscuits containing up to 20% chia flour of the total weight. The highest acrylamide concentration was observed at an addition of 10% of chia, which exceeded the indicative concentration (500 μg/kg) for biscuits as established by the European Commission. Becalski et al. (2003) analysed a range of food products on the presence of acrylamide. Roasted sunflower seeds contained 66 μg acrylamide/kg, which is much lower than concentrations found in potato chips and French fries (530-3700 and 200-1900 μg/kg, respectively).

3.3.6.1 Conclusion

An experimental study showed that when chia flour was added to wheat based biscuits, the concentrations of acrylamide, HMF and furfural increased. A additional search on processing contaminants in chia seeds itself did not result in additional papers on this topic. Acrylamide was found at low concentrations (66 μg/kg) in roasted sunflower seeds.

3.3.7 Processing aids and additives

Member States are required to monitor the consumption of food additives. In Ireland, 10 brands of the product group 'Nuts, seeds, herbs and spices' were tested upon the presence of additives. 1 brand of this group contained additives in 2010 (FSAI, 2010), while in 2015, 9 brands out of 31 (29%) investigated brands in this product group contained additives (FSAI, 2015a). However, this category is a broad product group and information on which seeds were monitored and contained additives were not indicated in these reports.

The FDA draft guidance document for industry on hazard analysis and risk-based preventive controls for human foods indicates potential chemical hazards in food commodities. This guidance document indicates that unapproved colours and additives are potential hazards to be included in a HACCP for roasted and seasoned edible seeds (FDA, n.d.).

3.3.7.1 Conclusion

Although additives were found in two Irish surveys for the product group nuts, seeds, herbs and spices, substances and concentrations found were not indicated.

3.3.8 Other chemical hazards

Akbari-Adergani et al. (2017) examined the concentrations of 16 PAHs in the shell and kernel of raw and roasted sunflower seeds from Iran. While 4 PAHs (anthracene, benzoapyrene, fluoranthene and phenanthrene) were detected in roasted seeds, no levels were found in the raw seeds. Higher concentrations were found in the shell of roasted sunflower seeds as compared to the kernels (average concentration of total PAHs 15.9 ± 4.8 and 9.5 ± 5 μg/kg, respectively). However, there are currently no legal limits for PAHs in seeds. PAH concentrations in raw seeds would generally point out to a PAH contamination in either air, soil or water, whereas the PAH concentrations in roasted sunflower seeds is linked to the heating process.
This was confirmed in a study by Potočnik and Košir (2017), who investigated the PAH formation in pumpkin seed oils that had undergone a roasting process with different temperatures (90 to 200 °C). This showed that when the seeds were roasted at a temperature of 150°C and higher, 5 PAHs (phenanthrene, anthracene, pyrene, benzofluoranthene, benzoapyrene) were detected in pumpkin seed oil samples. Concentrations of anthracene, pyrene and benzofluoranthene increased only slightly upon heating from 150 – 200 °C (0.07 – 0.09 μg/kg, 0.21 – 0.26 μg/kg, 0.03 – 0.04 μg/kg,

respectively) and the concentrations of benzoapyrene remained low at 0.02 μg/kg. However, phenanthrene showed the highest concentrations of 1.6 μg/kg at 150 °C to 7.85 μg/kg at 200 °C. The FSAI recommends to avoid the direct contact during the drying of oilseeds with combustion products, in order to prevent high concentrations of PAHs in oilseeds (FSAI, 2015b).

In an experimental study, Austel et al. (2017) investigated the influence of fumigants on sunflower seeds. Fumigants are used during the transport of stored food products in containers to protect from pests. Between 5-18% of the transported containers contain fumigant concentrations exceeding the recommended maximum exposure limit. In an experiment, the desorption time of fumigants (phosphine (PH3), methyl bromide (MeBr) or 1,2-dichloroethane (DCE)) differed considerably. PH3 and MeBr were outgassed (reaching the detection limit) within a few days, whereas for DCE a desorption time of up to several months was observed. Comparing the time to reach the established EU MRL for these compounds (DCE: 0.02 μg/g; MeBr: 0.01 μ/g; PH3: 0.1 μg/g) shows that it would require 24.0 ± 3.2 d (DCE, mean ± SE), 2.7 ± 0.3 d (MeBr) and 2.0 ± 0.0 days (PH3) of outgassing fumigated sunflower seeds before the MRLs are reached. In case storage rooms are not properly ventilated*,* the fumigant residues could represent a considerable risk to human health.

3.3.8.1 Conclusion

Fumigants have been detected above EU legal limits and some of them, especially DCE, have a long desorption time, which may result in elevated levels after transport and storage. Furthermore, PAHs may occur during the roasting of the oilseeds. There is currently limited information on PAH concentrations in (roasted) seeds.

An overview of chemical hazards included on the intermediate list and legal limits is indicated in section 3.5.

3.4 Overview of chemical hazards in nuts

The majority of the literature found described the presence of mycotoxins in nuts. Limited information was available for other hazard groups; the results of which are described below. Information regarding the use of cleaning agents and disinfectants in nuts were not found in this study, despite an additional search.

3.4.1 Heavy metals and trace elements

In 2011, the WHO Committee on Food Additives evaluated the presence of cadmium and lead in food commodities, inter alia nuts and oilseeds, upon data submitted by EFSA, and 11 other countries (Australia, Brazil, Canada, Chile, China, France, Ghana, Japan, Singapore, the USA and Viet Nam). In total, 350 global nuts and oilseeds samples contained a range of national mean cadmium concentrations of 0.02-0.1 mg/kg. Mean lead concentration in 184 samples was 0.005 mg/kg with a range of mean concentrations of < LOD- 0.024 mg/kg and a maximum concentration of 0.3 mg/kg. Nuts and oilseeds types were not further specified (WHO, 2011b). Maximum EU limits for cadmium and lead in nuts are not established.

A UK total diet study in 2006 investigated the concentrations of heavy metals and trace elements in food. With regard to cadmium and copper levels, nuts were among the groups with the highest concentrations (0.065 mg/kg and 9.15 mg/kg, respectively). However, no health risks were reported. The highest concentrations of the trace element barium were reported in nuts (131 mg/kg) (Food Standards Agency, 2006). Concentrations of heavy metals (chromium, manganese, iron, nickel, copper, zinc and lead) in hazelnuts were investigated in Turkey by Cevik et al. (2009). Based on the concentrations found, the estimated daily intake (EDI) was calculated based on a daily consumption of 20 g of hazelnuts. These calculations showed that the EDI was below the maximum daily intake recommended by USEPA and WHO. Cadmium concentrations in 8698 peanuts samples were collected in 2009-2014 in China and investigated by Dai et al. (2016). 243 samples (2.8%) exceeded the national limit of 0.5 mg/kg. Besides that, studies on Brazil nuts reported that these nuts can accumulate trace elements such as barium, strontium and radium. However, barium present is not

bioavailable and strontium and radium concentrations found do not result in human health risks according to the authors (Cardoso et al., 2017).
EFSA concluded in 2015 that the chronic dietary intake of nickel is of concern for the general population. The 95^{th} intake of nickel ranged from 3.6 to 20.1 µg/kg bw/day, which is above the TDI (2.8 µg/kg bw/day) for all age groups. For the young age groups, the TDI was also exceeded by the mean dietary intake. For acute dietary exposure EFSA concluded that there was a concern for Ni-sensitized individuals. High mean concentrations of nickel were reported for legumes, nuts and oilseeds (2 mg/kg), certain type of chocolate products (3.8 mg/kg) and cocoa beans and cocoa products (9.5 mg/kg). Overall, the main contributors to the dietary exposure to nickel were grain and grain-based products, non-alcoholic beverages, sugar and confectionery, legumes, nuts and oilseeds, and vegetables and vegetable product (EFSA, 2015d).

3.4.1.1 Conclusion

Only limited information was found on the presence of heavy metals and trace elements in nuts. A global WHO survey showed that the mean cadmium concentration ranged between 0.02 and 0.1 mg/kg and lead between <LOD and 0.024 mg/kg. However, no EU legal limits are established for these heavy metals. One Chinese study showed cadmium concentrations above the national limit of 0.5 mg/kg. Studies on other heavy metals and trace elements in hazelnuts and Brazil nuts did not reveal human health risks (daily intake did not exceed recommended maximum intakes). EFSA indicated that nuts and oilseeds are a main contributor to nickel dietary intake.

3.4.2 Persistent organic pollutants

Non-dioxin like PCB levels in foods were reported by different countries to the WHO in order to evaluate dietary exposure. Reported mean concentrations for PCB congeners in the category of ‘nuts and oilseeds were the following in ng/kg ww: PCB 28: 10.7; PCB 52: 6.66; PCB 101: not reported; PCB 138: 5.35; PCB 153: 5.37; PCB 180: 3.62 in Canada; PCB 28: 0.5; PCB 52: not detected; PCB 101: 0.046; PCB 138: 0.092; PCB 153: 0.094; PCB 180: 0.089 in Czech Republic; PCB 28: 4.63; PCB 52: not detected; PCB 101: not detected; PCB 138: 87.9; PCB 153: 78.0; PCB 180: 58.0 in Slovenia and PCB 28: 26.6; PCB 52: 11.6; PCB 101: not detected; PCB 138: not detected; PCB 153: 9.97; PCB 180: 8.31 in the United Kingdom. In general, non-dioxin like PCBs were found in higher concentrations in fish, milk, meat, eggs and their products, as well as fats and oils, as compared to nuts and seeds (WHO, 2016b).

In the Netherlands, dietary exposure to polybrominated diphenyl ethers (PBDE) were investigated in several food commodities. The five congeners (-47, -99, -153, -100 and -183) showed low concentrations in the category ‘nuts and seeds’ as compared to food of animal origin (milk, fish, meat and eggs). Calculations showed that the intake of three PBDEs (-47, -99 and -153) is so low that the risk to health is negligible. Due to the absence of guidance values for the two congeners -100 and –183, a health effect could not be assessed (RIVM, 2016).

3.4.2.1 Conclusion

Limited information was found for POPs in nuts. These chemicals are generally more associated with food of animal origin.

3.4.3 Radionuclides

Levels of radionuclides (^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs) were determined in hazelnuts from Turkey from a region that was contaminated by the Chernobyl contamination in 1986. The total effective dose from ingestion of these radionuclides through hazelnuts was calculated to be 9 µSv/year (range: 0 – 35 µSv/year). Compared with the global average annual radiation dose (2400 µSv), as proposed by UNSCEAR, calculated concentrations in hazelnuts were low, indicating no human health risk (Cevik et al., 2009).

3.4.3.1 Conclusion

Limited information on radionuclides in nuts was found. Radionuclides levels were not reported to be a health concern.

3.4.4 Pesticides

Residues of tebuconazole and azoxystrobin were investigated in peanut samples in a field trial in China. Residues were detected in the kernels and the shell, but concentrations were far below the Codex MRL (Hou et al., 2017).
Pesticide monitoring plans in the US reported exceedances of legal limits in imported food products, such as in the category that contains inter alia seeds and nuts (see section 3.3.3). With regard to nuts, cashew nuts and peanuts/peanuts products were found to have pesticide residues above the legal limits. Pesticide names were not mentioned in the report (FDA, 2014, 2015a, 2016).

EFSA published a reasoned opinion on an import tolerance for fenazaquin in almonds. An import tolerance is the adjustment of an existing MRL such to facilitate trade. In order to be able to import almonds from the USA, an import tolerance was requested for fenazaquin. Based on the data submitted, EFSA concluded that residues in almonds were not expected to be a health concern for EU citizens and the MRL was raised from former 0.01 to 0.02 mg/kg (EFSA, 2018f).

Liu et al. (2012) investigated the trends in pesticide use on almonds in the USA to assess their risk to the environment and biodiversity. While no monitoring data are provided in this study, the use of the California Database on pesticides use between 1992 - 2005 indicated that both organophosphate (OP) pesticides (acephate, azinphos-methyl, chlorpyrifos, diazinon, dicrotophos, dimethoate, disulfoton, ethoprop, fenamiphos, malathion, methidathion, methyl parathion, naled, parathion, phosalone, and phosmet) and pyrethroid pesticides (cyfluthrin, cypermethrin, esfenvalerate, lambda-cyhalothrin, permethrin, and tau-fluvalinate) were used on almonds. While use of OP pesticides reduced, use of pyrethroid pesticides increased. Zhan and Zhang (2014) used the data from the California Pesticide Database for 1996 – 2010, to evaluate the risk for the surrounding environments. This showed that almond growers in California use a large amount of pesticides. The state average use in that respective years for insecticides, fungicides, herbicides and fumigants were 17.00 kg/ha, 4.05 kg/ha, 3.21 kg/ha and 1.09 kg/ha, respectively. The top five pesticides in these categories were petroleum oil, mineral oil, sulfur, propargite and chlorpyrifos as insecticides; ziram, copper hydroxide, captan, sulfur, maneb as fungicides; glyphosate, paraquat dichloride, oryzalin, oxyfluorfen as herbicides; 1,3-dichloropropene, methyl bromide, sodium tetrathiocarbonate, metam-sodium, chloropicrin as fumigants.

Hou et al. (2017) performed an experiment investigating the behaviour and distribution of the pesticides tebuconazole and azoxystrobin in peanut kernels and shells during a boiling process. In China, peanut kernels are usually boiled together with the shells. Furthermore, the shells may be used as raw material in the production of soy sauce. The experiments showed that residues were generally detected more frequently in the shells than in the kernels, but both below the established MRL from the Codex Alimentarius. The cooking process decreased both residues in the shells and kernels (tebuconazole: 7 and 76%; azoxystrobin: 15 and 84%).

3.4.4.1 Conclusion

Limited information on pesticides in nuts was found. However, occurrence of pesticide residues in nuts cannot be excluded, as nuts are particularly vulnerable to fungi. Residues have been found in cashew nuts and peanuts above legal limits in the US and reports indicated the use of specific pesticides, for example on almonds.

3.4.5 Mycotoxins

Since the majority of relevant papers for nuts described mycotoxins (81%), only regions that were relevant for the Netherlands were included based on import data from Eurostat. Therefore, in particular papers on African countries, but also some from Asian countries, were excluded in this summary. However, they are evaluated in the accompanying Excel file.

Different institutions and governmental organisations point out that aflatoxin contamination can occur in peanuts and other tree nuts (FSANZ, 2006; FAO, 2010; WHO, 2015; FDA, 2018b). Besides that, aflatoxin were reported in several studies investigating nuts in countries around the world, in particular in peanuts and pistachio nuts. The EU MLs for total aflatoxins 10 µg/kg in almonds and pistachios, hazelnuts and Brazil nuts and 4 µg/kg in groundnuts (peanuts) and tree nuts other than almonds, pistachios, hazelnuts and Brazil nuts intended for direct human consumption (see Table 7).

