Advisory Report on Risks in the Potato Production Chain

Annexes

December 2020

TRCVWA/2020/6614

Contents

1. Risk assessment objective, scope and assessment framework of the Office for Risk Assessment & Research

1.1. Objective

The risk assessment of the potato production chain (hereinafter: potato chain) is aimed at identifying the hazards and assessing the risks to plant health and food safety that can occur in all stages of the potato chain and issuing advice on measures to reduce these risks. In addition, other risks to public health, nature and the environment arising from the production of potatoes and potato products have also been described.

1.2. Scope

1.2.1. Potato chain

The potato chain risk assessment is part of the risk assessment of the production chain of food crops performed by the Office for Risk Assessment & Research (BuRO).

Potatoes are the tubers of the plant species *Solanum tuberosum*. The potato plant itself is also referred to as 'potato'. Sweet potatoes (batata; tubers of *Ipomoea batatas*) and Japanese potatoes (also called Chinese artichoke; tubers of *Stachys affinis*) fall outside the scope of this risk assessment.

Depending on the context, the word 'potato' refers to potato plants grown under different conditions (for example, as a crop in the field, as a plant in a greenhouse of a breeding company or as a meristem culture in a laboratory) or to potato tubers at different stages of the potato chain. Potato products are processed potatoes, with the exception of composite products.

Potatoes are produced for human consumption (ware potatoes) and for the extraction of starch (starch potatoes). Ware potatoes can be divided into table potatoes and industrial potatoes. Table potatoes are sorted, and if necessary, washed and packaged, but are subsequently sold to consumers without any further handling. Industrial potatoes are delivered to potato processing companies for being processed into peeled chilled products, pre-fried chips, crisps, flakes, mash, etc. Starch potatoes are delivered to starch mills for processing into starch.

This risk assessment is limited to the part of the potato chain relating to the activities of companies in all stages of the production, processing and sale of potatoes and potato products in the Netherlands. The first stage of the chain is the breeding and selection of new cultivars by breeding companies, followed by the stages for the production of seed potatoes, production of ware and starch potatoes and processing of ware and starch potatoes. The disposal of soil tare, which is generated as a waste product during the processing of potatoes, is also considered as one of the above-mentioned activities. The final stage of the chain is the distribution of potatoes and potato products to consumers and mass caterers[1] as well as the preparation of potatoes and potato products. This risk assessment also describes how the method of preparation of the potatoes and potato products, used by consumers and professional food handlers working for mass caterers, influences the food safety risks introduced in the previous stages of the chain. Depending on the activities in the various stages, certain risks to plant health and food safety may arise.

The storage and transport of potatoes and potato products in every stage of the chain within the Netherlands, including transport of certified lots for export to countries outside the EU up to the external borders of the Netherlands, have been taken into account as part of the activities.

Import and export of potatoes and potato products in the various stages of the chain are included in this risk assessment. Potatoes and potato products originating from EU Member States may be imported and traded in the Netherlands without inspection. The competent authority of the Member State and the producer who

[1] Mass caterers: any establishment (including a vehicle or a fixed or mobile stall), such as restaurants, canteens, schools, hospitals and catering enterprises in which, in the course of a business, food is prepared to be ready for consumption by the final consumer.

As defined in: Regulation (EU) 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

brings the consignment onto the market are responsible for ensuring that the consignment complies with the requirements of the EU Plant Health Regulation[2] for the product concerned. Lots of potatoes and potato products, imported from third countries, are included in this risk assessment from the moment when the consignment becomes subject to obligatory customs control. A consignment remains under customs control until the phytosanitary inspection and inspections for residues of plant protection products, contaminants and genetically modified organisms (GMOs) have been completed. Non-compliant lots are rejected.

1.2.2. Out of scope

- Kitchens of food handlers (consumers in private households and professional food handlers at mass caterers). Food safety risks relating to potatoes and potato products, that are introduced in the product in the kitchen through the actions of the food handler, have not been taken into account in the risk assessment. The influence of the preparation method on the food safety risks that may have arisen in the preceding stages of the production chain has, however, been included in the risk assessment.
- The production of composite products: products in which, in addition to potatoes, ingredients from production chains other than the potato chain have been used, with the exception of added salt, herbs and spices.
- The use of potato starch and potato protein in composite foods and industrial non-food products.
- By-products created within the potato chain and processed within other production chains and waste products. The risks of using potato processing by-products in animal feed are assessed elsewhere (NVWA BuRO, 2019a).
- The use of biocides for rodent control in potato storage facilities and tool sheds.
- Allergens in potato.

1.3. Hazards and social values

The risk assessment concerns the risks posed by chemical, physical and microbiological hazards to food safety and by phytosanitary hazards to plant health. Apart from food safety risks, risks to public health, the environment and nature may also arise within the potato chain, such as the adverse effects of plant protection products on the health of farm workers or residents living in the vicinity of the potato plots. These risks are mentioned in Annex 10 but have not been assessed in detail since such an assessment falls under the purview of other Ministries.

The scope of the hazards has been defined in the relevant Annexes 4 to 10.

1.4. Assessment framework

BuRO has assessed the risks of the potato production chain in accordance with the Independent Risk Assessment (Netherlands Food and Consumer Product Safety Authority) Act (*Wet Onafhankelijke Risicobeoordeling NVWA*). It has done this based on two important criteria: scientific substantiation and independence. In keeping with the second criteria, BuRO has set up and performed the risk assessment independently. Other organisational units within the Netherlands Food and Consumer Product Safety Authority (*Nederlandse Voedsel- en Warenautoriteit, NVWA*) were not permitted to provide any inputs, unless contacted by BuRO on its own initiative to provide additional information.

To satisfy the criteria of scientific substantiation, scientific articles and other reports published before 1 April 2020 have been consulted.

The recommendations are aimed at facilitating the risk management activities performed by the NVWA directorates. These recommendations are based on an assessment of the risks that occur within the chain. Factors such as feasibility and costs have not been taken into consideration, since that is an explicit part of the risk management process. During the risk management, the present risk assessment is used as a basis for making the above consideration.

[2] Regulation (EU) 2016/2031 of the European Parliament and of The Council of 26 October 2016 on protective measures against pests of plants, amending Regulations (EU) No 228/2013, (EU) No 652/2014 and (EU) 1143/2014 of the European Parliament and of the Council and repealing Council Directives 69/464/EEC, 74/647/EEC, 93/85/EEC, 98/57/EC, 2000/29/EC, 2006/91/EC and 2007/33/EC.

For its risk assessment, BuRO applies the definition of risk as formulated by Rosa (Rosa, 1998): a risk is "a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain". Within this concept of risk, BuRO distinguishes between the *likelihood* of a threat and its *consequence*. In case of the potato production chain, we are concerned with the consequences for plant health and food safety values.

The risk assessment method used for the potato chain is largely based on the Codex Alimentarius and the working method followed by EFSA. This method is in line with the systematic risk assessment approach referred to in the General Food Law Regulation (GFL)4. Although the approach followed in this Regulation is specifically intended for assessing risks relating to food safety, it is essentially comparable to the international methods used for assessing plant health risks (EFSA Scientific Committee, 2012).

The risk assessment method consists of four steps:

- Hazard identification: identification of the hazards (threats) to plant health and food safety in the potato chain as described in various sources, including scientific literature and research reports.
- Hazard characterisation: assessment of the relevance of the hazards to plant health and food safety in the Dutch potato chain. In case of plant health, this involves an estimation of the potential consequences, due to the presence of harmful organisms in the Netherlands, for the yield and/or quality of potatoes and for the trade and export of potatoes and other plants. In case of food safety, this is an estimation of the extent to which microbiological, chemical and physical hazards arising out of the consumption of potatoes and potato products contribute to the burden of disease or negative long-term effects on human health.
- Exposure assessment: the probability of the occurrence of these hazards. For plant health, this is an assessment of the likelihood of a harmful organism entering and establishing itself in the Netherlands and the extent to which it can spread in the Netherlands. For food safety, this involves an assessment of the degree to which the consumer is effectively exposed to the microbiological, chemical and physical hazards present in potatoes and potato products.
- Risk characterisation: overall assessment of the nature and severity of each hazard and the likelihood or prevalence thereof in the Netherlands (conclusion of the risk assessment).

2. Laws and regulations and private quality assurance

The risk assessment of the potato chain has been carried out against the background of, but not limited by, the existing framework of laws and regulations and private quality assurance.

2.1. Regulations

The following EU laws and regulations are important with respect to risks in the potato chain:

Plant health	
Regulation (EU) 2016/2031	Protective measures against plant pests
Commission Implementing Regulation (EU) 2019/2072	Implementation of protective measures against plant pests
Commission Delegated Regulation (EU) 2019/829	Supplement to Regulation (EU) 2016/2031 for temporary derogations for official tests, scientific or educational purposes, trials, selection activities or breeding
Commission Delegated Regulation (EU) 2019/1702	Establishing the list of priority pests
Council Directive 69/464/EEC	Control of potato wart disease
Council Directive 93/85/EEC	Control of potato ring rot
Directive 98/57/EC	Control of *Ralstonia solanacearum* (Smith) Yabuuchi et al.
Directive 2007/33/EC	Control of potato cyst nematodes
Directive 2002/56/EC	Marketing of seed potatoes
Commission Implementing Decision 2014/20/EU	EU grades for basic and certified seed potatoes
Commission Implementing Decision 2014/21/EU	Minimum conditions for pre-basic seed potatoes
Food safety	
Regulation (EC) 178/2002	General requirements of food law
Regulation (EC) 852/2004	Hygiene of foodstuffs
Regulation (EC) 396/2005	Harmonised maximum residue levels of pesticides in or on food and feed of plant and animal origin
Regulation (EC) 2073/2005	Microbiological criteria for foodstuffs
Regulation (EC) 1881/2006	Maximum levels for contaminants in foodstuffs
Regulation (EU) 2017/2158	Mitigation measures and benchmark levels for the reduction of the presence of acrylamide in food
Plant protection	
Regulation (EC) 1107/2009	Rules for the authorisation and placing of plant protection products on the market and for their use and control within the EU
Directive 2009/128/EC	Sustainable use of pesticides
Biocides	
Regulation (EU) 528/2012	Rules for the marketing and use of biocides

Genetically modified organisms	
Directive 2001/18/EC	Deliberate release of genetically modified organisms into the environment
Regulation (EC) 1830/2003	Traceability and labelling of genetically modified organisms
Organic production	
Regulation (EC) 834/2007	Organic production and labelling of organic products
Regulation (EC) 889/2008	Implementing provisions for organic production and labelling of organic products
Official Controls Regulation	
Regulation (EU) 2017/625	Official controls on compliance with food, feed, animal health, animal welfare, plant health and plant protection products
Commission Implementing Regulation (EU) 2019/1793	Temporary increase of official controls and emergency measures with regard to the entry into the Union of certain goods from certain third countries implementing Regulations (EU) 2017/625 and (EC) 178/2002
Regulation (EC) 669/2009 (No longer in force since 2019)	Increased level of official controls on imports of certain feed and food of non-animal origin
Commission Implementing Regulation (EU) 543/2011	Marketing standards for fruit and vegetables

Based on the above laws and regulations, statutory controls are carried out and private quality assurance systems have been developed.

2.2. Statutory controls

2.2.1. Plant health

The Minister of Agriculture, Nature and Food Quality has been designated as the 'competent authority' for Regulation (EU) 2016/2031[2] (hereinafter: Plant Health Regulation) and the 'central authority' for Regulation (EU) 2017/625 (hereinafter: Official Controls Regulation)[3]. The implementation of the tasks and powers assigned under the Plant Health Regulation has been mandated by the Minister of Agriculture, Nature and Food Quality to the Netherlands Food and Consumer Product Safety Authority (hereinafter: NVWA). The NVWA has also been designated as the National Plant Protection Organization (hereinafter: NPPO) under the International Plant Protection Convention (IPPC). The Dutch General Inspection Service for Agricultural Seeds and Seed Potatoes (*Nederlandse Algemene Keuringsdienst voor zaaizaad en pootgoed van landbouwgewassen, NAK*), an independent administrative body under private law, has been designated as the competent authority with regard to agricultural crops for a number of specific sub-areas of the Plant Health Regulation such as the control of Regulated Non-Quarantine Pests (RNQP) and monitoring of the issuance of plant passports. The NAK and the Quality Control Bureau (*Kwaliteits-Controle-Bureau, KCB*) are authorised to carry out potato import inspections.

Specific legal cultivation regulations apply to the cultivation of potatoes (NVWA, 2018b). Compliance with the cultivation regulations for arable farming and horticulture are monitored by the NVWA and NAK.

In its role as the NPPO, the NVWA supervises all activities falling under the Plant Health Regulation.

[3] Regulation containing temporary measures under the Plant Diseases Act (*Regeling houdende tijdelijke maatregelen Plantenziektenwet*). https://wetten.overheid.nl/BWBR0042859/2019-12-14.

2.2.2. Legal quality of seed potatoes

Seed potatoes may only be marketed if it has been established during the official inspection that they meet the quality requirements relating to varietal purity, health, vigour, purity, classification, labelling, etc. as described in the Seeds and Planting Materials Act 2005 (*Zaaizaad- en plantgoedwet 2005*)[4]. The NAK is responsible for performing this quality inspection of seed potatoes.

2.2.3. Food safety of ware potatoes and starch potatoes

The companies within the potato chain that supply ware potatoes or starch potatoes and derived products are known as food businesses. According to Regulation (EC) 852/2004, the food business operators are directly responsible for the supply of safe food.

Food businesses that carry out primary production activities (farms) must comply with the provisions laid down in Annex I, Part A of Regulation (EC) 852/2004. This includes measures for controlling contamination via air, soil, water, manure, plant protection products and biocides. Activities must be carried out in accordance with good hygiene practices. Dutch arable farming is subject to the Arable Farming Food and Feed Safety (*Voedsel- en Voederveiligheid Akkerbouw, VVAK*) certification scheme, which is based on the conditions outlined in the VVAK Food and Feed Safety Guide (*Handboek voedsel- en voederveiligheid*) (Akkerbouw Certificeringsoverleg, 2019). The VVAK scheme has been approved by the Ministry of Agriculture, Nature and Food Quality[5] as a hygiene code for primary production in arable farming. The VVAK Guide contains guidelines for the use and storage of fertilisers and plant protection products, the use of machines, water usage and air conditioning during storage. Control of compliance by VVAK-certified arable farms is carried out by bodies recognised by the Arable Certification Committee (*Akkerbouw Certificeringsoverleg*).

Food businesses carrying out the production, processing and distribution of foodstuffs after primary production must comply with the provisions laid down in Annex II of Regulation (EC) 852/2004. Moreover, these food businesses must ensure that permanent food safety procedures are implemented based on HACCP[6] principles. This principle is further elaborated via a system of European regulations referred to as the 'Hygiene Package'. Based on these requirements, all food business operators must draw up a food safety plan that must be assessed by the NVWA (NVWA, 2020g). There are three options for this:

- A business-specific food safety plan
- A guide to good practice (in Dutch known as Hygiënecode) drawn up by a business sector and recognised by the NVWA (NVWA, 2020f)
- A certification scheme: a "Hygiënecode" combined with rules and requirements for testing by an independent organisation. The owner of a certification scheme can allow the scheme to be verified by the NVWA (Ketenborging.nl, 2020). Acceptance of the scheme by the NVWA can help reduce the intensity of supervision by the NVWA of the participating operators.

The government is responsible for overseeing compliance with EU food law. It does this in accordance with the Official Controls Regulation of the EU[7] via official inspections and other activities that are performed regularly and on the basis of a risk assessment. The NVWA has been designated as the competent authority for these activities. However, there is no legislation in place for food handling by the consumer. This is explicitly stated in Regulation (EC) 852/2004: the scope of the Regulation does not apply either to primary production for private domestic use or to the domestic preparation, handling or storage of food for private domestic consumption. Supervision by the NVWA therefore stops at the checkout: what consumers do with their products after purchase is no longer the government's responsibility. However, the NVWA does ensure the recall of products sold that present an unacceptable risk to consumers' health and ensures that consumers are informed of this, where necessary. The government also works in cooperation with the Netherlands Nutrition Centre (*Voedingscentrum*) to actively provide food safety information to consumers.

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[4] Seeds and Planting Materials Act 2005. https://wetten.overheid.nl/BWBR0018040/2020-01-01.

[5] Government Gazette 1 February 2006, no 23/pg. 27

[6] HACCP: Hazard Analysis and Critical Control Points

[7] Regulation (EU) 2017/625 of the European Parliament and of the Council of 15 March 2017 on official controls and other official activities performed to ensure the application of food and feed law, rules on animal health and welfare, plant health and plant protection products.

2.2.4. Environment and human health

The NVWA monitors compliance with the Plant Protection Products and Biocides Act (*Wet gewasbeschermingsmiddelen en biociden, Wgb*) when these products are used in agriculture and horticulture, including in the potato chain. It verifies whether the companies that cultivate, store, transport and process seed, ware or starch potatoes are only using authorised plant protection products and whether they are using these products correctly. It also oversees compliance with the obligation to inspect the equipment used for applying plant protection products.

2.2.5. Legal quality of ware potatoes

The general marketing standards for the quality of fruit and vegetables also apply to potatoes; no specific marketing standards have been laid down for potatoes (Annex I, Part A of the Implementing Regulation (EU) 543/2011). According to these general standards, the packaged product must be free of rot, visible foreign matter, smell or taste, and pests. The quality control is carried out by the NAK and the Quality Control Bureau.

2.2.6. Organic production

Stichting Skal Biocontrole - an independent organisation that monitors the organic chain in the Netherlands - legally monitors compliance with the rules for organic production in the potato chain. Skal Biocontrole is an autonomous administrative authority appointed by the Minister of Agriculture, Nature and Food Quality[8] as a control authority within the meaning of EU Regulation 834/2007.

2.3. Private quality assurance

2.3.1. Plant health

PCC Ring Rot Hygiene Protocol

The PCC Ring Rot Hygiene Protocol (*PCC Hygiëneprotocol Ringrot*) is a private certification scheme aimed at preventing infestation and spread within the chain of *Clavibacter michiganensis* subsp. *sepedonicus*, the bacterium that causes ring rot in potatoes (NAO, 2020a). This protocol has been developed by the Seed Potatoes Contact Committee (*Pootgoed Contact Commissie, PCC*), a partnership between the Dutch Potato Organisation (*Nederlandse Aardappel Organisatie, NAO*) and the Netherlands Agriculture and Horticulture Organisation (*Land- en Tuinbouw Organisatie Nederland, LTO*). The Hygiene Protocol consists of specific schemes for each type of business operator in the various stages of the seed potato production chain: growers, key processors, transport companies, companies that wash and disinfect the means of transport and traders. The NAK is responsible for the certification and supervision of growers and processors. The NAO is responsible for the certification and supervision of transport, washing and trading companies. The NVWA has published an advisory report describing the cleaning and disinfestation measures for preventing infestation by ring rot bacteria (NVWA, 2016b).

NAO Soil Tare Recognition Scheme

In consultation with the NVWA, the NAO has drawn up the NAO Soil Tare Recognition Scheme (NAO Scheme) (*NAO Erkenningsregeling Tarragrond voor Handelaren, NAO-regeling*) (NAO, 2015). The NAO Scheme is intended for traders dealing in potatoes grown on plots officially declared to be infested by potato cyst nematodes (PCN sections). The trader must ensure that the grower receives a document proving that its potatoes have been processed by a recognised processor (NVWA, 2020h). The trader is exempt from this requirement based on its participation in the NAO scheme.

[8] Article 15 of the Agricultural Quality Decree 2007 (*Landbouwkwaliteitsbesluit 2007*)

2.3.2. Food safety

Potato growers

Growers of ware potatoes that supply their product to a potato processing company affiliated to the Dutch Potato Processing Industry Association (*Vereniging voor de Aardappelverwerkende Industrie, VAVI*) must, in accordance with the supply conditions of the VAVI, hold a Food Safety Certificate for the Potato Processing Industry (VVA Certificate) (*Voedselveiligheid certificaat aardappelen verwerkende industrie, VVA-certificaat*) (VAVI, 2019). The conditions for the VVA Certificate are managed by the VAVI. They are included as a module in the VVAK certification scheme, which is recognised by the Ministry of Agriculture, Nature and Food Quality as a hygiene code for arable farms (see section 2.2.3). Potato processing companies may also accept other certificates in addition to the VVA certificate such as the GlobalG.A.P certificate (Aviko, 2020).

The VVAK certificate is accepted for the delivery of table potatoes to retailers via potato trading houses and wholesalers (Brancheorganisatie Akkerbouw, 2020a).

Growers of starch potatoes must possess the Food Safety Certificate for Starch Potatoes (*Voedselveiligheidscertificaat Zetmeelaardappelen*) in order to deliver to starch manufacturer Avebe. The requirements for this are included as a module in the VVAK certification scheme (see section 2.2.3).

For agricultural contractors that carry out cultivation activities on behalf of arable farms, the Food Quality Certificate for Agricultural Contractors (*certificaat VoedselKwaliteit Loonwerk*) applies (Stichting Pro aCt, 2020).

Traders and packers of potatoes

The NAO Hygiene Code (*NAO Hygiënecode*) has been developed for companies involved in trading and preparing unit packages of unpeeled potatoes and for washing, clay, salt and sorting companies (NAO, 2020c). This Hygiene Code has been approved by the Ministry of Health, Welfare and Sport[9] and is recognised by the NVWA (NVWA, 2020f).

Potato processing companies

Tailor-made quality systems, based on IFS Food or FSSC 22000, are applicable to potato processing companies. These have been accepted by the NVWA (Ketenborging.nl, 2020).

[9] Government Gazette, No 48861. 30 August 2017.

3. Description of the potato chain

3.1. Introduction

For this risk assessment, the potato chain has been subdivided into five stages and the scope has been defined as activities of food business operators dealing in potato or potato products (see Table 3.1 and Figure 3.1):

Table 3.1 Stages of the potato production chain

Stage		**Phase**
1	Breeding and selection of new cultivars	Plants for planting
2	Cultivation and storage of seed potatoes	
3A	Cultivation and storage of ware potatoes	Primary: Farm
3B	Cultivation and storage of starch potatoes	
4A	Handling of potatoes and processing of potatoes into potato products	Secondary: Industry, unit packaging companies, sorting companies
4B	Processing of starch potatoes	
5	Distribution of potatoes and potato products to food handlers (consumer, mass caterer[10]) and the preparation of potatoes and potato products	Tertiary: Distribution and consumption

[10] Mass caterers: any establishment (including a vehicle or a fixed or mobile stall), such as restaurants, canteens, schools, hospitals and catering enterprises in which, in the course of a business, food is prepared to be ready for consumption by the final consumer.

As defined in: Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

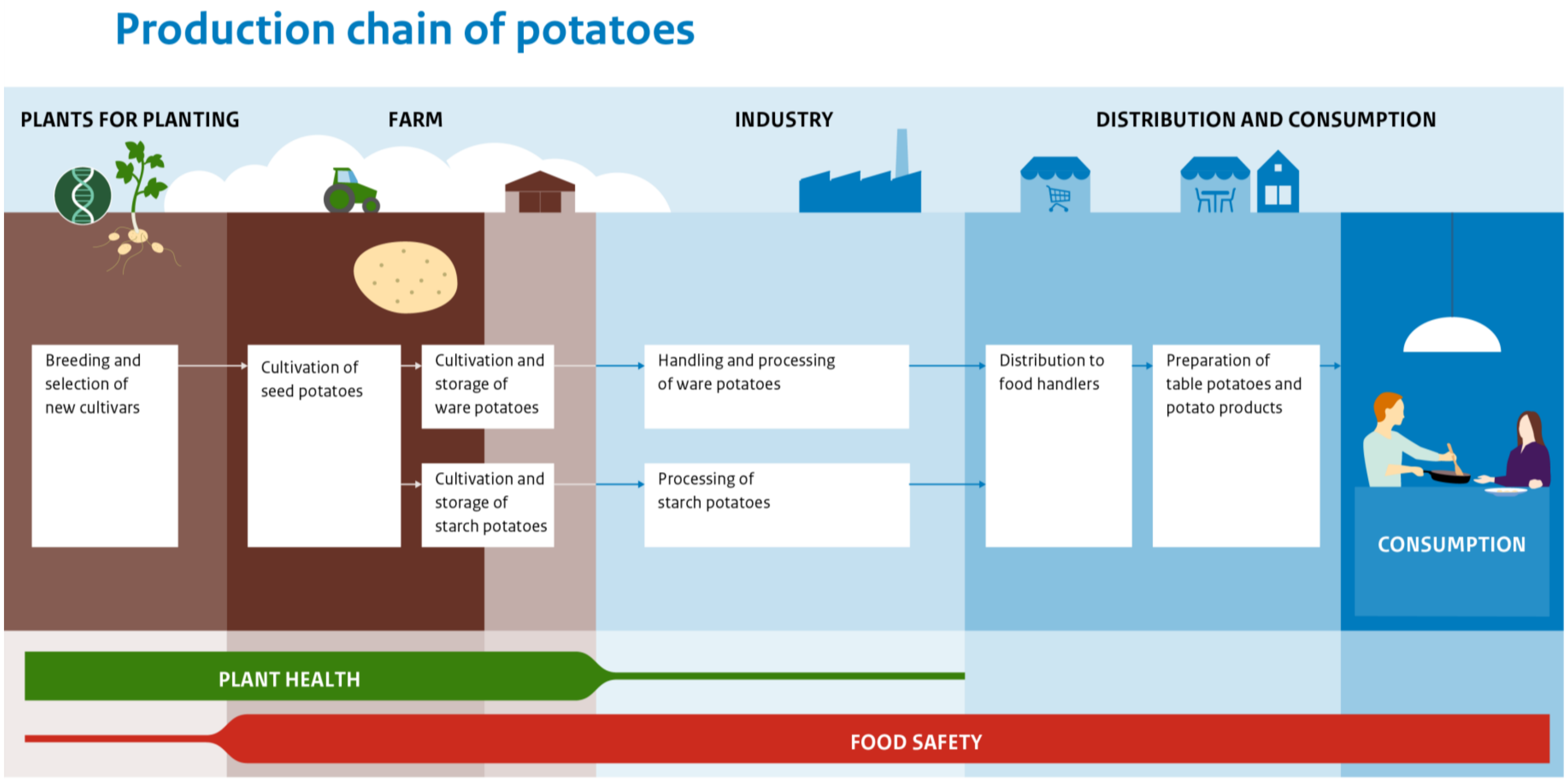

Figure 3.1 Five stages of the potato production chain (see Table 3.1).

The potato chain is characterised by a high degree of organisation and coordination between the various stages of the chain. Potato has traditionally been a vegetatively propagated crop, in which not the seed but the tubers of the plant are used as propagating material (seed potatoes) for the next potato crop. The production of seed, ware and starch potatoes takes place on arable farms. The basis of every arable farm is the crop plan: the overview of the plant species to be cultivated with the corresponding areas and plots chosen for the different crops. Crop rotation is carried out on each plot, i.e. after the harvest of one plant species, another plant species is grown on that plot. Crop succession is the order in which the different crops are grown on a single plot. The term 'crop rotation' is used when a fixed sequence of cultivation is followed for a series of crops on a plot of land. The cultivation frequency of a crop is the share of that crop in the crop rotation on a plot: a cultivation frequency of, for example, 1:4 indicates that the crop is grown on that plot once every four years. Crop rotation and succession are important measures used on arable farms to control the occurrence of soil-borne plant diseases and pests.

High quality requirements are defined for seed potatoes and their production takes place at specialised arable farms. Seed potato cultivation mainly takes place in the provinces of Friesland, Groningen, North Holland, Flevoland and Zeeland. Import of seed potatoes from EU Member States and from third countries takes place to very limited extent. A large part of the seed potatoes are supplied to other EU Member States or exported to third countries.

Zeeland, South Holland, North Brabant and Flevoland are the most important areas of cultivation for ware potatoes. In the Netherlands, most of the ware potatoes (approx. 90%) are processed as pre-fried, deep-frozen products, mainly in the form of chips. The remaining ware potatoes are processed as crisps and dehydrated potato products (flakes and mash powder), handled and packaged as peeled and pre-cooked chilled products or sold as fresh table potatoes. A part of the potatoes processed in the Netherlands is imported from EU Member States, mainly from Germany.

Starch potatoes are mainly grown in the northeastern sandy soil and reclaimed peatland areas and processed into starch at three Avebe factories. There is hardly any import and export of starch potatoes.

3.2. Stage 1: Breeding and selection of new cultivars

This stage of the chain starts with the management of planting material of potato cultivars and clones by potato breeding companies. This planting material is used as parental lines in hybridisation programmes aimed at producing new lines with unknown and new combinations of genes. The Dutch breeding companies produce approximately 1.5 million seedlings annually. Subsequently, offspring selection is carried out under field conditions for three years. The tubers of these new lines are planted annually and assessed for desired properties. Only the good lines are retained, the rest (about 90% annually) are destroyed. This selection process is partly carried out by the breeding companies and partly by the farmer-breeders or amateur breeders, on the basis of a contract with a breeding company. The best lines are further developed to form a new cultivar, for which the plant breeders' right is registered in the name of the trading house or breeding company. In 2019, this kind of clonal selection remains by far the most widely used method of potato breeding (van Loon, 2019).

This stage of the chain ends with the formation of a stock of approximately 50,000 seed potatoes of the new, registered cultivar by the breeding company (Table 5.1. in (van Loon, 2019)), which serves as the basis for the market introduction.

As of 2019, there are around 25 potato breeding companies in the Netherlands. Of these, 15 are associated with a seed potato trading house while the others are small breeders who do their own crossbreeding. Since the introduction of the Seeds and Planting Materials Act (1967), only the breeder (the holder of the plant breeders' right) of a registered cultivar has the right to produce and breed plant reproductive material of that cultivar. In response to this, large and medium-sized seed potato trading houses (approximately 15) have set up breeding companies in order to obtain the plant breeders' right over their own potato cultivars or have entered into licensing agreements for the exclusive production and sale of seed potatoes from cultivars of independent breeding companies (van Loon, 2019). As a result, potato breeding has become strongly linked to the production and trade of seed potatoes. In addition to the breeding companies, there are approximately 150 small breeders (farmer-breeders or amateur breeders) who, on the basis of a contract with a breeding company, select valuable new lines produced by breeding companies under field conditions.

Potato breeding focuses on a large number of characteristics of the plant, where the properties that determine a good yield during crop growth are combined with favourable properties for processing and consumption value (taste, shelf life, cooking type) of the harvested product. Breeding goals that are important for plant health and public health (due to human exposure to plant protection products) are resistance and tolerance to harmful organisms, including *Phytophthora infestans*, potato viruses and the regulated organisms *Globodera rostochiensis*, *G. pallida* and *Synchytrium endobioticum*. A licence from the NVWA is required for conducting research on regulated pests. An assessment of the level of resistance or tolerance to regulated organisms is carried out under the supervision of the NVWA. Important breeding goals for food safety are lowering the levels of glycoalkaloids (a group of toxic substances produced by plants, particularly solanine) as well as the levels of asparagine and reducing sugars in the potato tuber (due to the formation of acrylamide when heated above 120°C) (Haasse, 2010), (EFSA CONTAM Panel, 2015b). For the legal registration of new varieties of ware potatoes, the level of glycoalkaloids must not exceed the multi-annual average of the variety known as Innovator (Seeds and Planting Materials Act[4], Board for Plant Varieties (*Raad voor Plantenrassen*), 2020). The level of glycoalkaloids is determined as part of the Cultural and Practical Value Research (*Cultuur- en Gebruikswaarde Onderzoek*) being conducted by the NAK.

During the breeding and selection of new potato cultivars, there is frequent exchange of genetic material between international establishments of a breeding company and between breeding companies and contracted amateur breeders. If this material is infested by harmful organisms, there is a risk of harmful organisms being inadvertently introduced into a breeding programme (Tweede Kamer der Staten-Generaal, 2014) or of harmful organisms spreading outside the protected environment of the breeding companies. It is prohibited to import potato propagating material from countries outside the EU, except from Switzerland[11]. It is possible to obtain an exemption from this prohibition for breeding and selection activities with a temporary official clearance from the NVWA[12]. When lots of planting material are moved between different companies in the Netherlands or in EU Member States, each lot of planting material must be accompanied by a certificate (plant passport) based on an inspection of the material, to avoid risks to plant health. The NAK performs the inspection and issues the certificate under the supervision of the NVWA. This requirement does not apply when lots are moved between Dutch locations of the same company.

Since the end of the twentieth century, various new techniques have been developed to accelerate and improve the breeding process, such as tissue culture, potato cultivation from seeds and genetic modification techniques such as RNA interference and cisgenesis (Hameed et al., 2018). In case of genetic modification, the DNA of an organism (in this case, the potato plant) is altered with the aim of giving the organism a new or modified characteristic. Work involving genetically modified organisms (GMOs) and placing them on the market are subject to strict legislation. A licence is required for the cultivation and import of live GMOs[13]. The Joint Research Centre is the European reference laboratory for GMOs and it publishes the dossiers for GMOs for which a licence has been requested (JRC, 2020). The GMOs with a market authorisation are published in the EU Register of Authorised GMOs (EC, 2020a). Potato cultivars developed with genetic modification are currently not authorised in the EU. The import of genetically modified potatoes intended for consumption is also prohibited. This is checked during the import of potatoes and potato products (NVWA, 2020k) and infringements are reported via the RASFF database.

In 2010, the European Commission approved the potato cultivar Amflora to be used for the cultivation of starch potatoes. In this cultivar, the gene responsible for the production of the unwanted starch variant amylose has been switched off via genetic modification. However, in 2012, this authorisation was found to be unlawful and withdrawn (Reuters, 2013). The Innate potato - licensed in the US ((USDA APHIS, 2016)) and in Canada ((CFIA, 2019)) - has a number of characteristics that have been incorporated through cisgenesis, including reduced levels of asparagine, glucose and fructose and resistance to potato blight caused by *Phytophthora infestans*.

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[11] Annex VI, point 15 of: Commission Implementing Regulation (EU) 2019/2072 of 28 November 2019 laying down uniform conditions for the implementation of Regulation (EU) 2016/2031 of the European Parliament and of the Council, as regards protective measures against pests of plants, and repealing of Commission Regulation (EC) 690/2008 and amending Commission Implementing Regulation (EU) 2018/2019.

[12] Article 48 of Regulation (EU) 2016/2031[2].

[13] Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC.

Breeding companies are currently working on techniques to allow for the hybrid breeding of potato cultivars, which will make it possible to produce true potato seeds as the propagating material for potato cultivation (Edelenbosch & Munnichs, 2020). The basis for the seed is formed by two homozygous diploid parent lines. By crossing these parent lines, the hybrid seed is produced, in which the properties of both lines are combined. This technique offers a number of advantages. Desired properties of the potato, such as resistance to potato blight (caused by the pseudo-fungus *Phytophthora infestans*), can be introduced into a new cultivar more quickly so that fewer fungicides will be needed during cultivation. Significant bacterial diseases of potatoes, such as brown rot and ring rot, are transmitted via infested seed potatoes to a new crop, but these bacteria do not occur in or on the seed. This limits the spread of these bacteria. True potato seed is easier to store and transport than seed potatoes, making storage and transport easier. The introduction of such hybrid potato cultivars requires new legislation relating to plant breeders' rights, a new approach to the production and inspection of propagating material for potato cultivation and a new logistics organisation for the potato chain. The first hybrid potato cultivars are expected to be introduced in the Netherlands in a few years' time (Engwerda, 2018).

3.3. Stage 2: Production of seed potatoes

Seed potatoes are potato tubers that have been produced to serve as the propagating material for a next potato crop. This next crop may be another seed potato crop or the cultivation of an end product (ware potato or starch potato).

The production of seed potatoes starts with the development of clones for each potato cultivar through clonal selection by specialised growers, i.e. the clonal selectors. Three phases can be distinguished in the development of a clone: pre-basic, basic and certified seed. Developing a clone can start with the selection of healthy-looking plants of the cultivar in question while they are growing on a plot or with the cultivation of mini tubers produced *in vitro*. Seed potatoes are increasingly being propagated from mini tubers (Meijering, 2015). The tubers of each plant or the daughter tubers of the grown mini tubers are harvested separately, stored and registered under a unique code. In the following year, a first-year clone grows from these tubers. The first-year and subsequent clones are intensively monitored by the NAK for cultivar traits and the absence of harmful viruses and bacteria that can be transferred via the tuber to the next generation of plants (daughter plants). This monitoring is important for ensuring the plant health of the potato chain. With each successive generation, the number of tubers of the clone increases about tenfold (Kennisplatform Aardappels, 2020). After four generations of pre-basic seed potatoes, the clonal selection phase is complete. The next five generations are basic or certified seed potatoes and are propagated by seed potato growers. The seed potatoes produced can be used for developing the next generation of the clone or as the propagating material for the cultivation of the end product (ware potato or starch potato cultivation). The quality class of each generation of seed potatoes is reduced by one level via a 'cut-off system' (NAK, 2016). After 10 years, the clone loses the status of seed potato.

This stage of the chain ends with the supply of seed potatoes to arable farms for the cultivation of ware potatoes or starch potatoes.

There are laws and regulations for seed potato cultivation, which focus on plant health, varietal purity and vitality (see Annex 2). Any operator growing and processing agricultural seeds and/or seed potatoes must be affiliated with the NAK. Seed potatoes may only be placed on the market if it has been established during the official inspection by the NAK that they meet the quality requirements relating to varietal purity, health, vigour, purity, classification, labelling, etc. as described in the Seeds and Planting Materials Act 2005[4]. In addition, seed potatoes that are placed on the market must meet the requirements of the European Plant Health Regulation[2]. The NAK has been designated as the competent authority for performing these phytosanitary inspections, under the supervision of the NVWA[3].

On average, in the period 2016-2018, there were 2,360 farms involved in the cultivation of seed potatoes in the Netherlands (Table 3.2). In addition to seed potatoes, ware potatoes and/or starch potatoes are also cultivated by over 1100 farms. The seed potato acreage was approximately 42,000 ha on average and the total annual yield in the Netherlands was approximately 1.5 million tons. Approximately 1.1 million tons of certified seed potatoes were produced per year. The difference of an average of 0.4 million tons per year consists of seed potatoes produced for the cultivation of ware potatoes at the breeding company (approx. 0.03 million tons per year (NAK, 2020)), lots rejected by the NAK and oversized seed potatoes. Oversized seed potatoes are tubers larger than 55 mm in diameter and these are less suitable for use as propagating material. Some of the rejected lots and oversized seed potatoes are sold as ware potatoes. The quantity is determined by supply and demand in both the seed and ware potato markets.

Import of seed potatoes from EU Member States is permitted under the conditions laid down in Regulation (EU) 2016/2031. In addition, a plant passport must be issued for seed potato lot based on an inspection by the competent authority of the producing country. On average, approximately 82,000 tonnes of seed potatoes were imported from EU Member States per year during 2016-2018 (Table 3.2). Seed potatoes were imported from all Member States. Import of seed potatoes from countries outside the European Union is prohibited, except from Switzerland[11].

The export of seed potatoes (to EU Member States and third countries) during 2016-2018 amounted to approximately 800,000 tons/year, according to the NAO (NAO, 2020b). According to Statistics Netherlands, exports during this period amounted to about 940,000 tons/year (StatLine, 2019). Based on the NAO report, 370,000 tons per year on average were available for Dutch use in 2016-2018 (Table 3.2).

Table 3.2 Seed potato data: companies, acreage, production and trade, average per year for the period 2016-2018.