Investigations into mycotoxin levels in different nut types were conducted in Iran and Pakistan. Masood et al. (2015) investigated the aflatoxin concentrations in 307 samples of dry fruits and nuts (inter alia consisting of almonds, walnut, peanuts, pistachio nuts, pine nuts and cashew nuts) from retail markets in Pakistan. The highest detected aflatoxin concentration was found in peanuts without shell (16 out of 20 samples) with a mean total aflatoxin concentration of 7.9 ± 1.0 µg/kg (range: LOD – 21.3 µg/kg). The highest prevalence of aflatoxin was found in pistachio nuts without shell with a mean concentration of 7.5 ± 1.1 µg/kg (range: LOD – 21.5 µg.kg). In walnuts without shell, the mean concentration of total aflatoxins was 5.4 ± 0.8 µg/kg (range: LOD – 15.8 µg/kg) and 5.0 ± 0.6 µg/kg (range: LOD – 15.8 µg/kg) in almonds. Pine nuts and cashew nuts showed mean concentrations of 3.0 ± 0.3 µg/kg and 3.1 ± 0.4 µg/kg (range of LOD – 6.9 µg/kg; LOD – 5.9 µg/kg), respectively. Ostadrahimi et al. (2014) investigated the aflatoxin content in raw and salt-roasted nut samples (pistachios, peanuts, walnuts) from Iran. In general, mean concentrations of samples from raw nuts contained aflatoxin concentrations of 6.51 ± 9.4 µg/kg while salt-roasted nut samples showed higher concentrations of 19.9 ± 19.4 µg/kg. Walnuts were the most frequently contaminated (90% of the samples), whereas raw pistachios were the least frequently contaminated (2.3% of the samples). The mean concentrations of the raw nuts were 14.4 ± 8.4 µg/kg for walnuts, 0.5 ± 3.1 µg/kg for pistachios, and 3.0 ± 8.6 µg/kg for peanuts. The salt-roasted nuts exceeded the national limit of 15 µg/kg in 58.6%, 48.4% and 47.6% of the pistachios, peanuts and walnuts samples, respectively. Aflatoxin concentrations exceeding the EU ML were found in pistachio nuts from Iran. Cheraghali et al. (2007) investigated 3356 pistachio samples and found a non-compliance of 15.9% for aflatoxin B1 and 13.6% for total aflatoxin, whereas Pour et al. (2010) found a non-compliance rate of 36% and 29% for aflatoxin B1 and total aflatoxin in 100 samples, respectively. In *betel nuts*, the concentrations of aflatoxin B1 were determined in 278 samples from India, Indonesia, Sri-Lanka and Thailand imported to Pakistan. All samples in which aflatoxin concentrations were detected exceeded the EU ML. Prevalence of aflatoxin B1 and concentrations were the following: 100% of the samples from India contained concentrations of 11.7 – 262 µg/kg (mean: 92.5 µg/kg); 80.4% of the samples of Indonesia contained concentrations from 3.3 – 39.2 µg/kg (mean: 11.6 µg/kg); and 73.5% of the samples from Sri Lanka contained concentrations of 6.5 – 103.4 µg/kg (mean: 35.0 µg/kg). The lowest prevalence of 33% was detected in samples from Thailand with concentrations ranging from 3.3 – 77 µg/kg (mean: 6.6 µg/kg) (Asghar et al., 2014). In China, 1040 peanut samples were investigated for aflatoxin B1 and 10 samples exceeded the national limit of 20 µg/kg, whereas 39 samples exceeded the EU limit of 2 µg/kg (Ding et al., 2012). In Brazil, several studies reported exceedances of the national limit for total aflatoxin of 20 µg/kg in peanuts. 20 Out of 104 samples taken from 2013 - 2017 were reported by dos Santos et al. (2018) to have exceeded the national limit (mean concentration was 13.4 µg/kg). Hoeltz et al. (2012) found 5 out of 58 peanut samples from 2009 – 2010 exceeding the national limit (range of 24.0 – 87.5 µg/kg) and 4 out of 240 peanut samples from 2006 – 2007 contained high concentrations with a mean concentration of 55.7 µg/kg (Oliveira et al., 2009). Gonçalez et al. (2008) monitored aflatoxin levels in Brazil during various stages of the pod maturity, with the result that 62.5% exceeded the national limits. Fumonisin levels were also analysed, but not detected. Cardoso et al. (2017) reviewed the safety aspects of Brazil nuts in general. These nuts are known to contain aflatoxins. In the past, concentrations found above the EU limit have led to a significant decrease in exports to the European Union. Pacheco and Scussel (2009) investigated the level of total aflatoxins in 171 dry in-shell and shelled samples from a nut factory in Brazil after the drying process. 14 Samples exceeded the EU limit of 4 µg/kg (11 in-shell samples and 3 shelled Brazil nuts). Aflatoxin concentrations were studied in hazelnuts in Turkey. Ozay et al. (2008) analysed 2113 samples collected from 72 different orchards (harvesting and storage) in the years 2002 – 2004. 3.6% Of the samples had total aflatoxin concentrations higher than 4 µg/kg. Kabak (2016) examined 170 hazelnut samples collected from supermarkets and small-scale farmers from 2013-2015. Exceedances of the EU limit for aflatoxin B1 were found in 2 raw hazelnut kernels and 1 roasted sample and for total aflatoxins in 1 raw and 1 roasted sample. Aflatoxin concentrations were also investigated in almonds from Portugal. 21 Samples were collected from field, storage and processing. Aflatoxin levels were only detected in 1 storage sample at a concentration of 5.0 µg/kg, which is below the EU ML.

Apart from aflatoxins, ochratoxin A (OTA) may also be found in nuts (peanuts), although OTA predominantly occurs in cereal and cereal-based products (wheat, maize, barley, rye) (RIVM, 2002, 2009). Pistachio nuts in Spain, imported from Iran and the US, were investigated for aflatoxin and OTA concentrations in 50 samples by Fernane et al. (2010). 10% Of the samples contained aflatoxin concentrations above the EU MLs. Only 1 pistachio sample contained OTA at a concentration of 0.67 µg/kg (Fernane et al., 2010). Bui-Klimke et al. (2014) concluded that pistachios are considered to be the main contributor to dietary aflatoxin exposure from tree nuts, accounting for 7-45% of the total aflatoxin exposure from all dietary sources. In the Netherlands, mycotoxins are tested for nuts and seeds in the Multi Annual National Control Plan. Targeted controls of imports from outside the EU and at the production establishments were performed and product samples were taken from other EU countries. In 2013, 1930 nuts and seeds samples were investigated of which 3.9% showed non-compliance with EU MLs. Of 1128 peanuts samples, 57 samples contained aflatoxin levels and one sample OTA. 49 Samples were refused to be imported due to high concentrations above EU MLs (NVWA, 2013). In 2014, 1994 nut and seed sample were analysed and 4.0% were non-compliant with EU MLs (not specified which mycotoxins). In total, 59 peanut samples had aflatoxin concentrations above the EU limit of 2 µ/kg and were refused to be imported (NVWA, 2014). 2129 Samples of nuts and seeds were examined in 2015 and 5.4% were found to be non-compliant with EU limits (not specified which mycotoxins). 1310 Samples were peanuts samples of which 91 were refused due to high aflatoxin concentrations above EU MLs (NVWA, 2015). In 2016, non-compliance of 6.2% regarding aflatoxin concentrations in peanuts was slightly higher than in 2015. With regard to pistachio nuts, a non-compliance rate of 2.8% was found for aflatoxins upon imported pistachio nuts, while the non-compliance rate of pistachio nuts was 17.9% on the national market. (NVWA, 2016). The RIVM conducted a risk assessment of the dietary exposure to aflatoxin in young children (age 2 – 6) in the Netherlands, indicating that the consumption of nuts, peanut butter, maize, sunflower seeds and rice are the main contributors to the daily aflatoxin B1 exposure (RIVM, 2009). Surveillance programmes performed by the Food Standards Agency in the UK and by the Ministry for Primary Industries in New Zealand showed similar mycotoxin results as found in the Dutch monitoring program. In 2014, 7 out of 479 imported peanut consignments from China were rejected in the UK due to an aflatoxin concentration above the EU ML (Food Standards Agency, 2014), while in 2011, aflatoxin concentrations above the EU ML were found in 1 hazelnut/hazelnut products consignment (out of 415) from Turkey, 8 consignments including inter alia pistachios, figs and mixtures (out of 291) from Turkey, and 13 consignments out of 856 from China containing peanuts and peanut products (Food Standards Agency, 2013). In the monitoring program 2009-2010 in New Zealand, 305 samples of peanuts and peanuts products were investigated and 2 samples of each exceeded the national limit for aflatoxins, which was 15 µg/kg (MPI, 2010).

The mycotoxin citrinin, which has an analogy with OTA, can often be found together with OTA in food products, inter alia cereals and nuts. Citrinin seems to have an additional toxicological effect only in conjunction with OTA (RIVM, 2000).

With regard to *Alternaria* toxins (AME, AOH, TA, TEN) levels in food commodities, inter alia cereals, seeds and nuts, were investigated by (EFSA, 2016c). With regard to AME, tree nuts, in particular chestnut (mean concentration LB=16.8 µg/kg, UB=17.5 µg/kg), and oilseeds (sesame seeds) contained the highest concentrations. Chestnuts also contained relatively high mean concentrations of AOH (LB=43.9 µg/kg, UB=44.5 µg/kg) and TA (LB=793 µg/kg, UB=794 µg/kg).

In the past, fumonisins were found in Brazil nuts. However, more recent studies from 2013 and 2017 did not find any contamination (Cardoso et al., 2017).

3.4.5.1 Conclusion

Aflatoxin is the predominant mycotoxin found in nuts. In particular, EU ML exceedances in peanuts and pistachio nuts were reported frequently, but also in hazelnuts, walnuts, Brazil nuts and betel nuts. Furthermore, AOH, AME and TA were found at high concentrations in chestnuts (44.5 µg/kg, 17.5 µg/kg, 794 µg/kg UB, respectively), although information found is limited.

3.4.6 Plant toxins

Cyanogenic glycoside producing plants may contain compounds such as amygdalin or dhurrin, which can generate the toxin hydrocyanic acid (HCN). HCN may be found in a range of cyanogenic glycoside containing foods, such as bitter almonds. Concentrations of 4700 mg HCN/kg were reported in bitter almonds in New Zealand and a mean concentration of 4690 mg HCN/kg in the USA, whereas concentrations in almond products ranged from only <0.8 mg HCN/kg – 50 mg HCN/kg (WHO, 2012).

3.4.6.1 Conclusion

Cyanogenic glycosides may be present in bitter almonds and the formation of HCN thereof is highly toxic.

3.4.7 Processing contaminants

Levels of acrylamide were investigated in 48 samples of almonds, hazelnuts, peanuts, pine nuts, pistachios, and walnuts from several countries by De Paola et al. (2017). Acrylamide was only detected in peanut samples (10.0 – 42.9 μg/kg) because of the roasting process.
Schlörmann et al. (2015) investigated the influence of roasting conditions on inter alia the acrylamide content in in almonds, hazelnuts, macadamia nuts, pistachios and walnuts. Higher acrylamide concentrations were observed with increasing temperatures in almonds and pistachios. Concentrations in roasted almonds and pistachios ranged from 16 – 1220 μg/kg and 14 – 88 μg/kg, respectively. Compared with the recommended concentration of 1000 μg/kg for potato chips (Recommendation 2013/647), concentrations in almonds slightly exceeded that limit. The authors recommended applying low-middle temperatures in the roasting process for almonds.

3.4.7.1 Conclusion

Only limited information on processing contaminants in nuts was available. One study indicated high concentrations of acrylamide (> 1000 μg/kg) may occur during the roasting process of nuts. Currently, there are no legal limits or recommended concentrations for nuts.

3.4.8 Processing aids and additives

Member States are required to monitor the consumption of food additives. In Ireland, 10 brands of the product group 'Nuts, seeds, herbs and spices' were tested upon additives. 1 brand of this group contained additives in 2010 (FSAI, 2010), while in 2015, 9 brands out of 31 (29%) investigated brands in this product group contained additives (FSAI, 2015a). However, this category is a broad product group and information on which seeds were monitored and contained additives were not indicated in these reports (see section 3.3.8).

The FDA draft guidance document for industry on hazard analysis and risk-based preventive controls for human foods indicates the potential presence of chemical hazards in food commodities. Unapproved colours and additives are indicated to be a potential hazard in peanuts and tree nuts (FDA, n.d.).

3.4.8.1 Conclusion

The literature research and additional searches did not indicate a frequent presence of processing aids and additives in nuts.

3.4.9 Allergens

The literature study did not retrieve references on the presence of allergens in nut (products).
Regulation (EU) No 1169/2011 outlines the following nuts to be a possible substance causing allergies:

- *almonds (Amygdalus communis L.),*
- *hazelnuts (Corylus avellana),*
- *walnuts (Juglans regia),*
- *cashews (Anacardium occidentale),*
- *pecan nuts (Carya illinoinensis (Wangenh.) K. Koch),*

- *Brazil nuts (Bertholletia excelsa),*
- *pistachio nuts (Pistacia vera),*
- *macadamia or Queensland nuts (Macadamia ternifolia),*
- *and products thereof, except for nuts used for making alcoholic distillates including ethyl alcohol of agricultural origin;*

3.4.10 Other chemical hazards

The roasting of seeds was found to result in high concentrations of PAHs. Since nuts may also be roasted, an additional search was performed specifically for PAHs and nuts. An overview by Singh et al. (2016) indicated that PAHs may be formed during thermal processes like drying, smoking, baking, roasting, grilling and frying. As a result, they are found in a wide range of products, including nuts. Concentrations found in dried or processed nuts were, however, low (0.94-4.57 μg/kg PAH sum). A study by Lee et al. (2018) also showed that the PAH concentration in nuts (peanuts) was low (0.51 μg/kg PAH8) as well as the PAH intake via nuts (0.16% of total intake). Largest contribution to PAH intake was for coffee (71%) and cereals (12%) (Lee et al., 2018).

3.4.10.1 Conclusion

Roasting of nuts may result in PAH formation. Concentrations found were, however, low (0.51 μg/kg PAH8).

3.5 Intermediate list of chemical hazards

3.5.1 Intermediate list of chemical hazards in cereals

3.5.1.1 EU legal limits

EU legislation has established maximum limits for heavy metals and mycotoxins in cereals. An overview for unprocessed cereals – Regulation (EC) No 1881/2006- is indicated in Tables 1 and 2.

Table 1 *EU legal limits for cereals - Heavy metals – Regulation (EC) No 1881/2006.*

Heavy metal	Cereal type	Maximum limit (mg/kg)
Arsenic (inorganic)	Rice (polished or white)	0.2
	Rice (parboiled or husked)	0.25
	Rice (intended for production of infant food and young children)	0.1
Cadmium	Wheat	0.2
	Rice	0.2
	Other cereals	0.1
Lead	Cereals	0.2
Mercury	-	-

Table 2   *EU legal limits for cereals – Mycotoxins – Regulation (EC) No 1881/2006.*

Mycotoxins	Cereal type	Maximum limit (µg/kg)
Aflatoxin B1	Maize, rice	5
Aflatoxin B1	Other cereals	2
Aflatoxin B1+B2+ G1+G2	Maize, rice	10
Aflatoxin B1+B2+ G1+G2	Other cereals	4
	(Processed cereal-based foods for infants and young children)	
Ochratoxin A (OTA)	Cereals	5
	Wheat gluten (not sold directly to consumers)	8
Deoxynivalenol (DON)	Durum wheat, oats	1750
	Maize	1750
	Milling fractions of maize > 500 micronen	750
	Milling fraction of maize ≤ 500 micronen	1250
	Other cereals (excluding rice)	1250
	Cereals (excluding rice) for direct human consumption, cereal flour, brand and germ as end products marketed for direct human consumption	750
Zearalenone (ZEA)	Maize	350
	Maize intended for direct human consumption	100
	Milling fractions of maize > 500 micron	200
	Milling fractions of maize ≤ 500 micron	300
	Other cereals (excluding rice)	100
	Cereals (excluding rice and maize) for direct human consumption, cereal flour, brand and germ as end products marketed for direct human consumption	75
Fumonisins B1+B2	Maize	4000
	Maize intended for direct human consumption	1000
	Milling fractions of maize > 500	1400
	Milling fractions of maize ≤ 500	2000
T-2 and HT-2 toxin	Cereals (excluding rice)	Not established yet For indicative levels see Table 3
Citrinin	-	-
Ergot alkaloids	Cereals (excluding maize and rice)	Not established yet
	Cereal milling products (excluding maize and rice)	Not established yet

Commission Recommendation 2013/165/EU outlines indicative levels for T-2 and HT-2 toxins in cereals and cereals based products. These levels do not constitute a legal maximum limit, but are based on occurrence data outlined in the EFSA database. Concentrations found above these indicative levels should result in an investigation as to which factors lead to the presence of these toxins in these commodities. The following table outlines these indicative levels for unprocessed cereals.

Table 3 *Indicative levels for T-2 and HT-2 toxins in unprocessed cereals - Commission Recommendation 2013/165/EU.*

Cereal type	Indicative levels (Sum of T-2 and HT-2 toxin) in µg/kg
Unprocessed cereals	
Barley and maize	200
Oats	1000
Wheat, rye and other cereals	100
Cereal grains for direct human consumption	
Oats	200
Maize	100
Other cereals	50

Regarding ergot alkaloids, the European Commission encouraged Member States and professional stakeholders' associations to monitor these mycotoxins in cereals and cereal products and to report the findings to EFSA by end of September 2016. By July 2017 the legislator planned to establish maximum limits for ergot alkaloids in cereal and cereal products; however, up to now this has not happened, yet (Regulation (EC) No 1881/2006; Commission Recommendation 2012/154/EU).

Besides the established MLs for heavy metals and mycotoxins, Regulation (EC) No 1881/2006 outlines maximum limits for 3-MCPD, PCBs, PAHs and tropane alkaloids, but not for unprocessed cereals. In processed products, maximum limits for PAHs are set for processed cereal-based foods and baby foods for infants and young children (Benzoapyrene; and sum of benzoapyrene, benzoanthracene, benzofluoranthene and chrysene: 1,0 µg/kg) and for tropane alkaloids in processed cereal-based foods and baby food for infants and young children, consisting of millet, sorghum or buckwheat (Atropine: 1,0 µg/kg; Scopolamine: 1,0 µg/kg). Melamine maximum limits are set for food in general at 2.5 mg/kg.

For acrylamide, Commission Recommendation (2013/647/EC) outlines indicative values on acrylamide levels in food (inter alia several cereal-based products). These indicative levels do not constitute a safety threshold, but merely express that an investigation by official controls may be needed if levels are exceeded, which has to be evaluated case by case. In 2017, the European Commission established with Commission Regulation (EU) 2017/2158 mitigation measures for the reduction of acrylamide in certain food (inter alia cereal-based food). Food business operators are required to keep acrylamide concentrations as low as reasonably achievable, below the in the annex established benchmark levels.

3.5.1.2 Prioritised hazards in the cereal supply chain

Based on the literature review performed, chemical hazards were selected that are frequently detected in cereals, found at concentrations above the EU legal limits or for which data gaps were identified. These were included on the intermediate list of chemical hazards for cereals. Both the long list and the intermediate list are indicated in Table 4 as well as the rationale for inclusion/exclusion on the intermediate list. Substances that were found at such concentrations that they potentially could cause human health concerns, but for which there was limited information, were included on the list of knowledge gaps.

Table 4 *Prioritised hazards in the cereal supply chain.*

Long list Hazards that might be present in cereals	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Heavy metals (section 3.2.1)			
Arsenic	Arsenic		Multiple papers indicate presence and ML exceedances in rice
Cadmium	Cadmium		Levels > EU ML have been found in rice
Chromium	-		Only 1 paper from Iran reported an exceedance of the national limit
Cobalt	-		No exceedances of legal limits were reported
Copper	-		No exceedances of legal limits were reported
Lead	Lead		Multiple papers indicate presence and ML exceedances in rice
Manganese	-		No exceedances of legal limits were reported
Methylmercury	-	Methylmercury	May be a potential upcoming hazard in rice cultivated in polluted areas. Since there is no information on the occurrence of methylmercury in cereals on the market, this substance is identified as knowledge gap.
Nickel	-	Nickel	Nickel dietary intake is of concern and cereals are a main contributor to the dietary nickel intake (EFSA, 2015d). However, occurrence data are limited, so nickel is identified as knowledge gap.
Selenium	-		No exceedances of legal limits were reported
Zinc	-		No exceedances of legal limits were reported
Persistent organic pollutants			
Polychlorinated biphenyls (PCBs)	-		Cereals contain low concentrations of PCBs. Intake of PCBs is primarily via animal products.
Polybrominated diphenyl ethers (PBDEs)	-		Only 1 paper from Pakistan reported the presence of PBDEs in cereals. Only low concentrations were found (0.30-1.43 ng/g in wheat and 0.06-45 ng/g in rice)
Dechloran plus (DP)	-		Only 1 paper from Pakistan reported the presence of DPs in cereals. Only low concentrations were found (0.43 ng/g in wheat and N.D.-12 ng/g in rice)
Polychlorinated naphthalenes (PCNs)	-		Only 1 paper from Pakistan reported the presence of PCNs in cereals. Only low concentrations were found (3.28-36.7 ng/g in wheat and 2.36-109 ng/g in rice)
Organochlorine pesticides (OCPs)	-		Only 1 paper from Pakistan reported the presence of OCPs in cereals. Only low concentrations were found (4.37-67.4 ng/g in wheat and 2.60-27.3 ng/g in rice)
PAHs (section 3.2.3)	PAHs		Although levels are generally low, high concentrations may be found when cereals are grown in soil contaminated via industrial activities or traffic emissions. Moreover due to high consumption of cereals, they can cause human health risks ((EFSA, 2008; FAO, 2009))

Long list Hazards that might be present in cereals	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Radionuclides (section 3.2.4)			Radionuclides are present at low concentrations in cereals, which do not cause human health risks (intake is below the acceptable excess lifetime cancer risk (ELCR))
^{210}Pb	-		
^{210}Po	-		
^{40}K	-		
^{226}Ra	-		
^{228}Ra	-		
^{232}Th	-		
^{137}Cs	-		
^{238}U			
Pesticides (section 3.2.5)			
Overview of all pesticides found see section 3.2.4	2,4-D		Detected > EU MRL in wheat
	Alachlor		Residues detected in rice; Not approved in EU
	Ametryn		Residues detected in rice; Not approved in EU
	Bromide ion		Frequently found in wheat and rice. However, it should be noted that bromide ion also occurs naturally in plants and as such is not an unambiguous maker for the use of the pesticide methyl bromide
	Carbendazim		Detected > EU MRL in rice; Not approved in EU
	Chlormequat		Frequently found in wheat, rye and oats and > EU MRL in oats
	Chlorpropham		Detected > EU MRL in wheat
	Chlorpyrifos		Frequently found and > Chinese and EU MRL in rice and > EU MRL in wheat and oats
	Chlorpyrifos-methyl and its metabolite desmethyl-chlorpyrifos-methyl		Recommended by SCoFCAH to be voluntarily monitored by Member States in cereals
	Clothianidin		Detected > EU MRL in wheat; Not approved in EU
	Cyfluthrin		Detected > EU MRL in wheat (flour); Not approved in EU
	Deltamethrin		Frequently found in rice
	Diazinon		Frequently found in rice and > EU MRL in maize; Not approved in EU
	Dichlorodiphenyltrichloroethane (DDT)		Frequently found and > EU MRL in literature for p,p'-DDD (dichlorodiphenyldichloroethane) and o,p-DDD in rice; Not approved in EU
	Dichlorvos		Detected > Chinese MRL in rice and > EU MRL in oats, wheat and rye; Not approved in EU
	Dicofol		Frequently found and > EU MRL in rice; Not approved in EU

Long list Hazards that might be present in cereals	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
	Diflubenzuron		Detected > EU MRL in wheat
	Dimethenamid		Residues detected in rice; Not approved in EU
	Dimethoate		Detected > EU MRL in maize
	Diquat		Recommended by SCoFCAH to be voluntarily monitored by Member States in cereals; Not approved in EU
	Dithiocarbamate		Detected > EU MRL in wheat; Not approved in EU
	Fenitrothion		Detected > EU MRL in maize; Not approved in EU
	Fenthion		Detected > EU MRL in maize; Not approved in EU
	Glyphosate		Frequently found and > Canadian MRL in various cereals
	Guazatine		Recommended by SCoFCAH to be voluntarily monitored by Member States in cereals; Not approved in EU
	Hexachlorocyclohexane (γ-HCH)		Frequently found and > EU MRL in rice; Not approved in EU
	Hexaconazole		Detected > EU MRL in rye
	Imidacloprid		Detected > EU MRL in wheat
	Isocarbophos		Detected > EU MRL in maize; Not approved in EU
	Mepiquat		Frequently found in rye
	Methamidophos		Frequently found and > Chinese and EU MRL in rice; Not approved in EU
	Omethoate		Frequently found and > EU MRL in rice and maize; Not approved in EU
	Parathion		Frequently found and > EU MRL in rice and maize; Not approved in EU
	Parathion-methyl		Frequently found and > EU MRL in rice and maize; Not approved in EU
	Permethrin		Detected > EU MRL in wheat flour and rye; Not approved in EU
	Phorate		Detected > EU MRL in maize; Not approved in EU
	Phosphane and phosphide salts		Recommended by SCoFCAH to be voluntarily monitored by Member States in cereals
	Pirimiphos-methyl		Frequently found in wheat, rice and rye and detected > EU MRL in rye
	Prochloraz		Recommended by SCoFCAH to be voluntarily monitored by Member States in cereals
	Pyrethrins		Recommended by SCoFCAH to be voluntarily monitored by Member States in cereals
	Quinalphos		Detected > EU MRL in maize; Not approved in EU
	Quintozene		Frequently found in rice and > EU MRL; Not approved in EU
	Triazophos		Frequently found and > Chinese and EU MRL in rice; Not approved in EU

Long list Hazards that might be present in cereals	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Mycotoxins (section 3.2.6)			
Aflatoxin	Aflatoxin		Frequently present in cereals and exceedances of EU MLs found, primarily in rice and maize
Alternaria toxins (alternariol (AOH), alternariol monomethyl ether (AME), tenuazonic acid (TA), tentoxin (TEN) and altertoxins (ATX))		Tenuazonic acid (TA)	TA is found at high concentrations (> 100 µg/kg) in cereals and as a result has the highest contribution of dietary intake of *Alternaria* toxins especially for children with cereal-based food as the main source of intake. However, since there is limited information available, TA is identified as knowledge gap.
Beauvericin	-		Not frequently found and no health issues identified in literature
Citrinin	-		Only 1 paper indicated the presence of citrinin in rice from Pakistan and Iran. Therefore, there are no indications for a frequent presence in cereals.
DON	DON		Frequently present in cereals and exceedances of EU MLs found, primarily in wheat
Enniatins		Enniatins	High concentrations (up to 1100 µg/kg) were found in pasta and baby food. Since data are limited and no TDI have been established, this mycotoxin is identified as knowledge gap.
Ergot alkaloids	-		Only 1 paper reported on the prevalence of ergotalkaloids in cereals. Therefore, there are no indications for a frequent presence in cereals.
Fumonisins	Fumonisins		Frequently present in cereals and exceedances of EU MLs found, primarily in maize
Gliotoxin	-		Only 1 paper mentioned the possible presence of gliotoxin in maize and sorghum. Therefore, there are no indications for a frequent presence in cereals.
Nivalenol (NIV)	-		Only 1 paper examined NIV in rice. No legal limit was exceeded.
OTA	OTA		Frequently present in cereals and exceedances of EU MLs found, primarily in rice
Paxillin (PAX)	-		Only 1 paper reported the presence of PAX in rye and barley. Therefore, there are no indications for a frequent presence in cereals.
T-2/HT-2	T-2/HT-2		High concentrations above the EU indicative levels (Table 3) have been reported for oats.
ZEA	ZEA		Frequently present in cereals and exceedances of EU MLs found, primarily in maize and wheat
Plant toxins (section 3.2.7)			
Phytate and tannins	-		Naturally present anti-nutrients. Generally seen as not of concern for human health.
Pyrrolizidine alkaloids	-		Pyrrolizidine alkaloid concentrations were only reported in 1 reference with in general low concentrations (except for an outbreak in Afghanistan and Iran).
Tropane alkaloids (atropine, scopolamine)	Tropane alkaloids (atropine, scopolamine)		RASFF notifications were found for tropane alkaloids and the ARfD was exceeded with the maximum concentrations found.

Long list Hazards that might be present in cereals	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Processing contaminants (section 3.2.8)			Processing contaminants are not present in raw or milled cereals (the focus of this study). They may be formed during further processing although levels reported in bread are low.
Acrylamide	-		
Chloropropanols (3-MCPD)	-		
Furan derivatives	-		
Glycidamide	-		
Processing aids and additives (section 3.2.9)			
Leavening agents or acidity regulators (e.g. aluminosilicate, sodium aluminium phosphate acidic)	-		Although aluminium may be taken up via food additives in cereals, EFSA indicated no safety concern in cereals.
flour-treatment agents (e.g. chlorine and chlorine dioxide)	-		Chlorine and chlorine dioxide are forbidden to be used as flour-treatment agents. The literature review did not give indications that these are currently used.
dough conditioners (e.g. ascorbic acid, azodicarbonamide, potassium bromate)	-		Azodicarbonamide and potassium bromate are forbidden to be used as flour-treatment agents. The literature review did not give indications that these are currently used.
Cleaning agents and disinfectants (section 3.2)			
-	-		The literature review and additional searches did not retrieve information on cleaning agents and disinfectants. It can be concluded that health problems have not been reported in the past. Therefore, there is currently no reason to include cleaning agents and disinfectants on the intermediate list for cereals.
Allergens (section 3.2.10)			
Gluten from wheat, rye, barley and oats, allergen from buckwheat	-		Food allergen labelling is enforced to help sensitive consumers avoid adverse reactions as a result of the presence of gluten in cereals.
Other chemical hazards (section 3.2.11)			
Melamine	-		Melamine is a result of adulteration. Under normal circumstances melamine is not found in cereals.
Mineral oils (MOSH, MOAH)	-		Mineral oils can be present in all food products packaged in recycled cardboard containing residues of printing inks. As such it is not a specific hazard for cereal products.
Perchlorate	-		Although there is limited information on the presence of perchlorate in food, perchlorate concentrations in grain products are shown to be low compared to other products.
Plasticiser (DEHP, PAE)	-		The use of plasticiser in practice is limited and higher concentrations are usually found in fatty food as compared to cereals.

3.5.2 Intermediate list of chemical hazards in seeds

3.5.2.1 EU legal limits

The following table indicates the EU legal limits for chemical hazards in seeds as indicated in Regulation (EC) 1881/2006. MRLs for pesticides can be found in Regulation (EC) 396/2005.

Table 5 *EU legal limits for oilseeds - Regulation (EC) No 1881/2006.*

Mycotoxins	Commodity	Maximum limit (µg/kg)
Aflatoxin B1	**Oilseeds**[1] subject to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs	8
Aflatoxin B1	Oilseeds and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs	2
Aflatoxin B1+B2+ G1+G2	Oilseeds subject to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs	15
Aflatoxin B1+B2+ G1+G2	Oilseeds and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs	4

3.5.2.2 Prioritised hazards in the seed supply chain

Based on the literature study performed and described in section 3.3 both a long list of chemical hazards that may occur in the seed supply chain and an intermediate list of chemical hazards that are frequently found in seeds, found above the legal limits or for which knowledge gaps were identified is established and indicated in Table 6.

[1] Oilseeds falling under codes CN 1201, 1202, 1203, 1204, 1205, 1206, 1207 and derived products CN 1208; melon seeds fall under code ex 1207 99.
1201: soy beans; 1202: groundnuts; 1203: copra; 1204: linseed; 1205: rape seed; 1206: sunflower seeds; 1207: Other oils seeds (palm nuts and kernels, cotton seeds, castor oilseeds, sesamum seeds, mustard seeds, safflower seeds, melon seeds, poppy seeds, other seeds); 1208: flours or meals of oils seeds.

Table 6 *Prioritised hazard in the seed supply chain*

Long list Hazards that might be present in seeds	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Heavy metals (section 3.3.1)			Only one Chinese study found elevated levels of heavy metals in sunflower seeds for a specific region using sewage irrigation. These results were not confirmed in other studies.
Arsenic	-		
Cadmium	-		
Chromium	-		
Copper	-		
Lead	-		
Mercury	-		
Nickel		Nickel	Nickel dietary intake is of concern and oilseeds are a main contributor to the dietary nickel intake (EFSA, 2015d). However, no occurrence data in oilseeds were found, so nickel is identified as knowledge gap.
Zinc	-		
Persistent organic pollutants (section 3.3.2)	**Persistent organic pollutants (section 3.3.2)**		
Non-dioxin like PCBs	-		Limited information found, but PCBs are not known to accumulate in oilseeds.
PBDE			Limited information found, but PBDEs are not known to accumulate in oilseeds.
OCPs	-		Only one experimental study was found for a specific contaminated region in Nicaragua. No further information was found on the presence of OCPs in oilseeds.
Pesticides (section 3.3.3)			
Pesticides	Pesticides		Literature indicates that pesticide residues may be present in seeds, in particular quinoa and chia seeds. Active substances in most cases were not specified. Dutch monitoring data should be used to identify relevant pesticides for seeds consumed in the Netherlands.
Mycotoxins (section 3.3.4)			
Aflatoxins	Aflatoxins		Most commonly found mycotoxins in seeds with ML exceedances reported in literature.

Long list Hazards that might be present in seeds	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Alternaria toxins (altenuene, alternariol (AOH), alternariol monomethyl ether (AME), tenuazonic acid (TA), tentoxin (TEN))		AOH, AME, TA, TEN	Detected in sunflower seed and linseed. However, information is limited and as such these substances are indicated as knowledge gap.
Citrinin	-		Only 1 paper reported the possible presence of citrinin in sunflower seeds. Therefore, there are no indications for a frequent presence in seeds.
DON	DON		Multiple papers report the presence of DON in oilseeds
OTA	OTA		Multiple papers report the presence of OTA in oilseeds.
T-2/HT-2 toxin	T-2/HT-2 toxin		According to the review by Bhat and Reddy (2017), T-2 toxin is frequently found in safflower seeds. Since T-2 and HT-2 toxins often occur together, the latter was added to the list
ZEA	ZEA		ZEA was detected in 88% of sesame seed samples (Ezekiel et al., 2012).
Plant toxins (section 3.3.5)			
Cyanogenic glycosides	Cyanogenic glycosides		HCN, with a high toxicity, can be formed after hydrolysis of cyanogenic glycosides. Cyanogenic glycosides may be present in flaxseed/linseed.
Opium alkaloids	Opium alkaloids		A survey by López et al. (2018) showed that 60% of the poppy seed samples exceeded the German guidance value of 4 mg/kg for morphine.
THC	-		Only trace amounts of THC may be present in hemp seeds, which have no psychoactive effect.
Cannabidiol (CBD)	-		Only trace amounts of cannabidiol (CBD) may be present in hemp seeds, which have no psychoactive effect.
Radionuclides			
-	-		The literature review and additional searches did not retrieve information on radionuclides. It can be concluded that health problems have not been reported in the past. Therefore, there is currently no reason to include radionuclides on the intermediate list for seeds.