Average seed potato production and trade 2016-2018		
Number of companies NL[a]	2,360	-
Area NL[b]	42,426	ha
Total yield NL[b]	1,456,471	tons/year
Certified seed potatoes NL[d,e]	**1,086,704**	**tons/year**
Import from the EU[c]	82,040	tons/year
Stock NL	**1,168,744**	**tons/year**
Export to EU and third countries[f]	**800,000**	**tons/year**
Available propagating material NL	**369,012**	**tons/year**
Uncertified seed potatoes NL (difference between produced and certified seed potatoes)	369,767	tons/year

Sources (edited by the NVWA):

a) (StatLine, 2020a)
b) (StatLine, 2020b)
c) (StatLine, 2019)
d) (NAK, 2017)
e) (NAK, 2018)
f) (NAO, 2020b)

Seed potatoes are grown with other crops at a statutory cultivation frequency of once in three years or more to avoid the threat to plant health caused by *G. rostochiensis* and *G. pallida* (potato cyst nematodes) (NVWA, 2020e). This means that no potatoes should have been grown on the plot in the two years prior to the cultivation of seed potatoes (regardless of whether they were ware, starch or seed potatoes). This also helps slow down the development of other soil-borne organisms that are harmful to potatoes. Artificial fertilisers are used for fertilising the seed potato crop. Plant protection largely depends on the use of chemical plant protection products against weeds, lice and diseases (especially for potato blight caused by *Phytophthora infestans).* It is essential that there is sufficient moisture in the soil during the phase in which potato plants form underground stems (stolons), at the end of which new potato tubers are formed. In most years, irrigation using sprinklers is necessary. The use of surface water for this purpose is prohibited throughout the Netherlands because of the presence of the quarantine pest *Ralstonia solancearum*, the bacterium that causes brown rot[14], in surface water. When growing seed potatoes, only tap water or spring

[14] Commission Directive 98/57/EC and Council Directive on 20 July 1998 on the control of Ralstonia solanacearum (Smith) Yabuuchi et al.

water may be used for sprinkler irrigation and crop spraying. Prior to harvesting, the haulm is destroyed with a herbicide or by burning it off. The harvested tubers from a single plot are stored separately from those from other plots either at the grower's farm, at another seed potato grower's farm, at the trading house or at a specialised storage company. Sprout inhibitors are used during storage and lots can be treated with fungicides.

About 40% of farms that cultivate seed potatoes also grow ware or starch potatoes, which are also stored on the farm. Some farms also store seed, ware or starch potatoes from other farms. In private quality assurance systems, requirements for industrial hygiene are defined for different categories of farms that work with seed potatoes (NAO, 2020a).

Some of the seed potatoes produced are not certified by the NAK, for example, because the tubers do not meet the quality requirements or they are too large or too small. Only certified seed potatoes may be used as propagating material for potato cultivation and marketed for that purpose. The tuber size of the harvested potatoes depends on several factors, including the cultivar, soil conditions and weather conditions during stolon formation and tuber formation (Bus et al., 1996). Oversized seed potatoes (>55 mm diameter) produce fewer stalks per kilogram and are less suitable as propagation material for a new crop of potatoes (Reestman et al., 1960). These seed potatoes can be cut to a smaller size. The use of cut seed potatoes for the cultivation of new seed potatoes is prohibited in order to prevent the spread of harmful organisms (NVWA, 2018h). The use of cut seed potatoes is permitted on farms that are not involved in seed potato cultivation but which grow ware and starch potatoes.

Some oversized seed potatoes are placed on the market as ware potatoes (Van Berkhout et al., 2015). The quantity varies from year to year and is determined by supply and demand in both the seed potato market and the ware potato market. The VVAK Food and Feed Safety Guide states that seed potatoes that are sold as ware or starch potatoes must meet the requirements applicable to ware and/or starch potatoes (Akkerbouw Certificeringsoverleg, 2019).

3.4. Stage 3A: Cultivation and storage of ware potatoes

The production of potatoes intended for consumption or processing can be divided into two stages: the production of ware potatoes, which is discussed here, and the production of starch potatoes, which is described in section 3.5).

Ware potatoes are grown for human consumption and can be subdivided into table potatoes and industrial potatoes. Table potatoes are intended for direct consumption and are sold via supermarkets, itinerant trade or directly via the farmer. Industrial potatoes are grown for processing into pre-fried products, crisps, potato flakes and chilled processed products. Depending on what the potatoes will be used for, specific cultivars are grown and cultivation measures such as fertilisation and plant protection are adapted accordingly. Most of the ware potatoes are grown based on a contract with the buyer (Van Berkhout et al., 2015). Moreover, quality assurance systems such as GlobalG.A.P., VVA and the NAO Hygiene Protocol (see Annex 1) are applicable.

The stage in the chain involving the cultivation and storage of ware potatoes starts with the delivery of seed potatoes to arable farms for the cultivation of ware potatoes. Just like seed potatoes, ware potatoes are grown with other crops based on a legally imposed cultivation frequency of once in three years or more to avoid the threat to plant health caused by *G. rostochiensis* and *G. pallida* (potato cyst nematodes). This obligation does not apply to ware potato cultivation in the northeastern sandy soil and reclaimed peatland areas (NVWA, 2020e). For the fertilisation of the ware potato crop, both animal manure and chemical fertilisers are used prior to cultivation (Brancheorganisatie Akkerbouw, 2020b), (Van Geel, 2015), (RVO, 2020b). If necessary, chemical fertilisers are additionally applied during cultivation. Plant protection largely depends on the use of chemical plant protection products against weeds, lice and diseases (especially for potato blight caused by *Phytophthora infestans).* The use of surface water for irrigation of plots with ware potatoes is prohibited in a large part of the Netherlands, due to the presence of brown rot bacteria in the surface water (NVWA, 2020d). Prior to harvesting, the haulm is destroyed with a herbicide or by burning it off. The harvested tubers are stored either at the grower's farm, at another seed potato grower's farm, at the trading house or at a specialised storage company. Sprout inhibitors are used during storage and lots can be treated with fungicides. During storage, rotten and unwanted tubers are sorted from the lot and collected in waste heaps. Growers are obliged to cover these waste potato piles to prevent the early spread of *Phytophthora infestans*, the agent responsible of potato blight. Compliance with this obligation is monitored by the NAK (NVWA, 2020b).

From the storage at arable farms, trading houses and storage companies, lots are transported to companies that perform processing or handling activities and to specific locations for supply to EU Member States or export to countries outside the EU.

The stage involving the cultivation and storage of ware potatoes ends with the transport of potatoes from the storage locations to the potato processing companies and potato packaging companies. The VVAK Food and Feed Safety Guide (Akkerbouw Certificeringsoverleg, 2019) outlines hygienic measures to prevent contamination by foreign substances such as earlier transported materials (chemical fertiliser, manure, animal feed, etc.), stones and other objects.

Table 3.3 summarises the data on the production and trade of ware potatoes. This also includes the import by potato processing and handling companies. On average, in the period 2016-2018, there were 6853 farms involved in the cultivation of ware potatoes in the Netherlands. The area under cultivation was approximately 75,000 ha and the total annual yield in the Netherlands was approximately 3.4 million tons.

For the handling and processing of ware potatoes in the Netherlands, fresh ware potatoes are imported (Table 3.3). Import of fresh ware potatoes from EU Member States is permitted under certain conditions[15]. On average, over 1.5 million tons of ware potatoes were acquired from EU Member States per year during 2016-2018, of which over 1 million tons from Germany. This includes first early potatoes: fresh potatoes that are traded between 1 January and 30 June. Ware potatoes have been acquired from all Member States. Import of fresh ware potatoes from countries outside the European Union is prohibited, except from Switzerland and a few other specified countries[16]. The imported lots must comply with the requirements set out in Annex VII of this Implementing Regulation. On average, in the period 2016-2018, more than 45,000 tons of ware potatoes were imported from third countries per year (Table 3.3). Of this, 75% of this consists of first early potatoes from African and Asian countries around the Mediterranean.

During 2016-2018, an average of more than 600,000 tons of fresh ware potatoes per year were supplied to EU Member States and 265,000 tons per year were exported to third countries.

If the production in the Netherlands is offset against imports and exports, 4.3 million tonnes of ware potatoes were available for processing and handling in the Netherlands annually on average in the period 2016-2018.

[15] Annex VIII point 11 of Implementing Regulation (EU) 2019/2072[11].

[16] Annex VI, point 17, of Implementing Regulation (EU) 2019/2072[11].

Table 3.3 Ware potato data: companies, acreage, production and trade, average per year for the period 2016-2018.

Average ware potato production and trade 2016-2018		
Number of companies NL[a]	6,853	-
Area NL[b]	75,324	ha
Total yield NL[b]	**3,414,218**	**tons/year**
Oversized seed potatoes	184,883	tons/year
Import of fresh potatoes from the EU[c]	1,571,349	tons/year
Import of fresh potatoes from third countries[c]	45,052	tons/year
Stock NL	**5,215,502**	**tons/year**
Export of fresh potatoes to the EU[c]	622,642	tons/year
Export of fresh potatoes to third countries[c]	265,701	tons/year
Total export	**888,342**	**tons/year**
Available for use in NL	**4,327,160**	**tons/year**
1. Processed into a pre-fried product[d]	3,569,133	tons/year
2. Processed into chilled product[d]	420,000	tons/year
3. Other processing, including unit packaging (table potatoes)[d]	338,027	tons/year

Sources (edited by the NVWA):
a) (StatLine, 2020a)
b) (StatLine, 2020b)
c) (StatLine, 2019)
d) (NAO, 2019)

3.5. Stage 3B: Cultivation and storage of starch potatoes

Starch potatoes are cultivated for processing into potato starch and potato protein at potato starch plants. Cultivars for starch potatoes are bred and selected to create a high starch content. They may contain high levels of glycoalkaloids (a group of toxic substances produced by plants) and are therefore not intended or suitable for consumption as table potatoes or for being processed for producing chips or crisps. Due to the undesirable taste and cooking and baking quality, there are no cases of unintentional consumption of starch potatoes.

The stage of the potato chain involving the cultivation and storage of starch potatoes starts with the delivery of seed potatoes to arable farms for the cultivation of starch potatoes. Starch potatoes are primarily cultivated in the northeastern sandy soil and reclaimed peatland areas, where there is no restriction on the cultivation frequency of potato crops. In 2017, 57% of the plots had a cultivation frequency of once in two years, 28% a cultivation frequency of once in three years and 15% a cultivation frequency of once in four years or higher (Avebe, 2018). These intensive crop rotations lead to the build-up of high populations of soil-borne harmful organisms, especially nematodes *G. rostochiensis* and *G. pallida*. To limit the loss of yield due to these organisms, the soil on almost all plots is treated with nematicides prior to the cultivation of starch potatoes. The cultivation, harvest and storage take place in a similar manner as in the case of ware potatoes.

On average, in the period 2016-2018, there were 1,600 farms involved in the cultivation of starch potatoes in the Netherlands. The starch potato acreage was approximately 44,000 ha and the total annual yield in the Netherlands was approximately 1.8 million tons (StatLine, 2020b), (StatLine, 2020a).

Import of fresh starch potatoes from EU Member States is permitted under the conditions laid down in Regulation 2016/2031. On average, over 66,000 tons of starch potatoes were acquired from EU Member States per year during 2016-2018, of which over 62,000 tons from Germany. Starch potatoes were imported from all Member States. Import of fresh starch potatoes from countries outside the European

Union is prohibited, except from Switzerland and a few other specified countries[16], and this occurs only rarely. On average, in the period 2016-2018, 9 tons of starch potatoes were imported from Switzerland per year (StatLine, 2019).

During 2016-2018, 7,600 tons of fresh starch potatoes per year on average were exported to EU Member States and 6,000 tons per year were exported to third countries. More than 1.8 million tons per year on average was available for Dutch use.

3.6. Stage 4A: Handling of potatoes and processing of potatoes into potato products

The stage involving the handling of potatoes and their processing into potato products starts with the receipt of ware potatoes by food businesses that handle or process potatoes. This stage ends with the delivery of products to wholesalers of potatoes, vegetables and fruit (produce), retail trade (incl. supermarkets) and itinerant trade.

A distinction is made between the handling and processing of ware potatoes. Handling is understood to mean actions that do not result in a substantial change in the product, such as brushing and washing to remove soil and packing in unit packages. Handled potatoes are referred to as 'fresh potatoes' or 'table potatoes' and are intended for sale to the end user (consumer, mass caterer). Processing is understood to mean actions whereby the product undergoes changes. There are four categories of processed potato products: dehydrated, chilled, pre-fried and other processed products.

Dehydrated potato products have a long shelf life and are easy to store and transport. Examples of such products are potato powder and potato flakes. They are used as ingredients in other foods, such as for the production of snacks, potato croquettes and chips (Ras® Fries). Instant potato mash is a well-known end product.

Chilled potato products are divided into ready-to-cook and ready-to-eat categories. Ready-to-cook products are mildly heated but not fully cooked. The mild heating preserves sensory properties and nutrients, prevents loss of quality by inactivating the enzymes that cause browning and assists the cooking process. These products are often blanched to preserve quality. Sulphites, ascorbic acid or citric acid can be added to prevent further browning. Depending on the type of product and the desired shelf life, the chilled potato products are packed using vacuum packaging, modified atmosphere packaging or packed in an atmosphere of normal air. A post-packaging pasteurisation process may also be applied to the final packaging. Ready-to-cook products, such as pre-packaged chilled potato slices, baby potatoes and chips, still need to be cooked or fried by the end user. Ready-to-eat products are suitable for immediate consumption and therefore include fully cooked potatoes and potato products, although some need to be heated up to taste. This often concerns products in which, in addition to potatoes as the main ingredient, other ingredients have been incorporated, such as potato salads, potatoes in main-course salads and chilled mashed potatoes.

Pre-fried, frozen potato products include chips and potato wedges, potato croquettes, rösti, etc. which need to be additionally fried before use. Chips and other such products are blanched briefly and pre-fried, frozen and packaged.

Finally, the 'other processing' category includes products such as crisps and sterilised potato products (in cans or glass containers). The latter product group forms only a small flow of products within the potato chain, certainly in the Netherlands.

Over the period 2016-2018, the production of industrially processed and chilled potato products in the Netherlands amounted to, on average, approximately 2.3 million tonnes/year (NAO, 2019). Import of these products amounted to 0.5 million tons/year and export amounted to approximately 2.4 million tons/year (StatLine, 2019). In the Netherlands, approximately 0.4 tons of industrially processed and chilled products are consumed per year.

In addition to industrial processing and production of chilled products, more than 7% (0.3 million tonnes) of fresh ware potatoes were handled by packaging companies for sale as table potatoes. Potato packaging companies work in line with the relevant NAO Hygiene Code (NAO, 2020c).

Industrial processing of ware potatoes - Process

There are 13 potato processing companies in the Netherlands, with a total of 20 establishments (Knuivers, 2015). At these companies, ware potatoes are processed into pre-fried potato products, such as chips, and other products, such as crisps or potato flakes. Several types of processing are carried out at a number of companies. Six of these companies are members of the VAVI and they represent approximately 95% of the potato processing industry in the Netherlands (VAVI, 2020). There is an unknown number of arable farms that process their own potatoes and an unknown number of smaller processing companies, such as local or regional chip shops, that purchase potatoes from a limited number of regular suppliers (Smit & Jager, 2018). The operating processes and the amount of potatoes processed at these companies are not known.

In all forms of processing, an incoming inspection of each lot is performed and a dry and/or wet cleaning is carried out to remove unwanted organic materials, stones and soil. The soil removed from the potatoes is referred to as 'soil tare'. Since the potatoes to be processed may come from plots that are infested with potato cyst nematodes, the soil tare must be disposed of in accordance with the requirements of the EU directive on the control of potato cyst nematodes[17]. The processing company must be recognised by the NVWA, which means that the company must have a soil tare disposal method that guarantees that the soil is not disposed of on agricultural land in an uncontrolled manner. The potato processing company may deal with this in three ways (NVWA, 2020h):

- Disposal to a plot of agricultural land for which a Potato Cyst Nematode Infestation Declaration (*Besmetverklaring aardappelmoeheid*) has been issued by the NVWA
- Disposal to a location outside agricultural areas
- Treatment of soil tare prior to disposal in or outside agricultural areas

During the disposal of soil tare, certain requirements relating to the contents of chemical substances, including PFAS and PFOS[18], must be fulfilled. As of 1 December 2019, PFAS has been added to Appendix 1 of the Soil Quality Decree (*Besluit Bodemkwaliteit*) and the Temporary Action Framework for the Reuse of PFAS-containing Soil and Dredged Material (*Tijdelijk handelingskader voor hergebruik van PFAS-houdende grond en baggerspecie*) (Tweede Kamer der Staten-Generaal, 2019), which includes soil tare, has been updated. The background value of PFAS has been generally established as 0.8 µg/kg for dry matter and that of PFOS as 0.9 µg/kg.

Large quantities of clean spring or tap water are used during processing (Janssens & Smit, 2016), whereby this water becomes contaminated with soil residues, starch, fat, potato residues and minerals. The contaminated process water is usually decontaminated so that this water can be reused. Soil residues, starch residues and fats are collected and disposed of separately. Contaminated process water that is not reused is purified in wastewater treatment plants.

When being processed into pre-fried products (Aviko, 2016), the clean potatoes are successively:

- Peeled using high-pressure steam
- Sorted to remove foreign materials and rotten potatoes
- Cut
- Blanched to extract excess sugars
- Dried and optionally coated with herbs ('battered')
- Fried
- Chilled or frozen
- Packed in plastic film

For the processing into crisps, some products use unpeeled potatoes or the skin is removed by scraping the potatoes, after which the fried product is brought to the desired taste.

During processing into potato flakes, the peeled potatoes are cooked, dried and rolled.

When being processed into chilled products, the peeled and sorted potatoes are cut and blanched. They are packed in closed plastic bags, with a modified atmosphere (reduced oxygen and increased carbon dioxide level) or in a vacuum.

[17] Council Directive 2007/33/EC of 11 June 2007 on the control of potato cyst nematodes and repealing Directive 69/465/EEC.

[18] PFAS: per- and polyfluoroalkyl substances; PFOS: perfluorooctane sulfonate

In addition to the more than 2 million tons processed potato products produced in the Netherlands, nearly 500,000 tons of processed potato products were imported on average in the period 2016-2018 from almost all EU Member States, but mainly from Belgium (StatLine, 2019). Of this average annual Dutch stock of potato products, 85% was exported to EU Member States and countries outside the EU, which means that an average of about 400,000 tons of processed potato products were consumed in the Netherlands.

Table potatoes - Process

There are approximately 80 companies in the Netherlands selling fresh potatoes for the table potato market (Silvis, 2020). The potatoes are transported from the storage at arable farms to the packaging companies, where the potatoes are washed, sorted and packed. Spring or tap water is used for washing the potatoes. A number of these companies are also involved in the industrial processing of potatoes (for example, processing into pre-fried chips). At some of these companies, the waste water from the industrial process is treated and then used as washing water for the table potatoes (for example, (Waterstromen.nl)). For the disposal of soil tare by packaging companies, the same requirements apply as described above under 'Industrial processing of ware potatoes - Process'. The potatoes are packed in bags or bales, varying in size between 1 and 25 kg.

3.7. Stage 4B: Processing of starch potatoes

This stage starts with the delivery of starch potatoes to the potato starch production facility and ends with the delivery of potato starch to consumers and the establishments of Avebe or to other industrial plants for industrial processing.

In the Netherlands, 1.8 million tons of starch potatoes were available per year on average in the period 2016-2018, of which 97% came from domestic potato cultivation and 3% from Germany (Table 3.4). Intra-Community supplies amounted to only 0.4% of the produced starch potatoes. Avebe, a cooperative with over 2500 Dutch and German members (Avebe, 2020a), is the only company in the Netherlands that processes starch potatoes at its three production sites.

Table 3.4 Starch potato data: companies, acreage, production and trade, average per year for the period 2016-2018.

Starch potato production and trade NL 2016-18		
Number of companies NL[a]	1,600	-
Area NL[b]	44,097	ha
Total yield NL[b]	**1,779,849**	**tons/year**
Import from the EU[c]	66,621	tons/year
Import from third countries[c]	9	tons/year
Stock NL	**1,846,479**	**tons/year**
Export to the EU[c]	7,614	tons/year
Export to third countries[c]	5,961	tons/year
Total export [c]	13,575	tons/year
Consumption NL	1,832,904	tons/year

Sources (edited by NVWA):

a) (StatLine, 2020a)
b) (StatLine, 2020b)
c) (StatLine, 2019)

With a starch content of 20% in the tubers (Avebe, 2018), 366,000 tons of potato starch were produced annually (Table 3.5). Every year, almost 90,000 tons of potato starch was imported from EU Member States and more than 200,000 tons were exported, primarily to countries outside the EU.

Table 3.5 Production and trade of potato starch in NL on average in 2016-2018.

Potato starch production and trade NL 2016-18		
Potato starch production[a]	**366,581**	**tons/year**
Import [b]	89,472	tons/year
Available in NL before export[b]	456,053	tons/year
Export[b]	206,994	tons/year
Consumption in NL	**249,059**	**tons/year**

Sources (edited by the NVWA):
a) (StatLine, 2020b)
b) (StatLine, 2019)

Avebe produces 30% of the global supply of potato starch. Growers supply starch potatoes to Avebe based on their shares: growers with shares have a supply obligation. The potatoes are washed and ground to a pulp upon arrival at the production plant. Potato starch and potato protein are extracted from this pulp. These products are isolated and cleaned after which they are ready to be traded. Of the potato starch produced, 30% is used in food and the rest is used in other industrial processes, such as the production of bioplastics.

Potato protein has an amino acid composition that is potentially very suitable for processing in food. But, until recently, it was only used for animal feed because there was no effective technique to isolate the protein in pure form. Since 2007, a new technique has been developed with which Avebe extracts and sells pure potato protein under the name 'Solanic' (Avebe, 2020b). Solanic is used for the production of meat substitutes, dairy-free cheese and foam gum sweets.

3.8. Stage 5: Distribution of potatoes and potato products to food handlers and the preparation of potatoes and potato products

The end user of the potato chain is defined as the food handler. This is the consumer who prepares the food for the members of his or her household or the professional food handler working for a mass caterer. Potatoes and potato products can be prepared in many ways, such as by cooking, frying and deep-frying with or without the peel.

Packaged table potatoes are supplied by potato packaging companies directly or via wholesalers to retailers and to the food service industry. About 90% of table potatoes are sold via supermarkets, with the eight largest processing companies taking care of 80-90% of the supply to supermarkets (Silvis, 2020).

Packaged processed potatoes are supplied by potato processing companies directly or via wholesalers to retailers and to the food service industry.

Potato starch for use in kitchens is supplied in packaged form by Avebe to end users via wholesalers.

Short supply chains

A small proportion of the ware potatoes is supplied to end users via short supply chains. Short supply chains include direct delivery from farm to chip shops, farm sales to consumers, Internet sales, meal boxes, etc.

3.9. Production chain for organic potatoes

In the period 2016-2018, there were on average about 200 certified farms involved in the organic cultivation of potatoes, which is more than 2% of the total number of farms carrying out potato cultivation

(Table 3.6). These farms produce 0.8% of the total amount of seed potatoes and 1.3% of the total amount of ware potatoes. Organic potatoes may only be grown by companies that are certified for this by Skal Biocontrole. Specific conditions are laid down for the use of fertilisers, soil improvers, plant protection products and biocides (SKAL, 2019). Organic seed potatoes, just like conventionally produced seed potatoes, are inspected by the NAK.

Table 3.6. Number of farms, acreage and yield of organic potatoes 2016-18

Organic potato production on average in 2016-2018			
	Agriculture NL	Organic cultivation	Percentage of organic cultivation
Number of farms NL			
Potato	9,648	209	2.2%
Seed potato	2,360	59	2.5%
Ware potato	6,851	168	2.5%
Starch potato	1,603	3	0.2%
Acreage NL (ha)			
Potato	161,847	1,576	1.0%
Seed potato	42,425	418	1.0%
Ware potato	75,324	1,146	1.5%
Starch potato	44,097	12	0.0%
Yield NL (tons)			
Potato	4,870,688	55,952	1.1%
Seed potato	1,456,471	11,507	0.8%
Ware potato	3,414,218	44,445	1.3%

Source: (StatLine, 2020c). Edited by NVWA.

Organic ware potatoes are sold as table potatoes (possibly washed and packaged) or processed into pre-fried products, chilled products and salads. Companies involved in the processing of organic potatoes must be certified by Skal Biocontrole. Specific conditions apply to the use of additives and processing aids and the use of labelling in potato processing (SKAL, 2018b).

4. Risk assessment of organisms harmful to plants: legislation, scope and methodology

4.1. Introduction

There are a large number of organisms (viroids, viruses, bacteria, pseudofungi and other fungi, insects, mites, nematodes, snails and plants) that may affect or displace plants (weeds), hereinafter referred to as 'harmful organisms'. Based on phytosanitary legislation, harmful organisms can be divided into non-regulated organisms, regulated organisms and organisms that could potentially be regulated. Regulated organisms are those mentioned by name in EU legislation. Organisms that could potentially be regulated are those that are not currently mentioned in EU legislation but that meet the criteria for regulation. The following are discussed below: (i) EU legislation containing the different categories of regulated organisms, (ii) national cultivation regulations concerning harmful organisms and (iii) the approach followed in the risk assessment of regulated organisms with respect to the Netherlands.

4.2. EU legislation

Phytosanitary legislation is harmonised within the EU. European phytosanitary legislation is based on Regulation (EU) 2016/2031 (Plant Health Regulation)[2] and Regulation (EU) 2017/625 (Official Controls Regulation)[7].

The Official Controls Regulation (EU) 2017/625 not only applies to plant health but also to other areas that fall under the responsibility of the NVWA. With regard to plant health, the Official Controls Regulation lays down rules regarding official inspections to be performed during the import of plants and plant products and other objects[19] that may carry harmful organisms. The Regulation also designates reference or other laboratories authorised to perform diagnoses on samples taken during official controls. For example, the National Reference Centre - Plant Health (*Nationaal Referentie Centrum fytosanitair)* of the NVWA has been designated as the European Reference Laboratory (EURL) for bacteria and viruses.

The Plant Health Regulation (EU) 2016/2031 only applies to plant health. This Regulation is organism-oriented, which means that most plants and plant products can be imported without a prior risk assessment. When a new organism considered harmful in the EU is identified, it is placed on a special list, i.e. the list of Union Quarantine Pests (UQP), and special requirements are often imposed on the plants and products that may be carriers of such organisms. For a number of plants and products, general import requirements (special provisions that are not linked to a named organism) or even import bans apply in order to reduce the likelihood of the introduction of certain harmful organisms. There is also an article on the basis of which a temporary import ban may be imposed for "*plants, plant products and other objects*" whose import presents a major and unacceptable level of risk in terms of introducing new harmful organisms ('high-risk plants') into the EU. Based on this article, the import of 35 genera and species of plants for planting (excluding seeds, in vitro material and bonsais) and the import of a number of other products (from certain countries) is currently prohibited (Implementing Regulation (EU) 2018/2019)[20].

The Plant Health Regulation defines different categories of regulated organisms and lays downs rules for mitigating the risk of these organisms. The following categories of organisms are defined:

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[19] The term 'plants and seeds' is understood to mean plants for planting that have been defined in Regulation (EU) 2016/2031[2] as "plants intended to remain planted, to be planted or to be replanted". This includes all plant reproductive material such as seeds, tissue culture plants, cuttings and young plants as well as complete plants with root ball or in pots. 'Plant products' means products of plant origin that have not been processed or that have undergone basic handling, such as cut flowers, cut branches, vegetables, fruit and wooden packaging material, other than 'plants for planting'.

[20] Commission Implementing Regulation (EU) 2018/2019 of 18 December 2018 establishing a provisional list of high risk plants, plant products or other objects within the meaning of Article 42 of Regulation (EU) 2016/2031 and a list of plants for which a phytosanitary certificate is not required for introduction into the Union within the meaning of Article 73 of that Regulation.

- Union Quarantine Pest (UQP)
- Provisional Union Quarantine Pest
- Priority Pest
- Protected Zone Quarantine Pest (PZQP)
- Union Regulated Non-Quarantine Pest (RNQP)

In addition, the following terms have been used in this document and in the chain assessments:

- New harmful organism
- Potential Union Quarantine Pest
- NL-provisional Q-pest

These terms and the different EU categories are explained below.

Union Quarantine Pests (UQP)

UQPs are pests that are regulated throughout the EU. Legislation and measures against UQPs aim to prevent the introduction of these pests or prevent their spread if they are already established in a certain area. A UQP must meet all the following criteria (Article 4 of Regulation (EU) 2016/2031):

a) It has an established identity
b) It is not present or present only to a limited extent within the EU
c) It is capable of entering into, becoming established in and spreading within the territory
d) Its establishment and spread has unacceptable economic, social or environmental consequences
e) Feasible measures are available for mitigating the risk

UQPs are listed in Annex II of Implementing Regulation (EU) 2019/2072. In order to prevent the introduction and spread of certain UQPs, special requirements may apply to plants and products in or on which the pests may be present. These requirements are laid down in Annexes VII and VIII of Implementing Regulation (EU) 2019/2072. Member States are obliged to conduct surveys to determine the presence or absence of UQPs. To help them do this, EFSA, on the instructions of the European Commission, has drawn up general guidelines for conducting risk-based surveys (EFSA et al., 2020). When a UQP is detected in an area where it was not previously known to occur, eradication measures are mandatory. Specific measures for the control of a number of UQPs that are present in the EU are currently laid down in EU directives (also known as the 'Control Directives'). These directives will be replaced by implementing acts. The intention is to draw up implementing acts for all UQPs that have established themselves in the EU.

Provisional Union Quarantine Pests (temporary EU measures)

The Plant Health Regulation also specifies the measures to be taken by a Member State if a pest is found which is not yet included in the list of UQPs but which meets criteria (a) to (d) of a UQP (Article 29). If a Member State finds a harmful organism that may meet these criteria, it should carry out a preliminary risk assessment. If it is subsequently concluded that the organism meets the criteria, the Member State should immediately take the necessary eradication measures, or if the organism is found in a consignment of plants or products, measures to prevent the introduction and spread of the organism. The Member State must inform the Commission and other Member States about the organism, the risk assessment and the measures taken. If the Commission also concludes that the organism qualifies as a UQP, it will immediately adopt temporary measures in respect of the pest by means of an implementing act (Article 30). Even without notification of a new harmful organism by a Member State, the Commission may adopt temporary measures if it considers that the organism meets criteria (a) to (d) of a UQP. Organisms subject to temporary measures (emergency measures) are also referred to as UQPs in this document and the chain assessments[21].

Priority Pests

Among the UQPs, a number of pests have been designated as 'Priority Pests'. These are UQPs that are expected to have a very high impact in the EU upon establishment or further spread (Article 6, Regulation

[21] NB According to Regulation (EU) 2016/2031, only the organisms listed in Annex II of Implementing Regulation (EU) 2019/2072 are Union Quarantine Pests.

(EU) 2016/2031). For Priority Pests, additional requirements apply compared to the 'usual' UQPs. For example, an annual survey must be carried out to detect the presence/absence of these pests and Member States must have a contingency plan ready if the pest is found.

Protected Zone Quarantine Pests (PZQP)

PZQPs are pests that are regulated in certain areas in the EU specially designated as 'Protected Areas' (Article 32, Regulation (EU) 2016/2031). The same criteria apply to PZQPs as for a UQP, with the difference that the pest should not occur in the Protected Area. At present, the Netherlands does not have any Protected Areas.

Union Regulated Non-Quarantine Pests (RNQP)

RNQPs are pests that are regulated for certain plants. An RNQP is regulated as such throughout the EU and must meet the following criteria (Article 36, Regulation (EU) 2016/2031):

a) It has an established identity
b) It is present in the EU
c) It is not a UQP and there are no temporary measures applicable against the pest
d) It is transmitted mainly through specific plants for planting
e) Its presence on these plants for planting has an unacceptable economic impact, as regards the intended use
f) Feasible and effective measures are available to prevent its presence on the plants

Tolerance limits apply for each pest-plant combination. The established tolerance limit of an RNQP need not be zero but may, for example, be defined in terms of the maximum percentage of affected plants, if that is considered acceptable. There is no obligation to eradicate RNQPs, but lots infested above a certain tolerance limit may not be placed on the market.

New harmful organisms, potential UQPs and NL-provisional Q-pests

Harmful organisms that do not have full or provisional EU quarantine status but do meet criterion (b) for an EU Q-pest (the organism is not present or is not widely distributed within the EU) are considered for the purposes of this risk assessment to be 'new harmful organisms'. New harmful organisms that also meet the remaining criteria of a UQP and for which no emergency measures are yet applicable fall under the heading of 'potential UQPs'. A potential UQP becomes a UQP or provisional UQP if temporary measures are imposed in the EU or if the pest is included in Annex II of Implementing Regulation (EU) 2019/2072. If a pest is intercepted or found in the Netherlands that possibly meets the criteria of a UQP, the NVWA makes a preliminary risk assessment (Quick Scan), on the basis of which it is decided whether or not the organism meets these criteria. If the criteria are met, the pest is assigned a 'NL-provisional Q-pest' status. In addition, when a company or institution submits an application to work with a new harmful organism, a Quick Scan is performed to decide whether the organism can be designated as a NL-provisional Q-pest, and if so, the company or institution may only work with the pest subject to containment conditions. If the Commission decides to impose EU measures for a pest designated as NL-provisional Q-pest by the Netherlands, this pest will be assigned the status of a UQP or provisional UQP (and the NL-provisional Q-pest status will automatically lapse).

4.3. National cultivation regulations

National cultivation regulations apply to a limited number of harmful organisms, including some quarantine pests, that occur in the Netherlands (NVWA, 2018b). The purpose of these regulations is to prevent the spread of these specified pests. For seed potatoes, there are additional regulations that are more generally aimed at preventing the spread of harmful organisms (Cultivation Regulations for Approved Seed Potatoes (*Teeltvoorschrift goedgekeurd pootgoed*)).

4.4. Risk assessment methodology

Scope of the risk assessment

The Netherlands has many different crops and each crop can be attacked by many different harmful organisms. Due to the large number of harmful organisms, it has been decided to only assess the risk of the harmful organisms that are required to be officially controlled and that are included on a EU or national list: the UQPs (including the pests for which temporary measures apply based on Article 30 of Regulation (EU) 2016/2031) and the NL-provisional Q-pests. In addition, the potential UQPs per chain/sector have been briefly identified and a more general assessment has been made of the risk of potential UQPs partly based on knowledge of the introduction of new harmful organisms in the past.

Risk assessments of UQPs and NL-provisional Q-pests

A brief risk assessment has been made for each UQP and NL-provisional Q-pest unless the pest:

- almost certainly cannot survive in the Dutch climate and/or host plants are hardly present in the Netherlands;
- has a very low likelihood of introduction because the relevant pathways of introduction are closed via an import ban.

If the pest is indicated as a UQP at the level of a genus or higher taxon, the species considered to pose the highest risk from the genus or higher taxon has been selected based on the knowledge of NVWA experts.

The short risk assessments include the following:

- the most important pathways of introduction through which the pests can enter the Netherlands
- an estimation of the likelihood of introduction (entry and establishment)
- the potential impact on cultivation, green spaces[22] and export

These brief risk assessments estimate the likelihood of the entry of the pest through the import of plants and products from EU Member States and from third countries (P1), the likelihood that the pest will subsequently reach a place where it can establish itself (P2) and the likelihood that the pest will subsequently establish itself (P3) on a scale from 1 to 5. In addition, the likelihood of being able to eradicate the pest after detecting its presence via official measures has also been estimated (P4) on a scale of 1 to 4. Combining these scores yields a score for the likelihood of infestation in cultivated areas or green spaces (P1-P2), the likelihood of an outbreak (P1-P3) and the likelihood that the pest will establish itself despite official eradication measures (P1-P4). Harmful organisms are a hazard because they can lead to loss of yield and additional plant protection costs, but also because they can result in barriers to the trade and export of plants and plant products. Hence, for each pest, the potential impact on cultivation (damage due to loss of yield and increased plant protection costs) and on trade and export (damage due to loss of markets and/or extra costs for being able to guarantee that the pest is absent from the plants or products) has also been assessed. Moreover, an estimate has been made of the potential impact of the pest on green spaces based on the severity of the expected damage to the plant species affected by the pest and the extent to which these plant species occur in the green spaces concerned. The risk assessment takes into account all applicable laws and regulations, including national cultivation regulations. With regard to the export risks, an estimate has been made of the ease with which it can be guaranteed, based on the biology of the pest, that the product will be pest-free, without taking into account current third-country requirements, export volumes and export destinations. Therefore, the actual impact on export once a pest has already established itself can differ greatly from the potential impact. An extensive description of the methodology is contained in NVWA (2017a).

Risk assessments per chain

UQPs and NL-provisional Q-pests

The UQPs and NL-provisional Q-pests relevant to the chain have been selected, including pests nominated to become UQPs (i.e. a proposal is being prepared by EU working groups to include these pests in the list of UQPs). These pests are briefly discussed in the chain assessments. More information about the individual

[22] Green spaces: all open areas, private and public, in the Netherlands where no commercial cultivation takes place. The terms 'green spaces' and 'nature' are used synonymously in the chain assessments.

pests can be found in the aforementioned short risk assessments on the Internet (UQPs not established in the Netherlands) or in a separate annex (established UQPs).

Identification of the potential UQPs not yet indicated as NL-provisional Q-pest

For each chain, the new potential hazards have been briefly identified. As a rule, this list has been prepared based on the existing pest alert systems of EPPO[23] and APHIS[24] (EPPO, 2018a; PestLens, 2018) and the knowledge of NVWA experts. In a number of cases, the EPPO Global Database and the Crop Protection Compendium have been consulted for all the pests indicated in the database as being known to affect a particular plant species or genus (EPPO, 2018b; CABI, 2019).

[23] EPPO: European and Mediterranean Plant Protection Organisation, https://www.eppo.int/.

[24] APHIS: Animal and Plant Health Inspection Service of the United States Department of Agriculture.

5. Risks posed by UQPs and potential UQPs to the cultivation, trade and export of potatoes

5.1. Introduction

There is a large number of organisms (viroids, viruses, bacteria, pseudofungi and other fungi, insects, mites, nematodes, snails and plants) that may affect or displace plants (weeds), hereinafter referred to as 'harmful organisms'. This Annex focuses on the risks of harmful organisms that are relevant to potatoes and that have quarantine status in the European Union (UQPs) or are eligible for this (potential UQPs). Here, UQPs are understood to mean the pests listed in Annex II of Implementing Regulation (EU) 2019/2072 and the pests subject to emergency measures based on Article 30 of Regulation 2016/2031[21]. A European control obligation applies to these pests. Annex 4 contains more details about the phytosanitary legislation. Below we start with a discussion of the UQPs, where we first make a distinction between UQPs that are established in the Netherlands and those that are not. Then, harmful organisms that are not yet present or present only to a limited extent in the EU (new harmful organisms) and of which some may qualify for UQP status, are discussed. Details about the methodology followed can be found in Annex 4.

5.2. UQPs established in the Netherlands

Six UQPs are established in the Netherlands that are relevant to the potato plant (Table 5.1). These pests are harmful to potatoes, but yield losses are generally limited because growers take preventive measures. When these pests are found, infested lots must be destroyed, or depending on the particular pest involved, may be sold under certain restrictions as ware or starch potatoes. Detection of some of these pests implies that restrictions will apply for one or more years to the plot found to be infested (as well as adjacent and possibly infested plots) or even the entire production site. All six are soil pathogens, and in principle, infestation can be prevented by starting the cultivation with clean seed potatoes on a pest-free plot and using disinfested water for irrigation. However, the problem is that a number of the pests are already quite widespread in the Netherlands. In addition, there is always the chance that sampling and testing of soil will fail to detect the pest even when it is present. Six specific pests are discussed below (more details about these pests can be found in Annex 5.7).