Long list Hazards that might be present in seeds	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Rationale for inclusion/exclusion on intermediate list or list of knowledge gaps
Processing contaminants (section 3.3.6)			
Acrylamide	-		One experimental study found elevated levels of acrylamide after adding chia flour to wheat based products. According to Becalski et al. (2003) concentrations in sunflower seeds were low.
Furfural	-		One experimental study found elevated levels of furfural after adding chia flour to wheat based products.
Hydroxymethylfurfural (HMF)	-		One experimental study found elevated levels of HMF after adding chia flour to wheat based products.
Processing aids and additives (section 3.3.7)			
-	-		The literature research and additional searches did not indicate a frequent presence of processing aids and additives in seeds. It can be concluded that health problems have not occurred in the past and that these compounds are thus not relevant hazard groups in seeds.
Cleaning agents and disinfectants			
-	-		The literature review and additional searches did not retrieve information on cleaning agents and disinfectants. It can be concluded that health problems have not been reported in the past. Therefore, there is currently no reason to include cleaning agents and disinfectants on the intermediate list for seeds.
Other chemical hazards (section 3.3.8)			
Fumigants (phosphine (PH_3), methyl bromide (MeBr) or 1,2-dichloroethane (DCE))		Fumigants (e.g. (DCE))	Some fumigants, such as DCE, have a long desorption time, which may result in elevated levels after transport and storage. DCE is not approved in the EU. Occurrence data in seeds were not found. As such, fumigants are seen as knowledge gap.
PAHs		PAHs	High concentrations may be formed during the roasting process. Since there is limited information, PAHs are seen as knowledge gap.

3.5.3 Intermediate list of chemical hazards in nuts

3.5.3.1 EU legal limits

The following table indicates the EU legal limits for chemical hazards in nuts as indicated in Regulation (EC) 1881/2006. MRLs for pesticides can be found in Regulation (EC) 396/2005.

Table 7 *EU legal limits for nuts – Regulation (EC) No 1881/2006.*

Mycotoxins	Commodity	Maximum limit (µg/kg)
Aflatoxin B1	**Groundnuts (peanuts)** subject to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs	8
Aflatoxin B1	Groundnuts (peanuts) and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs	2
Aflatoxin B1+B2+ G1+G2	Groundnuts (peanuts) subject to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs	15
Aflatoxin B1+B2+ G1+G2	Groundnuts (peanuts) and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs	4
Aflatoxin B1	**Almonds and pistachios** subject to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs	12
Aflatoxin B1	Almonds and pistachios, intended for direct human consumption or use as an ingredient in foodstuffs	8
Aflatoxin B1+B2+ G1+G2	Almonds and pistachios subject to sorting or other physical treatment, before human consumption or use as an ingredient in foodstuffs	15
Aflatoxin B1+B2+ G1+G2	Almonds and pistachios, intended for direct human consumption or use as an ingredient in foodstuffs	10
Aflatoxin B1	**Hazelnuts and Brazil nuts** subject to sorting or other physical treatments, before human consumption or use as an ingredient in foodstuffs	8
Aflatoxin B1	Hazelnuts and Brazil nuts, intended for direct human consumption or use as an ingredient in foodstuffs	5
Aflatoxin B1+B2+ G1+G2	Hazelnuts and Brazil nuts subject to sorting or other physical treatments, before human consumption or use as an ingredient in foodstuffs	15
Aflatoxin B1+B2+ G1+G2	Hazelnuts and Brazil nuts, intended for direct human consumption or use as an ingredient in foodstuffs	10
Aflatoxin B1	**Tree nuts**, other than almonds, pistachios, hazelnuts and Brazil nuts, subject to sorting or other physical treatments, before human consumption or use as an ingredient in foodstuffs	5
Aflatoxin B1	Tree nuts, other than almonds, pistachios, hazelnuts and Brazil nuts, and processed products thereof, intended for direct human consumption of use as an ingredient in foodstuffs	2
Aflatoxin B1+B2+ G1+G2	Tree nuts, other than almonds, pistachios, hazelnuts and Brazil nuts, subject to sorting or other physical treatments, before human consumption or use as an ingredient in foodstuffs	10
Aflatoxin B1+B2+ G1+G2	Tree nuts, other than almonds, pistachios, hazelnuts and Brazil nuts, and processed products thereof, intended for direct human consumption of use as an ingredient in foodstuffs	4

Nuts (peanuts and hazelnuts) are subject to an increased level of official controls upon import into the EU. Several countries are outlined for which the aflatoxin content in these nuts have to be monitored at a prescribed frequency (Regulation (EC) No 669/2009). The commodities and countries indicated in this regulation are updated/changed on a regular basis (ca. 4 times a year).

Besides that, Regulation (EU) No 844/2014 also prescribes increased levels of certain commodities for aflatoxins (Brazil nut, peanuts, hazelnuts, pistachios) from certain countries.

3.5.3.2 Prioritised hazards in the nuts supply chain

Based on the literature study performed and described in section 3.4, both a long list of chemical hazards that may occur in the seed supply chain and an intermediate list of chemical hazards that are frequently found in seeds, found above the legal limits or for which knowledge gaps were identified is established and indicated in Table 8.

Table 8 *Prioritised hazards in the nuts supply chain.*

Long list **Hazards that might be present in nuts**	**Intermediate list** **hazards that are frequently found and/or above legal limits**	**Knowledge gaps**	**Reasoning of inclusion on intermediate list or on the list of knowledge gaps**
Heavy metals (section 3.4.1)			
Barium	-		Barium is not bioavailable (Cardoso et al., 2017)
Cadmium	-		Although one Chinese study found concentrations above the national limit of 0.5 mg/kg, a global WHO survey showed that concentrations did not exceed 0.1 mg/kg
Chromium	-		EDI for hazelnuts was below the maximum recommended daily intake (Cevik et al., 2009).
Copper	-		EDI for hazelnuts was below the maximum recommended daily intake (Cevik et al., 2009).
Iron	-		EDI for hazelnuts was below the maximum recommended daily intake (Cevik et al., 2009).
Lead	-		Mean concentrations ranged between <LOD and 0.024 mg/kg. No legal limits are available. EDI for hazelnuts was below the maximum recommended daily intake (Cevik et al., 2009).
Manganese	-		EDI for hazelnuts was below the maximum recommended daily intake (Cevik et al., 2009).
Nickel		Nickel	Nickel dietary intake is of concern and nuts are a main contributor to the dietary nickel intake (EFSA, 2015d). However, occurrence data are limited, so nickel is identified as knowledge gap.
Strontium	-		Concentrations found did not reach toxic levels according to Cardoso et al. (2017)
Radium	-		Concentrations found did not reach toxic levels according to Cardoso et al. (2017)
Zinc	-		EDI for hazelnuts was below the maximum recommended daily intake (Cevik et al., 2009).
Persistent organic pollutants (section 3.4.2)			Limited information was found for POPs in nuts. Since POPs are generally more associated with food of animal origin these compounds were not included on the intermediate list
PBDE	-		
Non-dioxin like PCBs	-		

Long list Hazards that might be present in nuts	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Reasoning of inclusion on intermediate list or on the list of knowledge gaps
Radionuclides (section 3.4.3)			Only 1 study reported radionuclide levels in nuts. Concentrations found did not lead to human health concerns.
^{226}Ra	-		
^{232}Th	-		
^{40}K	-		
^{137}Cs	-		
Pesticides (section 3.4.4)			
Pesticides	Pesticides		Limited information was found, but pesticides are regularly used and residues were detected above the US legal limits. Dutch monitoring data should be used to identify relevant pesticides for nuts consumed in the Netherlands.
Mycotoxins (section 3.4.5)			
Aflatoxins	Aflatoxins		Frequently found and above EU ML in nuts, especially in peanuts and pistachio nuts.
Alternaria toxins (AME, AOH, TA, TEN)	-	AME, TA, AOH	AME, TA and AOH were found at high concentrations in chestnuts. Since only limited information was available, these substances were identified as knowledge gaps.
Citrinin	-		Citrinin levels are not reported in nuts.
Fumonisins	-		In the past, fumonisins were found in Brazil nuts. However, more recent studies from 2013 and 2017 did not find any contamination.
OTA	-		OTA is only occasionally found in nuts (pistachio) at low concentrations.
Plant toxins (section 3.4.6)			
Cyanogenic glycosides	Cyanogenic glycosides		HCN, with a high toxicity, can be formed after hydrolysis of cyanogenic glycosides. Cyanogenic glycosides may be present in almonds
Processing contaminants (section 3.4.7)			
Acrylamide		Acrylamide	Acrylamide may be formed at high concentrations during the roasting process of nuts. Due to the limited information available, acrylamide is identified as knowledge gap.

Long list Hazards that might be present in nuts	Intermediate list hazards that are frequently found and/or above legal limits	Knowledge gaps	Reasoning of inclusion on intermediate list or on the list of knowledge gaps
Processing aids and additives (3.4.8)			
-	-		The literature review and additional searches did not reveal a frequent presence of processing aids and additives in nuts. It can be concluded that health problems have not occurred in the past and that these compounds are thus not relevant hazard groups in nuts.
Cleaning agents and disinfectants			
-	-		The literature review and additional searches did not retrieve information on cleaning agents and disinfectants. It can be concluded that health problems have not been reported in the past. Therefore, there is currently no reason to include cleaning agents and disinfectants on the intermediate list for nuts.
Allergens (section 3.4.9)			Food allergen labelling is enforced to help sensitive consumers avoid adverse reactions as a result of the presence of nuts in food products.
Almonds	-		
Hazelnuts	-		
Walnuts	-		
Cashews	-		
Pecan nuts	-		
Brazil nuts	-		
Pistachio nuts	-		
Macadamia	-		
Other chemical hazards (section 3.4.10)			
PAHs	-		Limited information was found on PAHs in nuts. Levels reported were low.

3.6 Information on toxicity of the prioritised chemical hazards

This section gives toxicological information (HBGVs) and the main contributions of the diet to the exposure of the chemical hazards of the intermediate list that can be used as input to establish a short list of chemical hazards. This information is summarised in Tables 9 to 11. Furthermore, EFSA opinions were consulted for the prioritised chemical hazards (except for pesticides as these were too many and these EFSA opinions do not give information on the contribution of cereals, seeds and nuts to the dietary intake) and summarised in the sections 3.6.3 to 3.6.20 (in some cases, sections from previous reports were taken over (Hoek-van den Hil and van Asselt, 2019; Nijkamp et al., 2019). EFSA opinions were available for arsenic, cadmium, lead, mercury, PAHs, DON, ZEA, aflatoxins, tenuazonic acid, OTA, enniatins, fumonisins, T-2 and HT-2 toxins, *Alternaria* toxins, tropane alkaloids, hydrocyanic acid and acrylamide. EFSA also published a report on opium alkaloids, which is already described in section 3.3.5. No EFSA opinion was available on the fumigant DCE.
The information described in this section can be used as input to obtain a short list of chemical hazards that are relevant for cereals, seeds and nuts based on both the probability of occurrence and the severity of the hazards. Additionally, concentration levels of the hazards are needed for such an evaluation. The Dutch monitoring data as gathered in the KAP database can be used for this purpose as well as the Excel files that were drafted based on the literature review described in this study. These Excel files were handed to the NVWA-BuRO as complementary documents to this report.

3.6.1 Health based guidance values and legal limits for chemical hazards relevant for cereals

For cereals, the following chemical hazards were included on the intermediate list: the heavy metals arsenic, cadmium, lead and methylmercury, PAHs, 41 pesticides, the mycotoxins aflatoxins, DON, fumonisins, OTA, enniatins, tenuazonic acid (TA), T-2/HT-2 and ZEA and the plant toxins atropine and scopolamine. Information on the pesticides can be found in Table 9. Information on the other chemical hazards is included in Table 10.

Table 9 *Health based guidance values of the pesticides from the intermediate list for cereals.*

Pesticides	Most relevant cereals	EU MRLs [a] (mg/kg)	ADI[a] (mg/kg bw/day)	ARfD[a] (mg/kg bw)	EU approval[a]
2,4-D	Wheat	2.0	0.02	0.3	Approved
Alachlor	Rice	0.01*	N	N	Not approved
Ametryn	Rice	0.01	N	N	Not approved
Methyl bromide (Bromide ion)	Wheat and rice	50.0, 50.0, respectively	0.001	0.003	Not approved
Carbendazim	Rice	0.1	0.02	0.02	Not approved
Chlormequat	Wheat, rye, oats	7.0, 8.0, 15.0, respectively	0.04	0.09	Approved
Chlorpropham	Wheat	0.01*	0.05	0.5	Approved
Chlorpyrifos	Rice, wheat, oats	0.5, 0.5, 0.6, respectively	0.001	0.005	Approved
Chlorpyrifos-methyl	-[b]	0.05 – 6.0	0.01	0.1	Approved
Clothianidin	Wheat	0.02*	0.097	0.1	Not approved
Cyfluthrin	Wheat	0.04	0.003	0.02	Not approved
DDT	Rice	0.05*	0.01	N	Not approved
Deltamethrin	Rice	1.0	0.01	0.01	Approved

Pesticides	Most relevant cereals	EU MRLs [a] (mg/kg)	ADI[a] (mg/kg bw/day)	ARfD[a] (mg/kg bw)	EU approval[a]
Diazinon	Rice, maize	0.01*, 0.01*, respectively	0.0002	0.025	Not approved
Dichlorvos	Rice, oats, wheat, rye	0.01*, 0.01*,0.01*, respectively	0.00008	0.002	Not approved
Dicofol	Rice	0.02*	0.002	0.15	Not approved
Diflubenzuron	Wheat	0.1	0.1	N	Approved
Dimethenamid	Rice	0.01*	0.02	0.25	Not approved
Dimethoate	Maize	0.01*	0.001	0.01	Approved
Diquat	-[b]	0.02 – 2.0	0.002	N	Not approved
Dithiocarbamate	Wheat	0.01	N	N	Not approved
Fenitrothion	Maize	0.05*	0.005	0.013	Not approved
Fenthion	Maize	0.01*	N	N	Not approved
Glyphosate	-[b]	0.1 – 20	0.5	0.5	Approved
Guazatine	-[b]	0.05	0.0048	0.04	Not approved
Hexachlorocyclohexane	Rice	0.01*	N	N	Not approved
Hexaconazole	Rye	0.01*	0.005	N	Not approved
Imidacloprid	Wheat	0.1	0.06	0.08	Approved
Isocarbophos	Maize	0.01	N	N	Not approved
Mepiquat	Rye	3.0	0.2	0.3	Approved
Methamidophos	Rice	0.01*	0.001	0.003	Not approved
Omethoate	Rice, maize	0.01*, 0.01*, respectively	0.0003	0.002	Not approved
Parathion	Rice, maize	0.05*, 0.05*, respectively	0.0006	0.005	Not approved
Parathion-methyl	Rice, maize	0.02*, 0.02*, respectively	N	N	Not approved
Permethrin	Wheat	0.05*	N	N	Not approved
Phorate	Maize	0.05	0.0007	0.003	Not approved
Phosphane and phosphide salts	-[b]	0.01 – 0.7	0.011	0.019	Approved
Pirimiphos-methyl	Wheat, rice, rye	5.0, 0.5, respectively	0.004	0.15	Approved
Prochloraz	-[b]	0.05 – 1.0	0.01	0.025	Approved
Pyrethrins	-[b]	3.0	0.04	0.2	Approved
Quinalphos	Maize	0.01*	N	N	Not approved
Quintozene	Rice	0.02*	0.01	N	Not approved
Triazophos	Rice	0.02*	0.001	0.001	Not approved

[a] MRLs, ADIs, ARfD, and information about the approval in the EU are extracted from the EU pesticide database (http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/)

[b] Not clear from the literature which cereal is most relevant for this pesticide

* Indicates lower limit of analytical determination

Table 10 *Health based guidance values of the non-pesticides on the intermediate list or identified as knowledge gap for cereals.*

Chemical hazard	Most relevant cereals	EU ML[a] (mg/kg)	Chronic effect (µg/kg bw/day)	Acute effect (µg/kg bw)
Arsenic	Rice	Rice: 0.1 – 0.25	0.3-8 ($BMDL_{01}$, (EFSA, 2014b))	N[b]
Cadmium	Rice	Wheat, rice: 0.2; other cereals: 0.1	2.5 µg/kg bw (TWI, (EFSA, 2009b))	N[b]
Lead	Rice	Cereals: 0.2	0.5 (dietary intake value corresponding to $BMDL_{01}$ (EFSA, 2012b)	N[b]
Methylmercury	Rice	-[c]	4 µg/kg bw (TWI, (EFSA, 2012c)	N[b]
Nickel	Cereals and nuts in general	- [c]	2.8 µg/kg bw (TDI, (EFSA, 2015d)	1.1 ($BMDL_{10)}$ (EFSA, 2015d)
PAHs	Cereals in general	Not for unprocessed cereals	Benzoapyrene: 0.07 ($BMDL_{10}$) PAH2: 0.17 ($BMDL_{10}$) PAH4: 0.34 ($BMDL_{10}$) PAH8: 0.49 ($BMDL_{10}$) (EFSA, 2008)	N
Aflatoxin	Maize, rice	See Table 2	N[b], genotoxic carcinogen	N[b]
DON	Wheat	See Table 2	1 ug/kg bw per day (EFSA, 2017c)	8 ug/kg bw per eating occasion (EFSA, 2017c)
Enniatins	Wheat	-[c]	N	N
Fumonisins	Maize	See Table 2	1 ug/kg bw per day (EFSA, 2018b)	N
OTA	Rice	See Table 2	0.12 (TWI, (EFSA, 2006))	N[b]
T-2/HT-2	Oats	-[c]	0.02 group TDI for T2 and HT2 (EFSA, 2017b)	0.3 group ARfD (EFSA, 2017b)
Tenuazonic acid (TA)	Cereals in general	-[c]	N	N
ZEA	Maize, wheat	See Table 2	0.25 ug/kg bw (EFSA, 2011b)	N
Tropane alkaloids (atropine, scopolamine)	Cereals in general	Not for unprocessed cereals	N	A group ARfD for (-)-hyoscyamine and (-)-scopolamine: 16 ng/kg bw (EFSA, 2018d)

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

[b] N, no information available

[c] No EU MLs available for this substance in cereals

3.6.2 Health based guidance values and legal limits for seeds and nuts

Both for seeds and nuts, aflatoxins and cyanogenic glycosides were included on the intermediate list and nickel was identified as knowledge gap. The health based guidance values of these chemical hazards can be found in Table 11. Pesticides were also seen as relevant for seeds and nuts, but the relevant pesticides for the Dutch consumer could not be established based on the literature review. It is recommended to use the Dutch monitoring data to identify pesticides that are frequently found in seeds and nuts and pesticides that are found above the MRLs.
For seeds, additionally, opium alkaloids and the mycotoxins DON, OTA, T-2/HT-2 toxin and ZEA were included on the intermediate list. Fumigants and PAHs as well as the mycotoxins *Alternaria* toxins (AOH, AME, TA and TEN) were identified as knowledge gaps. For nuts, additionally, acrylamide was identified as knowledge gap for roasted nuts. Information on these chemical hazards, if available, is

included in Table 11. Legal limits, if available, can be found in sections 3.5.1.1, 3.5.2.1 and 3.5.3.1 for cereals, seeds and nuts, respectively.

Table 11 *Health based guidance values of the non-pesticides from the intermediate list for seeds and nuts.*

Chemical hazard	Most relevant seeds and nuts	Chronic effect (µg/kg bw/day)	Accute effect (µg/kg bw)
Nickel	Seeds: oilseeds in general Nuts: nuts in general	2.8 µg/kg bw (TDI, (EFSA, 2015d)	1.1 ($BMDL_{10)}$ (EFSA, 2015d)
Aflatoxins	Seeds: several seeds Nuts: peanuts, pistachio nuts	N[b], genotoxic carcinogen	N[b]
Alternaria toxins (AOH, AME, TA, TEN)	Seeds: oilseeds in general Nuts: chestnuts	TA and TEN: TTC is 1.5 AOH and AME: TTC is 0.0025 (EFSA, 2011a)	N
DON	Seeds: oilseeds in general	1 ug/kg bw per day (EFSA, 2017c)	8 ug/kg bw per eating occasion (EFSA, 2017c)
OTA	Seeds: oilseeds in general	0.12 (TWI, (EFSA, 2006))	N[b]
T-2/HT-2 toxin	Seeds: safflower seeds	0.02 group TDI for T-2 and HT-2 (EFSA, 2017b)	0.3 group ARfD (EFSA, 2017b)
ZEA	Seeds: sesame seed	0.25 ug/kg bw (EFSA, 2011b)	N
Hydrocyanic acid	Seeds: flaxseed/linseed Nuts: almonds	N	20 (ARfD, (EFSA, 2019)
Opium alkaloids	Seeds: poppy seeds	N	10 ug morphine equivalents/kg bw (EFSA, 2018g)
PAHs	Seeds: roasted seeds	Benzoapyrene: 0.07 ($BMDL_{10}$) PAH2: 0.17 ($BMDL_{10}$) PAH4: 0.34 ($BMDL_{10}$) PAH8: 0.49 ($BMDL_{10}$) (EFSA, 2008)	N
Acrylamide	Nuts: roasted nuts	$BMDL_{10:}$ 0.43 mg/kg bw per day for peripheral neuropathy and 0.17 mg/kg bw per day for neoplastic effects (EFSA, 2015c)	N

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

[b] N, no information available

[c] No EU MLs available for this substance in seeds/nuts

3.6.3 Information on the toxicity of substances relevant for cereals, seeds and nuts

3.6.3.1 Arsenic

Food and drinking water are the major exposure routes of arsenic. Inorganic arsenic is more toxic than organic arsenic. Arsenic and inorganic arsenic are classified as carcinogenic to humans (group 1) by the International Agency for Research on Cancer (IARC). The previously set PTWI of 15 µg/kg bw was considered inappropriate by JECFA and EFSA. Therefore, a $BMDL_{01}$ between 0.3-8 µg/kg bw/day for an increased risk of lung, skin and bladder cancer, and skin lesions was established by EFSA. The food groups mainly contributing to the dietary exposure of inorganic arsenic are grain based processed products (wheat bread and rolls), with the exception of the youngest population. Other important contributors are rice, milk and dairy products and drinking water. For infants and toddlers, milk and dairy products were the main contributors to dietary exposure of inorganic arsenic (EFSA, 2014b).

3.6.3.2 Cadmium

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

Based on detailed individual food consumption data, a better estimation of dietary intake of cadmium has been made by EFSA in 2012 (EFSA, 2012a). Foods that are consumed in larger quantities have the greatest impact on the dietary cadmium 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%). For the more detailed food categories, across age groups, potatoes (13.2%), bread and rolls 11.7%) and fine bakery wares (5.1%), chocolate products (4.3%), leafy vegetables (3.9%) and water molluscs (3.2%) contributed the most to the dietary cadmium exposure.

An average weekly dietary exposure of cadmium was estimated at 2.04 ug/kg bw per week and a high exposure (P95) was estimated at 3.66 ug/kg bw per week. This review confirmed that 95th percentile exposure could exceed the TWI. There is a limited margin between the dietary exposure and the TWI. Although the risk for adverse effects on kidney function is low, EFSA concluded that the current exposure to cadmium should be reduced at population level (EFSA, 2012a).

3.6.3.3 Lead

The major exposure route to lead is via food. Lead can accumulate in the skeleton of the human body, the half-life time in bone is 10-30 years. In blood, the half-life of lead is approximately 30 days. The main target organ of lead toxicity is the central nervous system. Neurotoxicity associated with lead can affect the short-term verbal memory, fine motor skills, information processing and can cause psychiatric symptoms. In 2010, EFSA established a new health based guidance value, the previous established PTWI was concluded to be no longer appropriate. Therefore, 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 broad food categories contributing the most to lead exposure are: grains and grain products (16.1%), milk and dairy products (10.4%), non-alcoholic beverages (10.2%) and vegetables and vegetable products (8.4%).

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

3.6.3.4 Mercury

Methylmercury is the most common form of organic mercury in the food chain, which is present in fish and seafood. In other foods, mercury is present as inorganic mercury. The critical target organ for toxicity of inorganic mercury is the kidney. In line with JECFA, EFSA established a TWI of 4 μg/kg bw for inorganic mercury and a TWI of 1.6 μg/kg bw for methylmercury.

The highest mean total mercury concentrations were detected in fish and other seafood, wild mushrooms and dietary supplements. Major contributors to dietary intake of inorganic mercury are the food groups fish and other seafood, non-alcoholic beverages and composite food. Grain products are also mentioned as contributors to the dietary exposure of inorganic mercury.

The estimated mean exposures to inorganic mercury and organic mercury did not exceed the respective TWIs. However, high consumers of fish meat may exceed the TWI (EFSA, 2012c).

3.6.3.5 Nickel

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

The TDI of nickel is 2.8 μg/kg bw/day. The mean chronic exposure to Ni ranged from 2 to 13.1 μg/kg bw/day. There are no maximum limits for nickel in food, only for drinking water (20 μg/L). High mean concentrations of nickel were reported for legumes, nuts and oilseeds (2 mg/kg), certain type of chocolate products (3.8 mg/kg) and cocoa beans and cocoa products (9.5 mg/kg). Overall, the main contributors to the dietary exposure to nickel are grain and grain-based products, non-alcoholic beverages, sugar and confectionery, legumes, nuts and oilseeds, and vegetables and vegetable product. The influence of grain and grain-based products is most probably due to the high consumption of these products (EFSA, 2015d).

3.6.3.6 PAHs

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

EFSA used the margin of exposure (MOE) approach considering $BMDL_{10}$ values to evaluate potential concerns for human health. For high end consumers (P97.5) only, the margin of exposure (MOE) was around 10,000, which indicates a potential concern for human health (EFSA, 2008). 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) (EFSA, 2008).

3.6.3.7 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 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 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, 2018c).

3.6.3.8 Deoxynivalenol (DON)

The mycotoxin DON is mainly produced by *Fusarium* fungi and occurs predominantly in cereal grains. A group-TDI, for the sum of DON, 3-Ac-DON, 15-Ac-DON and DON-3-glucoside, of 1 ug/kg bw per day was established based on reduced weight gain in mice. Epidemiological data has been used to calculate a group-ARfD of 8 ug/kg bw per eating occasion. Grain and grain-based products are the main sources for dietary exposure to DON, especially bread and rolls, fine bakery wares and pasta. Estimates of acute dietary exposure were below the ARfD, and did, therefore, not raise a human health concern. Estimates of chronic dietary exposures were above the TDI for infants, toddlers and other children and at high exposure (95^{th} percentile) in adolescents and adults, which indicates a potential human health concern (EFSA, 2017c).

3.6.3.9 Enniatins

The mycotoxins enniatins are produced by several *Fusarium* species. EFSA did not perform a risk assessment for beauvericin and enniatins, because of a lack of toxicity data. Grains and grain-based products are the main contributors to chronic dietary exposure of enniatins, especially bread and rolls, fine bakery wares and pasta. EFSA concluded that an acute exposure is not of human health concern. There might be a concern with respect to chronic exposure; however, no firm conclusion could be drawn (EFSA, 2014c).

3.6.3.10 Fumonisins

EFSA established a TDI for fumonisin B1 of 1 ug/kg bw per day. This was based on increased incidence of magalocytic hepatocytes in mice after chronic exposure. Based on toxicity, mode of action and structural similarities of fumonisin B2-6, they were included in a group TDI with B1. Several modified forms of fumonisins (other than B1-B6) can be found, however, these could not be included in the group TDI, because of a lack of data. Fumonisins are mainly found in maize and products thereof (EFSA, 2018b). No exposure assessment has been performed by EFSA for fumonisins in food.

3.6.3.11 Ochratoxin A (OTA)

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

3.6.3.12 T2 and HT2 toxins

T-2 toxin (T2) and HT-2 toxin (HT2) are trichothecenes, which are *Fusarium* mycotoxins. In 2017, EFSA established an updated ARfD and TDI for T2 and HT2. The group ARfD was set at 0.3 ug for the sum of T2 and HT2 per kg bw per day and the group TDI at 0.02 ug/kg bw for T2 and HT2. Highest concentrations of T2 and HT2 were found in oat and oat-containing products. Highest mean chronic exposures were found in toddlers and infants (65 and 63 ng/kg bw per day). Chronic dietary exposure was 2-3 times higher in infant and young children compared to the adult population. Furthermore, the exposures estimated in 2017 were also higher than exposures estimated in 2011. The main contributors to the dietary exposure were grains and grain based products, specifically cereal flakes, fine bakery wares and for acute exposure also bread and rolls (EFSA, 2017b).

3.6.3.13 Zearalenone (ZEA)

The mycotoxin zearalenone (ZEA) is produced by several *Fusarium* species. The critical effect of ZEA is its estrogenic activity. A TDI for ZEA was established of 0.25 ug/kg bw, based on the estrogenic activity of ZEA and its metabolites.

Highest concentrations of ZEA were reported for wheat bran, corn and products thereof, such as corn flour and cornflakes. The main contributors to the dietary exposure of ZEA were grains and grain-based products (grains and grain milling products), bread and fine bakery wares. Vegetable oils also contributed to the dietary exposure.

The estimated chronic dietary exposures were below or in the region of the TDI for all age groups and were considered not to be of health concern. In a worst case scenario in which an individual consumes the same batch of breakfast cereals for two to four weeks, this could exceed the TDI (EFSA, 2011b).

3.6.3.14 *Alternaria* toxins

Alternaria toxins can be produced by fungi that can contaminate cereals, oilseeds and fruits and vegetables. The exposure of four *Alternaria* toxins was estimated by EFSA: AOH, AME, TA and TEN. A TTC approach has been used by EFSA to assess the level of concern for human health, because of very limited toxicity data available. For the non-genotoxic *Alternaria* toxins, TA and TEN, the TTC is 1,500 ng/kg bw per day and for the genotoxic *Alternaria* toxins, AOH and AME, the TTC value is 2.5 ng/kg bw per day. Among the four assessed *Alternaria* toxins the highest concentrations were reported for TA (100-1,614 ng/kg bw per day). Products with the highest concentrations varied between the different toxins. The highest mean values of tenuazonic acid were found in paprika powder (8.8 mg/kg) and in four samples of mulberries (5.7 mg/kg). For infants, the main contributor to the dietary exposure of tenuazonic acid was cereal-based food for infants and young children. In the adult population, fruiting vegetables (mainly tomatoes and tomato-based products) were the main contributors to the exposure. EFSA concluded that the dietary exposure to tenuazonic acid is unlikely to be of human health concern (EFSA, 2016c). For the four *Alternaria* toxins in general, relatively high concentrations were reported for tomato-based products, tree nuts, oilseeds, grains and fruits. The highest dietary exposure was found for toddlers and other children (EFSA, 2011a).

3.6.3.15 Tropane alkaloids

The most studied tropane alkaloids are (-)-hyoscyamine and (-)-scopolamine, the racemic mixture of (-)-hyoscyamine and (+)-hyoscyamine is called atropine. A group ARfD for (-)-hyoscyamine and (-)-scopolamine was established by EFSA at 16 ng/kg bw and it was concluded that the ARfD would also protect for effects of long term exposure.

High levels of atropine and scopolamine were found in tea and herbal infusions, cereal bars and spices. The main contributors to the dietary exposure were bread and cereal-based foods and tea and herbal infusions.

Dietary exposure was the highest for infants, toddlers and other children. The group ARfD was exceeded at the mean concentration for toddlers and other children, at P95 intake for all age categories (EFSA, 2018d).

3.6.3.16 Cyanogenic glycosides

When cyanogenic glycosides are present, hydrocyanic acid (HCN) may be formed after hydrolysis. Acute cyanide poisoning in humans includes amongst others headache, respiratory depression, metabolic acidosis, confusion, coma, and death. Some fatal poisoning cases have resulted from ingestion of amygdalin preparations, bitter almonds and cassava. Furthermore, neurological disorders have been associated with chronic exposure to cyanide, in populations where cassava is a main source of the diet. The ARfD was established at 20 ug/kg bw for cyanide. Food groups that highly contributed to the dietary exposure of cyanide are biscuits (cookies), juice or nectar and pastries and cakes. Estimated mean dietary exposure did not exceed the ARfD, the P95 intake could exceed the ARfD by 2.5 fold for children and adolescents. However, due to the assumptions made, the intake assessment for foods other than raw apricot kernels, bitter almonds and cassava roots is likely to be overestimated. Food processing is needed for some plants for detoxification of cyanogenic glycosides, for example for bitter cassava. During the process of manufacturing persipan, cyanogenic glycoside in apricot and bitter almond kernels are reduced to acceptable levels. Studies showed that cyanide is quickly released when chewing bitter almonds, although this was not the case for linseed and persipan. EFSA estimated that consumption of between 0.1 g and 1.4 g bitter almonds (based on highest concentrations reported in bitter almonds in the EFSA data base) results in an exceedance of the ARfD, which corresponds to an amount of less than half a small kernel for toddlers and 1 large kernel for adults, although uncertainty in the assessment is high. Chronic risks have not been assessed by EFSA, because a chronic health based guidance value could not be derived due to a lack of evidence from animal and human studies (EFSA, 2019).