5.2.1. Globodera pallida and G. rostochiensis

The potato cyst nematodes *Globodera pallida* and *G. rostochiensis* cause poor growth and reduced tuber yields. The nematodes attack the roots of the potato plant, slowing down its growth and decreasing the yield. *G. pallida* and *G. rostochiensis* are native to the Andes (South America) and are believed to have been introduced in Europe via potatoes in the mid-nineteenth century. Potato cyst nematodes were first found in the Netherlands in 1941 (Molendijk, 2018). Both species are now common in arable lands in the Netherlands. Transfer of the infested soil, through potatoes or otherwise, is the main route by which these nematodes are spread. There are EU regulations in place to prevent the spread of the nematodes (see also Annex I). For example, seed potatoes may only be grown on plots that have been found to be free of the nematodes after official investigation. Soil tare (and other waste) from ware and starch potatoes grown on an infested plot should be processed in such a way that there is no risk of the spreading the nematodes. Permitted disposal options for soil tare are (i) disposal on an agricultural plot after which this plot must be declared as infested, (ii) disposal outside agricultural areas and (iii) flooding of the land (inundation) (NVWA, 2020a). Inundation strongly reduces *G. pallida* and *G. rostochiensis* populations (Overbeek et al., 2014; Runia et al., 2014; Ebrahimi et al., 2016) as well as populations of another Q nematode, *Meloidogyne chitwoodi* (WUR, 2016). For this, it is important that the soil remains inundated for a sufficiently long period and that temperatures remain sufficiently high. In the Netherlands, companies authorised to process potatoes originating from plots infested with *G. pallida* and *G. rostochiensis* are required to process all soil tare in the same way and to take further measures on a voluntary basis to prevent the spread of soil-borne pathogens via soil tare. For example, soil tare from the potato starch industry is routinely inundated and disposed of outside agricultural areas to prevent the spread of soil-borne pathogens. However, the nematodes can also hitchhike with the soil attached to non-host plants and it is uncertain whether all soil tare is processed in a phytosanitary safe manner.

In 2007, the EU mandatory measures relating to *G. pallida* and *G. rostochiensis* were amended, with measures for non-host crops becoming less stringent. However, there are third countries that impose strict requirements on the import of non-host plants. That is why the Netherlands has created five Potato Cultivation Prohibition Areas (*Aardappelteeltverbodsgebieden*). These are areas where many nursery crops and flower bulbs are grown. The cultivation of potatoes is prohibited in these areas to keep them free from *G. pallida* and *G. rostochiensis* and thus meet third-country requirements. National measures also apply in the Netherlands for the frequency with which potatoes may be grown on the same plot (1:3 or lower), with a number of exceptions. These measures are aimed at preventing the build-up of *Globodera* spp. populations. A cultivation frequency of 1:3 is not sufficient to control potato cyst nematodes; a much lower cultivation frequency of once every six to eight years on average would be necessary for this (Molendijk, 2018). An important measure for preventing damage caused by *G. pallida* and *G. rostochiensis* is, therefore, the use of varieties with a high degree of resistance to the nematodes. Each year the NVWA draws up a list of potato varieties with their corresponding resistance levels in accordance with Directive 2007/33/EC (NVWA, 2020i). Without these high-resistance varieties, there would be much more damage, especially in the sandy soil and reclaimed peatland areas in the northeast, which are exempt from the 1:3 rule and where a lot of starch potatoes are grown in close rotations. The development of new virulent *Globodera* populations, which can break down existing resistance levels, could therefore have major consequences for cultivation. This seems most likely when potatoes are grown relatively frequently on the same plot (in close rotation). In 2015, new virulent populations of *G. pallida* were identified in the northeast of the Netherlands. These virulent populations multiply more strongly on certain varieties than would be expected based on the known resistance level. If these populations expand further, yield losses due to *G. pallida* may increase. New and more virulent populations of *G. rostochiensis* also seem to be developing (NVWA, 2018a). Non-European populations of both *Globodera* species, especially from South America, pose an additional threat. In South America, there are known *G. pallida* populations to which the resistant European potato varieties are 100% susceptible (Molendijk et al., 2017) and the introduction of new genotypes can have a major impact as it takes a long time to develop new resistant varieties (EFSA PLH Panel, 2012). However, the risk of introduction of non-European populations is low thanks to existing regulations (import bans on potato tubers and plants for planting of Solanaceae from most third countries (see also section 5.5). Therefore, the main risk as regards *G. pallida* and *G. rostochiensis* appears to be the development of new virulent populations within the EU, especially in areas with close rotations.

5.2.2. Meloidogyne chitwoodi and M. fallax

The root-knot nematodes *Meloidogyne chitwoodi* and *M. fallax* lead to the formation of galls on potatoes and various other crops. Both species have a very wide host plant range. The deformity caused by the galls can make potatoes unsuitable for industrial processing and for sale as table potatoes. *M. chitwoodi* and *M. fallax* have been present in the Netherlands for decades and probably even longer. The origin of the species is unknown. According to official sources, the species are only found in specific areas in the Netherlands known as the ‘Designated Areas’, but in reality, they are probably more widespread. For example, in 2016 these species were also found outside the Designated Areas (NVWA, 2017b). The main modes of spread of both nematodes are through trade and transport of infested propagating material and movement of infested soil (Van der Gaag et al., 2011b;2011a). Currently, there are special regulations for seed potatoes in the EU but not for other crops or for soil tare. Seed potatoes must come from areas or from places of production where these pests do not occur or a sample must be examined in the laboratory and found free from the pests (Implementing Regulation (EU) 2019/2072, Annex VII, point 20 and Annex VIII, point 8). In the Netherlands, these regulations have been implemented as follows: seed potatoes originating from a plot on which infestation has previously been found must be tested in the laboratory. In addition, an area with a radius of 1 km is demarcated around each new site of occurrence for the next year of cultivation and all seed potato lots from plots located wholly or partly within this area are tested. After one year, this demarcated area (called ‘Designated Area’) is limited to the so-called Topographic Plot[25] where the pests were originally detected. Each new detection leads to the demarcation of a new 1 km-wide area. A Topographic Plot may be declared free of infestation if the nematodes have not been detected over two consecutive seed potato crops on the infested plot. Outside the Demarcated Areas, some of the seed potato

[25] Topographic Plot: area of land enclosed by topographic, permanent or temporary boundaries such as roads, water, hedgerows, fences and buildings.

lots are tested at an average of one lot per grower per year (NVWA, 2020j). Propagating material of other crops is only inspected visually and many host plants show no or hardly any symptoms upon infestation, which makes it easy for such infestations to go unnoticed. There are various control measures that can help prevent or greatly reduce damage to the cultivation of ware and starch potatoes (and other crops). Hence, the greatest risk for the Netherlands is that, once infested, plots become unsuitable for the cultivation of seed potatoes and other propagating material. Cultivation on infested plots is not prohibited, but there is a high likelihood of the rejection of lots or spread of the nematodes if propagating material is grown on infested plots (Van der Gaag et al., 2011b;2011a).

5.2.3. Ralstonia solanacearum

The bacterium *Ralstonia solanacearum* causes brown rot in potatoes and can lead to yield reduction, especially at higher temperatures. *R. solanacearum* is established in surface water in the Netherlands, where its presence is maintained because of host plants (in particular *Solanum dulcamare*, bittersweet) growing along the banks. To prevent brown rot infestations, sprinkler irrigation of ware potatoes and starch potatoes with surface water is prohibited in large parts of the Netherlands. For seed potatoes, sprinkler irrigation with surface water is prohibited throughout the Netherlands. In addition, all seed potato lots are sampled and tested for the presence of this bacterium. Partly due to these measures, brown rot infestations only occur incidentally in potato cultivation (see also section 5.7.3). Incidental infestations caused, for example, due to the flooding of plots with infested surface water, are difficult to prevent.

5.2.4. Synchytrium endobioticum

The soil fungus *Synchytrium endobioticum* causes potato wart disease. The fungus forms wart-like structures on the potato tubers and reduces yield (fewer kilograms and affected tubers become unsaleable due to their appearance). *S. endobioticum*, like *Globodera pallida* and *G. rostochiensis,* originates from the Andes (South America) and was introduced into Europe in the nineteenth century. In the Netherlands, *S. endobioticum* was first observed in 1915 (Baayen et al., 2006). This pest now occurs in areas in the northeast and southeast of the Netherlands. The fungus is mainly spread through the transfer of infested soil via infested tubers and infested plant waste, and it can survive in the soil for many years. How far the wind contributes to this spread is uncertain. If the potatoes are found to be affected, this has major consequences for the grower because this means that no potatoes or propagating material may be grown on the site in question for at least 20 years. Restrictions on the cultivation of potatoes and propagating material also apply to land or lands adjacent to the infested land (buffer) and to the production unit (NVWA, 2015c). Under certain conditions and depending on the pathotype detected, the 20-year period can be reduced, but the impact for the grower remains significant. Different pathotypes have been distinguished and potato varieties may be resistant to one pathotype, yet susceptible to another. Each year the NVWA draws up list of the names of potato varieties that are resistant to the pathotypes occurring in the Netherlands (NVWA, 2020c). Of the pathotypes known in the Netherlands, pathotype 18(T1) is particularly dangerous because only a few potato varieties are available with a high level of resistance, whether proven or otherwise, to this pathotype. In addition, new and more virulent populations may arise through a process of selection. New pathotypes may also be introduced from other countries. In certain areas in the Netherlands (known as the 'Prevention Areas'), the only varieties that may be grown are those with a minimum resistance level against the known pathotypes in that area. However, recent research has shown that the cultivation of partially resistant varieties can facilitate the development of more virulent populations (van de Vossenberg et al., 2018; van de Vossenberg et al., 2019a). For the time being, varieties that are fully resistant seem to be the best choice. In addition to the use of fully resistant varieties, hygiene measures and a wide rotation period are considered appropriate measures to prevent the spread and build-up of populations. In recent years, the NVWA has discovered a few new detections of *S. endobioticum* during official surveys: three in the period from 2010 to September 2019. However, it is uncertain how effective these surveys are (i.e. regarding the percentage of infested plots). At the beginning of 2020, the fungus was found in soil tare from Germany. The soil was sampled following alerts from the sector. Current laws and regulations do not impose any requirements on soil tare originating from infested areas, whereas such soil poses a great risk of spreading the fungus. *S. endobioticum* is difficult to eradicate because the resting spores of this fungus are very persistent. Currently, deep burial and non-agricultural disposal are the only options for neutralising infested soil.

Table 5.1. UQPs established in the Netherlands that are relevant to the potato chain.

Pest (English name in brackets)	Official pest status in NL
Bacteria	
Ralstonia solanacearum (brown rot bacterium)	Transient: incidental findings, under eradication in the potato production chain; pest eradicated in *Solanum melongena*; present: in natural environment (surface water)
Nematodes	
Globodera pallida (white potato cyst nematode)	Present: except in specified pest-free areas (the Potato Cultivation Prohibition Areas)
Globodera rostochiensis (yellow potato cyst nematode)	Present: except in specified pest-free areas (the Potato Cultivation Prohibition Areas)
Meloidogyne chitwoodi (maize root-knot nematode)	Present: only in demarcated area(s)
Meloidogyne fallax (false maize root-knot nematode)	Present: only in demarcated area(s)
Fungi	
Synchytrium endobioticum (causal agent of potato wart disease)	Present: only in demarcated area(s)

5.3. Transient UQPs

One UQP - the ring rot bacterium *Clavibacter sepedonicus* - has been identified that can affect potatoes and which is transient (present but not leading to established populations) in the Netherlands. Infested seed potatoes and mechanical transmissions (via contact) are the main pathways of introduction and spread of this bacterium. In the past 10 years, *C. sepedonicus* has been found in potatoes on several farms. These findings and the measures taken are reported in the Annual Phytosanitary Reports (*Rapport fytosanitaire signaleringen*) (NVWA, 2018a). Detection of ring rot in seed potatoes in 2010 prompted a ban on the cutting of seed potatoes[26], with the exception of a number of situations where there is only a small likelihood of a rapid spread of ring rot due to the cutting of seed potatoes (Cultivation Regulations for Cut Seed Potatoes (*Teeltvoorschrift gesneden pootgoed*) (NVWA, 2018h)). The ban has been in place since 2014. In addition, the sector organisation and companies within the chain have developed a hygiene protocol known as the 'PCC Ring Rot Hygiene Protocol' (NAO, 2020a). The cutting ban, communication about the risk posed by the pest and the hygiene measures to be taken by the sector have probably contributed greatly to controlling the problem. The last finding of *C. sepedonicus* dates back to 2013. Import of potatoes from EU Member States where *C. sepedonicus* occurs seems to be the most likely route by which *C. sepedonicus* can be introduced into the potato chain (NVWA, 2018a).

5.4. Absent UQPs

From the list of UQPs, 16 pests and groups of pests have been identified that can affect potatoes but that do not occur in the Netherlands (Table 5.2). In case of one UQP, i.e. the bacterium *Ralstonia syzygii* subsp. *celebesensis,* it is uncertain whether or not it can affect potatoes. This pest is specifically mentioned in the EU regulations with regard to potatoes (Implementing Regulation (EU) 2019/2072, Annex VII, points 19 and 21), but no information has been found in the literature that it can affect potatoes. Safni et al. (2018) refer to a 1994 study by Baharuddin in which strains of this subspecies did not affect potatoes.

[26] When cutting seed potatoes, a tuber is cut in half to increase the amount of plant reproductive material: a potato plant can grow from each part.

For most of the 16 UQPs and groups of UQPs, the import of potato tubers is the major pathway of introduction into the Netherlands and the EU. In addition, plants for planting of Solanaceae are also considered an important pathway. However, the import of both potato tubers and plants for planting of Solanaceae is prohibited from most third countries, which means that these routes are essentially closed. Potato tubers and other plants and products can also enter via passenger baggage and parcel post, if import bans are intentionally or unintentionally circumvented (see also section 5.6).

Apart from possible illegal import and taking into account existing EU regulations, there seems to be a relatively high likelihood of the introduction of certain UQPs that are already present in the EU, i.e. the leaf beetles *Epitrix cucumeris* and *E. papa.* Just like the above-mentioned pests, the UQP *Tecia solanivora* (a moth) also occurs in mainland Europe (in Spain), but the Dutch climate is unfavourable for the establishment of this pest. For the time being, this pest does not seem to be a major risk for the Netherlands (climate change will probably make the climate more favourable for establishment). Since 2016, the NVWA has been conducting a survey for the detection of *T. solanivora* in which pheromone traps are placed at potato processing companies that are or may be importing ware potatoes from Spain. The pest has never been detected in this survey. A brief risk assessment of *T. solanivora* can be found on the website of the NVWA (NVWA, 2018j).

The bacteria *Ralstonia pseudosolanacearum* and *R. syzygii* subsp. *indonesienis* can also be introduced via the import of ornamental plants for which no import ban or special regulations apply. However, these bacterial species pose a low risk to potato cultivation due to the unfavourable climate in the Netherlands (Safni et al., 2018). The species are mainly known to occur in tropical regions. *R. pseudosolanacearum* has been detected several times in Dutch greenhouses, including in *Anthurium*, *Curcuma* and *Rosa* (identified at the time as *R. solanacearum* Race 1), it and has been subsequently eradicated (NVWA, 2015e;2016e;2019a).

The potential impact of the potato psyllid, *Bactericera cockerelli,* in combination with the bacterium '*Candidatus* Liberibacter solanacearum' has been assessed as very high. *Bactericera cockerelli* may be introduced through the import of fruits of Solanaceae. The risks of *Bactericera cockerelli* and of the two *Epitrix*species are discussed briefly below. Brief risk assessments of these pests can be found on the NVWA website.

5.4.1. Bactericera cockerelli

Bactericera cockerelli (potato psyllid) is the main vector of the Zebra chip disease in potatoes, which is caused by the bacterium '*Candidatus* Liberibacter solanacearum'. The bacterium causes various above-ground symptoms, such as leaf discolouration, wilting and stunting, leading to loss of yield. In addition, infested potato tubers develop stripes, usually when the potato is deep-fried (Zebra chip disease). This makes the tubers unsaleable as ware potatoes. '*Candidatus* Liberibacter solanacearum' is already present in Europe, where most infestations are found in Apiaceae (carrot and celery). Infestations have occasionally been found in potatoes (in Spain and Finland). Genetic variation has been observed within '*Candidatus* Liberibacter solanacearum' and different variants (haplotypes) have been distinguished. The haplotypes found in Europe are different from those found in America. For the time being, the European haplotypes are also suspected as being harmful to the potato because Zebra chip disease symptoms have been demonstrated in infested potatoes in Spain. In the absence of the vector *B. cockerelli*, none of the haplotypes appears to pose a major risk to potato cultivation because the vector species known in Europe rarely or never feed on potato plants. Without an efficient vector, hardly any spread will occur and the disease will be relatively easy to control. The main pathway for introduction of the vector *B. cockerelli* seems to be the import of Solanaceae fruits from areas where this pest occurs (North and South America, New Zealand, Australia and Norfolk Island). The UK has found *B. cockerelli* on imported fruits. Since 1 September 2019, special rules relating to *B. cockerelli* apply to Solanaceae fruits from Australia, North and South America, and New Zealand, but it is uncertain whether these requirements can guarantee absence of the vector species. Imports continue to be allowed from infested areas with one of the possible measures being that the fruits must originate from "*a place of production, where official inspections and surveys for the presence of Bactericera cockerelli (Sulc.) including its immediate vicinity are carried out during the last three months prior to export and subject to effective treatments to ensure freedom from the pest, and representative samples of the fruit have been inspected prior to export, and information on traceability is included in the certificate referred to in Article 71 of Regulation (EU) No 2016/2031*" (Implementing Regulation (EU) 2019/2072, Annex VII, point 67, option (c)). The species can be carried and spread over long distances by wind and may be present in various stadia in specific places, for example, under sepals on fruits, where they are difficult to detect and control. Therefore, the above-mentioned option is not sufficient for guaranteeing that the fruits will be completely free from the pest. EPPO (2012) also indicates 'country freedom' as the only effective option for fruits of Solanaceae or - only as part of a bilateral agreement - an insect-repellent production site. Yet another option is provided for tomatoes: "*grown under protected conditions, removal of green parts followed by washing and fumigation, and inspection of consignment (on the basis of a bilateral agreement)*". Countries can be very large and pests do not care about national borders. 'Area freedom' is therefore technically a better option than country freedom. In general, the effectiveness of the various special provisions in the EU regulations depends to a great extent on the degree of implementation by countries (the intensity and quality of surveys and inspections, the quality of insect-repellent material, etc.). However, due to the biological characteristics of *Bactericera cockerelli*, the abovementioned regulatory option (c) is considered to be of limited effectiveness. Partly for this reason, the risk of *B. cockerelli* has been assessed as high. The pest is on the European Priority Pests list[27] (Delegated Regulation (EU) 2019/1702), which means that Member States must have a contingency plan ready for eradicating an outbreak. It is estimated that an outbreak will only be detected quite late and the pest will spread rapidly in the EU (EFSA, 2019b). As a consequence, the likelihood of eliminating *B. cockerelli* is estimated as low. For more details, see the short risk assessment and the 2015 and 2016 Annual Phytosanitary Reports (NVWA, 2016d;2017b).

5.4.2. Epitrix cucumeris and E. papa

Epitrix cucumeris and *E. papa* are flea beetles of the leaf beetle family. EU emergency measures apply to these species as well as to two other *Epitrix* species, i.e. *E. subcrinata* and *E. tuberis*[28]. The risk of these last two species is estimated to be lower because of the lower likelihood of introduction; these species do not yet occur in Europe. The biology of the four species is similar. The adults feed on the leaves and the larvae stay in the soil and feed on the tubers and roots. Feeding damage by adults can lead to lower yields. There are differences between the species. For example, the larvae of *E. cucumeris* mainly feed on roots whereas damage to tubers, as observed in Spain and Portugal, is probably caused mainly by *E. papa*. Feeding damage to tubers as described for Portugal is superficial (cosmetic). Larvae of *E. tuberis* can feed up to 1 cm deep in the tuber (EPPO, 2016)

Epitrix cucumeris, E. subcrinita and *E. tuberis* occur in North and South America and *E. cucumeris* has been introduced into mainland Portugal and Spain. *E. papa* is a relatively recently described species, the area of origin of which is still unknown. For the Netherlands, *E. cucumeris* and *E. papa* pose a particular threat to the export of potatoes both to third countries and other EU member states (the loss of yield due to the establishment of these two species in the Netherlands is expected to be limited). The most likely route by which the organisms can be introduced is through the import of potatoes from EU Member States where these pests occur (Portugal and Spain). Larvae of the *Epitrix* species can be present on potatoes that have not been cleared of soil. Potatoes from infested areas must therefore be brushed or washed clean so that they are almost free of soil. However, it is uncertain whether potatoes that are free of soil are entirely free of live larvae. Moreover, it is difficult to detect the pest in a field, and areas may therefore already be infested for some time before the pest is officially identified and measures taken. Because of these uncertainties, there is a debate about whether the EU requirements provide sufficient guarantees. For example, the United Kingdom requires that potatoes from non-demarcated areas in Spain must be washed (in addition to the EU requirements applicable to potatoes from demarcated areas) (Defra, 2017). The NVWA has been carrying out inspections for several years on companies importing potatoes from Spain and Portugal. So far, the pest has not been detected. *Epitrix* has been assessed as posing a high risk to potatoes mainly because of the potential impact on the export of seed potatoes. More details about the *Epitrix* species are provided in the short risk assessment and the NVWA Annual Phytosanitary Reports (NVWA, 2018a;2018j).

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[27] Priority Pests are quarantine pests with the "most serious economic, social or environmental consequences" (Article 6, Regulation (EU) 2016/2031[2]). They are pests subject to special provisions, "in particular, the provision of information to the public, surveys, contingency plans, simulation exercises, action plans for eradication and co-financing of measures by the Union".

[28] Commission Implementing Decision 2012/270/EU of 16 May 2012 on emergency measures to prevent the introduction into and the spread within the Union of *Epitrix cucumeris* (Harris), *Epitrix similaris* (Gentner), *Epitrix subcrinita* (Lec.) and *Epitrix tuberis* (Gentner).

Table 5.2. UQPs relevant to potatoes that are not present in the Netherlands or have transient status, their distribution area and main existing or potential pathways for introduction into the Netherlands (situation as on 1 March 2020).

Pest	Distribution area (EPPO Global Database)	Main existing or potential pathways for introduction/products via which the pest can enter
Bacteria		
Clavibacter sepedonicus (ring rot bacterium)	Asia, Europe, North America (transient in the Netherlands)	Potato tubers
Ralstonia pseudosolanacearum	Asia, Africa (possibly on more continents)	Plants for planting of Solanaceae[2] and ornamental plants, other than seeds
Ralstonia syzygii subsp. *indonesiensis*	Asia (Safni et al., 2018)	Plants for planting of Solanaceae[2] and ornamental plants, other than seeds
Insects and mites		
Bactericera cockerelli (potato psyllid)	Australia, New Zealand, North America, South America, Norfolk Island	Plants for planting of Solanaceae[2], other than seeds; import of Solanaceae fruits
Epitrix cucumeris	Europe (Portugal, Spain), North and South America	Potato tubers with adhering soil from Spain and Portugal
Epitrix papa	Portugal, Spain (probable origin - North America)	Potato tubers with adhering soil from Spain and Portugal
Epitrix subcrinita	North America, South America (Peru)	Potato tubers with adhering soil[1]
Epitrix tuberis	North America, South America (Ecuador)	Potato tubers with adhering soil[1]
Naupactus leucoloma	Africa (South Africa), Australia, Europe (Azores), Australia, New Zealand, North and South America	Hitchhiking with plant products; plants for planting (with adhering growth medium)
Premnotrypes spp. (non-European)	South America	Potato tubers[1]
Tecia solanivora	Europe (Canary Islands, Spain), North and South America	Potato tubers from Spain[3]
Nematodes		
Nacobbus aberrans	North and South America	Potato tubers[1]; plants for planting (polyphagous organism)
Fungi and pseudo-fungi		

Pest	**Distribution area (EPPO Global Database)**	**Main existing or potential pathways for introduction/products via which the pest can enter**
Puccinia pittieriana	North and South America	Leaves of potato and tomato plants[4]
Septoria malagutii	South America	Leaves of potato and other tuberous *Solanum* species[4]
Stagonosporopsis andigena	South America	Leaves of potato plants[4]
Thecaphora solani	North and South America	Potato tubers[1]
Viruses, viroids and phytoplasmas		
Potato viruses, viroids and phytoplasmas such as[5]:		
Andean potato latent virus	South America	Potato tubers[1]
Andean potato mottle virus	North and South America	Potato tubers[1]
Arracacha virus B, oca strain	South America	Potato tubers[1]
Non-European isolates of the potato viruses A, M, S, V, X and Y (incl. Yo, Yn and Yc), and *Potato leafroll virus*	Multiple continents	Potato tubers[1]
Potato black ringspot virus	South America (Peru)	Potato tubers[1]
Potato virus T	South America	Potato tubers[1]

[1] There is an import ban on potato tubers from most third countries (Implementing Regulation (EU) 2019/2072, Annex VI, points 15 and 17). In the Regulation, certain specifically mentioned European and Mediterranean countries or parts thereof are exempted from this import ban. As far as is known, the pest does not occur in these countries or parts thereof.
[2] There is an import ban for plants for planting of Solanaceae, other than seeds, from most third countries (Implementing Regulation (EU) 2019/2072, Annex VI, point 18). In the Regulation, certain specifically mentioned European and Mediterranean countries or parts thereof are exempted from this import ban. As far as is known, the pests do not occur in these countries or parts thereof. Import of seed potatoes and true potato seeds is prohibited from all third countries other than Switzerland (Implementing Regulation (EU) 2019/2072, Annex VI, point 15).
[3] *Tecia solanivora* was found in mainland Spain in 2015 (see the brief risk assessment for this pest).
[4] There is no import ban on Solanaceae leaves. However, there is no known import of potato or tomato leaves or the use of these leaves for consumption purposes.
[5] The specifically named viruses or isolates thereof and all non-European viruses, viroids and phytoplasmas affecting potatoes are designated as UQPs.

5.5. New harmful organisms

Harmful organisms that do not occur in the EU or only occur to a limited extent and that are not, or not yet, designated as UQPs are referred to here as 'new harmful organisms'. Such organisms may qualify for UQP status. The risks relating to a number of such new harmful organisms is discussed below. The organisms have been identified based on EPPO publications and information from NVWA experts.

5.5.1. Globodera ellingtonae (nematode)

The nematode *Globodera ellingtonae* is a relatively recently described species and is known to occur in the northeast of the United States (US) and Argentina (Handoo et al., 2012; CABI, 2018). The species can affect potatoes and is closely related to the UQPs *Globodera pallida* and *G. rostochiensis* (Phillips et al., 2017). Besides potatoes, the species can also affect tomatoes and some weeds, such as *Solanum nigrum* (black nightshade), *S. dulcamare* (bittersweet) and *S. rostratum* (nightshade) of the Solanaceae family (Peetz et al., 2019). It is unclear to what extent the species can cause loss of yield in potatoes. US trials have yielded inconsistent results (Zasada et al., 2019). The likelihood of introduction via regular trade is small because the import of potato tubers and plants for planting of Solanaceae, other than seeds, is prohibited from most countries, including countries in North and South America. For the time being, the organism does not seem to pose a major risk to potato cultivation in the Netherlands.

5.5.2. Meloidogyne enterolobii (nematode)

The root-knot nematode *Meloidogyne enterolobii* can affect a large number of plant species. This nematode species has been intercepted several times by the Netherlands and has been found in several places in Europe (EPPO, 2020). The species may soon acquire a UQP status. Potato is indicated as an occasional host plant by EPPO (2020). It is a tropical nematode species and the Dutch climate is unfavourable for establishment (EPPO, 2010). Therefore, as far as the Netherlands is concerned, the species appears to be primarily a risk for crops grown under protected conditions and not for potatoes.

5.5.3. Meloidogyne luci (nematode)

In 2013, potatoes infested by the root-knot nematode *Meloidogyne luci* were found in Portugal (Maleita et al., 2018). Not much is known about economic losses in potatoes, but the organism is possibly a threat to potato cultivation in Europe (Maleita et al., 2018). *M. luci* is now known to occur in countries in Central and South America, Iran and Turkey and the EU Member States Greece, Italy and Portugal (EPPO, 2018b). In Slovenia, the species was found in crops grown under protected conditions (greenhouse cultivation) (Strajnar et al., 2011). The Dutch climate seems unfavourable for the development of the species; in studies, the species needed 67 days to complete its cycle at an average temperature of 18.3°C and there was no reproduction at 13.9°C (Strajnar et al., 2011). In comparison, the minimum temperature for the development of *M. chitwoodi* is about 5°C (Pinkerton et al., 1991) and the average temperature in July, the hottest month in the Netherlands, is 17.9°C (long-term average, weather statistics KNMI De Bilt). Therefore, as far as the Netherlands is concerned, the species appears to be primarily a risk for crops grown under protected conditions.

5.5.4. Scutellonema bradys (nematode)

The nematode *Scutellonema bradys* is known be a pest that affects the root vegetable yam, but it can also affect other crops including potatoes. Belgian research has shown that the organism is regularly introduced through the import of yam from Africa (Mwamula et al., 2015). However, the Dutch climate is unfavourable for the establishment of this organism and the risk of *S. bradys* for potato cultivation in the Netherlands has been assessed as very low.

5.5.5. Viruses and viroids

In the EU, all non-European potato viruses and viroids or isolates thereof are UQPs, with a number of viruses being specifically listed (Implementing Regulation (EU) 2019/2072, Annex IIA, F. Viruses, viroids and phytoplasmas, point 8). Although, strictly speaking, these viruses do not fall under the definition of 'new harmful organisms' (since they are designated as UQPs), they are briefly discussed below because most of them are not specifically mentioned in the regulations.

EFSA PLH Panel (2020a) has identified the non-EU viruses and viroids (as a group hereinafter referred to as 'viruses') that can affect potato and other tuber-forming *Solanum* species. Forty-five viruses have been identified: 40 viruses that are known to occur only outside the EU or that have a limited distribution area within the EU and another five viruses with an 'undetermined standing' (viruses whose presence and extent of spread within the EU is uncertain). One of these five viruses of undetermined standing is the *Tomato yellow leaf curl virus* (TYLCV), which is mainly known to be a pest that affects the tomato plant. However, TYLCV is already quite widespread in the EU. The EFSA PLH Panel (2014) had previously concluded: "*TYLCV appears to be present in almost all EU regions with suitable ecoclimatic conditions for its establishment in open fields*". Since 14 December 2019, this virus has been regulated as an RNQP[29] and not as a UQP. EFSA PLH Panel (2020b) assigns a Pest Categorisation to 33 of the 45 viruses. For 23 of these 33 viruses, it was concluded that they meet the criteria of a UQP. For eight viruses, no conclusion could be drawn because no information was found about any harm to crops or nature. For two viruses, it was concluded that they do not meet the criteria of a UQP. For the other 12 viruses (out of 45), an opinion had previously been published by the EFSA Panel on Plant Health. Four of these viruses (*Beet curly top virus, Cherry rasp leaf virus, Chrysanthemum stunt viroid* and *Tomato ringspot virus*) are specifically mentioned in the list of UQPs. These viruses mainly pose a risk to other crops, but can also potentially affect potatoes. Six viruses are tospoviruses. These viruses can affect a wide range of plant species including the potato plant and are naturally spread by certain thrips species. The remaining two viruses are the previously discussed TYLCV and the pospiviroid *Tomato planto macho viroid*. Some of the 45 viruses identified by the EFSA Panel on Plant Health are briefly discussed below: (i) Viruses that occur in the Netherlands: *Chrysanthemum stunt viroid*, *Tomato chlorosis virus, Tomato ringspot virus,* (ii) *Tomato leaf curl New Delhi virus,* which is present in several Member States and of which the likelihood of introduction in the Netherlands has been assessed as being relatively high and (iii) SB 26/29, a virus previously identified by the NVWA as a new threat to potatoes. Other viruses discussed include those associated with the root vegetable *Ullucus tuberosus* and which possibly poses a risk to potatoes. A temporary import ban applies to plants of the *Ullucus tuberosus* species since 14 December 2019 (Regulation (EU) 2018/2019).

Tomato chlorosis virus (ToCV) occurs in tomato cultivation in the Netherlands and is transmitted by the greenhouse whitefly and the tobacco whitefly. Based on data from a publication describing leaf symptoms observed on old leaves of potato plants in Brazil, EFSA PLH Panel (2020b) expects economic losses in potato production due to ToCV. However, the virus has been present in the EU for more than 20 years and no publications have been found reporting economic losses in potato production. In Spain, ToCV has been detected in asymptomatic potato plants growing in a field together with sweet pepper plants that were heavily infested with *Bemisia tabaci* (tobacco whitefly) (Fortes & Navas-Castillo, 2012). The risk of the virus for potato yields in the EU therefore appears to be very low. However, a study by Fortes & Navas-Castillo (2012) has demonstrated the virus in potato tubers, and depending on third-country requirements, the virus could pose a threat to seed potato exports.

In the Netherlands, the status of *tomato ringspot virus* is indicated as 'Transient, under eradication'. In 2018, it was found in the perennial *Iris germanica*. In the past and in other Member States, the virus has also been found in other ornamental plants and trees. The virus is mentioned by name in the UQP list but not under potato viruses. This virus, which is naturally

[29] RNQP: Regulated Non Quarantine Pest; see Appendix 4.2.

transmitted by certain nematode species, is particularly dangerous for ornamental plant cultivation and fruit production. As far as is known, no natural vectors of the virus occur in the Netherlands (see also the brief risk assessment of this virus on the NVWA website). The virus has been reported once in connection with potatoes (EFSA PLH Panel, 2020a), but it appears to be an insignificant pathogen for the potato plant.

Tomato leaf curl New Delhi virus (ToLCNDV) has been indicated by EFSA PLH Panel (2020b) as a potential UQP and harmful to potatoes. This virus is mentioned by name in the UQP list but not under potato viruses. The virus is transmitted by *B. tabaci*. ToLCNDV is present in the EU and is mainly a threat to the covered cultivation of fruit vegetables in the Netherlands (see the short risk assessment of this virus). There is some variation within ToLCNDV. The strain present in the EU mainly causes damage in Cucurbitaceae. No reports have been found of adverse effects on potatoes in the EU. *B. tabaci* is unable to establish itself outdoors in the Netherlands, which is also why the risk of ToLCNDV for potato cultivation in the Netherlands has been assessed as very limited. It should be noted that *B. tabaci* is also found outside greenhouses in the summer and it can potentially transmit viruses to plants outside the greenhouses, but the likelihood of this happening is estimated to be low for plants that are not located close to greenhouses.

The pospiviroid *Chrysanthemum stunt viroid* (CSVd) occurs in the Netherlands in ornamental plants. Since 14 December 2019, CSVd has been designated as an RNQP for plants for planting of *Argyranthemum* and *Chrysanthemum*, other than seeds (Implementing Regulation 2019/2072, Annex IV, Part D). Recently, a natural infestation of *Chrysanthemum stunt viroid* in potatoes has been reported in Russia (Matsushita et al., 2019). CSVd is related to the *Potato spindle tuber viroid* (PSTVd), a known potato pest. PSTVd causes growth malformations and quantitative yield losses in potato production and it is suspected that related pospiviroids may also have this effect (EFSA PLH Panel, 2011). Pospiviroids can be transmitted mechanically between different plant species. However, there is only a low risk of transmission from other crops to the potato, unless potato is grown in combination with infested plants in a greenhouse. The risk of transmission is greater at higher temperatures than at lower temperatures. Especially in the breeding phase, potato plants may be grown in greenhouses. However, if proper hygiene measures are implemented and starting material is used that has been tested and found to be free of pospiviroids, the likelihood of introduction into the potato chain is low.

In South America, there is a virus designated with the code SB26/29 that can cause high yield losses in potato production. According to EFSA PLH Panel (2020b), this virus also meets the criteria of a UQP. It is probably spread by the potato psyllid *Russelliana solanicola*, which is only known to exist in areas in South America (Salazar, 2006; NPPO, 2013a;2013b). *R. solanicola* is also a potential vector of the bacterium '*Candidatus* Liberibacter solanacearum' (see the section on *Bactericera cockerelli*). According to a recent modelling study, the European climate would not be very suitable or even unsuitable for the establishment of *R. solanicola* (Syfert et al., 2017). However, in an initial risk assessment (Quick Scan), NPPO (2013b) assessed that the species can survive in Europe, especially in Southern Europe. The species has a wide host plant range (Serbina & Burckhardt, 2017) and could, in principle, hitchhike with different species of plants and plant products. It is not known if the species affects fruits of Solanaceae (as the previously discussed potato psyllid *Bactericera cockerelli* does). There are no known interceptions or detection of *R. solanicola* outside of South America, and for the time being, the likelihood of introduction seems low.

Recently, viruses related to regulated potato viruses have been identified in the plant species *Ullucus tuberosus* (Fox et al., 2019). Just like the potato, *U. tuberus* is an important food crop in the Andes (South America), but it is not related to the potato. It is uncertain whether the viruses in *Ullucus* can affect the potato (in a natural manner) and vice versa. It is also not known whether these viruses can be spread via vectors. *U. tuberosus* seems to be mainly grown as a hobby in the Netherlands. The plants in which the viruses have been detected came from European companies and these virus-infested plants may have been present in Europe for many years. The viruses are probably found in *U. tuberosus* as early as the 1990s in South America (Lizarraga et al., 1999; Lizarraga et al., 2000; Lizarraga et al., 2001). At that time, they were identified as quarantine pests (potato viruses) but should now be considered as a new species based on the available virus genome sequence data. It is not known whether these viruses can affect potatoes and pose a risk to potato cultivation. As of 14 December 2019, it is forbidden to import plants for planting and plant products of *Ullucus tuberosus* from third countries[20].

5.6. Pathways of non-established UQPs and potential UQPs and risk mitigation measures

Potato pests can be introduced mainly via potato material (in particular, potato tubers) and plants for planting of related species. For example, many viruses that affect potato can also affect other species in the Solanaceae family (EFSA PLH Panel, 2020b). Potato tubers, true potato seeds, plants for planting of other stolons or tuber-forming species of *Solanum* L. and plants for planting of Solanaceae, other than seeds, are subject to import prohibitions from most third countries (Implementing Regulation (EU) 2019/2072, Annex VI, points 15-18). Taking these regulations into account, the most likely pathways for the introduction of UQPs and potential UQPs for potatoes have been identified as follows:

1. Import of potato tubers from EU Member States and import of potato tubers from third countries that (via a derogation) do not fall under the import ban
2. Illegal import of potato tubers, true potato seeds and plants for planting of Solanaceae by consumers and companies (incl. via passenger baggage and parcel post)
3. Import of fruits of Solanaceae, such as paprika, chili pepper and tomato
4. Use of material imported in the past for research and breeding purposes, which have been stored without testing
5. Import of plants for planting of Solanaceae, other than seed potatoes, from European and Mediterranean countries that are exempt from the import ban (import of seed potatoes is prohibited from all third countries, except Switzerland),
6. Import of potatoes and plants for planting of *Solanum* species for research and breeding purposes

NB There are more pathways for UQPs and potential UQPs that affect potatoes, and for certain specific organisms, other pathways may be more likely than ones mentioned above. For example, 'hitchhiking with plant or other products' seems to be the most or one of the most likely pathways for the introduction of the weevil *Naupactus leucoloma* (Table 5.2). Polyphagous organisms, such as *Ralstonia pseudosolanacearum* and *R. syzygii* subsp. *indonesiensis*, that affect plants from different families may also enter via the import of non-Solanaceae (Table 5.2). However, these two species pose a minor risk to potato cultivation in the Netherlands, as discussed earlier in section 5.4.