3.6.3.17 Acrylamide

Acrylamide can be naturally formed during high temperature processing of starchy food, like frying, baking, roasting or industrial processing. Because data from human studies were inadequate, EFSA selected $BMDL_{10}$ values of 0.43 mg/kg bw per day for peripheral neuropathy in rats and 0.17 mg/kg bw per day for neoplastic effects in mice to perform a risk assessment.
Acrylamide is present in high amounts in solid coffee substitutes and coffee, and in fried potato products. The main contributors to dietary exposure of acrylamide were fried potato products (except potato crisps and snacks). Roasted nuts were not mentioned as major contributors to the dietary intake of acrylamide. Highest estimated total diet intakes were up to 1.9 ug/kg bw per day (mean) and 3.4 ug/kg bw per day (P95).
EFSA concluded that the dietary exposure to acrylamide is not of concern for the non-neoplastic effects. Acrylamide has not been demonstrated to be a human carcinogen, however, the MOE for neoplastic effects indicated a concern based on animal evidence, because the MOEs calculated are substantially lower than 10.000 (EFSA, 2015c).

4 Trends in cereals, seeds and nuts

This chapter presents the trends in the cereals, seeds and nuts supply chains that may influence the presence of food safety hazards. The information was obtained from consulting experts and from grey and scientific literature. In total, 7 experts cooperated in the research representing branch organisations, research institutes and feed companies.

Trends for the nuts, seeds and cereal chain are divided into six aspects: consumer trends, new product introductions, sustainability, production, trade, and legal and policy aspects. New developments in the nuts, seeds and cereal chain were assessed for the upcoming five years (2018-2023).

4.1 Consumer trends

Current general consumer trends are convenience (CBI - Ministry of Foreign Affairs, 2016b; CBI, 2016; Future Market Insights, 2017)(expert opinion), indulgence, the discovery of new flavours (CBI - Ministry of Foreign Affairs, 2016b), increased consumption of plant based foods (CBI - Ministry of Foreign Affairs, 2016b)(expert opinion), increased awareness of health aspects of products (CBI - Ministry of Foreign Affairs, 2016b; CBI, 2016)(expert opinion), increased consumption of gluten-free products and increased concern about sustainability (CBI - Ministry of Foreign Affairs, 2016b; FoodInspirationMagazine; Innova Market Insights, 2018d). Furthermore, local food production is endorsed, and experts also mention the trend towards raw products, but they don't expect this trend to solidify. Eye catching information on packages of grain, seed and nut products focus on fibre content, use of wholegrain, organic production and the absence of additives and preservatives (Innova database). Packaging becomes more and more important to grab the attention of the consumer (Dudkiewicz, 2018). Packages can be explicitly portion-sized or meant for sharing. Furthermore, the convenience of the package is also important: easy to transport, to open (and re-close), to access and to share (Information Resources, 2017; Dudkiewicz, 2018). The packaging also determines in how far the product is suitable for on-the-go eating, which is an increasing habit (Marr, 2016), and well suited for nuts (Siegner, 2018).

Urbanisation results in increasing ethnic mixing and mixed eating habits, seen in the appearance of amaranth cereal, buckwheat groats, corn tortillas, porridge, quinoa pilaf, rye crisp, sorghum beer, rice noodles and bread from all over the world (Jones and Sheats, 2016).

4.1.1 Health

Consumption of nuts and seeds is increasing because of the trends towards healthy and plant based foods (Marr, 2016; Future Market Insights, 2017; Green, 2017; Innova Market Insights, 2018a). The combination of high protein, high fibre and healthy fat in nuts and seeds is attracting interest of consumers (Trendblog). Especially almonds are very popular in the nut category (Trendblog; Green, 2017). Nuts are perceived as a healthy snack (Global Industry Analysts, 2018; Innova Market Insights, 2018c), and consequently the 'nutty & seedy snacks' category is increasing its market share (Innova Market Insights, 2018b) and is currently the third largest snack category (Woollard, 2018). Nuts, seeds and dried fruits are combined as snacks, but are also used as an ingredient in bakery products (Marr, 2016; Global Industry Analysts, 2018). The healthy image of nuts and seeds also causes the applications to expand from cereals and snacks to salads, main dishes and desserts.

The trend towards health in combination with the interest in so-called 'superfoods' has increased the use of chia seeds and quinoa. Whether superfoods solidify in the market remains to be seen. Some of the experts mention that the superfoods are over their fastest growth but still growing, others mention it as a hype.

Seeds (often chia seeds) are applied in products like yoghurt, cereals, energy bars, smoothies and jams (Resources). Next to the popularity of chia seeds, also hemp seeds (marketed as 'most nutritious seeds' (Innova Market Insights, 2018b)) are more frequently applied, and consumer interest is increasing towards other seeds (Innova Market Insights, 2017c). Between 2011 and 2016, the amount of product introductions containing chia seeds increased with 69%, quinoa with 47%, hemp seeds with 40% and pumpkin seeds with 39% (Innova Market Insights, 2017c).

The trend towards wholesome, unprocessed food leads to increased use of ancient grains such as teff, einkorn, amaranth, millet and spelt (Roesler, 2018). The health trend also promotes the introduction of more wholegrain products (Innova Market Insights, 2018e), although processed grains are still overconsumed and wholegrain is under-consumed (Jones and Sheats, 2016).

Commonly used grains in breakfast cereals are oats, rice, barley, wheat and corn (Research, 2018), but there is a trend towards whole grains and new grains (Trendblog). In the US, breakfast cereal consumption has declined for some time due to the more health consciousness of the consumers combined with the high sugar level and thus increasingly unhealthy image of many breakfast cereal products (Innova database). In the Netherlands, the sugar content of breakfast cereals has been topic of discussion (leading to e.g. the Albert Heijn showing sugar content of the cereals in a colour coding in the supermarkets), showing a similar trend to that in the US. Since breakfast cereals are less suited for on-the-go consumption, and are thus in conflict with the trend for convenience (international, 2016), there is an increase in bars and biscuits in the breakfast product range (Innova Market Insights, 2017b). High sugar breakfast cereals are shifting in the US towards an indulgent snack (Gaille, 2016), a trend that may be followed in the Netherlands. Breakfast cereals in general are reducing sugar and salt and increasing fibre content. Oats, with its EFSA approved health claim is a popular choice as well.

4.1.2 Plant based diets

Nuts and seeds fit very well in the more plant-based diets such as paleo, vegan and vegetarian (Marr, 2016; Dudkiewicz, 2018). A more plant-based diet also promotes more meat alternatives, where cereals, nuts and seeds are used as ingredients next to pulses (Innova Market Insights, 2018a). Vegan milks based on nuts, seeds and grains (rice, coconut, almond) are gaining importance (Marr, 2016; Innova Market Insights, 2017a), while nut butters (peanut, cashew nut) are a high protein ingredient in bakery, curries and sauces (Innova database). The increasing popularity of hummus as a vegan dip (CBI, 2016) automatically increases sesame consumption via one of the essential ingredients of hummus: the sesame paste called tahin (Marr, 2016).

4.1.3 Indulgence

Consumers are offered the choice for nuts and seeds containing products with new flavours (Trendblog; Innova Market Insights, 2018c; Woollard, 2018). Despite the introduction of new flavours, salt is still a popular flavouring. However, increasing introductions use spices, chili and garlic as well as liquorice, green tea, purple potato and wasabi (Innova Market Insights, 2018c). Consumers are also open to ethnic foods to find new ingredients and flavours, boosting markets of e.g. sesame seeds (used both in Asian cuisine in dim sum or sushi and in Mediterranean cuisine in tahini, halva and hummus) (CBI, 2016). Premium placed products in the nuts and seeds category are also increasing in market share, which meets the trend of indulgence (Innova Market Insights, 2018c).
Concurrent to the indulgence trend, locally sourced foods also become more popular. One of the experts interviewed indicated that local production may have lower quality (i.e. baking quality for wheat), and that sales directly at the farm have lower control measures, which may lead to increased presence of mycotoxins (expert opinion).

4.1.4 Gluten free

Another trend of the past years that is expected to continue growing in the next years is towards gluten free products. Although from a health perspective, this shift is unnecessary for most of the population, expensive and possibly even lower in nutrients such as fibre and folate, gluten-free and wheat-free products are gaining popularity (Jones and Sheats, 2016). This trend spurs the use of ancient grains, like quinoa and buckwheat (Innova database). Reduction of wheat also promotes gluten free and higher protein pastas, often accomplished with pulse ingredients (Innova database). Gluten free pizza crusts are another example, and are realized by a combination of sorghum, teff, amaranth and quinoa (Roesler, 2018).

The consumer trends mentioned in this section may have consequences for the presence of chemical hazards in cereals, seeds and nuts. The increased consumption of raw nuts and seeds may lead to an increased human exposure to chemical hazards such as mycotoxins. It is especially important to pay attention to a possible increased exposure to HCN via increased consumption of linseed and almond products.

4.2 Product introductions

New product introductions were collected from the Innova database (Innova database). For all three categories (nuts, seeds and grains), the number of new product introductions have increased since 2007 (see Figure 3) with the largest percentage growth for the seed category.

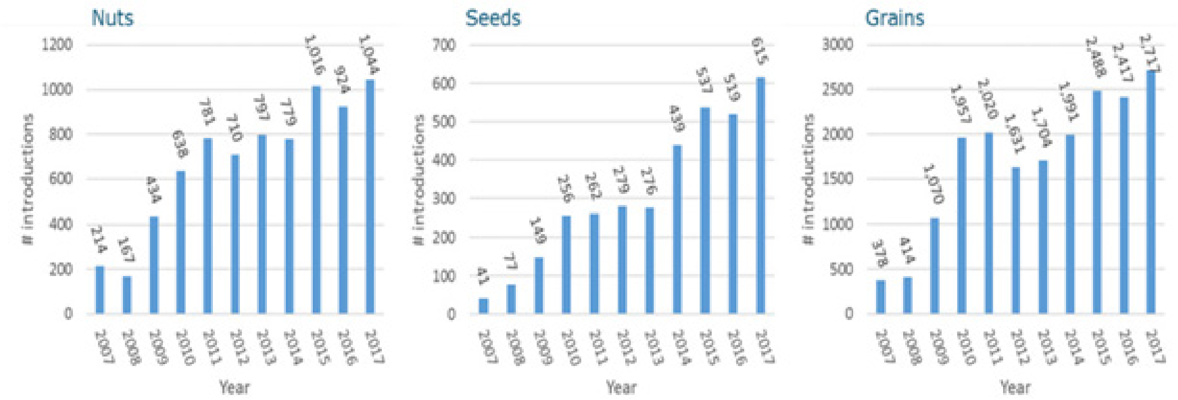

Figure 3 *Market introductions between 2007 and 2017 for nuts, seeds and grains.*

Most of the products are produced in the Netherlands (over 90%), followed by Germany, Belgium and the United Kingdom (Innova database). Please note that this does not give any information on the origin of the ingredients used in the products as these are sourced globally (see sections on production and trade).

4.2.1 Nuts

For nuts, the main categories for new market introductions are 1) confectionary, 2) bakery, 3) snacks, 4) cereals and 5) ready meals & side dishes (Innova database). Remarkably, introductions in 'confectionary' and 'bakery' stabilized around 2012, while introductions for 'snacks' are still increasing, with an uncharacteristically low number of new introductions in 2017. The fourth and fifth category ('cereals' and 'ready meals & side dishes') shows a yearly increase in new product introductions.

4.2.2 Seeds

For seeds, the five main categories of introduction follow the order: 1) bakery, 2) confectionery, 3) cereals, 4) ready meals & side dishes and 5) snacks (Innova database). For seeds, the 'confectionery' and 'cereals' categories annual introductions are still growing, while 'ready meals & side dishes' and 'snacks' reached a maximum in 2015 after which the yearly introductions declined. For 'bakery', not much growth is seen since 2014 or 2015.

4.2.3 Grains

The main categories for grains are 1) bakery, 2) ready meals & side dishes, 3) meat, fish & eggs, 4) snacks and 5) sauces & seasonings (Innova database). Grains are a large and established ingredient group, and the bakery, ready meals & side dishes and snacks show no clear increase in product introductions from 2014 onwards. Still, the 'meat, fish & eggs', 'sauces and seasonings' and 'cereals' categories show increase in product introductions over the last years, which may be caused by:

- the increase in products containing ancient grains (expert opinion),
- the increase in popularity of superfoods (mainly in the cereals category),
- the shift towards a more plant-based diet (the meat category includes meat replacers)
- the wish for consumers for new and exciting tastes and flavours (in the sauces & seasonings category).

Mixed products of grains with pulses are more often offered – such as rice or quinoa mixed with lentils (CBI - Ministry of Foreign Affairs, 2016b).
For all three product groups, most products are stored under ambient conditions, although the market share for cold and frozen products categories is increasing (see Figure 4) (Innova database).

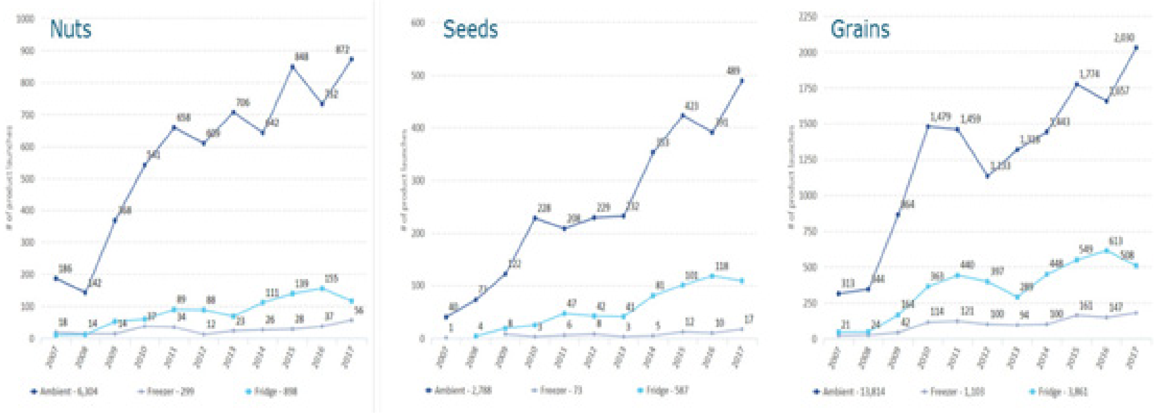

Figure 4 *Market introductions at room temperature, in the fridge and frozen between 2007 and 2017 for nuts, seeds and grains.*

4.3 Sustainability

The growing focus on sustainability has impact on the nuts, seeds and grains chain. Table 12 presents a few examples of trends in sustainability and their effects on the nuts, seeds and grains chain.

Table 12 *A number of sustainability trends and their effect on the nuts, seeds and grains chain.*

Sustainability trend	Effect on the nuts, seeds and grains chain
Organic produce	The market for some of the ancient grains and seeds (such as quinoa) is dominated by organic produce (CBI - Ministry of Foreign Affairs, 2017b), and cultivation is becoming more organic (expert opinion). At the same time, notwithstanding the increasing awareness on the importance of sustainability, the amount of 'nutty and seedy snacks' product introductions with an organic claim decrease (Innova Market Insights, 2018c).
Pest control	There is a shift from conventional control measures towards more sustainable methods such as the use of insects. However, currently that is still challenging on open fields (expert opinion). Experts think the limitation on the pest control measures increases the risk of fungal growth and mycotoxins.

Sustainability trend	Effect on the nuts, seeds and grains chain
Production	Consumers are more and more aware of production methods, which is reflected in the demands made by purchasers of produce. This resonates especially in those chains with import from developing countries, such as quinoa, chia and many of the other seeds (CBI, 2015; CBI - Ministry of Foreign Affairs, 2017a, 2017b). This consumer pressure may result in changes in production methods.
Income distribution	Next to production methods, consumers are also more aware of the income distribution in a chain and basing their purchases on this. For seeds for example, with high import from developing countries, this is getting increasingly important (CBI - Ministry of Foreign Affairs, 2017a). Fair trade similarly shows aspects of products that start to get more attention and be a more important incentive for consumers (Information Resources, 2017).
GMO free claims	GMO free claims are an important driver for consumer purchases, and is reflected a.o. in the nutty and seedy snacks (Innova Market Insights, 2018c). The increase in demand for niche products and labels such as GMO-free combined with the higher margins for these products may in the view of one of the experts increase the risk of fraud.
Sustainable packaging	Sustainable packaging and packaging that reduces food waste are getting more and more consideration in the design of new product packages (Information Resources, 2017)(expert opinion). Packaging is also very important in production and trade, and the branding of nuts and seeds as healthy, easy on-the-go snacks increase the attention on packaging for that category (Dudkiewicz, 2018; Siegner, 2018). Ethical packaging (possibility to recycle, using less packaging material) is the most prominent positioning of nuts and seeds snacks in the past years (Innova Market Insights, 2018c).
Animal welfare	Increasing concern for animal welfare is a trend that drives a more plant-based diet (Marr, 2016). Many meat replacers include nuts, seeds or grains (mainly ancient grains).
Water use in production	Although nuts have many advantages, both nutritionally and in animal welfare issues, water use may become an issue. Almonds, for example, can take up to 3.5L of water per nut (Siegner, 2018). Chia seeds, on the other hand, can grow in arid and semi-arid lands (Orona-Tamayo et al., 2017). For many other crops, during years of drought, surface water may be used for irrigation. Surface water may be contaminated, thus increasing risks (expert opinion).

Many trends regarding sustainability were described in this section. As a result of the increased awareness of sustainability, there may be an increased risk of labelling fraud.

4.4 Production

One of the fastest growing seeds is chia seed, which is named a ‘superfood’ because of its high omega 3 fatty acid content (CBI - Ministry of Foreign Affairs, 2017a). The US is the largest consuming country, with 78% of the global production, followed by Australia and Europe (Datamintelligence, 2018). In Europe, 16,000 tonnes of chia seeds are imported yearly where it is most popular in Germany, followed by the Netherlands and Spain. Suppliers are spread all over the world. Climate change has its influence on the production: in Bolivia for example the harvest is very variable. Because of the upcoming production in other countries, a disappointing harvest in one country is balanced out by the production in another country (CBI - Ministry of Foreign Affairs, 2017a).

Another upcoming pseudo-cereal is quinoa. Currently mainly produced in Bolivia and Peru, but cultivars have been developed for other climates and multiple European countries also start cultivation (CBI - Ministry of Foreign Affairs, 2017b). With the trend of more local sourcing (from within mainland Europe), this cultivation trend is promising (expert opinion). Increasing demand for new grains generally yields a shortage on the market for about a year, leading to a price increase followed by increased production and stabilisation of the market (expert opinion). According to experts, there is currently sufficient supply of niche grains like spelt, quinoa and sorghum, but a wider variety of seeds is expected to be grown in the future for specific properties.

A trend related to the cultivation of cereals is precision farming, using GPS and sensors and relying on intensive data support (Rabobank)(expert opinion). Precision farming may lead to a reduction in pesticide use (expert opinion) although one of the experts mentioned that currently the main use is in intensive, high value-added produce.

The increased use of precision farming is expected to increase food safety as it allows for a decreased pesticide use.

4.5 Trade

Seeds and nuts in Europe are a growing market with a large amount of import from developing countries (CBI, 2016). Import volumes grow, but the origin of the produce changes – China and India grow in population and therefore have increased local demands for nuts and seeds resulting in decreased export volumes from these countries. The import of groundnuts from China declined with 10% annually between 2011 and 2015 (CBI - Ministry of Foreign Affairs, 2017a) and from India even an annual decline of 28% was observed, although that may also have been attributed to quality issues (CBI - Ministry of Foreign Affairs, 2017a). As a result, import shifts to Africa (CBI - Ministry of Foreign Affairs, 2017a), and with that new risks may be present. For chia seeds, the main supplying countries are Paraguay, Bolivia, Peru, Argentina, Mexico, while Australia, Nicaragua and Ecuador supply smaller volumes. Initial cultivation trials are done in Uganda, Kenya, Tanzania, Ethiopia (CBI - Ministry of Foreign Affairs, 2017a). Market requirements will shift depending on consumption patterns. The EU market for chia seeds is expected to grow up to a factor of ten in the next 5 years (CBI - Ministry of Foreign Affairs, 2017a). The supermarkets in Europe have a dominating position in the market, making much of the market a buyers' market instead of a sellers' market (CBI - Ministry of Foreign Affairs, 2017b).

Cereals are largely grown within the EU, where Italy, Spain and the Netherlands are largest importers. Rye and oats are mainly sourced within Europe (CBI - Ministry of Foreign Affairs, 2016b), while maize is increasingly sourced in developing countries (CBI, 2015). For many other grains, there is a decreasing import from outside Europe (expert opinion). Specialty grains are sourced world-wide and the market for niche cereals (buckwheat and millet) and pseudo cereals (quinoa, amaranth, teff) as well as specialty rice is growing (CBI, 2015; CBI - Ministry of Foreign Affairs, 2016b)(expert opinion). For the Netherlands, slightly over 15% of the cereal import is from developing countries, mostly from Ukraine. Quinoa is mainly sourced from Peru and Bolivia (CBI - Ministry of Foreign Affairs, 2017b), and the import is increasing fast: fourfold between 2012 and 2016 (CBI - Ministry of Foreign Affairs, 2017b). The increasing niche markets result in smaller product streams and thus more complex chains, which may increase the possibilities for food fraud (expert opinion). Increasing transparency is mentioned as a trend (expert opinion) that can counteract the complexity of the value chains. Traceability of products is an important topic (Westlind, 2017)(expert opinion) and the experts foresee an important role for blockchain technology to increase traceability in the future (expert opinion).

Consumers are largely influenced by healthcare professionals, friends, bloggers and government to gain advice on food (Singh, 2017). With the increase of technology access (almost all consumers have access to internet and a smartphone) (Singh, 2017) both marketing and sales channels shift (expert opinion). Social media play an important role in advising and approaching customers (Rabobank, 2017; 2018; van Rijswick, 2018). Personalized products are becoming more and more important, thus changing business models from a few very successful products towards a range of more niche products (Singh, 2017). Experts also expect that people's diets will be personalized further. Big data and technology are getting more important in the development, marketing and sales of products (Singh, 2017). Trade models are likely to change even further with novel developments such as dynamic pricing of products (FoodBytes!, 2018).

The experts view on the Brexit is that it has limited influence on the trade for nuts, seeds and cereals. Still, they mention some influence will be exerted as the Netherlands is a trading country with export to the UK, and transport times may increase because of the Brexit. Specifically, the import duties on nuts may yield issues. Furthermore, the uncertainty that the Brexit induces is expected to have negative effects on trade.

Trends in trade show an increased complexity due to shifts in global trade. On the other hand, traceability is increasing resulting in a more transparent supply chain.

4.6 Legal and policy aspects

Food products sold in the Netherlands have to fulfil the general food safety requirements, including traceability, hygiene and control (CBI - Ministry of Foreign Affairs, 2016a, 2017a). Pesticide concentrations have to be below a maximum residue level, and also for other contaminants maximum levels are set (CBI - Ministry of Foreign Affairs, 2016a). Regulations on pesticides uses are getting stricter, which may lead to more microbial contamination on the products and increasing risk of mycotoxins presence (expert opinion).

For specific foods, there are additional requirements. For example, chia seeds were banned from the market until 2009 under the novel food regulation, but since then has been allowed in Europe in baked products, breakfast cereals and fruit, nut and seed mixes – in all categories with a maximum of 10%. Prepacked chia has been on the market since then as well, with an advised maximum consumption of 15 g/day mentioned on the package (CBI - Ministry of Foreign Affairs, 2017a). It is expected that the demand for certification of quality and food safety management will increase under pressure of requirements of supermarkets (CBI, 2016). GMO products are banned in Europe, resulting in an extremely limited sales market (CBI, 2016).
In the future, corporate social responsibility (CSR) is expected to play a more important role in product development (CBI - Ministry of Foreign Affairs, 2017a). Consumers are more interested in the 'story' behind products and are willing to pay more if the sustainability of the product is higher.

The changing legislation and policy towards pesticide use may result in a decreased use of pesticides.

5 Conclusions

Based on literature review, a long list of chemical hazards that may occur in cereals, seeds and nuts was established. Those substances from the long list that were frequently found in these products and/or found above EU legal limits were included on the intermediate list. This list is only based on information retrieved from literature. It is recommended to include the results of the Dutch monitoring data in order to confirm the established intermediate list. Toxicological information on the substances on the intermediate list was added, which can be used by NVWA-BuRO to come to a short list of substances: substances that may cause human health risks and as such should be included in the national monitoring program.
An evaluation of the trends in nuts, seeds and cereals indicated that there is an increased consumption of raw nuts and seeds due to their healthy image. This may lead to an increased exposure to HCN via increased consumption of linseed and almond products. Furthermore, due to more strict regulation regarding pesticide use and an increased awareness of sustainability, pesticide use is expected to decrease.

5.1 Cereals

The literature review retrieved 775 papers using the pre-defined search strings. After evaluation, 192 were regarded relevant for this study. The majority of these papers (73%) described the occurrence of mycotoxins. The most frequently detected mycotoxin, which also regularly exceeded the EU ML, was aflatoxins. These mycotoxins were thus added to the intermediate list. Other mycotoxins included were the *Fusarium* toxins DON and ZEA, fumonisins, OTA and T2/HT2-toxin. Tenuazonic acid was found at high concentrations in cereals, but information was limited. The same accounts for enniatins. Therefore, these mycotoxins were identified as knowledge gap. Heavy metals that were frequently found and found above EU MLs were arsenic, cadmium and lead. Methylmercury was seen as an upcoming hazard in rice cultivated in polluted areas. Since there was limited information on this heavy metal, it was identified as knowledge gap. Another knowledge gap was identified for nickel as EFSA indicated that cereals and cereal-based products are main contributors to nickel dietary intake. However, occurrence data are currently limited. POPs were not included on the intermediate list as only low concentrations were found. PAHs were included on the intermediate list, since high concentrations may be found when cereals are grown in contaminated areas (e.g. high density of traffic or industrial activities). According to the literature, cereals have a high contribution to the total PAH dietary intake. In total, 43 pesticides were included on the intermediate list as these were detected above EU MRLs, found and not approved in the EU or were recommended to be included in the monitoring. It is recommended to check the relevance of the identified pesticides using Dutch monitoring data as some of these pesticides may not have been detected above EU MRLs in the Netherlands. If all these pesticides are included in the multi-methods used within the national monitoring program, a further prioritization may not be needed. Plant toxins may be present when cereals are harvested. Since tropane alkaloids were notified in the RASFF database and the ARfD was exceeded with the maximum concentrations found, these substances were added to the intermediate list. The other hazard groups, i.e. radionuclides, processing contaminants, processing aids and additives, cleaning agents and disinfectants, allergens and other chemical hazards such as melamine, mineral oils, perchlorate and plasticisers were not included on the intermediate list as no evidence was found in literature on a frequent occurrence of these substances in cereals and/or no human health concerns were identified.

5.2 Seeds

A limited number of papers were retrieved in the literature review on seeds: 85 papers in total. After evaluating these papers, only 8 of these were relevant for this study. The literature review was complemented with a Google search (24 reports) as well as additional searches (6 papers) on persistent organic pollutants, radionuclides, processing contaminants, processing aids and additives, and cleaning agents and disinfectants. The mycotoxins aflatoxins, DON, OTA, T-2/HT-2 toxin and ZEA were added to the intermediate list as these were frequently found in seeds. *Alternaria* toxins were also frequently found, but information was limited and these toxins were thus identified as knowledge gap. The plant toxin cyanogenic glycosides was added to the intermediate list as these may be found in flaxseed/linseeds and the formation of HCN thereof is highly toxic. Opium alkaloids were added to the intermediate list as poppy seeds were found to exceed the guidance value for morphine. Fumigants have been detected above EU limits. However, due to limited data, these substances were identified as knowledge gap. Another knowledge gap was identified for nickel as EFSA indicated that oilseeds are main contributors to nickel dietary intake. However, occurrence data were not found in this study. PAHs may be formed during roasting; due to limited information, these substances were also identified as knowledge gap. Pesticides were also reported to be present in seeds. However, as the active substances were not indicated in literature, it is recommended to consult the Dutch monitoring data to specify which pesticides to include on the intermediate list.

5.3 Nuts

The literature review on nuts was based on a previous research on fruits and nuts (48 relevant hits) supplemented with an additional search in Scopus resulting in 188 hits. 33 Of these hits were relevant for this research. The majority of the papers described the presence of mycotoxins in nuts of which aflatoxins were frequently found and found above the EU MLs. Apart from aflatoxins, cyanogenic glycosides were added to the intermediate list as this substance may be present in almonds and the formation of HCN thereof is highly toxic. Pesticides were reported to be frequently used and were detected above US legal limits. However, in order to determine which pesticides should be included on the intermediate list, it is recommended to evaluate the Dutch monitoring data. Acrylamide was reported to be found when roasting nuts. Since only limited information was found on this substance, it was identified as a knowledge gap. Another knowledge gap was identified for the *Alternaria* toxins, AME, TA and AOH, which were found at high levels in chestnuts. Nickel was also added as knowledge gap since EFSA indicated that nuts are main contributors to nickel dietary intake. However, occurrence data in nuts were limited.

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Annex 1 English-Dutch terms

English	Dutch
Almond	Amandel
Barley	Gerst
Bran	Zemelen
Brazil nuts	Paranoten
Buckwheat	Boekweit
Cashew nuts	Cashewnoten
Cereals	Granen
Chestnut	Kastanje
Chia seed	Chiazaad
Coconut	Kokosnoot
Corn	Maïs
Durum wheat	Durumtarwe
Edible seeds	Eetbare zaden
Ergot	Moederkoren
Flakes	Vlokken
Flaxseed	Lijnzaad
Flour	Meel
Hazelnut	Hazelnoot
Hemp (seed)	Hennep(zaad)
Kernel	Pit
Linseed	Lijnzaad
Macadamia nut	Macadamianoten
Maize	Maïs
Nuts	Noten
Oats	Haver
Peanut	Pinda
Pecan nuts	Pecannoten
Pepitas	Pompoenpitten
Persipan	Banketbakkersspijs
Pine nuts	Pijnboompitten
Pistachio nuts	Pistachenoten
Poppy seed	Maanzaad
Processing aid	Technische hulpstof
Pumpkin seeds	Pompoenpitten
Quinoa	Quinoa
Rice	Rijst
Rice hull	Rijstvlies
Rye	Rogge
Safflower	Saffloer
Seeds	Zaden/pitten
Semolina	Griesmeel
Sesame seed	Sesamzaad
Shell	Schil
Sorghum	Sorghum
Sunflower seeds	Zonnebloempitten
Walnuts	Walnoten
Wheat	Tarwe
Wheat middlings	Tarwevoerbloem

Annex 2 Search terms Cereals, Seed, Nuts

I. Cereals

Finding search terms in Scopus
Changes are bolded

Option 1

#1:
TITLE-ABS-KEY (Cereals or oat* or soybean* or "soya bean*" or barley or rice or millet or rye or sorghum or wheat or maize or corn or poaceae or glycine)

And #2:
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 #3:
TITLE-ABS-KEY ("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*")

AND PUBYEAR >2007
= 4458

- ➔ Too many hits

Option 2

#1 only in **Title** and #2 AND #3 AND PUBYEAR >2007:1746

- ➔ Too many hits

Option 3 -5: definition of exclusion terms

#1 only in Title and #2 and #3 AND

NOT #4: **TITLE** (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" OR fung* or method* OR experiment* OR analytic* OR model*) AND PUBYEAR >2007: 1524

- ➔ Too many hits

NOT #4: TITLE (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" OR fung* or method* OR experiment* OR analytic* OR model* OR **environment* or ecological**) AND PUBYEAR >2007: 1467

- ➔ Too many hits

NOT #4:**TITLE-KEY-ABS** (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "microb* contamin*" or "foodborne disease*" OR fung* or method* OR experiment* OR analytic* OR model* OR environment* or ecological) AND PUBYEAR >2007: 496

- ➔ Adding exclusion terms in Title, Abstract, Keywords reduces the number of hits too much

NOT #4: TITLE-abs-key (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" OR environment* or ecological) **and not Title(fung* or method* or experiment* or analytic* or model*))** AND PUBYEAR >2007: 833

- ➔ Dividing exclusion terms into Title, Abstract, Keywords and only Title. Still too many hits

NOT #4: TITLE-abs-key (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" OR environment* or ecological or **bioavailability or water management or soil or nutritional***) and not Title(fung* or method* or experiment* or analytic* or model*)) AND PUBYEAR >2007: 579

- ➔ Adding additional exclusion terms results in a reasonable number of hits (579)

Option 6: addition of additional cereals

Cereals from the EFSA document were added: buckwheat, fonio and triticale. Quinoa is included in the search terms for seed (see below). Soybean was excluded as it will be part of a supply chain analyses on legumes

#1:TITLE(Cereals or oat* or barley or rice or millet or rye or sorghum or wheat or maize or corn or poaceae or glycine or **buckwheat or fonio or triticale**) AND #2 AND #3

AND NOT #4: TITLE-abs-key (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" OR environment* or ecological or bioavailability or water management or soil or nutritional*) and not Title(fung* or method* or experiment* or analytic* or model*)) AND PUBYEAR >2007: 557

Option 7: less exclusion terms, but focus on reviews

#1:TITLE(Cereals or oat* or barley or rice or millet or rye or sorghum or wheat or maize or corn or poaceae or glycine or buckwheat or fonio or triticale) AND #2 AND #3

NOT #4:
TITLE (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "microb* contamin*" or "foodborne disease*" OR fung* or method* OR experiment* OR analytic* OR model* OR environment* or ecological) AND PUBYEAR >2007 AND (**LIMIT-TO (DOCTYPE, "re")**) : 68

Additionally, the relevance of search string #3 (public health) was demonstrated by the following example (see Table below). Omitting search string #3 (Alternative 1) resulted in an extensive amount of hits (6797 hits), as compared to option 6. Comparing the 2 approaches, results of alternative 1 retrieved less relevant hits: Screening the title of the first 50 hits produced only 5 relevant articles as compared to 18 relevant articles with option 6. Of these 5 relevant hits from alternative 1, 4 were also retrieved with option 6. Alternative 1 did not only results in a high number of hits but also in a higher percentage of not relevant hits. Topics of non-relevance included for example cultivation, production of bio-oil, physiochemical properties, salinity, etc..