The likelihood of introduction (entry and establishment) is particularly high when a pest hitchhikes with seed potatoes or other plants for planting. After all, these seed potatoes (or other plants for planting) are intended for planting and therefore the pest does not need to look for another crop on which it can multiply. Organisms that hitchhike with ware or starch potatoes need to find a crop to establish themselves, a process referred to as 'transfer'. Transfer is possible, for example, from waste heaps (infested waste residues or soil tare), when spreading soil tare onto arable plots or when consumers use ware potatoes as seed potatoes. Organisms that can fly or be dispersed by wind can also enter cultivation naturally via imported potatoes, provided that the appropriate mobile stages of the organism are present or if the amount of time and conditions are sufficient for these stages to develop.

A relatively new development is the use of true potato seeds as propagating material instead of seed potatoes. For the time being, the import of true potato seeds is prohibited from third countries, except Switzerland (Implementing Regulation (EU) 2019/2072, Annex VI, point 16). In general, the likelihood of the seeds being associated with UQPs and potential UQPs is lower than in the case of tubers (Van der Gaag et al., 2015). Certain viruses could be associated with seeds (see, for example, Jones (1982)). Due to the current import ban, the risk of true potato seeds as a pathway is not assessed further here.

Taking into account existing legislation and regulations, Figure 5.1 lists the most likely pathways through which UQPs and potential UQPs can be introduced into the potato chain, including pests that are already established in the Netherlands in arable farming. The most likely pathways for the introduction of organisms not, or not yet, established in the Netherlands are briefly discussed below. The speed at which an organism will eventually spread in potato cultivation after introduction will strongly depend on its biology. More information on the spread mechanisms and spread rate of the organisms, can be found in the short risk assessments and existing datasheets (EPPO, 2018b; NVWA, 2018j).

5.6.1. Pathway 1: Import of potatoes from EU Member States and import from third countries that (via a derogation) do not fall under the EU import ban

Seed potatoes may only be imported into the EU from Switzerland and countries for whom a derogation applies. There is a derogation for Greece, Spain, Italy, Cyprus, Malta and Portugal for the import of seed potatoes from certain Canadian provinces[30]. This derogation does not apply to the Netherlands, but once potential UQPs have been introduced into the aforementioned EU Member States, they could subsequently enter the Netherlands via EU internal traffic. Switzerland and a large number of European and Mediterranean countries are exempt from the ban on the import of ware and starch potatoes, provided they comply with European regulations for *Clavibacter sepedonicus* (Implementing Regulation (EU) 2019/2072, Annex VI, point 17). There are derogations for certain areas in Cuba and Lebanon for the import of ware and starch potatoes[31]. Taking into account the current import bans, exceptions and derogations, the import of potatoes from EU Member States and from third countries are probably the most important pathways for the following UQPs:

- *Clavibacter sepedonicus,* particularly from countries where the bacterium is relatively widespread (NVWA, 2017b),
- *Epitrix papa* and *E. cucumeris* from Spain and Portugal,
- New pathotypes of Synchytrium endobioticum,
- Tecia solanivora from Spain,
- *Epitrix* spp. from Canada.

Emergency measures are in place within the EU to control the spread of *Epitrix papa* and *E. cucumeris* within the EU (see section 5.4).

Risk mitigation measures. In principle, the existing import ban on potatoes is very effective in preventing the introduction of UQPs and potential UQPs. For countries that are exempt from this ban, it is important that there are sufficient guarantees that no UQPs and potential UQPs can hitchhike with the potatoes. It is also necessary to remain alert to the possible introduction of UQPs and potential UQPs in these countries after a derogation is granted.

[30] Commission Implementing Decision 2014/368/EU of 16 June 2014 amending Implementing Decision 2011/778/EU authorising certain Member States to provide for temporary derogations from certain provisions of Council Directive 2000/29/EC in respect of seed potatoes originating in certain provinces of Canada.

[31] Commission Decision 2003/63/EC of 28 January 2003 authorising Member States to provide for temporary derogations from Council Directive 2000/29/EC in respect of potatoes, other than potatoes intended for planting, originating in certain provinces of Cuba. Commission Implementing Decision (EU) 2019/1614 of 26 September 2019 authorising Member States to provide for derogations from certain provisions of Council Directive 2000/29/EC in respect of potatoes, other than potatoes intended for planting, produced in the regions of Akkar and Bekaa in Lebanon.

5.6.2. Pathway 2: Illegal import of potato tubers, other potato material and plants for planting of Solanaceae

Besides the regular import of potatoes, illegal import of potato tubers and other potato material may form the greatest risk since the illegal nature of the import makes it impossible to guarantee the phytosanitary status of the material. Illegal imports may involve, for example, potato tubers either carried in passenger baggage or parcel post (Internet commerce) without a valid phytosanitary certificate or coming from countries from which import is prohibited. The introduction of the moth *Tecia solanivora* in the Canary Islands was possibly due to the illegal import of potatoes from South America (EPPO, 2005). On mainland Spain, the organism was found in the possession of private individuals and this may have also been due to illegal import from the Canary Islands to mainland Spain (although part of Spain, the Canary Islands are considered a third country under European phytosanitary legislation). The NVWA controls passenger baggage in collaboration with the customs authorities and controls parcel post in collaboration with customs and courier services (NVWA, 2018e). Potatoes are also offered for sale on the Internet. There are no known interceptions of potato material in parcel post, but Kaminski et al. (2012) were able to easily order seed potatoes of prohibited origin via the Internet in Germany. In the Netherlands, potatoes have been intercepted several times in passenger baggage at Schiphol Airport (NVWA, 2017b). In 2016, potatoes were intercepted in passenger baggage from Peru. Various harmful organisms were found in the potatoes, including *Synchytrium endobioticum* and various quarantine viruses. In June 2018, potatoes were found in three suitcases during the passenger baggage control of a flight from Peru. Baggage of passengers in transit is checked by customs authorities for narcotics, ammunition and weapons but not for the presence of plants that are prohibited for phytosanitary reasons. Passenger baggage with a final destination in the Netherlands is controlled for plants prohibited for phytosanitary reasons but this only occurs on a random basis. Therefore, the chances of intercepting prohibited material of plant origin in passenger baggage entering the EU are low and potatoes could be entering the EU via passenger baggage more often. The risk of the introduction of UQPs and potential UQPs via passenger baggage will generally be low if these potatoes are consumed, but it is also possible that these potatoes are being illegally imported for planting (for example, by amateur breeders). In that case, the likelihood of the introduction of harmful organisms is considerably greater.

Risk mitigation measures. The new regulation, which entered into force on 14 December 2019 (Regulation (EU) 2016/2031), requires "Member States, seaports, airports and international transport companies" to inform travellers about the phytosanitary requirements for travellers' baggage, including the import ban on potatoes. Postal services are also subject to an information obligation (Article 45). Whether providing this information about the risks will be sufficient will need to be demonstrated through the control of parcel post and passenger baggage.

5.6.3. Pathway 3: Import of Solanaceae fruits

Import of fruits of Solanaceae may be the main pathway for *Bactericera cockerelli* and possibly also for *Russelliana solanicola* (see the sections on these organisms). It is possible that fruits of Solanaceae can also be a pathway for other new organisms harmful to potatoes.

Risk mitigation measures. Since 1 September 2019, fruits of Solanaceae are subject to special rules relating to *Bactericera cockerelli* but not for other organisms that are harmful to potatoes. The most effective way to prevent the introduction of UQPs and potential UQPs is through the imposition of a ban, temporary or otherwise, on the import of Solanaceae fruits. If possible, import could be resumed if the risks of import (after specific measures are taken in the country of origin, during transport or upon arrival) prove to be low based on a risk assessment. Article 42 of the new regulation (Regulation (EU) 2016/2031) also sets out the legal options for this, but these are only applicable to a product that "*on the basis of a preliminary assessment, presents a pest risk of an unacceptable level for the Union territory*". However, the phrase 'risk of an unacceptable level' has not been clearly defined. The UK has intercepted *Bactericera cockerelli* four times in fruits of Solanaceae from Mexico in 2017 and 2018 (Defra, 2018) (Europhyt, 19.09.2019). With the exception of *B. cockerelli*, there is no evidence that UQPs and potential UQPs relevant to potatoes are able to enter via the import of Solanaceae fruits. Although there are many interceptions of harmful organisms in the EU (e.g. 244 notifications in the period 1 January 2018 - 25 June 2019 for *Solanum* fruits due to the presence of a harmful organism), most of these organisms pose little or no threat to potato cultivation in the Netherlands. In addition, they are organisms that are often also intercepted on other products or are already present but not regulated in the EU. An import ban solely on fruits of Solanaceae cannot prevent the entry of these organisms.

5.6.4. Pathway 4: Use of earlier imported material for research and breeding purposes

Potato material in collections and gene banks in Europe, which was imported before such material was extensively tested and assessed or before certain tests were available, may contain harmful organisms. In 2016, PSTVd was found in breeding material imported from Northern Ireland (NVWA, 2016a). The infestation was detected during a regular testing programme of breeding material for PSTVd. A few years earlier, in 2014, PSTVd had also been found in breeding material. These detections resulted in measures (sampling and testing of material) to reduce the risk of recurrence (NVWA, 2015b).

Risk mitigation measures. Research institutions and breeding companies can ensure that material from collections and gene banks is first tested for the presence of harmful viruses and viroids before use in research and breeding, in order to prevent introduction into the chain.

5.6.5. Pathway 5: Import of plants for planting of Solanaceae, other than seed potatoes, from European and Mediterranean countries exempt from the import ban

Plants for planting of Solanaceae are imported from third countries. This mainly involves plants imported from Israel (incl. petunia cuttings). No organisms have been identified in European or Mediterranean countries that are absent from the EU and pose a threat to potatoes in the Netherlands. However, PSTVd was found in plants of *Capsicum* (sweet pepper and chili pepper) in 2016. PSTVd was a UQP at the time and is a threat to potato cultivation. In 2016, it may had been introduced with the import of plants from Israel that had been vegetatively propagated (NVWA, 2016c). PSTVd is listed as an RNQP since 14 December. However, other unidentified UQPs and potential UQPs could also enter in similar ways via the import of plants for planting.

Risk mitigation measures. No UQPs and potential UQPs of potatoes have been identified in countries that are exempt from the import ban on plants of Solanaceae. Due to the exemption, it is important to remain alert about the possible introduction of new harmful organisms from these third countries.

5.6.6. Pathway 6: Import of potato and plants for planting of *Solanum* species for research and breeding purposes

An exemption from the import bans on potato and plants for planting of Solanaceae other than seeds (and other plants subject to an import ban) may be granted under Delegated Regulation (EU) 2019/829 for material intended for official testing, scientific or research purposes, trials, varietal selection or breeding where the material is quarantined for visual assessment and testing for all relevant UQPs (Werkman et al., 2004). Material found to be free from pests will be made available to the importer. Due to these measures, there is a very low risk of the introduction of UQPs and potential UQPs via this pathway.

Risk mitigation measures. Based on the current official requirements, the risk is very low.

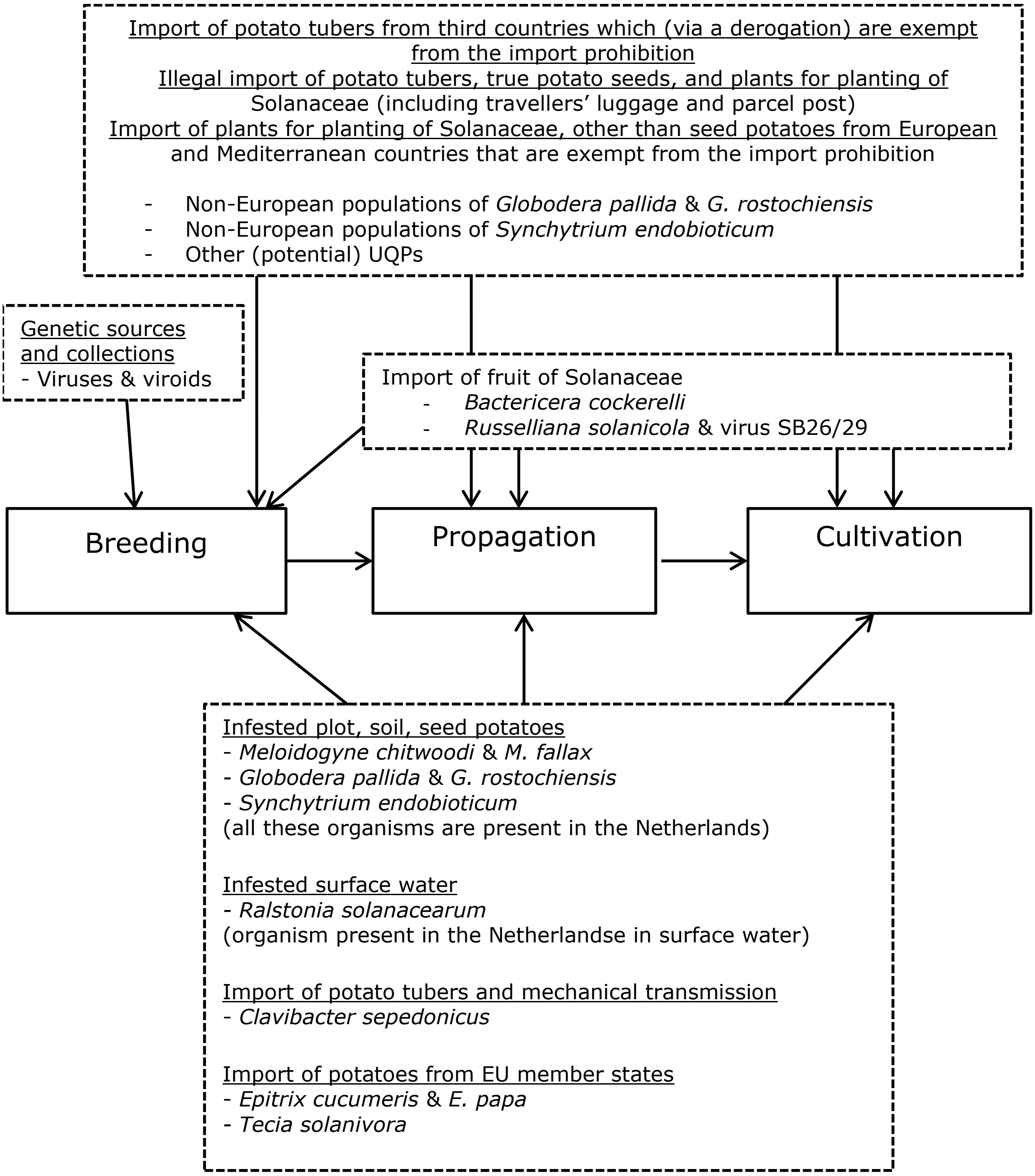


Figure 5.1 Overview of the most likely pathways by which UQPs and potential UQPs can be introduced into the potato chain. Within the potato chain, many of the organisms can be spread via infested seed potatoes. Organisms can enter the Netherlands via various plants and products and thereafter enter the potato chain via contact or natural spread.

5.7. Description of UQPs that are established in the Netherlands and are relevant to the potato chain.

5.7.1. Globodera pallida (Stone) Behrens and Globodera rostochiensis (Wollenweber) Behrens

Short description:

The nematode species *Globodera rostochiensis* and *Globodera pallida* (yellow potato cyst nematode and white potato cyst nematode respectively) cause growth retardation in the potato plant. The nematodes attack the roots of the plants and affected plants show retarded growth. This is visible in the field as patches of poor growth. Both species are potentially very harmful. In addition, both species pose a threat to the trade and export of seed potatoes. Much has been written about the effects of potato cyst nematodes on potatoes and detailed information on the biology of the nematode and control measures can be found in a recently updated brochure (Molendijk, 2018). A brief description is given below.

G. rostochiensis and *G. pallida* survive in the soil as eggs in 'cysts' (protective shells around the eggs formed from female nematodes). The roots of host plants secrete substances that cause the larvae to emerge from the eggs and then penetrate the root. The spread is mainly caused by the transfer of the infested soil (with seed potatoes, other potatoes, other plants, machines, tools, etc.). Besides preventing the spread via soil, there are several other measures available for controlling potato cyst nematodes (PCN):

- adjustment of cultivation frequency (the eggs in the cysts can survive for several years, but a portion of the eggs will die every year);
- use of resistant varieties (the NVWA publishes an official list each year with the resistance data for potato varieties, as required under Directive 2007/33/EC, but the problem with the use of resistant varieties is that, over time, resistances can be broken down through the build-up of more virulent populations);
- use of potato as a catch crop (a catch crop attracts the larvae but reproduction is prevented by killing the host plant (catch crop) in time by spraying it);
- use of sticky nightshade as a trap crop (a trap crop attracts the larvae, but reproduction is prevented because the crop is not a host plant);
- inundation (flooding the soil) is effective, (NVWA, 2015a): the problem with inundation may be that the soil used to create embankments around a plot may not get disinfested, a solution for which is to put up partitions rather than using soil to hold back the water
- anaerobic soil disinfestation (soil disinfestation by mixing organic material in the soil and then covering the soil with a plastic film to restrict oxygen supply);
- soil disinfestation using plant protection products based on metam sodium is an option, but this is only permitted to a very limited extent);
- granular soil-applied pesticides.

EU legislation

Annex VII of Implementing Regulation (EU) 2019/2072 contains special requirements relating to *Globodera pallida* and *G. rostochiensis.* Special regulations apply to the import of plants for planting with roots that have been grown in the open air, for potato tubers, for plants with roots for planting of *Capsicum* spp., *Solanum lycopersicum* L. and *Solanum melongena* L. and for the bulbs, tubers and rhizomes of a number of specifically named plant species. In addition, there are various import bans, including for seed potatoes, applicable to all third countries other than Switzerland (Annex VI) and special regulations for adhering soil when plants are imported for planting (Annex VII). An EU Control Directive is also in force for both nematode species (Directive

2007/33/EC)[17]. Annex VIII[32] of Implementing Regulation (EU) 2019/2072 refers to this Directive. The purpose of the Directive is to identify the spread of *Globodera pallida* and *G. rostochiensis* in the EU and prevent any further spread. To prevent this spread, requirements have been laid down for host plants as well as for a number of non-host plants, since these nematodes can hitchhike with adhering soil from both host plants and non-host plants. The strictest requirements in the directive apply to nematode host plants:

- *Solanum tuberosum* L. (potato)
- *Solanum lycopersicum* L. (tomato)
- *Solanum melongena* L. (aubergine)
- *Capsicum* L. (sweet pepper, chili pepper)

For the cultivation of propagating material of these crops, the plot must be declared free of these pests based on an official investigation. Since propagating material of tomato, eggplant, sweet pepper and chili pepper is not grown in soil in the Netherlands, the regulations are of little relevance to these crops in the Netherlands. However, nematodes can also be spread via adhering soil from non-host plants. Therefore, for a number of non-host crops ('lightly regulated plants'), there are requirements with regard to adhering soil. The minimum requirement is that either the adhering soil must be removed from the material or the plot must be found free of both nematode species after sampling and testing. The 'lightly regulated plants' are bulbs and tubers of dahlia, gladiolus, hyacinth, iris, lily, narcissus and tulip and plants of leek, beetroot, cabbage, strawberry, asparagus, onions and shallots. However, the requirements for exporting plants to countries outside the EU may be stricter. Consequently, there are a number of areas in the Netherlands (the Potato Cultivation Prohibition Areas) where potato cultivation is prohibited in order to prevent the establishment of *Globodera pallida* and *G. rostochiensis*. These are areas where a lot of propagating material is cultivated. More details about the regulations are available on the website of the NVWA.

It is not permitted to grow seed potatoes on infested plots. Ware and starch potatoes may only be grown on infested plots after official control measures have been implemented, including the cultivation of cultivars that have a sufficiently high level of resistance. Requirements also apply to soil tare originating from infested plots to prevent the nematodes from spreading. In order to withdraw a declaration of infestation, certain conditions (incl. a waiting period) must be met before this declaration can be withdrawn based on the results of the soil investigation. More information can be found on the NVWA website (NVWA, 2018g).

According to Directive 2007/33/EC, EU Member States also have to carry out a survey to detect the spread of *Globodera pallida* and *G. rostochiensis* in the cultivation of non-seed potatoes (final crop: ware and starch potatoes). At least 0.5% of the non-seed potato acreage must be examined annually for the presence of the nematodes.

National cultivation regulations

In addition to the EU requirements - including the use of fields that are free from the nematodes for cultivation of propagating material of host plants - there are national cultivation regulations to mitigate the risk of both *Globodera*-species (details can be found on the NVWA website):

- It is not allowed to grow potatoes on the same plot more than once every 3 years (1:3) (no potato cultivation in the previous two years), although there are a number of exceptions to this (NVWA, 2020e):
    - potato cultivation in the northeastern sandy soil and reclaimed peatland areas (excl. NAK seed potatoes),

[32] List of plants, plant products and other objects originating from Union territory and the corresponding special regulations for their movement within Union territory

  - via an exemption issued by the NVWA or
  - participation in the early lifting scheme, where the potatoes must be lifted before a certain date so that the potato cyst nematode has little chance of multiplying.
- There is a ban on potato cultivation in five areas where a lot of propagating material is grown (the aforementioned Potato Cultivation Prohibition Areas).
- Farms that grow potatoes on PCN-infested soil are only allowed to sell these potatoes to companies accredited by the NVWA. These are companies that dispose of the soil tare (adhering soil that comes loose from the potatoes during handling after harvest) with due regard for phytosanitary principles (NVWA, 2020a).

Situation in the Netherlands

G. rostochiensis and *G. pallida* are found throughout the Netherlands except in the Potato Cultivation Prohibition Areas. In the period 2012-2017, approximately 10,000 plots intended for the cultivation of seed potatoes were sampled annually, whereby infestations were found on 6-7% of the plots (NVWA, 2018a). The annual acreage declared infested based on this survey varied from 1,476 to 1,748 ha in the same period.

In the final crop survey, 120 to 129 plots were examined annually in the period 2015-2017, with infestations found on 3.9% to 6.7% of the plots (NVWA, 2016d;2017b;2018a). These surveys did not include any plots in the starch potato area in the northeastern Netherlands. In 2017, a separate survey was conducted in this area, whereby infestations were found in 19 of the 33 plots examined (NVWA, 2018a).

In 2015, in the northeast of the Netherlands, *Globodera pallida* populations were identified that multiplied relatively strongly on cultivars known to be pallida-resistant (Molendijk et al., 2017). There had been earlier reports of virulent populations of *Globodera pallida* in Germany. There are indications of more virulent populations in the case of *G. rostochiensis* as well (NVWA, 2018a). The more virulent populations have so far been found in the sandy soil and reclaimed peatland areas in the northeast where there are no restrictions on the cultivation frequency of starch and ware potatoes and where starch potatoes are usually grown at a frequency of 1:2. In 2016, more than 50% of the plots in this area were also infested with *Globodera pallida* and/or *G. rostochiensis* (TBM, 2018). Frequent cultivation of highly resistant potato cultivars plays a role in the development of more virulent populations (Molendijk et al., 2017). There is a danger that the more virulent populations will be spread further in the Netherlands through the transfer of plants and soil, which could also endanger the cultivation of seed potatoes.

Non-European populations

In South America, there are known *G. pallida* populations to which the resistant European potato cultivars are 100% susceptible (Molendijk et al., 2017) and the introduction of new genotypes can have a major impact, since it takes a long time to develop new resistant cultivars (EFSA PLH Panel, 2012).

5.7.2. Meloidogyne chitwoodi Golden et al. and Meloidogyne fallax Karssen

Short description:

Meloidogyne chitwoodi (maize root-knot nematode) and *Meloidogyne fallax* (false maize root-knot nematode) are two closely related root-knot nematodes, each of which has a very wide host plant range. These are mainly known to cause damage to potato, carrot and salsify in coarse textured soils. *M. chitwoodi* and *M. fallax* lead to the formation of galls on the products to be harvested from these crops, making them unsaleable (Van der Gaag et al., 2011b;2011a). Damage as a result of reduced growth has been reported for a number of other crops as well, including peas, yet in many host plant crops these pests cause little or no damage. But an infestation can have major consequences for the trade and export of plant propagating material in particular, given that *M. chitwoodi* and *M. fallax* are quarantine pests in the EU and a large number of third countries.

EU legislation

Special requirements apply in relation to *M. chitwoodi* and *M. fallax* for seed potatoes from third countries and EU Member States (point 20 in Annex VII and point 8 in Annex VIII of Implementing Regulation (EU) 2019/2072). Seed potatoes must either originate in areas or places of production where both pests are absent or a random sample of the tubers should have been tested after harvesting and found free from both pests. In addition, there are various import bans relating to these pests, including for seed potatoes from all third countries other than Switzerland (point 15 in Annex VI), and special requirements apply with respect to adhering soil when plants are imported for planting (point 1 in Annex VII).

Situation in the Netherlands

Both species are found in several cultivation areas in the Netherlands. Areas where these pests are officially detected are indicated as 'Designated Areas'. Within these areas, all lots of seed potatoes must be sampled and tested for *M. chitwoodi* and *M. fallax*. As of 1 January 2019, a number of changes have been made to this policy. Following detection, an area with a radius of 1 km is still supposed to be demarcated around the site and all seed potato lots from plots located entirely or partly within this area must be tested. But, since the change in the policy, after one year the Designated Areas will be limited to the so-called Topographic Plot[33] where the original detection was made. Each new detection leads to the demarcation of a new 1 km-wide area. A Topographic Plot may be declared free of infestation if the nematodes have not been detected over two consecutive seed potato crops on the infested plot. Outside the Designated Areas, some of the seed potato lots are tested at an average of one lot per grower per year (NVWA, 2020j). In addition, inspections (and tests) are carried out on the final potato crop as part of the annual survey programme (see for example Table 5.5 in NVWA (2018a)). There are a greater number of detections in seed potatoes than in the final crop. However, this may be because seed potatoes are systematically tested in areas where the pests are officially known to occur, whereas ware and starch potatoes are not. Flower bulbs, perennials and nursery plants are usually inspected visually. Overviews of the number of detections per year (till 2017) can be found in the Annual Phytosanitary Reports on the NVWA website. The detections mainly occur in potato cultivation. In 2017, there was a sharp increase in the number of detections compared to previous years (Table 5.3; NVWA (2018a)).

Table 5.3. Number of detections of *Meloidogyne chitwoodi* and *M. fallax* in the final crop (Final) and in seed potato cultivation (Seed), expressed in the number of plots of origin[1] in the period 2013-2019 (source: NVWA).

<table>
<tr><th rowspan="3">Pest</th><th colspan="10">Year</th></tr>
<tr><td colspan="2">2015</td><td colspan="2">2016</td><td colspan="2">2017</td><td colspan="2">2018</td><td colspan="2">2019</td></tr>
<tr><td>Final</td><td>Seed</td><td>Final</td><td>Seed</td><td>Final</td><td>Seed</td><td>Final</td><td>Seed</td><td>Final</td><td>Seed</td></tr>
<tr><td>M. chitwoodi</td><td>9</td><td>28</td><td>15</td><td>19</td><td>12</td><td>46</td><td rowspan="2">19</td><td rowspan="2">56</td><td rowspan="2">13</td><td rowspan="2">54</td></tr>
<tr><td>M. fallax</td><td>1</td><td>1</td><td>2</td><td>4</td><td>3</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>10</td><td>29</td><td>17</td><td>23</td><td>15</td><td>56</td><td>19</td><td>56</td><td>13</td><td>54</td></tr>
</table>

[1] Plots from which the infested potatoes originated

[33] Topographic Plot: area of land enclosed by topographic, permanent or temporary boundaries such as roads, water, hedgerows, fences and buildings

Since both *Meloidogyne* species have such a wide range of host plants and many of the host plants show little or no symptoms, there is a high risk of spread via planting material. In addition, the nematodes can be spread via soil. It is suspected that both species occur in more places than is officially known at present, but in many cases they do not cause significant damage and may go therefore undetected.

A lot of research has been performed on how to control the nematodes. Disinfestation of the soil with plant protection products is only possible to a limited extent and is not fully effective (Runia et al., 2006). For *M. chitwoodi*, inundation has been demonstrated as being very effective and biological soil disinfestation is also a good control measure. It is not known whether inundation also works against *M. fallax* (Termorshuizen et al., 2020). Growers can also partly prevent losses by following an integrated approach of allowing soil samples to be analysed for the presence of plant-parasitic nematode species, and depending on the results of the analysis, taking a decision regarding the rotation schedule, cultivar and/or crop choice (resistant cultivars or less sensitive crops), sowing period and duration of the cultivation period (for example, later sowing for carrots or a shorter cultivation period for potatoes) and/or the use of nematicides.

Extensive information about the biology of the pests, the range of host plants, a description of the pathways by which the pests can be spread and an estimate of the impact can be found in (Van der Gaag et al., 2011b;2011a).

5.7.3. Ralstonia solanacearum (Smith) Yabuuchi et al. emend. Safni et al.

Short description:

The bacterium *Ralstonia solanacearum* causes brown rot in potato. Affected tubers display a brown ring when cut through. Plants can wither under warm conditions, although this rarely occurs in the Netherlands. The bacterium is mainly spread via infested seed potatoes and infested surface water.

EU legislation

Annexes VII and VIII of Implementing Regulation (EU) 2019/2072 contains special requirements with regard to *Ralstonia solanacearum* for plants of certain species. In addition, various import bans apply that are relevant to the pest, including a ban on the import of seed potatoes from all third countries other than Switzerland (Annex VI). For potatoes from Egypt, special regulations have been laid down with regard to *Ralstonia solanacearum* in Implementing Decision 2011/787/EU. There is also a European Control Directive for *Ralstonia solanacearum* in force (Directive 98/67/EC amended by Directive 2006/63/EC). The purpose of this Directive is to identify the spread *Ralstonia solanacearum* in the EU and prevent any further spread. For this, Member States are required to conduct annual surveys. The Directive outlines sampling and detection methods in detail and the measures to be taken in case of detection.

Situation in the Netherlands

In the Netherlands, this bacterium is established in surface water, where it is maintained by the presence of host plants growing along the banks, in particular *S. dulcamare* (bittersweet) (Wenneker et al., 1999; Janse et al., 2009). The greatest likelihood of an infestation of potatoes is through the use of surface water or via infestation with surface water. The latter may happen, for example, when the water flows into a plot during a storm. Hence, in the Netherlands, there is a ban on the use of surface water for the cultivation of seed potatoes throughout the country. For other potatoes, the use of surface water is prohibited in those areas where the pests are known to occur (the Sprinkler Irrigation Prohibition Areas (*Beregeningsverbodsgebieden*)). In the period 2010-2019, brown rot was found in a total of 19 farms (Table 5.4). Detailed information on detections up to 2017 can be found in the Annual Phytosanitary Reports (NVWA, 2018a). If *R. solanacearum* is found in seed potatoes, measures are taken not only for the infested lot but also for lots that may be infested, i.e. the probably infested lots. A potato cultivation ban applies for four or five years to the plot on which the infestation is detected. For the entire production site, there is a ban on the cultivation of seed potatoes in the year following the year of detection. The NVWA measures to be taken in case of detection are specified in NVWA (2019b)

Table 5.4. Number of farms with brown rot infestation in the period between 2010-11 and 2019-20.

Crop	Cultivation season						
	2010-11	2011-12	2012-13 to 2015	2016-17	2017-18	2018-19	2019-20
NAK seed potatoes[1]	0	0	0	4	2	2	3
ATR and TBM seed potatoes[2]	0	0	0	0	0	0	0
Final crop	1	4	0	0	0	2	1
Total	1	4	0	4	2	4	4

[1]NAK seed potatoes: seed potatoes certified by the NAK
[2]ATR seed potatoes (seed potatoes compliant with the Potato Cultivation Regulations (*Aardappelteeltregeling, ATR*)): propagation of farm-saved seed potatoes for ware potato cultivation; TBM seed potatoes (seed potatoes approved by the Foundation for Crop Protection Measures for Starch Potatoes (*Stichting Teeltbeschermingsmaatregelen Zetmeelaardappelen, TBM*)): propagation of farm-saved seed potatoes for starch potato cultivation.

5.7.4. Synchytrium endobioticum (Schilbersky) Percival

Short description

The fungus *S. endobioticum* causes warts (bulges) on potatoes (potato wart disease), which makes potatoes unsaleable and greatly reduces the yield. The pathogen originates from South America and was introduced into Europe in the nineteenth century. In the Netherlands, *S. endobioticum* first observed in 1915 (Baayen et al., 2006). The pathogen can remain viable in soil for more than 30 years, but this survival time is probably much less in well-tilled soil (see below). Spread of the pathogen mainly takes place through human action relating to seed or other potatoes, waste and adhering or other soil. Wind-borne spread is also possible, but it is unknown to what extent the wind contributes to the spread of this pest in the Netherlands.

Survival time in soil

Winter spores of *S. endobioticum* can survive for a long time. Studies by Schaffnit & Voss (1918) and Köhler (1931) indicate that winter sporangia can remain viable in soil for at least 9-10 years. Hartman (1955) describes experiments in Pennsylvania on crop beds in which survival was demonstrated for 15 years, but after 20 years all 'units' were free of wart disease. However, a citation from the same study (Hartman, 1955) says "*definite evidence is at hand which shows that potato wart has persisted in sods, abandoned gardens, and over-grown weed patches for 25 or more years and in one instance, 30 years"* (no references were provided with this statement). Pratt (1976) refers to a study by (Holmberg, 1944) in Sweden showing that winter spores were still viable after 16 years "under grassland", but no survival was reported in soil tilled annually. This means that regular tilling of the soil seems to shorten the survival span. Germination kills the resting spores and a lack of oxygen probably inhibits the ripening and germination of winter spores (Esmarck, 1924; Weiss, 1925).

Pathotypes

There are various *S. endobioticum* pathotypes that can be distinguished from one another based on cultivar testing (the degree to which a potato cultivar is resistant to *S. endobioticum* can differ from one pathotype to another). The development or introduction of a new pathotype can have major consequences for a cultivation area if the potato cultivars commonly cultivated there are susceptible to this new pathotype. Dozens of pathotypes have been described, among which pathotypes 1(D1), 2(G1), 6(O1), 8(F1) and 18(T1) are considered the most widespread and most economically relevant to Europe (Busse et al., 2017; Van de Vossenberg, 2019). A recently published EPPO Standard uses a set of cultivars based on which the pathotypes 1(D1), 2(G1), 6(O1) and 18(T1) can be distinguished from one another (EPPO, 2017). There is a debate about the extent to which isolates characterised as pathotype 8(F1) belong to a clearly different pathotype than isolates characterised as 18(T1). There would be partial differences between pathotype 8(F1) and pathotype 18(T1) in terms of the degree to which some potato cultivars are adversely affected (Przetakiewicz, 2017). In a pathotype identification carried out by the NVWA, which only makes a distinction between the 'Susceptible' and 'Fully resistant' categories for a specific set of cultivars, a German pathotype 8(F1) isolate found close to the Dutch border was classified as pathotype 18(T1).

Many potato cultivars are fully resistant to pathotype 1(D1) and infections with this pathotype are rarely found in Europe (EPPO, 2017), but there are fewer cultivars known that are fully resistance to the other pathotypes. New pathotypes can occur in an area due to selection within existing populations of the fungus or the introduction of an existing pathotype from another area. A recent study has shown that isolates of *S. endobioticum* are genetically heterogeneous and that selection can make the populations more virulent for the cultivated potato cultivars (van de Vossenberg et al., 2018; van de Vossenberg et al., 2019a). The study showed that the pathotypes 2(G1) and 6(O1) most likely emerged several times independently of each other through selection from genetically diverse isolates/populations and that pathotype 18(T1) was probably introduced into Europe. Various pathotypes have been described in Europe and countries outside Europe that, as far as is known, are not present in the Netherlands and other Western European countries. For example, in Poland, pathotypes 3(M1), 39(P1) and 40(BN1), and in Turkey, pathotype 38(Nevsehir) have been described (Çakır et al., 2009; Przetakiewicz, 2010; Van de Vossenberg, 2019). In addition, pathotype 8(F1) has been reported in Germany close to the Dutch border, but as indicated earlier, there is uncertainty as to how far this is different from pathotype 18(T1). New pathotypes can enter the Netherlands via import of potatoes. Import of potatoes is prohibited from most third countries but is allowed from European countries and a number of Mediterranean countries, including Turkey (see also below under 'EU legislation').

EU legislation

EU requirements aimed at reducing the risk of introduction from third countries

Annex VI of Implementing Regulation (EU) 2019/2072 contains import bans for potato tubers, where a distinction is made between seed potatoes and other potato tubers:

List of plants, plant products and other objects whose introduction into the Union from certain third countries is prohibited			
	Description	CN code	Third country, group of third countries or specific area of third country
15.	Tubers of *Solanum tuberosum* L., seed potatoes	0701 10 00	Third countries, with the exception of Switzerland

17.	Tubers of species of *Solanum* L., and their hybrids, other than those specified in entries 15 and 16	ex 0601 10 90 ex 0601 20 90 0701 90 10 0701 90 50 0701 90 90	Third countries, with the exception of: a) Algeria, Egypt, Israel, Libya, Morocco, Syria, Switzerland, Tunisia and Turkey or b) those which fulfil the following provisions: i) this involves one of the following countries: Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Faroe Islands, Georgia, Iceland, Liechtenstein, Moldova, Monaco, Montenegro, North Macedonia, Norway, Russia (only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo-Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo-Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug)), San Marino, Serbia, and Ukraine and (ii) - they are either recognised as being free from Clavibacter sepedonicus (Spieckermann and Kottho) Nouioui et al., in accordance with the procedure referred to in Article 107 of Regulation (EU) No 2016/2031, or - their legislation is recognised as equivalent to the Union rules concerning protection against Clavibacter sepedonicus (Spieckermann and Kottho) Nouioui et al. in accordance with the procedure referred to in Article 107 of Regulation (EU) No 2016/2031.

Annex VII of Implementing Regulation (EU) 2019/2072 contains a number of special requirements with respect to *S. endobioticum*:

List of plants, plant products and other objects, originating from third countries and the corresponding special requirements for their introduction into the Union territory				
	Plants, plant products and other objects	CN codes	Origin	Special requirements
3.	Plants for planting with roots, grown in open air	ex 0601 20 30 ex 0601 20 90 ex 0602 20 20 ex 0602 20 80 ex 0602 30 00 ex 0602 40 00 ex 0602 90 20 ex 0602 90 30 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 48	Third countries	Official statement that: a) the place of production is known to be free from Clavibacter sepedonicus (Spieckermann and Kottho) Nouioui et al. and Synchytrium endobioticum (Schilb.) Percival, and b) the plants originate from a field known to be free from Globodera pallida (Stone) Behrens and

		ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99 ex 0706 90 10		Globodera rostochiensis (Wollenweber) Behrens.
17.	Tubers of *Solanum tuberosum* L.	0701 10 00 0701 90 10 0701 90 50 0701 90 90	Third countries where *Synchytrium endobioticum* (Schilb.) Percival is known to occur	Official statement that: a)the tubers originate in areas known to be free from *Synchytrium endobioticum* (Schilb.) Percival (all races other than Race 1, the common European race), and no symptoms of Synchytrium endobioticum (Schilb.) Percival have been observed either at the place of production or in its immediate vicinity for an adequate period, or b)provisions recognised as equivalent to the provisions of Union law on combating *Synchytrium endobioticum* (Schilb.) Percival in accordance with the procedure referred to in Article 107 of Regulation (EU) No 2016/2031 have been complied with in the country of origin.