Therefore, it was concluded that using search string #3 (public health) makes the search more feasible by downsizing the number of hits, but also more specific as more relevant papers are found percentagewise. Using search string #3 resulted in 18 relevant references upon the first 50 hits, as compared to only 5 relevant references out of the first 50 hits when the search string #3 is not used. Moreover, out of these 5 relevant references, 4 were also found with option 6, which includes search string #3.

Search option	Hits	Relevant articles
Option 6: #1 and #2 and #3 and NOT #4	557 hits	In first 50 hits, 18 seem to be relevant.
Alternative 1: #1 and #2 and NOT #4	6796 hits	In first 50 hits, 5 seem to be relevant. 4 out of these 5 can be retrieved with the above mentioned option. Articles on cultivation, production of bio-oil and bio-gas, decomposition comparison, physiochemical properties of a protein in a cereal, salinity tolerance, improving enzymatic hydrolysis, analytical methods ...
Alternative 2: #1 and #2 and #3 (no exclusion terms)	1683 hits	Not checked, as still too many hits

Conclusion
Option 6 with an expanded list of exclusion terms gives a reasonable amount of hits, which seem relevant. However, as option 6 uses quite some exclusion terms, we might miss some relevant papers. Therefore, additionally option 7 will be used, which has a more limited set of exclusion terms, but focuses on review papers. By combining options 6 and 7 we think we will retrieve the most relevant papers which are feasible to study within the limited available time and budget.

Finding search terms in Web of Science

Web of Science
(same as option 6 Scopus):
(Ti=(cereals OR oat* OR barley OR rice OR millet OR rye OR sorghum OR wheat OR maize OR corn OR poaceae or glycine or buckwheat or fonio or triticale) 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 consumer* OR "Food safety" OR "risk assessment*" OR "risk analys*" OR "hazard analys*" OR "Human health*" OR "Health impact" OR "health risk*") NOT TS= (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" OR environment* or ecological or bioavailability or water management or soil or nutritional*) NOT TI=(fung* or method* or experiment* or analytic* or model*)): 406 hits

(same as option 7 Scopus):
(Ti=(cereals OR oat* OR barley OR rice OR millet OR rye OR sorghum OR wheat OR maize OR corn OR poaceae or glycine or buckwheat or fonio or triticale) 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 consumer* 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 "microb* contamin*" OR "foodborne disease*" OR fung* OR environment* OR ecological OR method* OR experiment* OR analytic* OR model*)). Refine on review: 70 hits

II. Seeds

<u>Scopus</u>

Option 1:

#1:
TITLE(flax OR linseed* OR "cannabis seed*" OR "hemp seed*" OR "safflower seed*" OR "marrow seed*" OR "pumpkin seed*" OR pepitas OR "ginko seed*" OR "sunflower seed*" OR "poppy seed*" OR "sesame seed*" OR camelina OR cannabis OR carthemus OR cucrubita OR ginko OR helianthus OR linum OR papaver OR sesamum OR amaranth* OR kaniwa OR quinoa OR chenopodium OR chia OR salvia)

And #2:
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 #3:
TITLE-ABS-KEY ("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*")

NOT #4:
TITLE (pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" or method* OR experiment* OR analytic* OR model* OR environment* or ecological) AND PUBYEAR >2007

79 hits

Option 2: Option 1 + removed "cannabis seed*"

The term cannabis and "cannabis seed" was excluded from the search string, as a search on the internet came to the conclusion that only hemp seed are eaten, either raw or processed into a product

#1:
TITLE(flax OR linseed* OR "hemp seed*" OR "safflower seed*" OR "marrow seed*" OR "pumpkin seed*" OR pepitas OR "ginkgo seed*" OR "sunflower seed*" OR "poppy seed*" OR "sesame seed*" OR camelina OR hemp OR carthamus OR cucurbita OR gingko OR helianthus OR linum OR papaver OR sesamum OR amaranth* OR kaniwa OR quinoa OR chenopodium OR chia OR salvia) AND #2 AND #3 AND NOT #4

= 69 hits

Option 3: Option 2 + adding "seed*"

= 243 hits (Web of Science: 177) --> Too many irrelevant hits. Examples are (upon first 50 hits):
- Soapberry seeds (toxin in that seed)
- Seed germination
- Mango seed extract (antibacterial agent)
- Jabooni seeds (cadmium and lead content)
- (Maize) seedlings
- Seeding
- Mustard seed
- Gromwell seeds
- Grape seeds (protection against lung toxicity)
- Antibiotic effect of seed germination

- EFSA: modification of MRL for a certain pesticide in a seed
- Seed yield
- Peanut seeds
- Radish seeds (effects of nonthermal plasma treatment on decontamination and sprouting)
- Grain spoilage by seedborne fungi
- Challenges and issues concerning mycotoxins contamination in oilseeds and their edible oils
- Moringa oleifera seeds for water clarification

Option 4: Option 2 + adding "edible seed*"

= 70 hits

<u>Web of Science</u>
Same as option 4 from Scopus

= 51 hits

The starting point for the chosen seed terms was the Excel-file ("Ketenklassen GF") provided by the NVWA. A quick Google search for these seed terms was conducted in order to distinguish seeds commonly used for human consumption and seeds merely consumed in a local region. The latter seeds were not included in the search terms.

Moreover, for the selection of the seed terms, an overview of the products available at the Albert Heijn online webshop[2] as well as from Ingredient Top 50s in new products mentioned in the Innova database[3]. Ingredient Top 50s were composed from the following product categories: Snacks (Snack Nuts & Seeds), Snacks (Other Snacks, Snack Mixes, Snack Nuts & Seeds), Bakery (Baking Ingredients & Mixes); All Cereals; All Cereals; All Snacks.

III. Nuts

<u>Scopus</u>

Option 1:
#1:

In title:
nut OR *nut OR almond OR chestnut OR coconut OR hazelnut OR macadamia OR "nut bar" OR peanut OR pistachio OR walnut OR "brazil nut" OR cashew OR pecan

AND #2:

In title, abstract, 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:

In title, abstract, 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*"

[2] https://www.ah.nl, accessed at 15-10-2018
[3] https://www.innovadatabase.com/, accessed at 18-10-2018

AND NOT #4:

In title:
pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" or method* OR experiment* OR analytic* OR model* OR environment* or ecological) AND PUBYEAR >2007

= 268 hits

- ➔ Too many hits

Option 2: Refine nut-terms

The term "pine nut" was included, as it is a commonly consumed nut. Additionally, the general terms 'nut' and '*nut' were removed to downsize the number of hits.

#1:
Almond* OR "Brazil nut*" OR cashew OR chestnut* OR coconut* OR hazelnut* OR "macadamia nut*" OR peanut* OR pecan OR "pine nut*" OR pistachio OR walnut*

AND #2 AND #3 AND NOT #4

= 206 hits

Option 3: Option 2 + adding "oil" to exclusion terms

The hits of option 2 resulted in several articles focusing on a specific nut-oil, which is not part of the chain analysis.

#1 AND #2 AND #3

AND NOT #4
In title:
pathogen* or streptococcus or listeria or virus or bacillus or salmonella or clostridium or staphylococcus or outbreak or "foodborne disease*" or method* OR experiment* OR analytic* OR model* OR environment* or ecological **OR oil***) AND PUBYEAR >2007

= 188 hits

The starting point for the chosen nuts terms was the Excel-file ("Ketenklassen GF") provided by the NVWA. A quick Google search for these nuts terms was conducted in order to distinguish nuts commonly used for human consumption and nuts merely consumed in a local region. The latter nuts were not included in the search terms.

Moreover, for the selection of the nut terms, an overview of the products available at the Albert Heijn online webshop[4] as well as from Ingredient Top 50s in new products mentioned in the Innova database[5]. Ingredient Top 50s were composed from the following product categories: Snacks (Snack Nuts & Seeds), Snacks (Other Snacks, Snack Mixes, Snack Nuts & Seeds), Bakery (Baking Ingredients & Mixes); All Cereals; All Cereals; All Snacks.

[4] https://www.ah.nl, accessed at 15-10-2018
[5] https://www.innovadatabase.com/, accessed at 18-10-2018

Annex 3 Results Google Search

Cereals

Searches	WHO	FAO	BfR	CFIA
1. (Wheat OR maize OR barley OR cereal) AND “food safety”	3020	12700	296	1270
2008-2018	373	1640	**137**	438 **(200)**
Only pdf	248 **(200)**	1370 **(200)**		4
2. (Wheat OR maize OR barley OR cereal) AND contaminant	2690	5800	**127**	355
2008-2018	821	670		**196**
Only pdf	505 **(200)**	482 **(200)**		
3. (Wheat OR maize OR barley OR cereal) AND residue	4330	29300	400	695
2008-2018	1310	2970	**136**	424
Only pdf	1370 **(200)**	2200 **(200)**		**25**
4. (Wheat OR maize OR barley OR cereal) AND “risk assessment”	1120	5590	255	293
2008-2018	289	862	**74**	**175**
Only pdf	240 **(200)**	707 **(200)**		
Total hits	2363 **(800)**	4759 **(800)**	**474**	834 **(596)**
Total relevant hits	**16**	**5**	**13**	**11**

The bolded figures indicate the number of hits which were checked. If the search string resulted in more than 200 hits, only the first 200 hits were checked.

Seeds

Searches	WHO	Anses	FDA	FSAI
1. (Seed OR quinoa) AND “food safety”	1240	213	1080	1300
2008-2018	251	**77**	715	**173**
Only pdf	**180**		417 **(200)**	
2. (Seed OR quinoa) AND contaminant	3130	715	1650	781
2008-2018	727	343	798	**62**
Only pdf	573 **(200)**	341 **(200)**	394 **(200)**	
3. (Seed OR quinoa) AND residue	4520	1010	5270	2420
2008-2018	1380	246	1950	**197**
Only pdf	1270 **(200)**	214 **(200)**	1150 **(200)**	
4. (Seed OR quinoa) AND “risk assessment”	1160	321	227	**82**
2008-2018	311	**90**	**137**	
Only pdf	301 **(200)**			
Total hits	2324 **(780)**	722 **(567)**	2098 **(737)**	**478**
Total relevant hits	**7**	**4**	**7**	**6**

The bolded figures indicate the number of hits which were checked. If the search string resulted in more than 200 hits, only the first 200 hits were checked.

Annex 4 Additional searches

Additional searches for cereals:

#1 was searched for in the Title, the other search groups in Title, Abstract, Keywords. A search string for the specific hazard/hazard group were always included. Depending on the number of hits an additional search string for generic hazard terms was added ("food safety" OR hazard* or risk*) and a year limitation of the last ten years applied.
The following searches were conducted in Scopus:

- bulgur AND #2 AND #3 AND #4 of search-query 2, resulted in 1 relevant hit
- #1 (+ bulgur) AND ("Persistent organic pollutant*" OR POP OR PAH OR PCB OR PFA OR BFR OR dioxin*) AND ("food safety" OR hazard* or risk*) for 2008-2018 resulted in 56 hits, 6 relevant references were found with regard to persistent organic pollutants in cereal crops
- #1 (+ bulgur) AND (radionuclide*) AND ("food safety" OR hazard* or risk*) for 2008-2018 resulted in 16 hits, 5 relevant references were found with regard to radionuclides in cereal crops
- #1 (+ bulgur) AND (cleaning OR disinfect*) AND ("food safety" OR hazard* or risk*) for 2008-2018 resulted in 38 hits, no relevant hits were retrieved about cleaning and disinfection agents used for cereals
- #1 (+ bulgur) AND ("processing aid*" OR additive* OR "aluminosilicate" OR "aluminium sulph*" OR "aluminium phosph*") AND ("food safety" OR hazard* or risk*) for 2008-2018 resulted in 110 hits, zero relevant references were found with regard to processing aids or additives in cereals
- #1 (+ bulgur) AND "flour treatment agent*" OR "improving agent*" OR "bread improver*" OR "dough conditioner*" OR "dough improver*" OR chlorine* OR "ascorbic acid" OR azodicarbonamide OR "potassium bromate") AND ("food safety" OR hazard* or risk*) for 2008-2018 resulted in 54 hits, no relevant hits were found
- # 1 (+ bulgur) AND (melamine) for 2008-2018 resulted in 19 hits, 1 relevant reference was found with regard to melamine in cereal products
- # 1 (+ bulgur) AND (plasticiser* OR plasticizer* OR DEHP) AND ("food safety" OR hazard* or risk*) for 2008-2018 resulted in 4 hits, zero relevant references were found with regard to plasticiser in cereals
- # 1 (+ bulgur) AND ("plant toxin*" OR phytotoxin* OR "pyrrolizidine alkaloid*" OR "tropane alkaloid*") for 2008-2018 resulted in 68 hits, 1 relevant references was found related to tropane alkaloids in cereal flour

Additional searches for seeds:

#1 was searched for in the Title, the other search groups in Title, Abstract, Keywords. A search string for the specific hazard/hazard group were always included. Depending on the number of hits an additional search string for generic hazard terms was added ("food safety" OR hazard* or risk*) and a year limitation of the last ten years applied.
The following searches were conducted in Scopus:

- #1 AND ("Persistent organic pollutant*" OR POP OR PAH OR PCB OR PFA OR PFC OR BFR OR dioxin*) resulted in 78 hits, 4 relevant references were found related to persistent organic pollutants, polycyclic aromatic hydrocarbons and the plant toxins opium alkaloids
- #1 AND (radionuclide*) resulted in 17 hits, zero relevant hits were found with regard to radionuclides in seeds
- #1 AND ("processing contaminant*" OR acrylamide OR chloropropanol*) resulted in 36 hits, 1 relevant reference were found related to processing contaminants in chia flour
- #1 AND (cleaning OR disinfect*) AND ("food safety" OR hazard* or risk*) resulted in 8 hits, no relevant hits were retrieved about cleaning and disinfection agents used for seeds
- #1 AND ("processing aid*" OR additive*) AND ("food safety" OR hazard* or risk*) resulted in 18 hits, no relevant hits were retrieved regarding processing aids and additives in seeds

Additional searches for nuts:

#1 was searched for in the Title, the other search groups in Title, Abstract, Keywords. A search string for the specific hazard/hazard group were always included. Depending on the number of hits an additional search string for generic hazard terms was added ("food safety" OR hazard* or risk*) and a year limitation of the last ten years applied.
The following searches were conducted in Scopus:

- #1 AND ("processing aid*" OR additive*) AND ("food safety" OR hazard* or risk*) AND ("food safety" OR hazard* or risk*) resulted in 28 hits, no relevant hits were retrieved regarding processing aids and additives in seeds
- #1 AND pesticide* AND ("food safety" OR hazard* or risk*) resulted in 44 hits, 4 relevant hits were retrieved
- #1 AND (cleaning OR disinfect*) AND ("food safety" OR hazard* or risk*) resulted in 9 hits, no relevant hits were retrieved about cleaning agents and disinfectants used for nuts

Annex 5 Questionnaire for evaluating trends in cereals, seeds and nuts (in Dutch)

Vragen

1. Welke veranderingen en ontwikkelingen verwacht u de komende 10 jaar in de granen-, zaden- en notensector?
   a. Verwacht u veranderingen door de Brexit?
   b. Verwacht u veranderingen in import?
   c. Verwacht u specifieke ontwikkelingen voor bepaalde soorten?
2. Welke trends verwacht u in primaire sector van granen, zaden en noten? (bijv. andere oogstmethoden, andere bestrijdingsmethoden, precisielandbouw, robotica)
3. Welke trends verwacht u de verwerkende industrie? (bijv. nieuwe producten, andere technologieën)
4. Zijn er bepaalde consumententrends die relevant zijn voor de granen-, zaden- en notensector? (meer convenience food, andere nieuwe soorten)
5. Wat verwacht u van de superfoodtrend in de komende 10 jaar?
6. Welke microbiologische gevaren vindt u het belangrijkst in granen, zaden en noten en verwerkte producten?
   a. Voor welke soorten en waarom?
7. Welke chemische gevaren vindt u het belangrijkst in granen, zaden en noten en verwerkte producten?
   a. Voor welke soorten en waarom?

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