EU requirements in case of detection

The national measures to be taken in case of detection are formulated based on a European Control Directive (69/464/EEC). This Control Directive prescribes the minimum measures to be taken if *S. endobioticum* occurs. These measures are as follows:

- Demarcation of infested areas and a safety zone around these areas, wide enough to protect surrounding areas, where an area is considered infested if symptoms have been found on at least one plant (Article 2)
- Treat the potato tubers and haulms from an infested area in such a way that the organism is destroyed (Article 3)
- No potatoes may be grown on infested areas and no plants for planting may be grown, ensiled or stored (Article 4)
- Only potato cultivars that are resistant to the pathotype found may be grown in the safety zone, where 'resistant' means that there is no risk of secondary infections and through that the spread of *S. endobioticum* (Article 5)
- Measures may be revoked only if *S. endobioticum* is found to be no longer present (Article 6).

Situation in the Netherlands

S. endobioticum occurs in the northeast and southeast of the Netherlands. In the northeast, pathotypes 2(G1), 6(O1) and 18(T1) are present, and in the southeast, pathotype 1(D1). In the Netherlands, a detection of *S. endobioticum* leads to a cultivation ban for at least 20 years on the infested plot (before 2000, this was 5 years). A partial lifting of the ban (cultivation of resistant ware or industrial potato cultivars) is possible except for pathotype 18(T1) after a minimum of 5 or

10 years if, after intensive (after 5 years) or extensive sampling (after 10 years), presence of *S. endobioticum* can no longer be demonstrated. More details about the measures to be taken in case of detection and the difference between an intensive and extensive sampling are described in an information leaflet available on the NVWA website (NVWA, 2015c).

National cultivation regulations: Prevention Areas

In addition to the measures to be taken based on EU legislation if *S. endobioticum* is found, national cultivation regulations also apply in a number of areas where *S. endobioticum* has been found in recent decades. The Dutch potato sector first introduced these cultivation regulations in 2000 via the Product Board Regulations (*Productschapsverordening*) in effect at the time. After the discontinuation of the Product Boards, the cultivation regulations were incorporated into Dutch legislation as of 1 January 2015. These cultivation regulations prescribe that only starch potatoes or other potatoes with a minimum resistance level (a minimum resistance rate) against the prevailing *S. endobioticum* pathotypes may be grown in a larger area surrounding the infestation site, i.e. the Prevention Area. The Prevention Areas cover the entire starch potato cultivation area in the northeast and east (Areas A and B in Figure 5.2) and two smaller areas in the southeast (Area C in Figure 5.2) of the Netherlands. In Prevention Area A, the minimum resistance level is lower for seed potatoes than for ware and starch potatoes. In Prevention Area B, where wart disease has only been occasionally detected (two detections in 1997), the minimum resistance level only applies to starch potatoes. In Prevention Area C, only pathotype 1(D1) occurs and many cultivars with a high degree of resistance against this pathotype are available. In Area C, where mainly ware potatoes are grown, the minimum resistance level is the same for all potato types. Within the Prevention Areas, smaller areas known as 'Core Areas' are demarcated, where additional requirements apply to a pathotype found only in those areas, i.e. pathotype 18(T1). A Core Area is an area of 1 km radius around the place where pathotype 18(T1) is detected. The exact resistance rate against pathotype 18(T1) is known only for a relatively small number of the available cultivars. The applicable cultivation regulations are summarised below:

Cultivation regulations in the Prevention Areas (March 2019)

There are specific requirements relating to the resistance level of potato cultivars to be cultivated in the Prevention Areas. The resistance level is expressed as a number on a scale from 1 to 10, where '10' stands for full resistance under laboratory conditions. A cultivar with a resistance level of 9 is fully resistant under field conditions but shows some development of the relevant pathotype under laboratory conditions.

Area A (pathotype 2(G1)/6(O1)): minimum resistance rate of 6 for all potatoes, with the exception of NAK seed potatoes for which a minimum resistance rate of 5 applies

Area B (pathotype 2(G1)/6(O1)): minimum resistance rate of 6 for starch potatoes

Area C (pathotype 1): minimum resistance rate of 6 for all potatoes

Core Areas: pathotype 18(T1):

- 1 km around place of detection
    - Minimum resistance rate of 6 for starch potatoes
    - No requirements for ware potatoes and NAK seed potatoes

Pathotype 18(T1) has only been found in Area A (northeast Netherlands) until now

For details and the most current regulations, see the NVWA website: https://www.nvwa.nl/onderwerpen/teeltorders-akkerbouw-en-tuinbouw/dicht/teeltvoorschrift-wratziekte

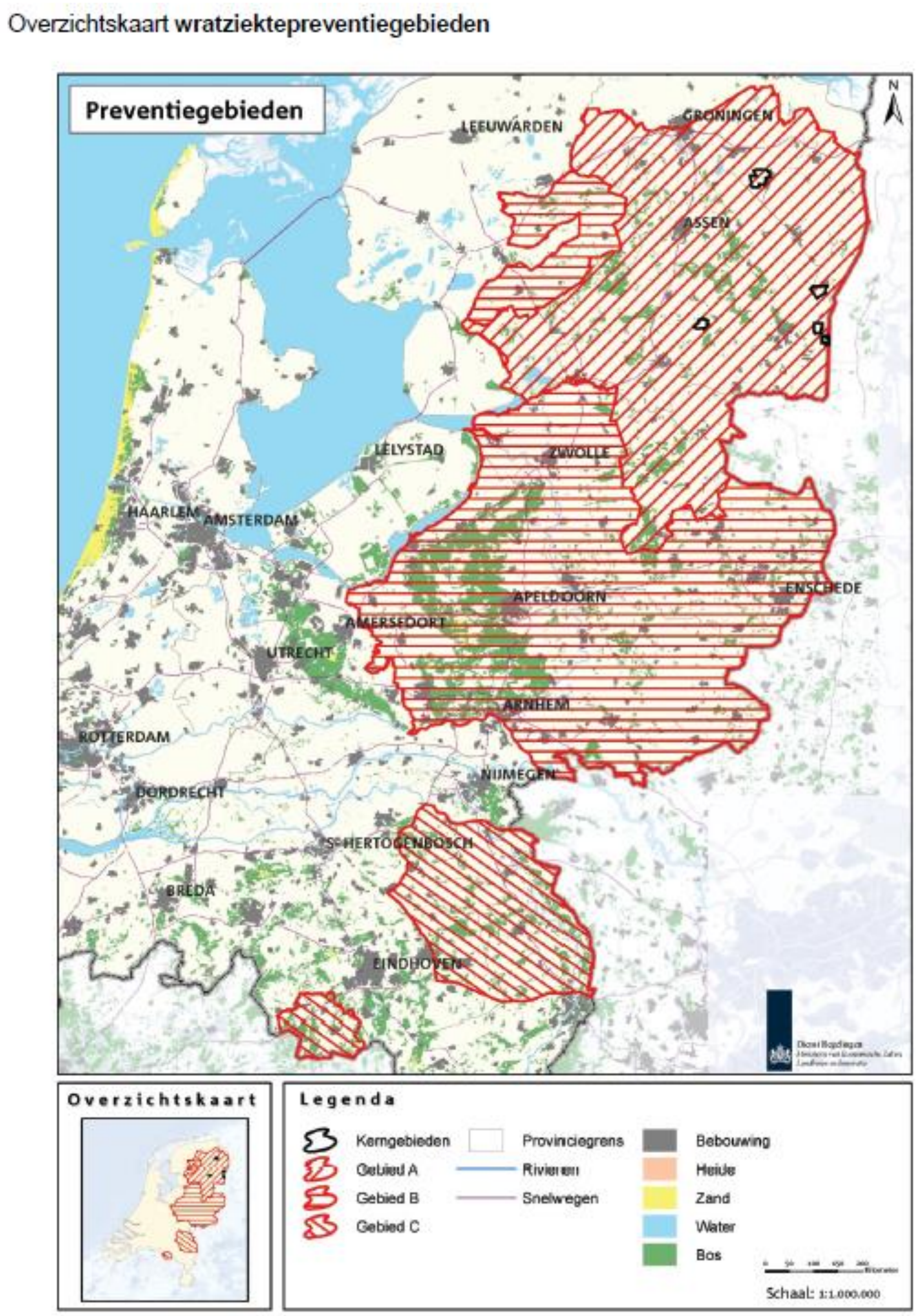


Figure 5.2 Prevention Areas for potato wart disease in the Netherlands

Number of detections

Since 2000, the number of newly detected infestations has declined significantly (Figure 5.3; Table 5.5). The decline may be due to a decrease in the infestation level in the Prevention Areas but infestations may also go undetected due to an increase in the resistance level of the cultivated cultivars. In general, starch potato growers have cultivated cultivars with a high level of resistance, much higher than the minimum required. In the period from 2000 to 2015 and 2011 to 2015, approximately 68% and 81% of the acreage, respectively, had a cultivar with a resistance rate of 9 or 10 against pathotype 6(O1) (fully resistant (under field conditions)). In the period 1997-1999, this percentage was much lower, i.e. 15%, although it should be noted that the category 'Various cultivars with unknown resistance level' was relatively large at 16% (in comparison: this 'Remaining category' was 2% for the periods 2000-2015 and 2011-2015) (Figure 5.4). In calculating the percentages, it has been assumed that the percentage of the TBM seed potatoes acreage of a particular cultivar in one year is equal to the percentage of the same cultivar in the final crop in the following year. The resistance rate of the cultivated cultivars against pathotype 2(G1) was often unknown, but the number of detections of pathotype 2(G1) has also decreased sharply, just as those of pathotype 6(O1) (Table 5.5). It is possible that most of the cultivated cultivars also had a high degree of resistance to pathotype 2(G1). Obidiegwu et al. (2015) found a strong correlation in potato genotypes between the resistance level against pathotypes 2(G1) and 6(O1).

For pathotype 18(T1), for which a minimum resistance level only applies in the Core Areas, the average resistance rate was lower and a cultivar with a level of 9 or 10 was grown on 47% and 52%, respectively, of the starch potato acreage in the periods from 2000 to 2015 and 2011 to 2015. Since 2000, pathotype 18(T1) is the most commonly found pathotype in Prevention Area A (northeast Netherlands) (Table 5.5).

For Prevention Area C (southeast Netherlands), it is likely that many cultivated cultivars have a high level of resistance to the prevailing pathotype (pathotype 1(D1)) because there are many cultivars that are completely resistant to that pathotype.

Ware potatoes are also grown in the starch potato cultivation area. There are no acreage figures for ware potatoes available for the Prevention Areas, but these figures are available per province. For example, in Drenthe, the province with the most detections of pathotype 18(T1), the acreage for ware potatoes has increased from 1291 ha in 2006 to 4498 ha in 2018 and is now significantly higher than in 2000, the year in which the Prevention Areas were established. The acreage of starch potatoes has decreased in the same period (Figure 5.5). The average resistance rate of ware potato cultivars is probably lower than that of the starch potato cultivars in the starch potato cultivation area. This is because there are fewer ware potato cultivars available with targeted breeding to achieve a high resistance rate against the pathotypes occurring in the area. In view of the increase in acreage, the risk of wart disease could actually increase in the cultivation of ware potatoes.

Differences in the number of detections between various years can be partly explained by the size of the surveys. For example, after it was established in 2003 that two detections from 2001 concerned pathotype 18(T1), extensive surveys were carried out in 2003 and 2004 in connection with these detections (PD, 2006), which may explain the higher number of detections in those years compared to 2002.

Control measures

Resistance

Resistance plays an important role in the control of, and fight against, potato wart disease. Here, a distinction is made between partial and full resistance. There is discussion, especially at an international level, on whether the cultivation of partially resistant cultivars is a good strategy for controlling potato wart disease. Such a strategy may encourage the development of new, more virulent populations. For example, after propagation of a partially resistant potato cultivar, van de Vossenberg et al. (2018) obtained an isolate of pathotype 6(O1) from an isolate of the pathotype 1(D1). For this reason, a workshop on *Synchytrium endobioticum* held in 2019 advised against the use of partially resistant cultivars in infested areas (Van de Vossenberg et al., 2019b). However, the problem is that few or no ware potato cultivars with full resistance to the higher pathotypes are currently available. Until now, in the Prevention Areas, where only partially and fully resistant cultivars may be grown since 2000, there have been no indications of the emergence of new pathotypes. Although one new pathotype - 18(T1) - was found in Prevention Area A (Figure 5.2) after 2000, it is probable that this was introduced from an area outside Europe and that it probably did not develop from populations already present in Europe (van de Vossenberg et al., 2018).

Cultivation measures

It is possible that all infestations cannot be detected via surveys, which means that the fungus can spread undetected. Preventive cultivation measures to combat the spread and build-up of populations are important, since earlier-developed resistances can break down, and for certain pathotypes, there are no, or hardly any, resistant ware or other potato cultivars available at present. These preventive measures are as follows:

- cultivation of seed potatoes in areas free from *S. endobioticum*;
- cleaning of footwear, machines, etc. before entering the next plot;
- carrying as little soil as possible into and from infested areas and only using soil tare from areas where *S. endobioticum* occurs for non-agricultural purposes or returning it to the plot from which it originates.

A wider rotation may also help in controlling the disease. *S. endobioticum* populations can survive in the soil for many years, but the level of infestation may decrease significantly in the initial years if the soil is regularly tilled. Extending the rotation period by one year may also have an effect and contribute to the control of other soil diseases. A wider rotation can also help control other soil pathogens.

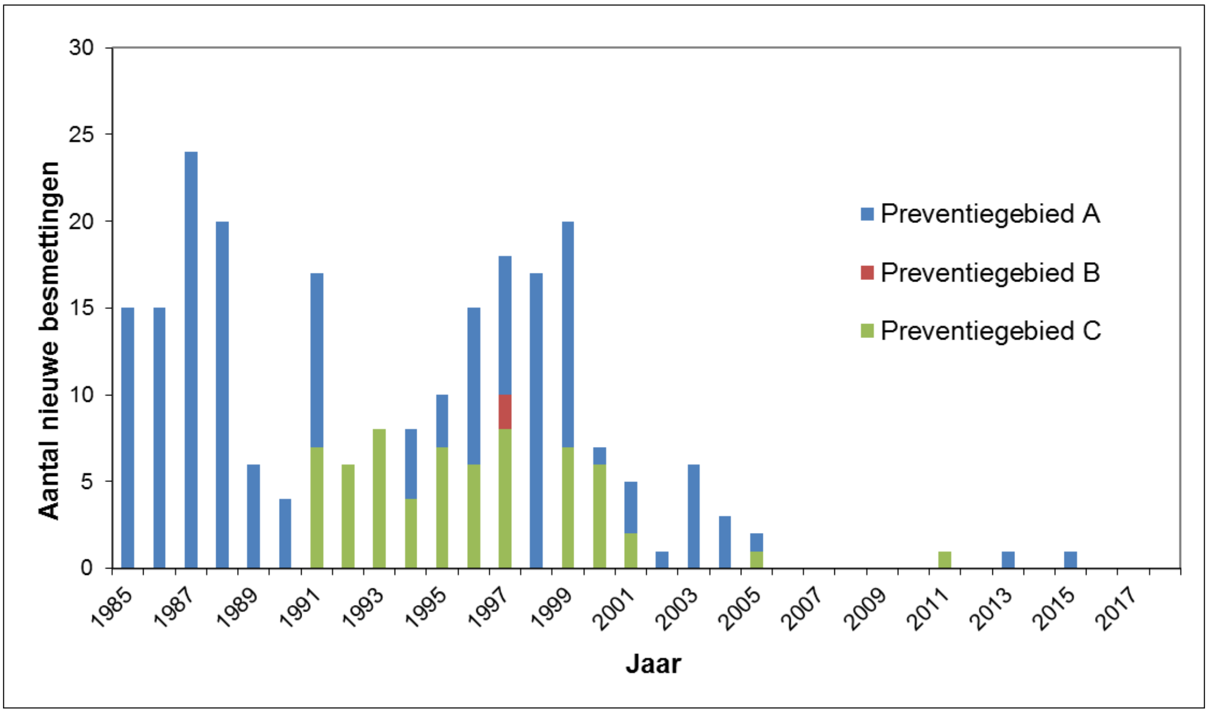
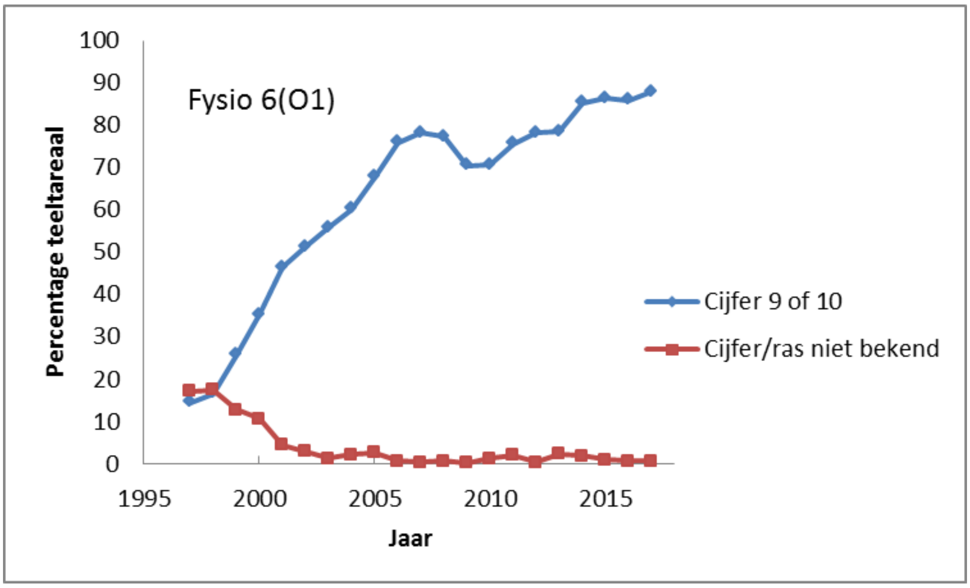


Figure 5.3 The number of new plots in the Netherlands where *Synchytrium endobioticum* was detected annually in the period 1985-2018 within the Prevention Areas (see Figure 5.2).



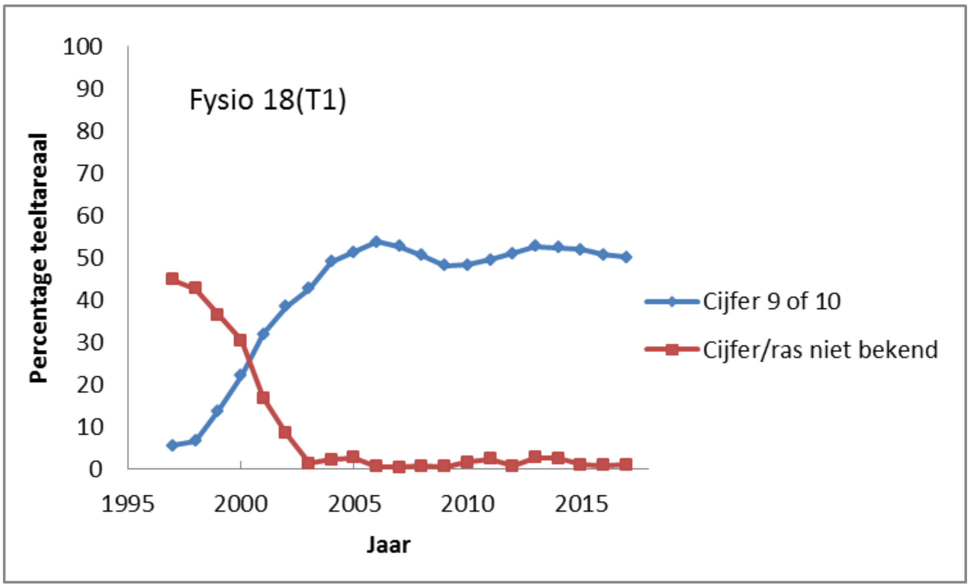


Figure 5.4 Percentage of acreage of starch potatoes with cultivars with a resistance rate of 9 or 10 against *Synchytrium endobioticum* pathotypes 6(O1) and 18(T1) in the period 1997-2017.

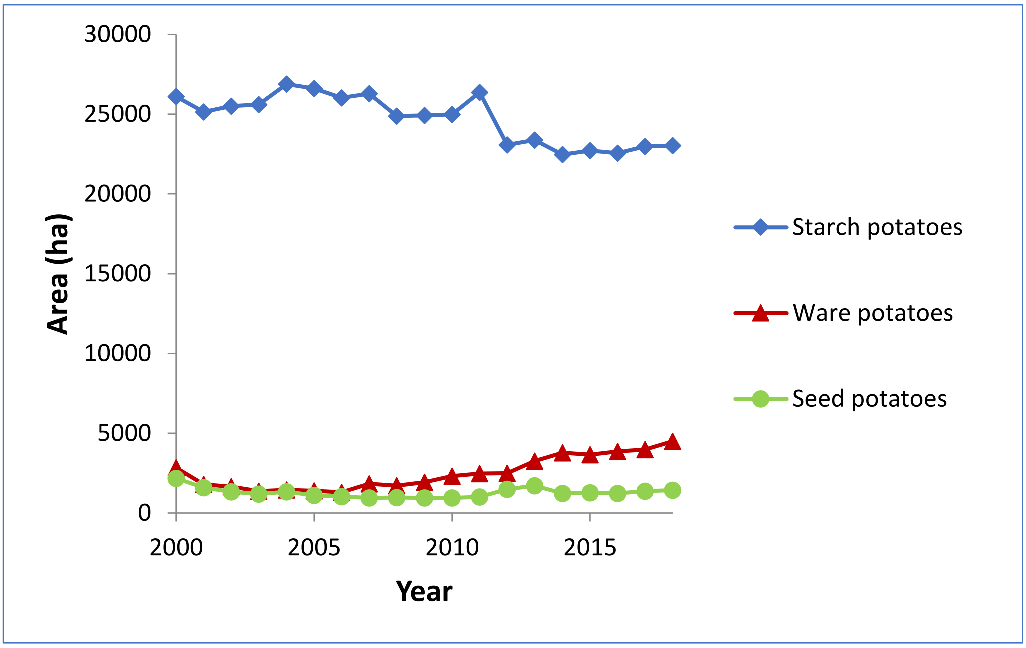


Figure 5.5 The potato acreage (cultivated area) in Drenthe in the period 2000-2018 (http://statline.cbs.nl/, 7 August 2019; 2018 figures are provisional).

Table 5.5. The number of new plots in the Netherlands where *Synchytrium endobioticum* was detected annually in the period 1985-2018 after testing of potatoes with symptoms per area and pathotype[1].

Year	NEN Pathotype 2	NEN Pathotype 2 and/or 6	NEN Pathotype 6	NEN Pathotype 18	NEN Pathotype 2/ Pathotype 18[3]	SEN[2] Pathotype 1	De Kempen Pathotype 1	Schaarsbergen Pathotype 2	Giethoorn Pathotype 6
1985	15	-	-	-	-	-	-	-	-
1986	15	-	-	-	-	-	-	-	-
1987	24	-	-	-	-	-	-	-	-
1988	20	-	-	-	-	-	-	-	-
1989	6	-	-	-	-	-	-	-	-
1990	4	-	-	-	-	-	-	-	-
1991	10	-	-	-	-	7	-	-	-
1992	-	-	-	-	-	6	-	-	-
1993	-	-	-	-	-	8	-	-	-
1994	4	-	-	-	-	4	-	-	-
1995	3	-	-	-	-	7	-	-	-
1996	9	-	-	-	-	6	-	-	-
1997	8	-	-	-	-	7	1	2	-
1998	1	-	16	-	-	-	-	-	-
1999	3	-	10	-	-	7	-	-	-
2000	-	-	1	-	-	6	-	-	-
2001	-	-	-	2	1	2	-	-	-
2002	-	-	-	-	-	-	-	-	1
2003	2	1	2	1	-	-	-	-	-
2004	-	-	-	3	-	-	-	-	-
2005	-	-	1	-	-	1	-	-	-
2006	-	-	-	-	-	-	-	-	-
2007	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	1	-	-
2012	-	-	-	-	-	-	-	-	-
2013	-	-	-	1	-	-	-	-	-
2014	-	-	-	-	-	-	-	-	-
2015	-	-	-	1	-	-	-	-	-
2016	-	-	-	-	-	-	-	-	-
2017	-	-	-	-	-	-	-	-	-
2018	-	-	-	-	-	-	-	-	-
2019	-	-	-	-	-	-	-	-	-

[1] All detections in NEN (northeast Netherlands), Giethoorn and the two detections in Schaarsbergen concerned starch potatoes. In addition, one infestation in 2003 was found in TBM seed potatoes in NEN. Detections in the rest of the Netherlands concerned ware potatoes.
[2] SEN: southeast Netherlands
[3] Mixed infestation: pathotypes 2(G1) and 18(T1) on the same plot

6. Food safety in the potato chain

6.1. Introduction

Food should be safe. This principle is also laid down by law[34]: "Food shall not be placed on the market if it is unsafe. Food shall be considered unsafe if it is deemed to be injurious to health or unfit for human consumption". The term 'unsafe' relates to a hazard, which is defined as "a biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect". The associated risk of a hazard is defined as a "function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard". Despite all the measures taken to ensure that our food is safe, there are agents (microbiological, chemical or physical) in our food that can be harmful to health. This makes people fall ill and therefore leads to a burden of disease.

The estimates of the disease burden of food-related pathogens in the Netherlands are annually published by the National Institute for Public Health and the Environment (*Rijksinstituut voor volksgezondheid en milieu, RIVM*) (Pijnacker et al., 2019). The RIVM estimates that, each year, there are almost 654,000 cases (average for 2013-2018) of disease caused by the consumption of food contaminated with pathogens. With around 20 billion servings consumed in the Netherlands per year, this amounts to around 1 in every 30,000 servings.

In most cases, the symptoms are mild. However, in roughly 1 out of 100 to 1 out of 1000 foodborne infections, there may be more prolonged symptoms (lasting a few weeks) or more serious effects. Based on estimates, long-term health effects occur in several hundreds of cases, including kidney failure, Guillain-Barré syndrome, inflammatory bowel disease or irritable bowel syndrome. Around 90 people die annually due to a primary or secondary infection resulting from the consumption of contaminated food. Mainly young children, the elderly, pregnant women (foetus) and those with impaired immune systems are at greater risk of developing the more serious conditions. The burden of disease caused by pathogenic microorganisms in our food is estimated at 4300 DALYs (a measure of the loss of healthy life years across the entire population) for 2018 (Pijnacker et al., 2019).

As opposed to the exposure to microbiological agents, exposure to chemical substances in food usually does not result in a directly demonstrable burden of disease (van Kreijl et al., 2004). This is because chemical substances generally affect health in the long term, whereas illnesses due to microorganisms arise within hours or days or at most a few weeks. In some cases, however, exposure to a chemical substance can have acute consequences, for example, due to poisoning by toxins - often originating from algae - in crustaceans and shellfish or contamination of plant products (for example, herb mixtures) with plant toxins.

Physical hazards in food are contaminants present in a product that can pose a threat to the health of the consumer when the product is used or consumed. These are foreign objects that can be unintentionally introduced into the food and cause choking, cuts and other physical injury. This includes pollutants, foreign objects such as stones, glass, animal or plant material (including wood), metal and plastics.

[34] Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

6.2. Data

6.2.1. Consumption data

The assessment of microbiological hazards is based on the relative consumption volume of potatoes within the produce category. The reason for this is that the RIVM's burden of disease estimates are based on different categories of food, rather than individual products. Potatoes fall under the produce category. The total consumption volume of produce per person (1 to 79 years) per day amounted to 337 grams, of which 21% are potatoes.

Consumption data are required for estimating the level of exposure to chemicals. The absolute consumption volume of potatoes by the Dutch population has been taken as the basis for the assessment of chemical hazards. The Food Consumption Surveys (*Voedsel Consumptie Peilingen, VCP*) of 2012-2016 provided the data for this assessment (RIVM, 2018a;2020a).

On average, potatoes are eaten three to four times a week in the Netherlands[35], which amounts to an average of 72 grams per day. Men consume more potatoes than women (resp. 83 g per day and 61 g per day) and adults (18 to 80 years) consume more than children (1 to 18 years) (resp. 76 g per day and 59 g per day) (RIVM, 2018a).

Average serving sizes are 154.9 g (ranging from 46.1 g (P5, small eaters) to 308 g (P95, large eaters)) for adults. For children up to the age of 18, the average serving sizes are 116.9 g (ranging from 26.5 g (P5, small eaters) to 258 g (P95, large eaters)) (RIVM, 2020a).

6.2.2. Databases

For the risk assessment of the microbiological, chemical and physical risks (Annexes 7, 8 and 9), data were collected from various (sometimes the same) databases.

NVWA database

Data on the occurrence of contaminants in food in the Netherlands are available in the NVWA database. This database contains the analytical results of samples (microbiological and chemical) obtained based on selective as well as random sampling.

Chemical database (KAP)

The Quality Programme for Agricultural Products (*Kwaliteitsprogramma Agrarische Producten, KAP*) database contains data on the occurrence of residues of plant protection products and contaminants in food and feed in the Netherlands, as measured by the government (NVWA and Wageningen Food Safety Research). This database, managed by the RIVM, provides data to EFSA. EFSA uses these data to prepare risk assessments.

EFSA databases

Data on the occurrence of pathogenic microorganisms in food in Europe are available from the annual zoonoses report prepared by EFSA and ECDC. This report contains data from monitoring and surveillance programmes in the field of microbiological food safety reported annually by EU Member States to EFSA.

Product recalls in Europe (RASFF)

Data on recalls of unsafe food on the international market of the EU are included in the database of the Rapid Alert System for Food and Feed (RASFF). The RASFF system is used by EU countries

[35] This includes potatoes, potato products and other root vegetables

(incl. the Commission, EFSA, Norway, Liechtenstein, Iceland and Switzerland) to exchange information quickly with each other about such situations. The database contains few or no reports of products that are only marketed within one Member State. Moreover, it is possible that this database over-represents product-parameter combinations for which specific standards have been established within the EU or which fall under national regulations. The data in the RASFF system are therefore only an indication of the microbiological, chemical and physical hazards that may be present in various food products in the EU and beyond. They do not give an overall picture of the occurrence on/in potatoes and potato products. Nor does these data provide a picture of the relative contribution of the various reported hazards.

In the RASFF system, all reports in the period 1990-2018 containing the words of 'potato', 'gnocchi', 'chips' or 'crisps' in the subject have been retrieved and analysed. This involves a total of 131 reports. Of these, 104 relate to potatoes and potato products.

Recalls in third countries

Data on recalls of unsafe food in the US market, available via the United States Food & Drug Administration website, (FDA, 2019b) have been used during the hazard identification step of this risk assessment.

7. Microbiological risks to food safety

7.1. Introduction

EFSA defines the biological hazards of food as animal diseases (zoonoses), TSEs (transmissible spongiform encephalopathies; prion diseases), pathogenic and food spoilage microorganisms and antimicrobial resistance that can be transmitted to humans via food. TSEs are transmitted via the consumption of risk materials (brains, spinal cord) of ruminants. There is no risk of the transmission of TSEs from food crops, such as potatoes. Spoilage microorganisms have not been taken into consideration in this risk assessment as they are not harmful to human health.

The term 'microorganisms' is defined by law[36]. Microorganisms include bacteria, viruses, yeasts, moulds, algae, parasitic protozoa and microscopic parasitic helminths and their toxins and metabolites. This concerns both zoonotic and non-zoonotic microorganisms. Fungal toxins (mycotoxins) are addressed under the chemical risk assessment.

Microorganisms occur everywhere and humans can come into contact with an enormous range of such organisms. They also occur in food, sometimes in high numbers; in fact, microorganisms are needed to produce certain types of food (bread, beer, dry sausage, sauerkraut). Most types of microorganisms are not harmful to human (or animal) health. However, there is a limited group of microorganisms capable of causing disease in humans. This latter group of pathogenic microorganisms is considered a biological hazard.

In this substantiation of the microbiological food safety risks, it is investigated which pathogenic microorganisms originating from the potato chain can end up in humans and pose a risk to public health in the Netherlands via the consumption of potatoes and potato products (section 7.3). In order to assess the microbiological risks to humans that could originate from the potato chain, the four standard steps of a risk assessment have been followed:

hazard identification, hazard characterisation, exposure assessment and risk characterisation.

Subsequently, based on the assessment of the individual hazards, an assessment of the risks has been formulated from a chain perspective, while also examining options for managing these risks (section 7.4).

7.2. Approach to the microbiological risk assessment

7.2.1. Hazard identification

Various sources have been consulted for the identification (and assessment) of the possible microbiological hazards that may occur in the potato chain. One of the main sources is the literature study entitled '*Microbiological hazards related to the consumption of potato products'* (*Microbiologische gevaren gerelateerd aan de consumptie van aardappelproducten*) carried out by Wageningen Food & Biobased Research (WFBR, 2018) as part of this risk assessment. In addition, the sources described below were also consulted.

7.2.2. Hazard characterisation

To assess the risk of a pathogen, knowledge about the pathogen itself is important. What are the health effects of the pathogen and when do you get sick from food that is contaminated with the pathogen? Is the growth of the pathogen in the product - possibly with toxin formation - necessary

[36] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs.

for this or not? And what are the processes or circumstances that influence this, either positively or negatively?

To answer these questions, information has been collected about the pathogen itself, such as the symptoms caused by it and how serious these symptoms are. The way in which pathogens can enter the potato chain has been examined and whether growth on or in the products is necessary to cause disease in humans. And if growth was found to be necessary, the circumstances under which this can take place were examined. This depends on the properties of the product, including water activity (Aw) and acidity (pH), as well as the characteristics of the microorganism. Water activity refers to the amount of available water in a product. Microorganisms need water for their growth.

An overview of product properties (Aw and pH) of potatoes and various types of potato products is provided in Table 7.3. An overview of the growth characteristics of a number of pathogenic bacteria is provided in Table 7.4.

The overview in Table 7.4 only contains those pathogens that have been found in the potato chain and that can be transmitted via food and/or cause a relevant burden of disease in the Netherlands. This table also indicates whether growth in the product is at all necessary to cause disease in humans. This depends on the minimum infectious dose (MID) of the microorganism. This is the minimum number of microorganisms necessary to cause food infection or food poisoning. Food infection is caused by ingestion of the microorganism itself while food poisoning is caused by ingestion of the toxin produced by the microorganism in the food. For the latter, growth within the product is always a necessary condition.

An overview of the legal standards applicable to potatoes and potato products for each pathogen has also been provided.

7.2.3. Exposure assessment

To get an idea of whether, where, how often and to what extent the pathogenic microorganisms occur in the potato chain, pathogen prevalence data on potatoes and potato products were collected, as well as data on relevant recalls of potatoes and potato products from the market. To determine whether this exposure leads to disease and which factors contribute to it, relevant data on outbreaks and cases of foodborne infections and food poisoning were sought. This was supplemented with relevant data from the burden of disease estimates of food-related pathogens in the Netherlands.

Prevalence data

The prevalence data collected includes data from the literature (worldwide), supplemented with data from the EU Member States reported to EFSA (Europe) as well as data from the NVWA (the Netherlands).

The data reported to EFSA is available from the annual zoonoses report of EFSA and ECDC. For this risk assessment, data from the period 2011-2018 were consulted (EFSA & ECDC, 2013;2014;2015a;2015b;2016;2017;2018;2019)[37]. The databases were searched for the words 'potato', 'gnocchi' and 'chips'. Based on this, it can be assumed that most, if not almost all, relevant data with regard to this risk assessment have been collected from the databases.

In the period 2011-2018, the NVWA did not conduct any microbiological research on potatoes and potato products.

[37] The references are cited in the text collectively as '(EFSA: 2011-2018)'.

An exhaustive overview of various research data on the presence and prevalence of pathogens in different products within the potato chain is presented in Table 7.5 and Table 7.6.

Recalls

Recall data from the EU and US have been collected and analysed.

Data on recalls of unsafe food on the international market of the EU are included in the database of the Rapid Alert System for Food and Feed (RASFF). In the RASFF system, all reports in the period 1990-2018 containing the words of 'potato', 'gnocchi', 'chips' or 'crisps' in the subject have been retrieved and analysed. This involves a total of 131 reports. Of these, 104 relate to potatoes and potato products. Seven of these reports were of a microbiological nature, four of which concerned the detection of pathogenic microorganisms (Table 7.7). Wherever the text of this microbiological risk assessment refers to 'RASFF notifications', this concerns notifications from the aforementioned period relating to microorganisms.

Recall data for unsafe food on the US market are available from the US FDA website (FDA, 2019b). In the US, 42 recalls were registered by the US FDA in the period 2010-2018 with regard to the detection of pathogens in potatoes and potato products or products containing potatoes. Of these, 19 were relevant or potentially relevant to this risk assessment (Table 7.8).

Disease cases and outbreaks

An overview of outbreaks and cases of foodborne infection and food poisoning caused by potatoes and potato products is presented in Table 7.10. This table contains an exhaustive overview of data from scientific literature (worldwide) and data overviews on foodborne outbreaks and cases in Europe and in the US.

The overview of European outbreaks caused by consumption of food contaminated with pathogenic microorganisms comes from the EFSA database for the period 2011-2017 (EFSA & ECDC, 2013;2014;2015a;2015b;2016;2017;2018)[38]. The data for 2018 are not specific enough to trace outbreaks caused by the prepared potato dishes category.

Of the outbreaks reported to EFSA, only the data on outbreaks supported by strong evidence[39] have been taken into consideration. Strong-evidence outbreaks are those in which the association between the pathogen, the food and the patient is established based on epidemiological and/or microbiological studies. Within the strong-evidence outbreaks reported by EFSA, searches were conducted based on the words 'potato', 'chips', 'crisps' and 'gnocchi'.

In the period 2011-2017, 41 potentially relevant outbreaks involving potatoes were mentioned. Based on the literature, it is known that there was an outbreak caused by mashed potatoes contaminated with *B. cereus* and *S. aureus* in Austria in 2013 (WFBR, 2018). Although this outbreak is recorded in the EFSA database, mashed potatoes was not specifically mentioned as a source; this outbreak has been added to the dataset. A total of 42 outbreaks caused or possibly caused by potatoes and potato products relevant to this risk assessment were registered with EFSA. For four of these, the potato product was specifically indicated as the source and hence only these four reports are included in Table 7.10.

Outbreaks that occur in the Netherlands are also reported to EFSA. Any outbreaks that have taken place in the Netherlands are specifically indicated in this risk assessment.

[38] The references are cited in the text collectively as '(EFSA, 2011-2017)'.

[39] All references in this text to 'EFSA outbreaks' pertain to 'strong-evidence foodborne outbreaks' from the period 2011-2017.

Data on outbreaks caused by consumption of food contaminated with pathogenic microorganisms in the US have been taken from the online NORS database of the Centers of Disease Control and Prevention (CDC) for the period 1998-2017 (CDC, 2018b) and the CDC's National Botulism Surveillance reports for the period 2001-2017 (CDC, 2018a).

The NORS database was searched for outbreaks where 'potato' was mentioned as a possible source. In the period 1998-2017, 331 outbreaks met this criterion. This mainly concerns (85%, n=282) outbreaks in which potato is part of a suspect meal (several components, e.g. potatoes, vegetables and meat) or part of a suspect dish (potato salads, wraps). In the other cases (15%, n=49), only a potato dish was considered suspect (e.g. mashed potatoes) or it was specifically indicated that potato as an ingredient was the source of the outbreak. Of these 49 outbreaks, the pathogen was actually found (confirmed) in 16 (33%) cases. One of these was chemical/toxic in origin, hence this has not been taken into consideration. Only the 15 confirmed outbreaks caused by pathogenic microorganisms are included in Table 7.10**.**

In addition to the database on outbreaks in general, the CDC also has information on botulism cases and outbreaks (CDC, 2018a). This information has been examined (2001-2017) and additional data is also included in Table 7.10**.**

This overview of outbreaks only gives an indication of which pathogens may be present in the potato chain within the EU and elsewhere and may pose a risk, but does not constitute an absolute or relative measure.

In part, these outbreaks will have been caused by post-process contamination in the last phase of the chain: preparation by the food handler (mass caterer, consumer). Although this stage falls outside the scope of this risk assessment, insight into the food safety risk caused by potatoes is also based on data regarding cases of disease. Information on where the contamination originated, i.e. before or after purchase by a food handler, and how the contamination has led to disease is essential to determine where and how control measures can be taken within the chain.

To better assess the risk arising from potatoes, a broader view was taken than just focusing on cases of disease caused by the fresh potatoes, prepared or otherwise. Products made from potatoes (incl. chips) or products in which potato is used as the main ingredient (incl. mashed potatoes) are also included in the assessment of the risk of the potato chain. Composite products (incl. potato salads) have not been taken into account because the variety of the ingredients in such products do not allow to determine which specific ingredient has caused the cases of illness.

Burden of disease estimates

Not all cases and outbreaks of disease caused by pathogenic microorganisms, whether or not through the consumption of contaminated food, are recorded by the appropriate authorities and even far less are described in the literature. The recorded cases of disease and death are only the tip of the iceberg of the total number of people who become infected and then possibly become ill or die as a result of the infection. The RIVM has developed a model to estimate the total incidence of disease and deaths in the Netherlands caused by pathogenic microorganisms that are also transmitted via food and the associated burden of disease and costs. This model is based on the recorded cases of disease and deaths. The RIVM publishes an annual update of these estimates. The total estimated burden of disease (and costs) is subsequently attributed, based on expert estimates, to various routes of contamination: food, environment, humans, animals and travel. Within the foodborne route, a further distinction is made between the categories beef & lamb, pork, chicken, eggs, dairy, fish & shellfish, produce, drinks, grains, other foods and human & animals (Pijnacker et al., 2019).

Therefore, no burden of disease estimates are available specifically for potatoes. For those pathogens that are relevant to the potato chain, an estimate will be made, based on consumption data, of the relative share of potatoes in the burden of disease attributed to the produce category (WFBR, 2018).

7.2.4. Risk characterisation

To characterise the risk of each pathogen, it was examined whether this pathogen is likely to occur in the potato chain in the Netherlands, whether it contributes to foodborne disease cases in the Netherlands and whether potatoes play a role in this. The pathogens selected in this manner are the real microbiological hazards for the Dutch potato chain. For these real hazards, the share of potatoes in the earlier-mentioned burden of disease estimates has been examined, based on consumption data.

7.2.5. Explanation of the risk assessment

This risk assessment is based on the four above-mentioned steps, but the hazard characterisation and exposure assessment steps have been combined. At present, the substantiation of the risk of each identified potential hazard follows the route taken by the pathogenic microorganism (the hazard) through the potato chain to reach humans: how does the pathogen get into the chain, does it actually occur in the chain, can the risk increase (can growth take place), is the risk reduced and do people actually fall ill due to this pathogen after consumption of potatoes and potato products. Based on this information, the risk characterisation is formulated.

The risk assessment was carried out in a semi-quantitative manner, using as much quantitative data as possible.

Firstly, the risk assessment for each potential hazard is described (section 7.3). Subsequently, this is done at chain level, where the measures that can be taken to control the possible public health risk arising from pathogenic microorganisms from the potato chain are also discussed (section 7.4).

7.3. Risk assessment of microbiological hazards

In order to assess the risk of microbiological hazards in the potato chain, the four steps of a risk assessment (hazard identification, hazard characterisation, exposure assessment and risk characterisation) were carried out as described earlier. The last step - risk characterisation - describes BuRO's assessment of the risk of each hazard for food safety in relation to the consumption of potatoes and potato products available on the Dutch market. The results of this are presented below for each of the potential hazards.

7.3.1. Hazard identification

An overview of the pathogenic microorganisms, identified using the sources mentioned above, that have been detected in potatoes and potato products or that have been associated with cases of disease caused by the consumption of potatoes and potato products is provided in Table 7.1. The data presented are not limited to the Netherlands but are mainly data from Europe and other parts of the world.
NB To provide a clear overview, the results of the risk assessment is shown in the column headed 'Relevant'. The risk assessment is described in section 7.3.

Table 7.1 Overview of pathogenic microorganisms isolated from or associated with cases of disease caused by potatoes and potato products

Parameter	Occurs in stage[1,2]			Disease[3]	Relevant[4]	Refs[5]
	1	2	3			
Bacteria						
Bacillus spp.	X	X	X			
Bacillus cereus (*sensu lato*)[6]	X		X	**Yes**	Yes	*, $
Bacillus licheniformis				No	No	*
Campylobacter spp.	X		X	Yes	No	$, a
Clostridium spp.						
Clostridium botulinum Type A, E	X	X	X	**Yes**	Yes	*
Clostridium butyricum			X	No[7]	No	*
Clostridium perfringens			X	**Yes**	No	*, $
Pathogenic *Escherichia coli* (STEC)			X	**Yes**	No	*, $
Listeria monocytogenes	X		X	**Yes**	Yes	*, $
Salmonella spp.	X	X	X	**Yes**	No	*, $
Staphylococcus aureus	X		X	**Yes**	No	*, $
Other bacteria						
Corynebacterium spp.		X		No	No	b
Cronobacter spp.		X	X	No	No	*
Enterobacter (cloacae/spp.)		X	X	No	No	b, c
Hafnia alvei		X	X	No	No	*
Klebsiella oxytoca			X	No	No	*
Pantoea spp.		X		No	No	b
Pseudomonas spp.[8]		X	X	No	No	*
Vibrio spp.			X	No	No	*, b
Viruses						
Norovirus			X	**Yes**	No	$
Rotavirus				**No**	No	$
Hepatitis A virus				**No**	No	$
Hepatitis E virus				**No**	No	$
Parasites						
Ascaris	(X)			No	No	*
Cryptosporidium spp.				**No**	No	$
Giardia spp.	(X)			**No**	No	$
Taenia saginata	X			No	No	*
Toxoplasma gondii				**No**	No	$

[1] Chain stage 1: Cultivation, 2: Handling and processing industry, 3: Sales, food preparation (caterer, consumer)
[2] X: effectively isolated, (X): not described, only in field experiment
[3] Disease: proven cases and/or outbreaks of disease; in bold: burden of disease attributed to produce
[4] Relevant: assessment of whether the hazard is relevant from the point of view of the potato chain
[5] Refs: literature references: *: Doan & Davidson, 2000; Wageningen Food and Biobased Research (WFBR), 2018, $: burden of disease estimates RIVM Pijnacker et al., 2019, a: Park & Sanders, 1992, b: Manani et al., 2006, c: Nyenje et al., 2012
[6] *B. cereus* group, *B. cytotoxicus* also occurs in potatoes and potato products
[7] *C. butyricum* can exceptionally produce botulinum toxin E.
[8] Nosocomial transmission

7.3.2. Bacillus spp.

The genus *Bacillus* belongs to the family *Bacillaceae*. Among the *Bacillus* species that may be pathogenic in humans, *B. cereus* is most well-known. This pathogen causes a relevant burden of disease, also in the Netherlands. *B. cereus* belongs to the *B. cereus* group, which is a group of related bacilli. This group is also called *B. cereus sensu lato*[40]. It includes the species *B. cereus* (*sensu stricto*), *B. anthracis*, *B. thuringiensis*, *B. mycoides*, *B. pseudomycoides*, *B. weihenstephanensis*, *B. cytotoxicus* and *B. toyonensis* (EFSA BIOHAZ Panel, 2016; WFBR, 2018).

The pathogenic potential of the species varies enormously. *B. anthracis* is very virulent, while *B. mycoides*, *B. pseudomycoides* and *B. weihenstephanensis* have never been associated with foodborne disease cases (EFSA BIOHAZ Panel, 2016).

B. thuringiensis is used as an insecticide in agriculture but not in potato cultivation (Ctgb, 2020f). In the risk assessment of the food crops chain, the possible risk of *B. thuringiensis* will be examined more closely.

B. cereus is a Gram-positive, facultative anaerobic spore-forming microorganism. For other relevant properties, see Table 7.4.

However, there are also other Bacilli that can cause disease in humans. One species that is associated with potato is *Bacillus licheniformis*. This bacterium is mainly pathogenic to people with a weakened immune system, but it has also been associated with cancer and catheterised patients (Blue et al., 1995; Park et al., 2006; Haydushka et al., 2012). In addition to food poisoning, this pathogen also causes disorders such as bacteraemia, peritonitis and eye infections (Blue et al., 1995; Haydushka et al., 2012). However, descriptions of cases remain sporadic (Blue et al., 1995; Park et al., 2006), especially when it comes to food poisoning. Therefore, despite its pathogenic potential, *B. licheniformis* is not considered a risk to public health with regard to the potato chain, based on the extent (likelihood of illness) to which this bacterium can cause a foodborne burden of disease.

B. cereus can cause disease in humans in two ways: either via the production of emetic toxin (cereulide) in food (food poisoning or intoxication) or through the production of enterotoxins in the intestines (after ingestion of cells or spores) leading to diarrhoea (toxicoinfection) (FDA, 2012). The likelihood of disease arises in case of high numbers of *B. cereus* in food (>10^5 cfu[41]/g) (Table 7.4). The likelihood of death due to *B. cereus* is assessed as very low (<1:1,000) (van Kreijl et al., 2004).

B. cytotoxicus is a thermotolerant *Bacillus* species. There are *B. cytotoxicus* isolates that are known to be highly virulent (Heini et al., 2018). The extent to which *B. cytotoxicus* contributes to the burden of disease caused by the *B. cereus* group is unknown. It is also unknown whether the likelihood of death differs from that on account of *B. cereus (sensu stricto)*.

Legislation

No specific food safety criteria have been laid down in EU legislation[36] for *B. cereus* in potatoes and potato products. However, there is national legislation applicable[42] to this pathogen for “food and beverages, except for food and beverages that have not undergone any germicidal treatment and that, in case of normal use, are only suitable for human consumption after heating by the end user”.

[40] In the text, the name ‘*B. cereus*’ is used to refer to *B. cereus sensu lato* as well as *B. cereus sensu stricto*. This is mainly because the analytical determination does not go further than an indication of ‘presumed *B. cereus*’, i.e. *B. cereus sensu lato* (ISO 7932:2004). If additional information is available about the *Bacillus* species, it will be specifically mentioned.

[41] Cfu= colony-forming unit.

[42] WBBL: Preparation and Processing of Foodstuffs (Commodities Act) Decree (*Warenwetbesluit Bereiding en behandeling van levensmiddelen*)

Routes of contamination

Bacillus spp. are spore-forming bacteria. A bacterial spore is a survival mechanism intended to help the bacterium survive for a long time under conditions that are unfavourable for the bacterium itself (vegetative form). Bacilli are commonly found in the environment, such as in soil (FDA, 2012). There are almost no agricultural crops that do not contain *B. cereus*. Therefore, vegetables and fruits grown in soil or which come into contact with the soil in any other way, can become contaminated via the soil (WFBR, 2018).

B. cereus is known to occur in the rhizomicrobiome (the microbial community established on and around the roots of a plant) of plants. Moreover, *B. cereus* has been shown to occur internally (endophyte) in plants and root vegetables, such as potatoes (Hoornstra et al., 2013; WFBR, 2018). Hoornstra et al. (2013) also showed that these endophyte strains are capable of producing cereulide (emetic toxin) (WFBR, 2018).

B. cereus is also capable of forming biofilms on surfaces in the production environment (NVWA BuRO, 2017; WFBR, 2018). In this way, products may be exposed to post-process contamination. This has also been described for industrially prepared mashed potatoes (WFBR, 2018).

Detection in the chain

Several publications have been published that have studied the presence of bacilli in potatoes and potato products (Table 7.5). This mainly concerns *B. cereus* and *B. cytotoxicus*.

The literature search conducted by WFBR reveals eight references with data on the prevalence of *B. cereus* in potatoes and potato products (Table 7.5). In addition, four other references are included in the table. This involves a total of 341 samples, of which 155 (45%) tested positive for this bacterium. Various products were examined (incl. fresh potatoes, various types of mashed potatoes and dehydrated products). The observed prevalences range from 10% to 100%. Limited attention has been paid to the level of contamination, which varies between 10-10^3 cfu/g product.

The studies show that *B. cereus* is present in all stages of the chain on fresh potatoes and in various products.

The literature search conducted by WFBR reveals one reference with data on the prevalence of *B. cytotoxicus* in potatoes and potato products (Table 7.5). Another additional reference is included in the table. This involves a total of 170 samples, of which 61 (36%) tested positive for this bacterium. Various products were examined (incl. fresh potatoes, various types of mashed potatoes, pre-cooked/fried products, dehydrated products and crisps). The observed prevalences range from 0% to 100%. Dehydrated items or products made from them were found to be positive relatively often (>50%) (Contzen et al., 2014; WFBR, 2018). The study conducted by Heini et al. (2018) also demonstrates presence of *B. cytotoxicus* (around 40%) in mashed potatoes made from dehydrated products (no clear prevalence data). However, the studies show that *B. cytotoxicus* is present in every stage of the chain and in many types of products.

For the period 2011-2018, the EFSA database does not contain any records of samples from the potato chain that had been tested for the presence of *B. cereus* (Table 7.5).

In the period 1990-2018, the RASFF system received two notifications of potatoes and potato products contaminated with excessively high numbers of *B. cereus* (>10^5 cfu/g) (Table 7.7). Both the reports related to gnocchi, which are pre-cooked potato dumplings. It is not known how the product became contaminated; it may have been via one of the ingredients (potato flakes, potato starch and/or potato flour or wheat flour) or through post-process contamination. The contamination level of the products ranged from 10^4-10^6 cfu/g.

In the US, there were no recall notifications in the period 2010-2018 for the occurrence of *B. cereus* in potato products (Table 7.8).

Growth

B. cereus will only lead to a foodborne burden of disease if it was able to grow in the food. This applies to both the syndromes caused by *B. cereus,* i.e. vomiting and diarrhoea. The emetic syndrome (vomiting) is caused by the *B. cereus* emetic toxin (cereulide) that is produced in food. This toxin is only produced when outgrowth to a higher number of cells (approx. 10^6 cfu/g) has occurred in the product. The diarrhoea syndrome is caused by the ingestion of high numbers (approx. 10^5 cfu/g) of vegetative cells or spores of *B. cereus*, which after surviving gastric transit, produce diarrhoea-causing enterotoxins in the intestines (King et al., 2007; FDA, 2012).

Bacterial spores will germinate when conditions are right. For *B. cereus,* this is assumed to take place when the spores come in contact with organic material or an animal (including human) host. *B. cereus* can also germinate, grow and form spores in soil (Stenfors Arnesen et al., 2008; Ceuppens et al., 2013). Spore germination can be triggered by external influences, such as the application of heat. Cooking or otherwise heating food therefore encourages bacterial spores to germinate, while vegetative bacteria are killed. This is beneficial for the newly germinated spores because there is no inhibitory effect of, or competition for nutrients with, other microorganisms. Whether germinated spores are able to grow depends on the storage time and temperature (too long at a too high temperature) and whether or not any growth-inhibiting substances (preservatives) are present (King et al., 2007). For example, research on the effect of different preservatives on the growth of *B. cereus* in chilled gnocchi (industrially prepared, vacuum packed, shelf life of 50 days) shows that, at 8°C, growth can be prevented by using various acids, but at a slightly higher temperature (12°C), the type of acid used has an influence on whether or not growth occurs during the shelf life (Del Torre et al., 2001; WFBR, 2018).

B. cereus can grow in different types of food but strains that produce the emetic toxin mainly grow in starchy products (King et al., 2007). The general growth characteristics of *B. cereus* can be found in Table 7.4.

There are descriptions of several studies on the growth of *B. cereus* in potato products. An exhaustive overview of this is provided in Table 7.9. Growth in potato products can take place from 5°C but only after a longer storage time (>4 weeks). At 7-8°C, an approx. 2.5 log increase occurs after 9-12 days of storage. To limit the growth of *B. cereus* in food, EFSA recommends storage at ≤7°C (preferably even ≤4°C) (EFSA BIOHAZ Panel, 2016).

B. cereus can quickly grow to large numbers if the storage temperature is not adequate. For example, at temperatures between 10-60°C, up to 4-5 log cfu/g can be formed within a few hours. These numbers can cause disease (WFBR, 2018).

According to a hazard analysis performed by Van Gerwen et al (WFBR, 2018) for vacuum-packed, cooked or pre-fried potatoes, *B. cereus* is one of the relevant hazards because this pathogen is present in the raw material (fresh potatoes), survives the cooking process and can grow in the final packaging (chilled fresh product).

No studies were found for growth and/or toxin formation in uncooked, fresh potatoes and potato products. It is assumed that this is possible since *B. cereus* can also grow and sporulate in the soil.

Reduction/decontamination

Vegetative cells of *B. cereus* are heat-sensitive. However, spores of *B. cereus* can survive both the pasteurisation process and the normal cooking process for potatoes. Subsequently, the spores can germinate and grow in food.

Emetic toxin may be formed during growth in the food. This only happens if sufficiently high numbers (approx. 10^6 cfu/g) of cells have formed in the product. This toxin is heat stable and it cannot be inactivated once it has formed in food (FDA, 2012).

Strains causing the diarrheal syndrome must also grow in the food to sufficiently survive gastric transit. The toxin produced by these strains is heat-labile (<56°C), but pre-formed toxins in the food play a less important role in the development of disease (King et al., 2007). Therefore, heating food can have an effect on preventing this syndrome since vegetative cells are sensitive to heat.

Not many studies have been found in the literature on the reduction of *B. cereus* during the various processes in the chain (WFBR, 2018). Pre-fried chips on which *B. cereus* spores had grown and which were then fried completely (2 to 3.5 min at 185°C) showed a decrease of *B. cereus* of approx. 4-5 log cfu/g (Doan & Davidson, 1999).

Cases and burden of disease

Outbreaks & cases of disease

Several outbreaks have been described (literature) or reported (EFSA, US) that were caused by *B. cereus* and where a potato product was the source of the outbreak (Table 7.10).

This usually concerns mashed potatoes (made from either dehydrated products or fresh potatoes), but in some cases cooked potatoes are also involved. While the source of contamination is the potato product, incorrect storage (too long at a too high temperature) of the prepared end product by the food handler is the cause of the outbreaks.

In France, outbreak strains from several outbreaks caused by *B. cereus sensu lato* (*B. cereus* group) in the period 2007-2014 were typed based on virulence genes. From this it can be concluded that some of the outbreaks were caused by *B. cytotoxicus*. This implies that *B. cytotoxicus* contributed to the outbreaks (and therefore the disease cases) caused by the *B. cereus* group (Glasset et al., 2016).

The EFSA database (2011-2017) contains one record of a *B. cereus* outbreak that could be linked to the potato chain. This involved cooked potatoes that were not properly stored at a cooling temperature and were then used in a salad.

EFSA has issued an opinion on the risk of pathogens in food of non-animal origin in the EU (EFSA BIOHAZ Panel, 2013). This included an analysis based on outbreaks recorded by EFSA in the period 2007-2011. Based on this analysis, a strong association was found between *B. cereus* and mashed potatoes.

The database of foodborne outbreaks in the US (1998-2017) lists 21 outbreaks (confirmed, suspected) caused by, among others, *B. cereus*, where potato is mentioned as one of the ingredients used. Two of the cases concern confirmed outbreaks where potatoes are identified as the source.

Burden of disease estimates

In the Netherlands, cases of food poisoning or infection caused by *B. cereus* are not recorded; notification is mandatory only in the event of an outbreak, which is then recorded (see 7.5.1). Human incidence data of cases caused by *B. cereus* in the Netherlands are based on estimates. In 2018, the number of people with a *B. cereus* intoxication or toxicoinfection was estimated as

53,000[43] (with 0 deaths). Based on this incidence data, the estimated burden of disease is 32 DALYs and the cost to society is €11 million for that year.

Source attribution based on expert opinions estimate that 91% (29 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 29 DALYs caused by *B. cereus,* the share of produce is 2% (rounded off) (0.6 DALY, 950 cases). Of the total burden of disease of 32 DALYs caused by *B. cereus*, 2% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 0.2% is attributed to *B. cereus* (Figure 7.3), and for the total number of cases, this is 2% (Pijnacker et al., 2019).

Risk characterisation

B. cereus is found in potatoes and various potato products (incl. chilled and dehydrated powder). The potatoes get contaminated from the environment (via the soil). This pathogen has been found in the processing environment and hence cooked products are subjected to post-process contamination. As a spore-former, *B. cereus* survives the cooking process of potatoes. *B. cereus* can grow on pre-cooked or cooked potatoes and potato products at temperatures starting from 7°C. In case of non-refrigerated storage, growth will occur within a few hours. This pathogen causes proven cases of disease as a result of the consumption of potatoes and potato products, where the contamination (the hazard) originates from the potato chain but the risk arises due to improper storage - almost always by the food handlers – that allows *B. cereus* to grow to concentrations high enough to cause symptoms. In fact, this pathogen can also cause problems in industrially prepared, chilled products. Such problems can also occur in dehydrated products (instant mash powder), if the prepared product is not stored properly.

B. cereus is considered a relevant hazard for prepared/pre-cooked or cooked potatoes and potato products. The risk is assessed as low based on likelihood (reasonable) and consequence (minor). The risk can be controlled through appropriate (refrigerated) storage (for chilled products, at temperatures <7°C) or immediate consumption of the prepared product.

7.3.3. Campylobacter spp.

The genus *Campylobacter* belongs to the family *Campylobactericeae*. There are several *Campylobacter* species, of which *C. jejuni* is mainly responsible for causing disease in humans, followed by *C. coli,* and to a lesser extent, other species such as *Campylobacter* spp. *C. lari*, *C. upsaliensis* and *C. fetus* (RIVM, 2006b; FDA, 2012).

Campylobacter spp. are Gram-negative, non-spore-forming bacteria. For other relevant properties, see Table 7.4.

Campylobacter infection is also known as campylobacteriosis. *Campylobacter* infections can cause gastroenteritis. However, a large proportion of infections occur without symptoms. Post-infection complications associated with campylobacteriosis include reactive arthritis, Guillain-Barré syndrome (GBS), inflammatory bowel disease (IBD) and irritable bowel syndrome (IBS). These conditions are chronic (RIVM, 2006b).

The infectious dose is low, which means that symptoms can occur even if less than 1,000 cells are ingested (RIVM, 2006b). For example, the ID_{50} - the dose at which 50% of exposed people become infected - in milk is estimated to be 37 cells (Rose et al., 2014). With effective treatment, mortality rates are moderate (1:100-1:1,000) (van Kreijl et al., 2004).

[43] Although this figure suggests a high level of precision, it is an estimate of the order of magnitude in which incidence occurs.

Legislation

No specific food safety criteria have been laid down in EU legislation[36] for *Campylobacter* spp. in potato products. However, there is national legislation applicable[42] to this pathogen for "food and beverages, except for food and beverages that have not undergone any germicidal treatment and that, in case of normal use, are only suitable for human consumption after heating by the end user".

Routes of contamination

Campylobacter is part of the normal gut flora of many warm-blooded animal species, such as chickens, wild birds and pets (dogs, cats) and therefore is present in their faeces. Via these animal faeces, *Campylobacter* is introduced into the environment, for example, the soil and water (Kuhn et al., 2018). As a result, food crops grown in the open field may become contaminated with *Campylobacter* spp. via these environmental sources or via manure (WFBR, 2018).

Using water of inferior quality for irrigation can also be a possible pathway of introduction. Examples of such inferior-quality water include treated or untreated waste water or run-off water. In countries where water is scarce (around the Mediterranean Sea, Israel, Australia), such water is commonly used for irrigation. Forslund et al. (2011) investigated the transmission of human pathogens (*C. jejuni*, STEC, *Salmonella* and a bacteriophage as virus indicator) to potatoes when using pathogen-contaminated water in combination with an underground irrigation system. Underground water systems are efficient in terms of water consumption and therefore a solution in areas with water scarcity. However, with such an irrigation system, bacteria are no longer exposed to the negative effects of UV radiation or dehydration, which could increase their chances of survival. The study shows that potatoes irrigated weekly (until the day before harvest) for one month before harvest were contaminated with the pathogens being studied. Prior to performing the analysis, the potatoes were stored at 5°C for three more weeks. This may have led to the decline of the *C. jejuni* species. *Campylobacter* happens to be very sensitive to moisture loss and does not have a high rate of survival on dry surfaces (Forsythe, 2000; FSANZ, 2019). However, the water had a relatively high level of contamination compared to sewage water (3 log higher), which means that this study assumes a worst-case scenario.

It is known that people can contract campylobacteriosis through contact with soil or water. Various campylobacteriosis outbreaks have been described with environmental sources as the cause, such as contact with mud or muddy water during outdoor activities (Stuart et al., 2010; Zeigler et al., 2014) and other contaminated water (untreated drinking water/water from a well, swimming in open water) (Ravel et al., 2016; Kuhn et al., 2018). In Denmark, there are descriptions of campylobacteriosis outbreaks caused by drinking water or other water supplies where, in all cases, the cause could be traced back to the flooding of the sewage system after heavy rainfall, as a result of which this drinking water or other water supply became contaminated (Kuhn et al., 2018).

Based on these data, it is not unlikely that potatoes may become contaminated with *Campylobacter* spp. from the soil during the cultivation stage.

Detection in the chain

The WFBR report does not include any information about studies on the occurrence of *Campylobacter* spp. in potatoes and potato products. However, the report includes two literature references concerning the publication of such studies (Table 7.6). The studies cited in these references involved approximately 240 samples (fresh potatoes). This pathogen was found in two (0.8%) of the samples.

These samples, in which *Campylobacter* spp. were found, consisted of fresh potatoes from a farmers' market (Park & Sanders, 1992). In the study conducted by Park & Sanders (1992), other vegetables were also tested, both from the farmers' market and the supermarket. *Campylobacter* spp. were demonstrated (1.7%) only in the samples from the farmers' market. Given the small number of samples, no statement can be made about the difference between the supermarket and farmers' market.

In a meta-analysis performed by Mohammadpour et al. (2018), *Campylobacter* spp. prevalence in root/tuber vegetables was 0.3% (9 of 961 samples were positive).

For the period 2011-2018, the EFSA database contains records of a total of four samples from the potato chain that had been tested for the presence of *Campylobacter* spp. Sampling was selective or based on suspected contamination. This involved samples of crisps. *Campylobacter* spp. were not detected in any of the products (these data are not included in Table 7.6).

In the period 1990-2018, the RASFF system received two notifications of potatoes and potato products contaminated with *Campylobacter* spp. (Table 7.7). Also in the US, in the period 2010-2018, there were no recall notifications for the occurrence of this pathogen in potatoes and potato products (Table 7.8).

Growth

Campylobacter is microaerophilic and does not grow at temperatures below 30°C (Table 7.4). Therefore, no growth will normally take place in potatoes and potato products because they are stored at a lower temperature. However, given the low infectious dose, growth is not necessary to cause a burden of disease (Forsythe, 2000). No studies are known that have examined the growth possibilities of *Campylobacter* in potatoes and potato products.

Reduction/decontamination

Campylobacter spp. are very sensitive to environmental conditions, such as temperature and the availability of water and oxygen. *Campylobacter* is sensitive to dehydration (Forsythe, 2000) and has a limited capacity to survive environmental stress (FSANZ, 2019). It can be assumed that the number of *Campylobacter* spp. present on fresh potatoes will decrease during the storage time.

Park & Sanders (1992) studied the effect of washing on the presence of *Campylobacter* spp. in potatoes. *Campylobacter* was found on unwashed potatoes (1.3%) but not on washed potatoes (washed with chlorinated drinking water). However, due to the limited amount of samples, positive or otherwise, it is not possible to say whether washing is effective in reducing *Campylobacter* on potatoes.

Campylobacter does not survive pasteurisation, and therefore does not survive the cooking process (Forsythe, 2000). Hence, the presence of this pathogen on pre-cooked or cooked potatoes and in potato products will therefore arise due to contamination after this step in the preparation.

Cases and burden of disease

Outbreaks & cases of disease

No campylobacteriosis outbreaks and cases of disease caused by potatoes and potato products are described or recorded in the literature or in the EFSA database (Table 7.10). Although it should be noted that outbreaks of campylobacteriosis often go unobserved, with the exception of those caused by raw milk and chicken meat. Campylobacteriosis cases often seem to exist in isolation (EFSA & ECDC, 2019). Tracing of sources for these types of 'single cases' (one patient) is almost impossible, which means that the source of these single cases will rarely or never be traced and/or found. Especially when it concerns a very commonly consumed product like potatoes.

The US database of foodborne outbreaks (1998-2017) lists a number (11) of campylobacteriosis outbreaks where potatoes and potato products are mentioned as the source. These are outbreaks in which either potato salad is mentioned as a source or in which potatoes/mashed potatoes were part of the meal (with meat and/or gravy). There is rarely any information provided about the cause of the product contamination in these outbreaks. Additional searches in the literature and other Internet sources for additional information about these outbreaks have yielded no results. It is assumed that the potato itself was not the source in any of these outbreaks because *Campylobacter* does not survive the potato preparation process. These outbreaks are therefore not included in Table 7.10.

Burden of disease estimates

Campylobacteriosis is not a notifiable disease in the Netherlands, unless there is an outbreak with food as a suspected source of contamination (see 7.5.1). Laboratory-based surveillance is nevertheless carried out by the RIVM. The observed incidence of campylobacteriosis in the Netherlands amounted to 35 patients per 100,000 inhabitants in 2018. The total estimated incidence of this pathogen in that year is estimated at 71,000 cases (with 47 deaths). Based on this incidence data, the estimated burden of disease is 3,200 DALYs and the cost to society is € 60 million for that year.

Source attribution based on expert opinions estimate that 41% (1,300 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 1,300 DALYs caused by *Campylobacter,* the share of produce is 5% (rounded off) (71 DALYs, 1,600 cases). Of the total burden of disease of 3,200 DALYs caused by *Campylobacter*, 2% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 25% is attributed to *Campylobacter* (Figure 7.3), and for the total number of cases, this is 4% (Pijnacker et al., 2019).

Risk characterisation

Campylobacter spp. can occur on fresh potatoes, where the contamination is contracted via manure or via soil, irrigation water or other water supplies that are contaminated with manure. It is assumed that *Campylobacter* spp. are unable to survive on fresh potatoes (due to dehydration). This pathogen does not survive the cooking process and cannot grow in refrigerated or non-refrigerated storage conditions. There are no known outbreaks in which potatoes and potato products were identified as the source. *Campylobacter* spp. are therefore not regarded as a relevant threat in the potato chain. The risk of *Campylobacter* spp. in the potato chain is estimated as negligible based on likelihood (negligible).

7.3.4. Clostridium spp.

There are various types of clostridia, of which *Clostridium botulinum* and *Clostridium perfringens* in particular are associated with foodborne disease cases. *Clostridia* spp. are Gram-positive spore-forming bacteria. For other relevant properties, see Table 7.4**.**

C. botulinum causes the serious condition of botulism. Of the seven types of *C. botulinum*, types A, B, E, and F are capable of causing botulism in humans. The most common route of infection in humans is via self-preserved food; other forms are wound botulism and infant botulism which are not relevant here. The toxin causes severe symptoms. The botulinum toxin is extremely poisonous and very little of it is needed to cause disease symptoms. Toxin production only takes place during the growth of *C. botulinum* (RIVM, 2011c; FDA, 2012).

Botulism is a serious condition. Even with proper treatment, the mortality rate is high (>1:100) (van Kreijl et al., 2004).

C. perfringens strains can be subdivided into types A to E. *C. perfringens* can produce various toxins, of which the enterotoxin (CPE) is responsible for *C. perfringens* type A food poisoning. In addition to type A food poisoning, type C food poisoning may also occur. This condition is rare in developed countries and no longer occurs in Europe (Brynestad & Granum, 2002; FDA, 2012).

Symptoms of type A food poisoning are caused by cells or spores that germinate and grow in the intestines and then sporulate, releasing the enterotoxin into the gut. However, not all strains are capable of producing CPE (Brynestad & Granum, 2002; FDA, 2012).

The type of food poisoning caused by *C. perfringens* leads to mild symptoms (gastroenteritis), with a low mortality rate (<1:1,000) (van Kreijl et al., 2004). Symptoms only occur after ingestion of $>10^6$ cfu/g (Table 7.4).

In addition to the two well known human pathogenic species mentioned, the lesser known pathogen *Clostridium butyricum* occurs naturally both on and in potatoes. This bacterium causes potato rot (WFBR, 2018). However, only a very limited number of strains of this pathogen are capable of potentially causing disease in humans through the production of botulinum toxin E (De Medici et al., 2009; RIVM, 2011c). The fact that this effectively concerns a low percentage of strains is confirmed by research in the United Kingdom, where none of the nearly 100 *C. butyricum* strains isolated from food were able to produce this toxin (WFBR, 2018). However, a number of cases have been described that were caused by *C. butyricum*, usually involving infant botulism. In addition, as far as is known, a very limited number (two) of foodborne outbreaks have been described (Meng et al., 1997; WFBR, 2018). Although some cases of disease have been described and *C. butyricum* has been found to occur on potatoes, the risk of this pathogen in general, and for potatoes in particular, is considered to be negligible.

Legislation

No specific food safety criteria have been laid down in EU legislation[36] for *C. botulinum* and *C. perfringens* in potatoes and potato products. However, there is national legislation applicable[42] to *C. perfringens* for "food and beverages, except for food and beverages that have not undergone any germicidal treatment and that, in case of normal use, are only suitable for human consumption after heating by the end user".

Routes of contamination

Clostridia are commonly found as spores in the soil and can therefore contaminate agricultural crops (WFBR, 2018).

For example, *C. botulinum* type E is widespread in the natural environment along the Baltic Sea. In Sweden, this pathogen was found in potato cultivation fields, where the potatoes themselves were often contaminated (Table 7.6) (WFBR, 2018). Animals can also be carriers of *C. botulinum*, without them falling sick (Fohler et al., 2016; NVWA BuRO, 2019b). In this way, further spread takes place via the manure, but it is unknown how far this contributes to the spread.

C. perfringens is commonly found in the digestive tract of animals and humans (Brynestad & Granum, 2002; FDA, 2012). Studies on the occurrence of *C. perfringens* in different types of cultivated soils (incl. potato fields) shows that it is the spores in particular that are found in the soil, and to a lesser extent, the vegetative cells. In addition, higher numbers of spores of this pathogen are associated with soil that is contaminated with faeces (manure) (Voidarou et al., 2011).

Detection in the chain

C. botulinum is ubiquitously present on unprocessed agricultural products. However, this usually concerns a low or very low level of contamination (EFSA BIOHAZ Panel, 2005). This need not be a problem if growth and the associated production of toxins is prevented (Driehuis et al., 2018).

The literature search performed by WFBR reveals three references with data on the occurrence of *C. botulinum* in potatoes and potato products. Two of these contain prevalence data (Table 7.6). In addition, three other references have been found that contain prevalence data. The studies cited in the references were based on approximately 325 samples.

C. botulinum was found in two of the studies. This concerned fresh potatoes, with data from Sweden in particular showing a high prevalence (68%), which is strongly related to the contamination of the environment in that region. The other studies examined too few samples to be able to form a reliable picture of the extent to which *C. botulinum* occurs in the various potatoes and potato products. In most of the studies, *C. botulinum* was not found.

The literature search conducted by WFBR did not reveal any data on the occurrence of *C. perfringens*. However, one of the references cited does mention a prevalence study. This pathogen was not found in any of the 50 samples (fresh potatoes) (Table 7.6).

For the period 2011-2018, the EFSA database does not contain any records of samples from the potato chain that had been tested for the presence of clostridia (Table 7.6).

In the period 1990-2018, the RASFF system received two notifications of potatoes and potato products contaminated with clostridia (Table 7.7). Also in the US, in the period 2010-2018, there were no recall notifications for the occurrence of this pathogen in potatoes and potato products (Table 7.8).

Growth

To cause disease, both *C. botulinum* and *C. perfringens* need to grow in the food. For *C. botulinum*, it is also important that toxins can be formed. This only takes place during the growth of vegetative cells. Spores do not produce toxins (and are therefore not pathogenic) but can grow into vegetative cells after germination (EFSA BIOHAZ Panel, 2005; RIVM, 2011c).

Bacterial spores germinate easily after heat activation, such as during the cooking process. Clostridia only grow under anaerobic conditions. Since the cooking process reduces the amount of oxygen in the food, this is beneficial for growth. Certainly in the case of more solid masses, such as mashed potatoes, this condition will be maintained for a longer period of time (EFSA BIOHAZ Panel, 2005).

C. botulinum can be subdivided into four groups. Strains that cause botulism in humans belong to Groups I and II. Group I contains strains that are proteolytic, mesophilic (growth temperature from 10-12 °C) and the spores formed are highly heat-resistant. It includes the human pathogenic species types A, B and F. Group II consists of strains that are non-proteolytic and psychrophilic (growth temperature from 2.5°C). It includes the human pathogenic species types B, E and F (EFSA BIOHAZ Panel, 2005; Carter & Peck, 2015; WFBR, 2018).

Several studies show that spores of *C. botulinum* (both non-proteolytic and proteolytic strains) on fresh and cooked, packed (vacuum or film) potatoes can germinate, grow and produce toxins if the storage temperature is above 8-10°C (WFBR, 2018) (Table 7.9).

The addition of sulphite can help prevent the growth of *C. botulinum*. However, under certain conditions (combination of storage temperature and concentration of sulphite), toxins may still be formed without the product being organoleptically assessed as spoilt (Solomon et al., 1998).

C. botulinum can also grow in gnocchi. Research shows that non-proteolytic (psychrotrophic) *C. botulinum* can grow in this product in the absence of further measures to restrict growth (growth at 20°C, no preservative). Use of preservative (sorbic acid) and/or a low temperature (8-12°C) was sufficient to prevent toxin formation in the tested product (WFBR, 2018).

Based on a hazard analysis performed by Van Gerwen et al. (WFBR, 2018) with chilled vacuum-packed cooked potatoes, it was found that C. *botulinum* and *C. perfringens* are the only hazards, besides bacilli, that may be present in the product (if produced under hygienic conditions). Under refrigerated conditions, only *B. cereus* and *C. botulinum* types E and F are relevant hazards. This is because these bacteria are able to grow at low temperatures (Table 7.4). However, outbreaks are mainly caused due to insufficient control of the production and/or storage process. This also explains why *C. botulinum* type A is mentioned fairly often in outbreaks, while this type of *C. botulinum* only grows at slightly higher temperatures. The type of *C. botulinum* that causes outbreaks is also region-dependent, i.e. depending on the type most common in the regional environment.

C. perfringens is less strictly anaerobic than *C. botulinum* and tolerates a slightly less oxygen-deficient environment. Growth at refrigerator temperature (from 4°C) is possible, but in most cases this will only take place at slightly higher temperatures (>10°C). *C. perfringens* is mainly associated with protein-rich foods, such as meat dishes/gravy and soups containing meat, but it also occurs in other foods (Brynestad & Granum, 2002; EFSA BIOHAZ Panel, 2013).

Cases of disease are associated with products that have been stored for too long at a too high temperature, as a result of which growth to high numbers (>10^6 cfu/g) has occurred in the food (EFSA BIOHAZ Panel, 2005; FDA, 2012).

C. perfringens can also grow rapidly in mashed potatoes at 25°C (Bourland et al., 1974). No other studies examining the growth potential of *C. perfringens* in potatoes and potato products have been found (WFBR, 2018).

Reduction/decontamination

Spores of *C. botulinum* and *C. perfringens* are difficult to remove from food. Spores in general, but those of *C. botulinum* in particular, are very heat-resistant and therefore can survive the normal cooking process. The spores can germinate in the cooked food and the resulting vegetative cells can grow and/or form toxins if the conditions are suitable. Only pressure cooking the food (121°C/3 min) can inactivate these spores, which is known as a 'botulinum cook'.

The toxins produced by *C. botulinum* are relatively heat-sensitive. A 10-min process at 80°C is sufficient, which means that a proper warming-up process is enough to inactivate the toxins (EFSA BIOHAZ Panel, 2005).

Cases and burden of disease

Outbreaks & cases of disease

An overview of the potato-related outbreaks and disease cases caused by clostridia and recorded (US) or described in the literature is provided in Table 7.10.

In the period 1998-2017, 27 outbreaks (suspected/confirmed) were recorded in the US in the NORS database that had been caused by *Clostridium* spp., with potato being mentioned as one of the ingredients of the meal. In five outbreaks where the pathogen was confirmed as the causative agent, potatoes or potato products were identified as the source. This involved two *C. botulinum* outbreaks and three *C. perfringens* outbreaks. In case of the *C. perfringens* outbreaks, it is unclear whether potatoes were the actual cause of the outbreak, since either the dish contained gravy or the outbreak involved a ready meal/composite product.

In addition to the NORS database, additional data on botulism cases in the US can be found in the annual National Botulism Surveillance reports (2001-2017). Both records taken together list six *C. botulinum* outbreaks and six single cases caused due to the consumption of a potato product. A total of 78 cases of disease were involved.

Of the recorded outbreaks, one was caused by home-canned potatoes. All other outbreaks and cases of disease involved heated potatoes or products made with potatoes, which had been stored unrefrigerated for a longer period of time (days). This involved five outbreaks and an isolated case caused by pruno, a self-made alcoholic drink (made from cooked/baked potatoes; prison). In two isolated cases, the source was potato soup (packaged). Baked or jacket potatoes were the cause of three single cases. In the literature, there are descriptions of outbreaks (US: 1978 and 1994) and a sporadic case (CA: 2002) involving jacket/baked potatoes as the source.

The EFSA database (2011-2017) contains records of five *Clostridium* spp. outbreaks where potato was mentioned as one of the ingredients of a ready meal. However, potatoes were not indicated as the specific source. All of these outbreaks were related to *C. perfringens*.

Botulism is a notifiable disease in the Netherlands (see 7.5.1) and is rare in humans. In the period 2000-2018, botulism was diagnosed in 20 patients. This involved 14 cases of foodborne botulism, 7 of which were part of an outbreak. As far as is known, potatoes did not play a role in any of the botulism cases (Aalten et al., 2011; Maassen et al., 2012; Graveland et al., 2013; Zomer et al., 2014; Zomer et al., 2015; Uiterwijk et al., 2016; Uiterwijk et al., 2017; Uiterwijk et al., 2018; Vlaanderen et al., 2019).

Cases of diseases caused by *C. botulinum* are often associated with products that have been preserved at home (canning/preserving) or products that come from smaller entrepreneurs. In both cases, a lack of knowledge and expertise in the area of safe food production plays a role. As a result of this, growth and toxin production are facilitated due to errors in the recipe (no or insufficient preservative effect), process (insufficient heating, leakage in packaging) or storage conditions (for too long at too high temperatures) (EFSA BIOHAZ Panel, 2005; FDA, 2012).

Burden of disease estimates

In the Netherlands, individual cases of food poisoning caused by *C. perfringens* are not recorded; only outbreaks are recorded. Due to the mild nature of the symptoms caused by *C. perfringens,* many cases of disease and minor outbreaks will go unnoticed. Human incidence data of cases caused by *C. perfringens* in the Netherlands are based on estimates. In 2018, the number of people that fell ill due to *C. perfringens* was estimated at 171,000 (with 5 deaths). Based on this incidence data, the estimated burden of disease is 200 DALYs and the cost to society was €29 million for that year.

Source attribution based on expert opinions estimate that 90% (180 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 180 DALYs caused by *C. perfringens,* the share of produce is 7% (rounded off) (12 DALYs, 11,000 cases). Of the total burden of disease of 200 DALYs caused by *C. perfringens*, 6% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 4% is attributed to *C. perfringens* (Figure 7.3), and for the total number of cases, this is 28% (Pijnacker et al., 2019).

No burden of disease estimates are available for *C. botulinum*.

Risk characterisation

The types of clostridia that play a role in human foodborne disease cases in the Netherlands are *C. botulinum* and *C. perfringens*. Clostridia occur widely in the environment (soil) as spores and are found in animal manure, both of which are possible routes of contamination for fresh potatoes. *C. botulinum* has been found on fresh potatoes, survives the cooking process and can grow and form toxins on both fresh (peeled) and cooked potatoes and products made from these potatoes. Refrigeration (<8°C) and the use of preservatives can help prevent this problem. Described cases and outbreaks of botulism caused by potatoes are all due to improper control of the method of preparation used by the food handler (mass caterer, consumer). Botulism occurs very rarely in humans in the Netherlands and has never (in the period 2000-2018) been attributed to potatoes.

C. botulinum causes proven cases of disease through the consumption of potatoes, where the contamination (the hazard) arises from the potato chain, but the actual risk arises from the inadequate preparation and storage procedures followed (in almost all cases) by the food handler. In fact, this pathogen can also cause problems in industrially prepared, chilled products.

C. botulinum is considered a relevant hazard for prepared/pre-cooked or cooked potatoes and potato products. The risk is assessed as minor based on likelihood (very unlikely) and consequence (major). The risk can be controlled through adequate (refrigerated) storage (<8°C) and the use of preservatives (chilled products).

It is assumed that *C. perfringens* also occurs in potatoes and that outgrowth can occur, especially at temperatures >7°C. However, there is hardly any data available to support this assumption. Hardly any outbreaks involving potatoes or potato products have been described and if so, it remains unclear whether potatoes are the actual cause. *C. perfringens* is therefore not regarded as a relevant hazard in the potato chain. Therefore, the risk of *C. perfringens* in the potato chain is estimated as negligible based on likelihood (negligible) and consequence (minor).

7.3.5. Pathogenic Escherichia coli (STEC)

Escherichia coli belongs to the family *Enterobacteriaceae*. It is a bacterium that is occurs in the intestines of many warm-blooded animals and therefore also occurs in faeces/manure. Not all *E. coli* types are pathogenic to humans since only a small proportion belongs to the group of pathogenic *E. coli*. This group consists of several diarrhoea-causing *E. coli* species, the most well-known of which is the shiga toxin-producing *E. coli* (STEC). Earlier, this used to be also called 'vero(cyto)toxin-producing *E. coli* (VTEC)' (RIVM, 2010).

STEC is a Gram-negative, facultative anaerobe that does not form spores and that cannot, or cannot grow easily, at refrigerator temperatures (Table 7.4).

Gastroenteritis and hemorrhagic colitis are among the milder symptoms caused by STEC. Haemolytic uraemic syndrome (HUS) is among the more severe symptoms and end-stage renal disease is chronic. With proper treatment of an STEC infection, the mortality rate is moderate (1:100-1:1,000) (van Kreijl et al., 2004).

The infectious dose is low, especially in the risk groups (young children, elderly, immunocompromised persons). Although the ID_{50} is estimated at 10^3-10^6 cells, outbreaks have been described involving a much lower dose (10^1 cells) (Forsythe, 2000; Teunis et al., 2004; FDA, 2012).

Legislation

No specific food safety criteria have been laid down in EU legislation[36] or in national legislation[42] for pathogenic *E. coli* in potatoes and potato products. However, the NVWA has drawn up an intervention policy[44] with regard to the detection of STEC in foodstuffs in implementation of Article 14 of the General Food Law[34].

Routes of contamination

Ruminants (cow, goat, sheep) are the main source of STEC. This pathogen is excreted in manure (Farrokh et al., 2013). The incidence of *E. coli* (pathogenic or not) in food is associated with contamination via manure or unhygienic practices. Food crops may become contaminated by (pathogenic) *E. coli* due to the use of manure or the use of (irrigation) water contaminated with manure (WFBR, 2018). STEC can survive for a long period of time in the environment (Fremaux et al., 2008; Farrokh et al., 2013).

However, two studies that examined the transfer of *E. coli* from the environment (soil irrigated with sewage sludge or processed urban waste water) to potatoes have shown that little or no transfer takes place (WFBR, 2018). This also applies to the study performed by Battilani et al. (2014) using treated wastewater.

However, studies involving an exposure to higher concentrations of *E. coli* show that transfer to potatoes is possible. This concerned a study in which, one week before the harvest, the potato field was contaminated with manure (simulation with exposure to wild animals) or flooded with contaminated irrigation water (Hutchison et al., 2017). The second was the aforementioned study by Forslund et al. (2011) involving the use of water contaminated with pathogens (worst-case scenario) in combination with an underground irrigation system.

During the further handling and processing of potatoes, post-process contamination can occur via, for example, hand contact or the processing environment. In a dated study from the US (1967), inspections and samples were taken at approximately 30 potato processing plants. In this study, *E. coli* was found in chips. The frozen product was frequently handled with bare hands (unwashed, not disinfected) during packaging. In addition, *E. coli* was found to frequently occur in the product in processing plants with poor hygiene (incl. visible dirt) throughout the production process, except immediately after steps involving heating of the product (steam peeling, blanching, deep-frying). Once the process hygiene was improved, there were hardly any occurrences of *E. coli* (Surkiewicz et al., 1967; WFBR, 2018).

Detection in the chain

Studies on the occurrence of pathogenic *E. coli* in the potato chain are scarce. The literature search conducted by WFBR reveals one reference with data on the prevalence of *E. coli* in potatoes and potato products (Duran et al., 1982). These products included rösti (dehydrated and frozen), chips (frozen), mashed potatoes (dehydrated) and potato salad. The study included approximately 7,550 samples. In addition, another reference also appeared to contain data on the presence of STEC O157:H7 in table potatoes (Selma et al., 2007) (Table 7.6).

STEC O157:H7 was not found to occur in fresh potatoes (limited number of samples). Of the potato products included in the study, higher numbers of *E. coli* were only found in potato salads (>2.2 log cfu/g) (0.9%). In the other products, *E. coli* was either not found or found to a limited extent (3% positive, <1.8 log cfu/g).

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[44] Intervention Policy for the presence of STEC in food, available via https://www.nvwa.nl/onderwerpen/e-coli-bacterien-stec-ehec/documenten/consument/eten-drinken-roken/bacterien/e.-coli/beleidslijn-interventie-aanweigheid-stec-in-levensmiddelen.

For the period 2011-2018, the EFSA database has records of a total of five samples from the potato chain that had been tested for the presence of pathogenic *E. coli* (Table 7.6). This did not involve any selective sampling or suspect sampling. None of the samples tested positive.

In the period 1990-2018, there was one RASFF notification about potatoes and potato products contaminated with *E. coli* (Table 7.7). This concerned an excessively high count of *E. coli* (10^3 cfu/g) in chips, and where *E. coli* was recorded as a pathogen. This probably did not specifically involve a contamination with STEC, since the contamination level in relation to the type of product (heated, therefore post-process contamination) appears to be too high, although its presence cannot be ruled out.

In the US, there were no reports of pathogenic *E. coli* in potato products (Table 7.8) in the period 2010-2018, apart from a report in which a different ingredient (celery in potato salad) was the source.

Growth

Pathogenic *E. coli* has a low infectious dose and does not need to grow in order to cause disease symptoms. STEC cannot grow properly in the refrigerator (<7°C) (Table 7.4).

No studies have been found in the literature on the growth potential of pathogenic *E. coli* in potatoes and potato products (WFBR, 2018).

Reduction/decontamination

A study conducted by Hutchison et al. (2017) shows that the washing step during the production of fresh potatoes has no effect on the amount of *E. coli* present on the tubers. During storage (two weeks), the level of contamination decreased but did not disappear.

Pathogenic *E. coli* is killed during pasteurisation and thus during the cooking process of potatoes. This implies that the presence of STEC in cooked potatoes and potato products is due to contamination that occurs after this processing step.

Cases and burden of disease

Outbreaks & cases of disease

An overview of the potato-related outbreaks and disease cases caused by STEC and recorded (US, EFSA) or described in the literature is provided in Table 7.10.

The EFSA database (2011-2017) contains a record of one STEC outbreak linked to the potato chain (fresh potatoes and fresh leek). Another outbreak has been described in the literature in which *E. coli* O157 was the causative agent and fresh potatoes the possible source. Furthermore, a major outbreak is described where *E. coli* O153:H45 was the causative agent and a prepared potato dish was the vehicle (Table 7.10).

The database of foodborne outbreaks in the US (1998-2017) does not list any outbreaks caused by pathogenic *E. coli* that mention potato products as the source. In the Netherlands as well (2009-2018), no STEC outbreaks caused by products from the potato chain were recorded. STEC infections caused by products from the potato chain are therefore rare.

The probable cause of the two STEC outbreaks caused by fresh potatoes was sought in the soil adhering to the potatoes. This soil was probably transferred to ready-to-eat products (cross-contamination). The exact source of contamination of the potato dish could not be determined.

The dish had been stored at room temperature for too long, which may have contributed to the outbreak (Roels et al., 1998).

Burden of disease estimates

STEC infections are notifiable (within defined frameworks) and are recorded in the Netherlands (see 7.5.1). Disease burden estimates for STEC in the Netherlands are only based on STEC O157 infections (Pijnacker et al., 2019). During the active monitoring of STEC O157 in 2018, 59 patients were reported, at least 23 of whom were admitted to hospital. There were five cases of HUS and no reported deaths due to STEC. Based on these data, it was estimated that 2,100 people contracted an STEC O157 infection in 2018 (of whom four died). Based on this incidence data, the estimated burden of disease is 150 DALYs and the cost to society was €6 million for that year.

Source attribution based on expert opinions estimate that 41% (61 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 61 DALYs caused by STEC O157, the share of produce is 7% (rounded off) (4 DALYs, 61 cases). Of the total burden of disease of 150 DALYs caused by STEC, 3% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 1% is attributed to STEC (Figure 7.3), and for the total number of cases, this is 0.2% (Pijnacker et al., 2019).

Risk characterisation

Pathogenic *E. coli* (STEC) occurs in the cultivation phase of the potato chain (manure, soil, irrigation water) and can contaminate potatoes via that route. Hardly any data is available on the occurrence of STEC in potatoes and potato products. However, two STEC outbreaks have been attributed to fresh potatoes, where the route of contamination was presumed to be via the soil attached to the potatoes. STEC does not survive the cooking process of potatoes.

An STEC contamination originating from the potato chain has led to proven cases of disease only on a very incidental basis. In these cases, the contamination (the hazard) originated from the potato chain. STEC is therefore not considered a relevant hazard for potatoes. The risk is assessed as negligible based on likelihood (negligible).

7.3.6. ***Listeria monocytogenes***

The genus *Listeria* belongs to the family *Listeriaceae*. Of the different *Listeria* spp., *L. monocytogenes* is the most significant with regard to public health. *L. ivanovii* acts as a causative agent to a lesser extent. The other types - including *L. innocua* and *L. whelshimeri* - are not pathogenic. *L. monocytogenes* causes listeriosis, a disease common to both humans and animals. *L. monocytogenes* is subdivided into serotypes, of which 1/2a, 1/2b and 4b are most frequently associated with cases of disease in humans (FDA, 2012; RIVM, 2016a).

L. monocytogenes is Gram-positive, does not form spores and is a facultative anaerobic bacteria. For specific data and other relevant properties of this pathogen, see Table 7.4.

For most people, an *L. monocytogenes* infection leads to no symptoms or only mild ones (such as gastroenteritis); severe symptoms caused by *L. monocytogenes* include encephalitis and meningitis, sepsis and miscarriage. Of the patients who experience severe symptoms, the majority (>93%) either suffer from severe underlying conditions and/or use immunosuppressants and/or antacids or are pregnant (unborn foetus). Even with optimal treatment, the mortality rate in this vulnerable group is high (>1:100) (van Kreijl et al., 2004), which was 5-31% in recent years (2006-2016) in the Netherlands (Friesema et al., 2015b; Friesema et al., 2016b; RIVM, 2016a; Friesema et al., 2017b; Friesema et al., 2017c). In case of pregnancy-related listeriosis, the risk lies mainly with the unborn child. The mother may be asymptomatic, but *L. monocytogenes* is able to cross the mother-child barrier (vertical transmission) and reach the vulnerable foetus (RIVM, 2016a).

The infectious dose of *Listeria* is not precisely known but is estimated to be around 1,000-100,000 cells for the most susceptible population (Farber et al., 1996; FDA, 2012). However, it may be a bit lower (Pouillot et al., 2016). It is estimated that 90% of listeriosis cases are caused by food containing >2,000 cfu/g of the pathogen at the time of consumption (EFSA BIOHAZ Panel, 2018).

Legislation

For *L. monocytogenes,* food safety criteria are laid down in EU legislation[36] with respect to ready-to-eat foods that are able or unable to support the growth of *L. monocytogenes*. A limit value of 100 cfu/g applies during the shelf-life of the product. In products in which significant growth can occur, *L. monocytogenes* must be absent (in 25 g) by the end of the production process.

Routes of contamination

Listeria monocytogenes can be found in animals, plants, soil and water. This pathogen occurs in many types of environments, albeit in low numbers (RIVM, 2016a; WFBR, 2018). However, there is also a study in which high numbers (10^3-10^5 cfu/g) of *L. monocytogenes* were found in agricultural land with and without organic fertilisation (Selma et al., 2007; WFBR, 2018). In soil, the presence of listeria, including *L. monocytogenes*, is associated with plant-based compost and animal manure (Vivant et al., 2013; WFBR, 2018). Potatoes can therefore become contaminated via these routes.

There are several studies showing that *L. monocytogenes* occurs in the soil and on the potatoes grown there (Weis & Seeliger, 1975; Doan & Davidson, 2000; Selma et al., 2007; Szymczak et al., 2014; WFBR, 2018). However, one study examining the transfer of *L. monocytogenes* from natural manure to potatoes showed that *L. monocytogenes* survived in the soil for one to two months after fertilisation (performed before planting), but then disappeared and was not found on the harvested potatoes (WFBR, 2018).

Although contamination of raw materials (in this case, fresh potatoes) can take place in the primary phase of the chain, post-process contamination from the processing environment is considered to be the most important source of *L. monocytogenes* contamination for ready-to-eat products. *L. monocytogenes* can be introduced into the processing environment via the raw materials (fresh potatoes). Other pathways of introduction into the processing environment are via the environment outside the processing plant (animals, soil, dust, water). This pathogen can survive easily in the processing environment within the plant, especially in biofilms. The biofilm makes this fairly-resistant bacterium even less sensitive to various environmental influences. Moreover, biofilms are more difficult to remove than bacteria that do not form a biofilm (Zomer et al., 2015; RIVM, 2016a; EFSA BIOHAZ Panel, 2018). Post-process contamination caused by processing equipment can also play a role in the potato chain (Smittskydd Västra Götaland, 2018), although hardly any publications have been published regarding this.

Detection in the chain

The literature search conducted by WFBR reveals four references describing studies on the occurrence of *L. monocytogenes* in potatoes and potato products. One of these studies only investigated the contamination level of the potatoes, which amounted to an average of 10^3 cfu/g. The other three references contained prevalence data. One other reference has also been found (Table 7.6). The studies cited in the references include approximately 185 samples. All of these involved fresh potatoes, both in the cultivation phase and in retail (market, supermarket). The observed prevalences were between 10% and 40%, with an average of 20%.

Although it is likely that *L. monocytogenes* also occurs in industrially prepared potato products (chilled, frozen), no studies regarding this have been found in the literature (WFBR, 2018). This may be explained by the fact that most of these products still need to be heated before they are suitable for consumption. Hence, these products do not fall under the category of 'ready-to-eat food' referred to in the Microbiological Criteria Regulation[36], which makes research on *L. monocytogenes* less relevant.

This is also reflected in the lack of notifications regarding this product-pathogen combination in the RASFF system (1990-2018; Table 7.7). However, in the US (2010-2018), 19 reports were recorded of products containing potatoes that had been withdrawn from the market because they were found to be contaminated with *L. monocytogenes*. Of these, 12 reports concerned composite products in which a different ingredient was the source of the contamination. The other seven reports concerned potato wedges (1), salads (3) and miscellaneous/composite products (3) (Table 7.8). The potato wedges became contaminated from the production environment, just like the other products (with the exception of a report involving an unknown cause of contamination).

For the period 2011-2018, the EFSA database has records of a total of 262 samples (crisps, prepared potato dishes) from the potato chain that had been tested for the presence of *L. monocytogenes*. Excluding the selective sampling or suspect sampling, this amounts to a total of 236 samples. The pathogen was only found in prepared potato dishes (0.4%) (Table 7.6).

Growth

L. monocytogenes is one of the pathogenic bacteria that can grow at refrigerator temperature. Growth can occur from 0°C, both in an environment with and without oxygen. In addition, it is a fairly resistant bacterium that can survive or even grow under various difficult conditions (high salt concentration, low pH) (FDA, 2012; EFSA BIOHAZ Panel, 2018; CDC, 2019b).

The infectious dose of *L. monocytogenes* is somewhat higher (Table 7.4) than that of, for example, *Salmonella* or STEC. This means that, in case of a contamination with a low number of cells, growth within the product is necessary to cause symptoms of disease in humans.

Only a few studies have been published on the possibilities of the growth of *L. monocytogenes* in potato products (WFBR, 2018) (Table 7.9). However, growth in fresh potatoes (peeled) appears to be possible from 4°C.

Reduction/decontamination

Growth of *L. monocytogenes* in peeled, fresh, vacuum-packed potatoes during refrigerated storage (4°C) can be prevented by adding sulphite or commercially available products to control discolouration (with and without rinsing with water). The disadvantage is that these treatments also influence the sensory (odour, appearance) perception of spoilage. Certainly in the case of temperature abuse, products were found to be spoiled or to contain high numbers of *L. monocytogenes,* without this being perceptible. This will make the consumer think that the products are safe, which can lead to risks (Juneja et al., 1998).

Besides preventing growth during storage, the risk of *L. monocytogenes* can be further reduced by the heating step required for fresh potatoes, and often also for pre-cooked chilled or frozen potato products, in order to make these products ready for consumption (WFBR, 2018). *L. monocytogenes* does not survive the cooking process. The presence of *L. monocytogenes* in cooked potatoes and potato products can therefore be attributed to from post-process contamination.

Cases and burden of disease

Outbreaks & cases of disease

Only one report could be found of a listeriosis outbreak caused by a potato product (Table 7.10). This was an outbreak in Sweden (2018) caused by a chilled ready-to-heat meal containing mashed potatoes. The contamination originated from the processing equipment (mashed potato machine) in the plant and could also be detected in the processing environment. The cause of the contamination was the failure to properly heat up the product for consumption (Smittskydd Västra Götaland, 2018).

EFSA (2011-2018) and US (1998-2016) databases on foodborne outbreaks do not contain any records of listeriosis outbreaks where potato products were indicated as a source.

Burden of disease estimates

Listeriosis is a notifiable disease in the Netherlands and is subject to active laboratory-based surveillance (see 7.5.1). In 2018, 78 patients with listeriosis were reported, of whom six died. Seven cases involved pregnancy-related listeriosis (involving the death of two infants). Based on this incidence data, the estimated burden of disease is 260 DALYs and the cost to society was €3 million for that year.

Source attribution based on expert opinions estimate that 69% (180 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 180 DALYs caused by *L. monocytogenes,* the share of produce is 5% (rounded off) (14 DALYs, 4 cases). Of the total burden of disease of 260 DALYs caused by *L. monocytogenes*, 5% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 5% is attributed to *L. monocytogenes* (Figure 7.3), and for the total number of cases, this is 0.01% (Pijnacker et al., 2019).

Risk characterisation

L. monocytogenes occurs in the environment (soil), is found on fresh potatoes, can grow in the refrigerator (4°C) in fresh potato products but does not survive the cooking process. Post-process contamination can, however, occur in pre-cooked or cooked products, which has very sporadically resulted in cases of disease. Data on incidence and growth in ready-to-eat products are largely lacking. Since *L. monocytogenes* occurs naturally in the potato chain (fresh potatoes), it is necessary to remain alert so that introduction (and biofilm formation) into the processing environment of processed ready-to-eat potato products (post-process contamination) can be prevented. This pathogen is therefore considered to be a hazard relevant to the potato chain, especially for ready-to-eat products. However, the number of cases appears to be very limited. Hence, the risk to public health due to *L. monocytogenes* in the potato chain is assessed as low based on likelihood (negligible) and consequence (major).

7.3.7. Salmonella spp.

Salmonella belongs to the family *Enterobacteriaceae*. The genus *Salmonella* consists of two species: *Salmonella enterica* and *Salmonella bongori*. The species is divided into subspecies (subsp.) and serovars. There are over 2,600 known serovars. Most *Salmonellae* that cause disease in humans and warm-blooded animals belong to the *Salmonella enterica* subsp. *enterica* group. Within this group, the full nomenclature is often shortened to only the serovar, e.g. *Salmonella* Enteritidis instead of *Salmonella enterica* subsp. *enterica* Enteritidis (Brenner et al., 2000; Agbaje et al., 2011; FDA, 2012; Issenhuth-Jeanjean et al., 2014).

The name '*Salmonella'* as used in this risk assessment refers to serovars belonging to the *Salmonella enterica* subsp. *enterica* group.

Salmonella is a facultative anaerobic, Gram-negative, non-spore-forming microorganism. For other relevant properties, see Table 7.4.

Salmonella causes typhoid fever, paratyphoid fever and salmonellosis.

Typhoid fever is caused by *S.* Typhi and paratyphoid fever by *S.* Paratyphi A, B and C. Humans are the only reservoir of *S.* Typhi. For *S.* Paratyphi as well, humans are practically the only reservoir, although occasionally animals, especially livestock, are also carriers of *S.* Paratyphi (RIVM, 2001a;2001b; FDA, 2012).

In fact, typhoid fever as well as paratyphoid fever are only, or almost only, spread through the consumption of water or food contaminated with the faeces of patients/carriers. In water, *S.* Typhi and *S.* Paratyphi can survive for a considerable period of time (weeks/months), especially at low temperatures and under aerobic conditions.

Infection with *S.* Typhi or *S.* Paratyphi causes severe symptoms (typhoid fever or paratyphoid fever). With effective treatment, the mortality rate is moderate (1:100-1:1,000) (van Kreijl et al., 2004).

Typhoid fever and paratyphoid fever are notifiable diseases (see 7.5.1). Both diseases are rare in the Netherlands. In the period 2012-2018, less than 35 patients with typhoid, paratyphoid A or paratyphoid B fever were reported annually. For paratyphoid C fever, this was less than five cases (RIVM, 2018c). Typhoid fever and paratyphoid fever in the Netherlands mainly occur as imported diseases.

Salmonellosis is caused by all other types of *Salmonella*. While some serovars are more commonly found in humans as a pathogen, all of them are considered pathogenic (EC, 2003). Although there may be very specific strains that are not pathogenic to humans, these are exceptions (Cheng et al., 2019).

Salmonellosis symptoms vary from mild (gastroenteritis, reactive arthritis) to severe (bacteraemia) and can also be chronic (irritable bowel syndrome, and to a lesser extent, inflammatory bowel disease). With effective treatment, the mortality rate is moderate (1:100-1:1,000) (van Kreijl et al., 2004; Bouwknegt et al., 2014).

The infectious dose of *Salmonella* can be low (10-100 cells, although >1 cell is also mentioned), especially in more high-fat products (RIVM, 2006a; de Jonge & Aarts, 2010; FDA, 2012), while there are also studies that show higher doses with an ID_{50} of 10^4-10^5 cells (Rose et al., 2014).

In this risk assessment, the typhoidal *S. enterica* serovars have not been taken into consideration. This is because the disease syndrome caused by these serovars is rare in the Netherlands and is mostly regarded as an imported disease.

Legislation

No food safety criteria are laid down in EU legislation[36] for potatoes and potato products with regard to *Salmonella*. However, there is national legislation applicable[42] to this pathogen with respect to “food and beverages, except for food and beverages that have not undergone any germicidal treatment and that, in case of normal use, are only suitable for human consumption after heating by the end user”.

Routes of contamination

In general, *Salmonella* is found in almost all environments, animal intestines (manure) and soil, as well as in surface water and animal feed (FDA, 2012). *Salmonella* can survive in soil for a certain period of time (weeks) (Jacobsen & Bech, 2012; Jechalke et al., 2019).

It can contaminate potatoes during the cultivation process via the soil, fertilisation or water that is contaminated with faeces. This is corroborated by the aforementioned study of Forslund et al. (2011) in which transmission of human pathogens (incl. *S.* Senftenberg) to potatoes is demonstrated when using water contaminated with pathogens (worst-case scenario). Other research using sewage sludge demonstrate the presence of *Salmonella* in the soil but not in the potatoes (WFBR, 2018).

Salmonella can end up in the product after the potatoes are processed. Known post-process contamination routes include the addition of a contaminated ingredient to a prepared potato product, cross-contamination during preparation or via a food handler who is infected with *Salmonella* (WFBR, 2018).

In general, *Salmonella* regularly occurs in dehydrated products, partly due to post-process contamination via the processing environment (Beuchat et al., 2011).

Detection in the chain

The literature search conducted by WFBR reveals no references with data on the prevalence of *Salmonella* in potatoes and potato products. However, additional search revealed three references that contained such data (Table 7.6). The cited studies examined approximately 125 samples consisting entirely of fresh potatoes. *Salmonella* was found in two of these studies, with a prevalence rate of 1% and 100% (average 11%).

Although *Salmonella* occurs in various dehydrated products (incl. spices, grains and milk powder) (Podolak et al., 2010), no studies are known in which such dehydrated potato products have been tested for this pathogen (WFBR, 2018).

Research by Wells & Butterfield (1997) shows that *Salmonella* is more common in fruit and vegetables with soft rot. However, this did not apply to potatoes in this study, since all of them, whether with and without rot, tested positive for *Salmonella*.

For the period 2011-2018, the EFSA database has records of a total of 511 samples from the potato chain that had been tested for the presence of *Salmonella*. These were samples of potato protein intended for animal feed, crisps and prepared potato dishes. Excluding the selective sampling or suspect sampling, this involved a total of 401 samples (crisps and prepared potato dishes) (Table 7.6). The pathogen was only found in the prepared potato dishes (1%).

In the period 1990-2018, there was one RASFF notification about the presence of *Salmonella* in potatoes and potato products (Table 7.7). It concerned a potato dish produced in the Netherlands.

In the period 2010-2018, 19 recalls were carried out in the US due to contamination of different types of potato-based products with *Salmonella*. In 15 cases, this concerned products relevant to the potato chain (crisps (13), potato products (2)) (Table 7.8). All the cases involved contamination via an added ingredient: spices, chocolate, milk or hydrolysed vegetable protein. Milk or milk powder was one of the ingredients of the added spice mixture.

Growth

Under ideal conditions, *Salmonella* can grow at refrigerator temperature (from 5°C). However, the amount of cells needed to cause an infection can be very low (Table 7.4), which means that growth in the food is not always necessary to cause disease in humans.

Salmonella can grow (room temperature) in fresh potatoes if they are damaged. Growth is stimulated by soft-rot bacteria (*Erwinia carotovora*) and fungi (*Bottrytis* and *Rhizopus*) (Wells & Butterfield, 1997;1999). Whether or not this is also possible at refrigerator temperature has not been investigated (Table 7.9).

Few publications have been published describing the growth potential of *Salmonella* in potato products. However, these studies show it can grow in cooked potatoes at 5°C.

Reduction/decontamination

Salmonella does not survive the pasteurisation process and therefore does not occur in cooked potatoes and potato products under hygienic production conditions. The presence of *Salmonella* in cooked potatoes and potato products can therefore be attributed to post-process contamination.

Salmonella is associated with dehydrated products (Podolak et al., 2010; Beuchat et al., 2011). The preparation process of dehydrated potato products, which includes both a blanching step and a steam-dehydration step, is sufficient for killing vegetative bacteria (such as *Salmonella*) (WFBR, 2018). As a result, the processing environment remains clean and post-process contamination plays a small role compared to, for example, spray drying processes that do not kill *Salmonella*.

Cases and burden of disease

Outbreaks & cases of disease

Various salmonellosis outbreaks are known to have been caused by the consumption of a potato product. A non-exhaustive overview of this is provided in Table 7.10.

A notable case involves the consumption of crisps, where the contamination came from the spices used. The contamination level was low (4-45 cfu/100 g), yet approximately 1000 people fell ill (WFBR, 2018). It is known that, in fatty products, *Salmonella* is protected during gastric transit, so that even a low level of contamination is sufficient to cause infection (RIVM, 2006a). For potato salads as well (not listed in the table), the causative factor is the addition of contaminated ingredients (e.g. eggs).

It should be noted that, when a cause of the outbreaks was indicated, the potatoes themselves were not the source. The actual cause of the contamination lay elsewhere, for example, via cross-contamination during preparation or due to a food handler infected with *Salmonella*. This often occurred in combination with an excessively long period of non-refrigerated storage (WFBR, 2018). The same applies to the outbreaks mentioned in Doan & Davidson (2000).

The EFSA database (2010-2017) does not contain any record salmonellosis outbreaks linked to the potato chain.

There were only three salmonellosis outbreaks in the US in the period 1998-2017 where a potato product was mentioned as the sole cause. These outbreaks were caused by mashed potatoes (2) and cooked potatoes (1).

Burden of disease estimates

Non-typhoidal salmonellosis is not a notifiable disease in the Netherlands, unless there is an outbreak with food as a suspected source of infection (see 7.5.1). Laboratory-based surveillance is nevertheless carried out by the RIVM. In 2018, the incidence of laboratory-confirmed salmonellosis cases in the Netherlands was 9 per 100,000 inhabitants. Based on this observed incidence, it is estimated that 27,000 people contracted a salmonellosis infection in 2018, of whom 25 died. The burden of disease is estimated at 1,100 DALYs with a cost to society of €19 million for that year.

Source attribution based on expert opinions estimate that 56% (620 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 620 DALYs caused by *Salmonella,* the share of produce is 6% (rounded off) (39 DALYs, 910 cases). Of the total burden of disease of 1,100 DALYs caused by *Salmonella*, 4% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 14% is attributed to *Salmonella* (Figure 7.3), and for the total number of cases, this is 2% (Pijnacker et al., 2019).

Risk characterisation

Salmonella occurs in the environment (soil, water, manure) and is found in both fresh potatoes and prepared potato dishes. *Salmonella* can grow at room temperature in fresh potatoes (damaged). *Salmonella* can grow in potato products in the refrigerator (5°C). However, *Salmonella* does not survive the cooking process or the process for producing dehydrated potato products. As far as is known, recalls, salmonellosis outbreaks and cases of disease involving potato products all involve a different source of contamination (post-process contamination) rather than the potato itself.

Salmonella causes proven cases of disease through the consumption of potato products or products in which potato has been processed. The contamination (the hazard) does not originate from the potato chain but is caused by inadequate preparation procedures (poor hygiene/cross-contamination) or the addition of other ingredients (e.g. herbs or spices) (contaminated with *Salmonella*).

Salmonella is not considered a hazard emanating from the potato chain itself, but it is necessary to remain alert to prevent the contamination of fatty ready-to-eat potato products (crisps) in particular. The risk is assessed as negligible based on likelihood (negligible).

7.3.8. Staphylococcus aureus

The genus *Staphylococcus* belongs to the family *Staphylococcaceae* and consists of 36 different species. The staphylococci relevant to food safety are the coagulase-positive species, the most well-known of which is *Staphylococcus aureus*. *S. aureus* is part of the normal microbial flora of the skin and mucous membranes of mammals, including humans and birds.

S. aureus is a facultative anaerobic, Gram-positive, non-spore-forming microorganism. For other relevant properties, see Table 7.4.

Cases of food poisoning caused by *S. aureus* result from the ingestion of heat-stable enterotoxins formed in the food, which are produced by enterotoxigenic strains of *S. aureus* (Hennekinne et al., 2012). These enterotoxins are abbreviated as SET, i.e. staphylococcal enterotoxins.

The disease is characterised by nausea, vomiting and stomach cramps with or without diarrhoea. The disease is usually self-limiting and the symptoms disappear after two to four days. More severe symptoms, sometimes leading to hospitalisation, can occur in high-risk groups, such as young children, the elderly and people with poor health (Argudin et al., 2010).

The symptoms are mild (gastroenteritis) and are self-limiting. With effective treatment, the mortality rate is low (<1:1,000) (van Kreijl et al., 2004; Bouwknegt et al., 2014).

Legislation

No specific food safety criteria have been laid down in EU legislation[36] for coagulase-positive staphylococci in potato products. However, there is national legislation applicable[42] to *S. aureus* with respect to "food and beverages, except for food and beverages that have not undergone any germicidal treatment and that, in case of normal use, are only suitable for human consumption after heating by the end user".

Routes of contamination

S. aureus is part of the skin flora (throat, nose and hands) of many people. It is estimated that 20 to 30% of people are permanently and 60% transiently colonised with *S. aureus* (Argudin et al., 2010). That is why *S. aureus* can be easily transferred to potatoes and potato products during processing and preparation. Contaminations may result from unhygienic handling, cross-contamination via equipment or via contact with kitchen surfaces or other surfaces and improper storage temperature and duration (FDA, 2012). However, colonised food handlers are the main source of food contamination (Argudin et al., 2010).

In some of the studies that found *S. aureus* to be present in potatoes and potato products, hygiene during production was indeed poor (Surkiewicz et al., 1967), the pathogen was found in raw hand-peeled potatoes (Giannuzzi & Zaritzky, 1990) or in prepared potato products sold under poor hygienic conditions (Pakistan street vending) (Bryan et al., 1992). In the other studies, the source of contamination was unclear (Duran et al., 1982; Manani et al., 2006).

Detection in the chain

The literature search conducted by WFBR reveals four references with data on the presence/prevalence of *S. aureus* in potatoes and potato products. One other reference has also been found (Table 7.6). The cited studies examined approximately 7,600 samples. This was essentially part of one large study investigating the occurrence of pathogens in various potato products in the US (rösti (dehydrated or frozen), mashed potatoes, chips, potato salad). *S. aureus* was detected (>2 log cfu/g) with a prevalence of 0.4%.

One of the studies shows that, under poor hygiene standards, not only can *S. aureus* occur in high concentrations (10^3-10^5 cfu/g) in potato products before deep-frying, but it could also be found in products after deep-frying (Surkiewicz et al., 1967). Good hygiene practices are also essential for such products, even though frozen products need to be heated up before use to make them suitable for consumption.

For the period 2011-2018, the EFSA database has records of a total of 30 samples from the potato chain that had been tested for the presence of *S. aureus*. All of them were samples from prepared potato dishes. Excluding the selective sampling or suspect sampling, this involved 12 samples (Table 7.6) in which the pathogen was found twice (17%).

In the period 1990-2018, there were no RASFF notifications regarding the presence of *S. aureus* in potatoes and potato products (Table 7.7). Also, no recalls were carried out in the US in the 2010-2018 period (Table 7.8).

Growth

Food poisoning by *S. aureus* is caused by a toxin (SET) that has been produced in the food. This only occurs during the exponential growth phase of *S. aureus*. Thus, growth in the product is required to cause disease. *S. aureus* can cause food poisoning only when it is present in numbers higher than 10^5 cfu/g (Schmid-Hempel & Frank, 2007; FDA, 2019a).

Under anaerobic conditions, the growth and production of SET is less optimal than when oxygen is present in the environment (ICMSF, 1996). This pathogen can survive for a longer period of time in dehydrated products (FDA, 2012).

S. aureus does not grow very well at refrigerator temperature (Table 7.4). The minimum temperature required for growth in potato products is somewhere between 6-9°C (Table 7.9). *S. aureus* generally competes poorly with other microorganisms that may be present in uncooked food (Argudin et al., 2010). But it can grow well in cooked products, including potato products. This is confirmed by various outbreaks (Table 7.10) and studies (Bryan et al., 1992; Jorgensen et al., 2005) where *S. aureus* was able to grow to high numbers and produce toxins in potato products that had been stored outside the refrigerator for a few hours.

Reduction/decontamination

Like many other pathogens, *S. aureus* is sensitive to pasteurisation and therefore does not, in principle, occur in cooked potatoes and potato products. The presence of *S. aureus* in cooked potatoes and potato products can therefore be attributed to post-process contamination.

However, the enterotoxins formed in food (SET) are resistant to high temperatures (sterilisation) and low pH (stomach acid) (ICMSF, 1996; WFBR, 2015).

Cases and burden of disease

Outbreaks & cases of disease

Various cases of *S. aureus* food poisoning have been described that were caused by consumption of a potato product (Table 7.10). In some of these cases, the source of contamination has been identified, such as manual peeling and slicing of potatoes after cooking or addition of raw milk to mashed potatoes. Sometimes this is combined with excessively long storage of the prepared product at room temperature before serving, which facilitates growth and toxin formation.

No other outbreaks of *S. aureus* have been registered in the EFSA database (2011-2017) other than the previously mentioned outbreak in Austria (2013) where *B. cereus* was also detected (Table 7.10).

In the period 1998-2017, there were several (suspected/confirmed) *S. aureus* outbreaks in the US involving a potato product. Five of these were potato products that are relevant to this risk assessment or otherwise potato was identified as the contaminated ingredient: fried potatoes (2), deep-fried potatoes/chips (1), mashed potatoes (1) and potato soup and salad (1). *S. aureus* was effectively confirmed as the causative agent in only one of the outbreaks and hence only this outbreak is included in Table 7.10 (CDC, 2018b; WFBR, 2018).

Burden of disease estimates

In the Netherlands, gastroenteritis caused by *S. aureus* is not a notifiable disease, except in the case of an outbreak with food as the suspected source (see 7.5.1). Therefore, human incidence data of intoxications caused by toxin-forming foodborne pathogens are based on estimates in the Netherlands. In 2018, the number of people with an *S. aureus* intoxication was estimated at 288,000 (with 7 deaths). Based on this incidence data, the estimated burden of disease is 220 DALYs and the cost to society is € 61 million for that year. Source attribution based on expert opinions estimate that 86% (190 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 190 DALYs caused by *S. aureus*, the share of produce is 2% (rounded off) (4 DALYs, 5,000 cases). Of the total burden of disease of 220 DALYs caused by *S. aureus*, 2% is specifically attributed to produce (Figure 7.4).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 1% is attributed to *S. aureus* (Figure 7.3), and for the total number of cases, this is 13% (Pijnacker et al., 2019).

Risk characterisation

S. aureus does not naturally occur in fresh potatoes, but it has been demonstrated in potato products (low prevalence, low concentrations). *S. aureus* does not survive the cooking process and enters the chain via post-process contamination. The food handler (natural carrier) is the main source of contamination, although contamination may also occur via the processing environment.

To cause disease, growth and toxin formation in the product is required. *S. aureus* can grow in potato products, but this growth mainly takes place at temperatures >7°C. In case of unrefrigerated storage, growth can occur within a few hours. Outbreaks of *S. aureus* food poisoning can be caused by potato products. This is due to an unhygienic method of working (hand contact) or the addition of contaminated ingredients (raw milk), in combination with improper storage procedures by the foodpreparer (mass caterer, consumer).

S. aureus causes proven cases of disease and outbreaks through the consumption of potato products. The contamination (the hazard) mainly arises via the foodhandler (mass caterer, consumer) or other ingredients (added by the food handler) and the risk arises due to the improper preparation and/or storage conditions used by food handlers. Although this pathogen is also found in industrially prepared products, *S. aureus* is not considered a relevant hazard to the potato chain. The risk within the potato chain is assessed as negligible based on likelihood (negligible) and consequence (minor).

7.3.9. Other bacteria

The literature search conducted by WFBR reveals four references with data on the presence/prevalence of the remaining species of bacteria in potatoes and potato products *(*Table 7.6). The occurrence of bacteria other than the most common foodborne pathogenic microorganisms has also been described in a number of other publications. All of these relate to non-spore-forming bacteria that do not survive the preparation process. Presence of these pathogenic microorganisms in cooked potatoes and potato products can therefore be attributed to post-process contamination. None of these pathogens have been described as causative agents for diseases caused by the consumption of potatoes and potato products (Table 7.10).

These pathogens partly belong to bacterial genera considered to be part of the spoilage flora of vegetables and fruit, such as *Pseudomonas* spp., *Corynebacterium* spp. and different genera of the family of the *Enterobacteriaceae* (Tournas, 2005; Barth et al., 2009; Raybaudi-Massilia et al., 2009; Gellatly & Hancock, 2013; Cunningham & Leber, 2018). The pathogenic species found in potatoes and potato products are *Corynebacterium diphtheriae* (Manani et al., 2006), *Pseudomonas aeruginosa* and *Klebsiella oxytoca* (Nyenje et al., 2012). In addition, *Vibrio* spp. was also found.

For *C. diphtheriae,* humans are the only reservoir and it cannot be transmitted via food (RIVM, 2011a). Presence of this pathogen indicates contamination by humans. This emerged from a study from Africa (Manani et al., 2006), where diphtheria can be endemic.

P. aeruginosa is a plant pathogen that causes spoilage but is an opportunistic pathogen for humans and is mainly transmitted nosocomially (via hands or equipment) or via water (ear infection). Food does not play a role in transmission (CDC, 2019a).

Vibrio spp. occur naturally in seawater or brackish water, sometimes in freshwater. Fish, crustaceans and shellfish are considered to be the only relevant food sources for *Vibrio* spp. Presence in potatoes indicates contamination with unclean water.

A number of *Enterobacteriaceae* that are found in potatoes and potato products belong to the normal intestinal flora (commensal flora) of humans. This includes *Klebsiella* spp., *Enterobacter* spp., *Hafnia* spp., *Cronobacter* spp. and *Pantoea* spp. These microorganisms are opportunistic pathogens and mainly cause nosocomial infections (RIVM, 2011b;2012; Cunningham & Leber, 2018). *Klebsiella* spp. and *Enterobacter cloacae* are found in a variety of foods (Uhitil et al., 2000; Veldman et al., 2014; Harada et al., 2018), but there are hardly any/no descriptions of cases of disease caused by food. The role of *Hafnia alvei* as a causative agent of gastroenteritis is unclear

(WFBR, 2018). *Cronobacter* spp. are common in the environment and also in food but are primarily a risk to newborns and is associated with infant formula products.

Presence of these bacteria in potatoes and potato products is probably due to insufficient hygiene while working with these products, such as hand contact with the product. This picture is consistent with the described results (Giannuzzi & Zaritzky, 1990; Nyenje et al., 2012).

For the period 2011-2018, the EFSA database does not contain any records of samples from the potato chain that had been tested for the presence of bacteria other than those referred to earlier (Table 7.6).

In the period 1990-2018, there were two RASFF notifications regarding the presence of the bacteria other than those referred to earlier in potatoes and potato products (Table 7.7). These notifications were about yeast and coliforms. In the period 2010-2018, no recalls were carried out in the US for the detection of bacteria other than those referred to earlier (Table 7.8).

Risk characterisation

There are several human pathogenic *Enterobacteriaceae*, *Pseudomonas* spp., *Corynebacterium* spp. and *Vibrio* spp. that have been isolated from potatoes, potato products or the production environment. Some of these species are associated with the spoilage of potatoes and therefore originate from the potato chain itself, while others are pathogens for which humans are the only reservoir (post-process contamination). None of these bacteria survive the cooking process. Most of these pathogens are part of the normal human flora, opportunistic pathogenic, usually not transmitted through food and mainly associated with hospital infections (nosocomial transmission). Exceptions to this are *Vibrio* spp. (post-process contamination). No cases of disease caused by these pathogens associated with potatoes and potato products have been described.

Therefore, the group of 'other pathogenic bacteria' does not pose a threat to public health in the Netherlands from the potato chain. This means that the risk is negligible.

7.3.10. Viruses and parasites

Viruses and parasites are relatively host-specific, although some viruses and parasites have multiple hosts. There are no known viruses or parasites that are pathogenic to plants (phytopathogenic) as well as pathogenic to humans (Mandal & Jain, 2010; Balique et al., 2015; Nikitin et al., 2016; Al-Sadi, 2017). The viruses and parasites that are pathogenic to humans originate from animal reservoirs, including from humans. In this respect, food crops (potato) are only a vehicle or possible vehicle that may transfer the hazard.

Legislation

No specific food safety criteria have been laid down in either EU[36] or national legislation[42] for viruses and parasites.

Routes of contamination

A limited number of publications report parasitic contaminations in the potato chain. This concerns a field study in which untreated sewage water was used as irrigation water for potatoes. *Giardia* cysts and *Ascaris* eggs were subsequently found on the potatoes (WFBR, 2018). It is not permitted to use this type of water for irrigation in the Netherlands (Akkerbouw Certificeringsoverleg, 2019).

In addition, two outbreaks of cysticercosis have been described (*Taenia saginata*) in cattle, caused by contaminated animal feed (potato by-product) (WFBR, 2018). It is assumed that the feed was contaminated by human faeces.

Of the viruses and parasites that contribute to the burden of disease in humans transmitted via produce (Table 7.1), only norovirus appears to be significant for the potato chain. There are no known records of cases of disease for the other viruses and parasites.

Humans are a natural reservoir for noroviruses and it is only introduced into the chain by humans. Transmission takes place via direct or indirect contact with vomit or faeces, where food may be an intermediate route. In its opinion on foodborne viruses, EFSA lists norovirus as a relevant hazard for prepared products (EFSA BIOHAZ Panel, 2011). Foodborne outbreaks of norovirus are therefore a regular occurrence, including in the Netherlands (Friesema et al., 2018; EFSA & ECDC, 2019).

For the remaining viruses and parasites, the food handler plays only a marginal role as a source of contamination. The only exception to this is the hepatitis A virus, but this virus is not endemic in the Netherlands. In all cases, transmission from humans or the environment to food can be prevented by applying good general hygiene practices during the preparation or processing of food.

Detection in the chain

In the literature search carried out by the WFBR, no publications were found in which human-pathogenic viruses or parasites had been associated with fresh potatoes. Only norovirus outbreaks caused by potato products have been described (WFBR, 2018).

For the period 2011-2018, the EFSA database does not contain any records of samples from the potato chain that had been tested for the presence of viruses and parasites (Table 7.6).

In the period 1990-2018, there were no RASFF notifications regarding the presence of norovirus in potatoes and potato products (Table 7.7). Also, no recalls were carried out in the US in the 2010-2018 period (Table 7.8).

Growth

Human-pathogenic viruses and parasites cannot reproduce outside their living host. That is why they cannot grow in food crops (potato) or products made from them.

Reduction/decontamination

Norovirus is the only virus mentioned as a cause of disease through the consumption of potatoes and potato products. This virus does not survive the pasteurisation process and therefore does not occur in cooked potatoes and potato products under hygienic production conditions. Hence, the presence of norovirus in cooked potatoes and potato products can be attributed to post-process contamination.

Cases and burden of disease

Outbreaks

Data on the occurrence of outbreaks or cases of disease caused by viruses and parasites as a result of the consumption of potatoes and potato products only relate to five norovirus outbreaks, where prepared potatoes or potato products were the route of contamination (Table 7.10).

Burden of disease estimates

As far as viruses and parasites are concerned, in the Netherlands there is only a duty to report infections caused by the hepatitis A virus; for all other viruses and parasites, such an obligation only applies if it concerns an outbreak with food as a suspected source (see 7.5.1). Active laboratory-based surveillance is carried out for the hepatitis A virus. In addition, laboratory-based surveillance for norovirus (only in case of hospitalisation), rotavirus, hepatitis E virus and *Cryptosporidium* spp. is performed by the RIVM. No recent data are available on giardiasis and toxoplasmosis. The incidence of viral or parasitic infections at the population level has been estimated based on these data. In 2018, this was estimated at 1,014,970 patients, of whom 145 died. Based on the separate incidences per agent, the estimated burden of disease was 5,990 DALYs and the cost to society was €235 million for that year. Source attribution based on expert opinions estimate that, in total, 28% (1,685 DALYs) of this burden of disease can be attributed to food. Within this food-attributed burden of disease of 1,685 DALYs caused by viruses and parasites, the share of produce is 8% (rounded off) (142 DALYs, 20,250 cases). Of the total burden of disease of 5,990 DALYs caused by viruses and parasites, 2% is specifically attributed to produce (Figure 7.2).

Of the total burden of disease attributed to produce (287 DALYs, 30,770 cases), 50% is attributed to viruses and parasites (Figure 7.3), and for the total number of cases, this is 51% (Pijnacker et al., 2019).

Risk characterisation

Viruses and parasites seem to occur very occasionally in the potato chain. Parasitic contamination is associated with the use of sewage water in the farm phase (not permitted in the Netherlands) and contamination with viruses (norovirus) via food handlers in the last phase of the chain. Viruses and parasites do not survive the cooking process of potatoes. The only known outbreaks are those caused by norovirus. This pathogen is solely transmissible from person to person, with food only acting as a vehicle.

The contamination (the hazard: norovirus) does not originate from the potato chain but via food handlers, and the risk arises when good hygiene practices are not applied in the final phase of the chain.

Viruses and parasites from the potato chain do not pose a threat to public health. This means that the risk is negligible.

7.4. Potato chain risk assessment and control measures

7.4.1. Introduction

A wide variety of microorganisms can be found in potatoes and potato products. Which of these microorganisms will occur depends on many factors, including cultivation, climate, production and storage conditions and the type of product (WFBR, 2018). Not all of these microorganisms are harmful to human health. An overview of the pathogenic microorganisms found in potatoes and potato products is provided in Table 7.1.

In the previous section (7.3), the risk of each hazard has been assessed. It has been examined how the pathogen can enter the chain, whether it is actually detected in the chain, and if so, whether growth can occur and whether there are processes to help reduce its presence in the chain. And finally, it was also examined whether people fell ill due to the pathogen after consumption of potatoes and potato products. Human-pathogenic parasites are not part of this group. Therefore, this group of microorganisms is not taken into consideration in this chapter.

This section looks at the hazards and risks from a chain perspective. For each stage of the chain, the possible routes of contamination, the applicable pathogens and whether they are relevant to the Dutch potato chain have been investigated. In addition, the processes within the chain that have an effect on microbiological food safety and the measures that are necessary to control the risk of pathogenic microorganisms have been examined (see Figure 7.1).

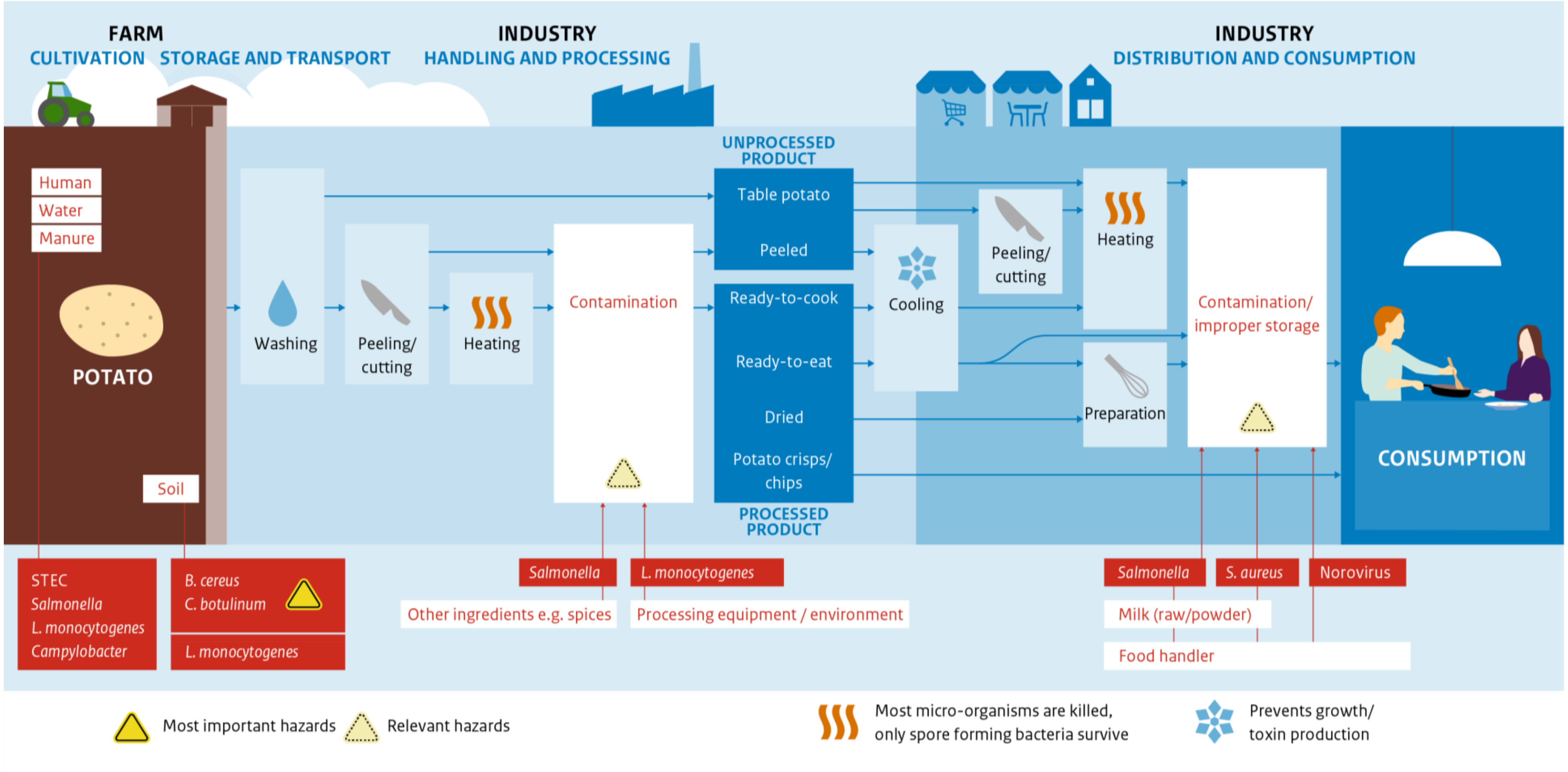

Figure 7.1. Microbiological hazards in stages of the potato production chain

7.4.2. Cultivation, storage and transport (primary phase)

Plants are naturally infected with soil-related microorganisms. Some of these bacteria that are present in the soil can cause disease in humans. This mainly refers to clostridia and bacilli, but *L. monocytogenes* also occurs in the soil.

In this way, potatoes can also become contaminated with these pathogenic bacteria. These pathogens especially are found on fresh potatoes (Table 7.5 and Table 7.6).

However, the microorganisms that are capable of causing disease in humans mainly originate from the animal and human reservoir. This means that they always originate from humans or animals and that plants only become directly or indirectly contaminated (ICMSF, 1986; EFSA BIOHAZ Panel, 2014).

As far as direct contamination from the human reservoir is concerned, food crops whose cultivation or harvest involves (a great deal of) manual work have the greatest chance of becoming contaminated. A lack of sanitary facilities (incl. toilet or hand-washing facilities) can also contribute to the contamination caused by humans.

However, potatoes grow under the ground (no direct contact with humans during cultivation), and harvest, transport and storage usually take place via mechanical means. Yet, potatoes are sorted by hand to, for example, remove the ones affected by rot. This can lead to contamination in case of poor hygiene. No data are available on the extent to which this route of contamination contributes to the total contamination of fresh potatoes. According to BuRO, this route is of less significance.

Plants can get contaminated from animal reservoirs via natural growth promoters (manure), excrement of wild animals, reptiles, rodents and pets that pass through the fields and via birds (ICMSF, 1986; EFSA BIOHAZ Panel, 2014). The risk of pathogenic microorganisms that can be transferred to humans via manure or animal excrement is highest in case of *Salmonella* and pathogenic *E. coli* (STEC) (van Os et al., 2018). In potato cultivation, fertilisation with animal manure is only done before planting, while chemical fertilisers are used during cultivation. As a result, the microbiological pressure at the time of harvest will not be high, since only the pathogenic microorganisms from manure that can survive for a longer period of time in soil may be transferred to the potatoes. Manure from wild animals and birds will play a lesser role, because in potatoes not the above-ground parts of the plant (leaves, fruits), but the parts underground are consumed.

Therefore, BuRO assesses the risk of manure, as a route of contamination for potatoes, as low.

The risk associated with the use of sewage sludge has been investigated in various studies. This sludge may contain human-pathogenic microorganisms (WFBR, 2018). In the Netherlands, the use of sewage sludge in agriculture is regulated in the Fertiliser Use Decree (*Besluit Gebruik Meststoffen*) (pursuant to Regulation 86/278/EEC[45]). The Decree implementing the Fertiliser Act (*Uitvoeringsbesluit Meststoffenwet*) sets out conditions for the use of fertilisers in agriculture. In case of sewage sludge, pathogens must be effectively eliminated before use (Regelink et al., 2017). However, due to possible contamination with heavy metals, sewage sludge is not allowed to be used as a fertiliser in potato cultivation in the Netherlands (Akkerbouw Certificeringsoverleg, 2019). Hence, the contamination route via sewage sludge can be ruled out in the Netherlands.

[45] Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture.

An indirect route of contamination, either from human or animal reservoirs, is via water: for example, if treated or untreated sewage water or ditch water (surface water) contaminated with manure or sewage water is used for irrigation. Contamination can also take place due to flooding (ICMSF, 1986; EFSA BIOHAZ Panel, 2014).

For potatoes grown under the VVAK certificate, only high-quality water may be used for sprinkler irrigation, such as well, tap and rain water, and the surface water used must be clean (contain less than 1,000 cfu/ml *E. coli*) (Akkerbouw Certificeringsoverleg, 2019). This applies to the majority of the ware potatoes grown in the Netherlands.

Moreover, sprinkler irrigation with surface water is not expected to lead to the contamination of fields and potato plants in the Netherlands since there is a ban on sprinkler irrigation for potatoes in a large part of the Netherlands[46]. This ban is imposed because of the risk of infection with the potato disease known as brown rot, which is caused by a bacterium present in surface water. For seed potatoes, which are sometimes also marketed as table potatoes, there is a ban on sprinkler irrigation with surface water throughout the Netherlands (NVWA, 2020l).

Ditchwater can become contaminated with larger amounts of manure if animal manure ends up in the ditch when fertilising grass or agricultural land. However, in the Netherlands, the regulations specify that low-emission fertilisation options should be used (RVO, 2020a). This method of fertilisation ensures that the manure does not get into the ditch. In cases where the manure is spread out, without being immediately mixed into the soil, a distance must be maintained between the fertilised area and the ditch. The likelihood of direct contamination of surface water with larger amounts of manure is thus minimised.

Existing regulations reduce the likelihood of manure-related pathogenic microorganisms spreading to potatoes via ditchwater or other water sources. In addition, BuRO does not consider this route to be an important contamination route, because potatoes grow under the ground (no direct contact).

There is an increasing demand for organic products, as well as organic potatoes. No data have been found on the effect of organic farming on the microbiological quality of potatoes or potato products (WFBR, 2018).

7.4.3. Handling of potatoes and processing of potatoes into potato products (secondary phase)

The handling and processing of potatoes involves various processes, such as washing, peeling and/or heating, that can help reduce the presence of microorganisms, to a greater or lesser extent. But there are also processes through which pathogenic microorganisms can be introduced, for example, due to the addition of ingredients or post-process contamination. After the potatoes have been processed, in many cases the growth of bacteria in the processed product will need to be prevented or slowed down sufficiently, for example, via cooling.

Washing

No data were found about the washing of potatoes and how this affects the presence of microorganisms. However, it has been shown that washing vegetables hardly has any effect on the amount of bacteria present on these vegetables (Murray et al., 2017).

Peeling

Potatoes are usually peeled before eating. It is assumed that peeling will reduce the number of microorganisms present on the potato. Particularly in case of industrially peeled potatoes, the

[46] The areas subject to the sprinkler irrigation ban are extended after the detection of brown rot. It is also examined whether certain areas can be released from the ban. The areas that are currently subject to the sprinkler irrigation ban can be found at https://www.nvwa.nl/onderwerpen/plantenziekten-en-plagen/bruinrot/verbodsgebied-gebruik-ruimtetewater.

extent of reduction will be greater if steam is used to loosen the skin of the potato. At the temperature/time combinations used, inactivation of vegetative microorganisms will occur (WFBR, 2018). But spores will survive this process. Scraping and knife peeling will also help reduce the number of microorganisms. It is not known how great this reduction will be, but in any case this will be less effective than steam peeling.

Currently, there is a growing trend of eating potatoes with their skin on (WFBR, 2018).

Heating

The heating step in the preparation process is the most effective step for reducing the number of microorganisms. The effectiveness of this step is determined both by the type of microorganism and the type of heating process. The heating process may vary from blanching, pre-cooking to cooking fully and sterilisation.

Blanching is the least effective of these processes. The main purpose of blanching is to prevent enzymatic browning. For this, the potatoes are briefly immersed in water at 58-100°C. As a side effect, this process results in a reduction of the microbial load. Blanching potato cubes in boiling water (100°C for 60 sec) results, for example, in a plate count reduction of 3 log cfu/g (Eshtiaghi & Knorr, 1993). Blanching potato slices at 88°C in steam (10 min) or water (4 min) will reduce *Salmonella* by 4.5-4.8 log cfu/g and >5.4 log cfu/g, respectively (DiPersio et al., 2005).

Pre-cooked or cooked products undergo a heat treatment that kills vegetative microorganisms and viruses, but this does not sterilise the products. Spores of *B. cereus* and *C. botulinum* will survive the preparation process. In fact, the heating process activates the spores, which can then easily germinate and grow in the product if no measures are taken to prevent this.

Post-process contamination can also occur.

Products that have been sterilised and have undergone a so-called botulinum cook will no longer contain any bacterial spore-formers.

After blanching, chips are pre-fried in hot oil (170-190°C), whereby all microorganisms present in the potatoes are killed. However, post-process contamination may still occur.

Dehydration

The production process for dehydrated potato products involves several heating steps. The first of these is blanching, for which a time-temperature combination of 3 minutes at 100°C is usually used. Steam is used for the drying process. Only spores of bacterial spore-formers will survive this process. The presence of heat-sensitive bacteria in these types of products therefore indicates post-process contamination (Table 7.5 and Table 7.6) (WFBR, 2018).

Dehydrated products do not support growth of bacteria due to a lack of available water. The water activity of these types of products is around 0.3 (WFBR, 2018), while bacterial growth requires a water activity of >0.6 (NVWA BuRO, 2016). Microorganisms, especially the species that form spores, can survive for a longer period of time (from months to years) in dehydrated products. When these products are rehydrated for preparing dishes, these microorganisms can grow if the storage conditions (time, temperature) are suitable (WFBR, 2018).

Cooling

Unless the process ensures a microbiologically stable product (dehydration, sterilisation), cooling will be necessary immediately after production as well as during storage to prevent or limit the growth of residual bacteria (especially spore-formers) and bacteria originating from any possible post-process contamination (incl. *L. monocytogenes*).

The spores of *B. cereus* and *C. botulinum* are not inherently pathogenic; to become pathogenic, they must first germinate and the new vegetative cells need to grow, whether or not in combination with toxin formation. *B. cereus* and *C. botulinum* can grow and form toxins in pre-cooked or cooked potatoes. For *C. botulinum*, this is known to be possible in raw potatoes (sliced), and it is assumed that this is also possible for *B. cereus* because of its saprophytic properties. *L. monocytogenes* can grow at refrigerator temperature. It is therefore essential to cool down prepared products quickly and store processed potatoes in the refrigerator (<7°C, preferably <4°C).

To further limit this growth, modified atmosphere packaging or vacuum packaging can be used to guarantee the microbiological quality for a longer period of time (WFBR, 2018). The growth of microorganisms that need oxygen for their growth will be inhibited when the amount of oxygen in the packaging atmosphere is reduced. This does not apply to *C. botulinum,* which grows anaerobically (WFBR, 2018).

Preservatives may also be added. Products used to prevent these products from browning (sulphite, ascorbic acid or citric acid) also act as preservatives and therefore have an inhibitory effect on the growth of bacteria. This involves a balancing act between the wishes of the consumer who wants both a ‘clean label’ (no E numbers) and a product with a longer shelf-life that has preferably undergone a mild preservation process (WFBR, 2018).

In frozen products, the growth of microorganisms is prevented due to the low temperature. It is assumed that these products will always undergo a heating step before consumption and consequently they do not pose a risk.

Post-process contamination

Various data sources (literature, monitoring studies, outbreaks, recalls) demonstrate that pathogenic bacteria that do not survive the cooking process do, however, occur on pre-cooked, cooked or fried potatoes and potato products. The presence of these heat-sensitive microorganisms in prepared dishes can only be explained by post-process contamination.

In various recalls as well as in the case of an outbreak, herbs have been cited as the cause of a *Salmonella* contamination in crisps. Other products have also become contaminated in this way. The source of the contamination is the milk component in the herb mix or the spices themselves.

Chocolate was also mentioned as a contaminated ingredient in chocolate-coated crisps. Herbs are also a well-known source of spore-formers (bacilli and clostridia) (WFBR, 2018).

In a number of recalls and in the case of one outbreak, contaminated processing equipment has been mentioned in relation to the presence of *L. monocytogenes* in various potato products. The outbreak involved mashed potatoes in a chilled ready-to-heat meal (contaminated potato masher machine). The recalls were related to various frozen potato products in the US.

L. monocytogenes, as well as bacilli (incl. *B. cereus*), are notorious for their ability to form biofilms in the processing environment and thus contaminate ready-to-eat products.

7.4.4. Spread and food preparation (tertiary phase)

The tertiary phase of the chain, i.e. trade and food preparation (mass caterer, consumer), does not fall within the scope of this risk assessment. However, the consequence of a possible hazard, i.e. the cases of disease and outbreaks, only become visible in this phase of the chain. It is precisely this phase of the chain that provides the most insight into the existing hazards, which of them constitute a risk and how these hazards can be controlled, whether or not in the production chain itself or in the last stage involving trade and food preparation.

The pathogens that are known to have caused cases of disease and outbreaks through the consumption of potatoes and potato products are *B. cereus* (incl. *B. cytotoxicus*), *C. botulinum*, *C.*

perfringens, pathogenic *E. coli* (STEC), *L. monocytogenes*, *S. aureus*, *Salmonella* and norovirus (Table 7.10).

This can be deduced from data reported to EFSA (Europe), CDC (US) and various scientific publications. In the Netherlands (2011-2017), no outbreaks were observed that could be related to the potato chain.

The pathogens most often associated with potatoes and potato products are *B. cereus* (incl. *B. cytotoxicus*), *C. botulinum*, *S. aureus* and *Salmonella*.

B. cereus (incl. *B. cytotoxicus*) and *C. botulinum* come from the potato itself, where dehydrated mashed potatoes (*B. cereus*, *B. cytotoxicus*) are also mentioned as a source of various outbreaks. These pathogens are regarded by BuRO as a relevant hazard originating from the potato chain.

S. aureus and *Salmonella* enter the product through additives (*S. aureus*: raw milk; *Salmonella*: herbs and spices) or through cross-contamination or post-process contamination (*Salmonella*: cross-contamination from raw eggs; *S. aureus*, *Salmonella*: contact with the hands of the food handler).

Apart from *Salmonella*, these pathogens need to grow in the product, which means that the hazard can only become a risk in the event of improper storage. Usually the outbreaks are caused by inadequately refrigerated storage during the preparation process (number of hours at room temperature) by the food handler (mass caterer, consumer), whether or not in combination with post-process contamination.

A product that is often cited as causing these outbreaks is mashed potatoes. This product is difficult to cool down and the added liquid (often milk) promotes the growth of bacteria. A particular product in the list of outbreaks is paprika-flavoured crisps, where *Salmonella* from the herb mix was the causative agent.

In the botulism cases, other types of products appear to have been involved. These included baked or jacket potatoes in aluminium foil that had been stored at room temperature for a longer period (one or more days), home-canned potatoes (improper canning), various products that should have been kept refrigerated (incl. canned soup or a pot of soup) and pruno, an alcoholic drink produced illegally in American prisons. In all cases, omissions made by the food handler (mass caterer, consumer) in controlling the storage and/or production process were the cause of the growth and toxin formation of *C. botulinum* in the product.

The pathogens that are less frequently mentioned as the cause of disease or outbreaks as a result of the consumption of potatoes and potato products are *C. perfringens*, pathogenic *E. coli* (STEC) and *L. monocytogenes*.

Based on this risk assessment, *C. perfringens* and pathogenic *E. coli* (STEC) are not considered relevant hazards. However, the STEC outbreaks show that fresh potatoes can be a source of cross-contamination in the kitchen.

The *L. monocytogenes* outbreak was caused by post-process contamination (potato masher machine) of a microwave meal containing mashed potatoes. However, for any ready-to-eat product, *L. monocytogenes* is a relevant hazard that needs to be controlled. But the risk arising from the potato chain is estimated as low.

Norovirus is spread by humans, and in case of most products, enters the product during preparation by the food handler (i.e. mass caterer, at home). This is not specific to potatoes or the products made from them.

EFSA has issued an opinion on the risk of pathogens in food of non-animal origin in the EU (EFSA BIOHAZ Panel, 2013). This included an analysis based on outbreaks recorded by EFSA in the period 2007-2011. With regard to potatoes, this only concerned outbreaks caused by prepared products (Table 7.10). No risk was specifically attributed to potatoes and the association with STEC was assessed as “weak”. However, there was a strong association between *B. cereus* and mashed potatoes.

Burden of disease estimates

Each year, the RIVM estimates the burden of disease caused by foodborne pathogens in the Netherlands. This also includes an estimation of the route via which humans became infected: food, environment, human, animal and travel (Figure 7.2). Within the foodborne route, a further distinction is made between the categories beef & lamb, pork, poultry, eggs, dairy, fish & shellfish, produce, beverages, grains, other foods and humans & animals (Figure 7.3) (Pijnacker et al., 2019).

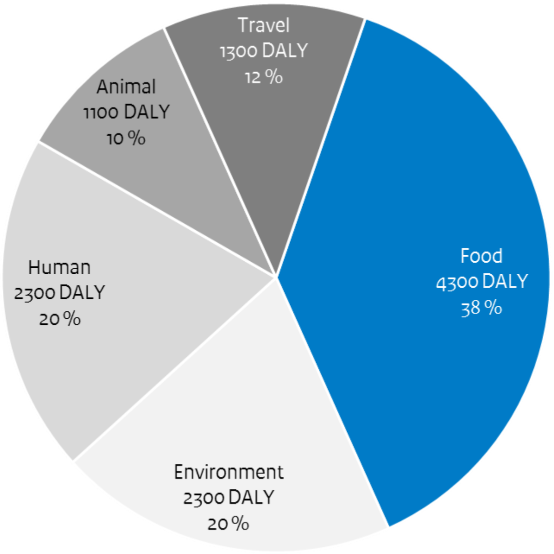

Figure 7.2 Estimated attribution of the burden of disease caused by food-related pathogenic microorganisms by main pathway of exposure in 2018 (Pijnacker et al., 2019).

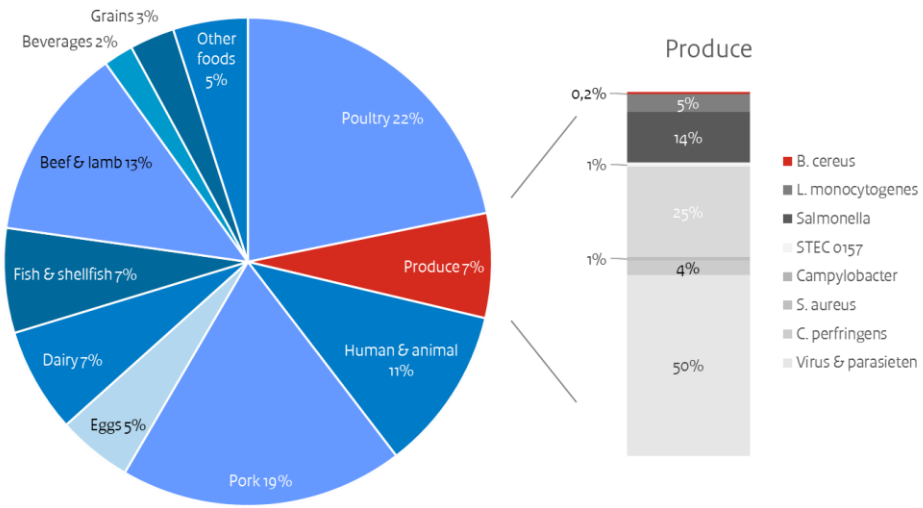

Figure 7.3 Estimated attribution of the burden of disease caused by food-related pathogenic microorganisms within food as pathway of exposure in 2018. A breakdown of the produce pathway based on the contribution of different pathogens is displayed (Pijnacker et al., 2019). The relevant hazards originating from the potato chain are indicated in red; *Clostridium botulinum* is also a relevant hazard but is not included in the burden of disease estimates.

In 2018, an estimated 1,627,150 people fell ill due to pathogens that can also be transmitted via food[43] (of whom 240 died). Based on this incidence data, the estimated burden of disease is 11,150 DALYs and the cost to society was €424 million for that year. Food is not the only pathway via which these pathogens can affect people. Source attribution based on expert opinions estimate that, in 2018, 38% of this burden of disease can be attributed to food (Figure 7.2). This is about 4,245 DALYs, involving 652,500 cases and 76 deaths. The estimated cost to society was €171 million.

Within this food-attributed burden of disease of 4,245 DALYs, the share of produce is 7% (rounded off) (285 DALYs, 39,770 cases, 5 deaths) (Figure 7.3) (Pijnacker et al., 2019).

Therefore, no burden of disease estimates are available specifically for potatoes. The RIVM has made a rough estimate of the share of potatoes within the produce category (WFBR, 2018). This is a rough estimate because there is no insight into the extent to which each type of fruit and vegetable contributes to the burden of disease caused by each pathogen. Only the relative consumption of potatoes compared to other products in the produce category - calculated as 21% - has been taken into account. However, exposure also depends on how frequently and how many pathogens are present in the various products and what proportion of the product is eaten raw or after heating.

For estimating the burden of disease caused by potatoes, the RIVM has based itself on the hazards that WFBR (2018) has indicated as being the most relevant and which originate from the potato chain itself. This only applies to *B. cereus*. In 2018, the burden of disease of *B. cereus*, as a result of the consumption of food, was 29 DALYs (91%). Of this, 0.6 DALY was caused by produce (2.1% of the total burden of disease caused by *B. cereus*) (Figure 7.4). Based on this rough estimate, the burden of disease caused by potatoes is then 0.1 DALY. This is estimated as being 203 cases (with 0 deaths).

It is difficult to arrive at estimates for *L. monocytogenes*, because this does not relate to the consumption of potatoes but the share of ready-to-eat potatoes in ready-to-eat products. No data are available in this regard.

Potato is estimated as contributing 0.003% (0.1 DALY) to the total food-attributed burden of disease in 2018 (4,245 DALYs). This represents 0.03% (203 cases) of a total of 652,500 foodborne disease cases. Based on the available data, it has been assessed that potatoes play a negligible role in the burden of disease in the Netherlands.

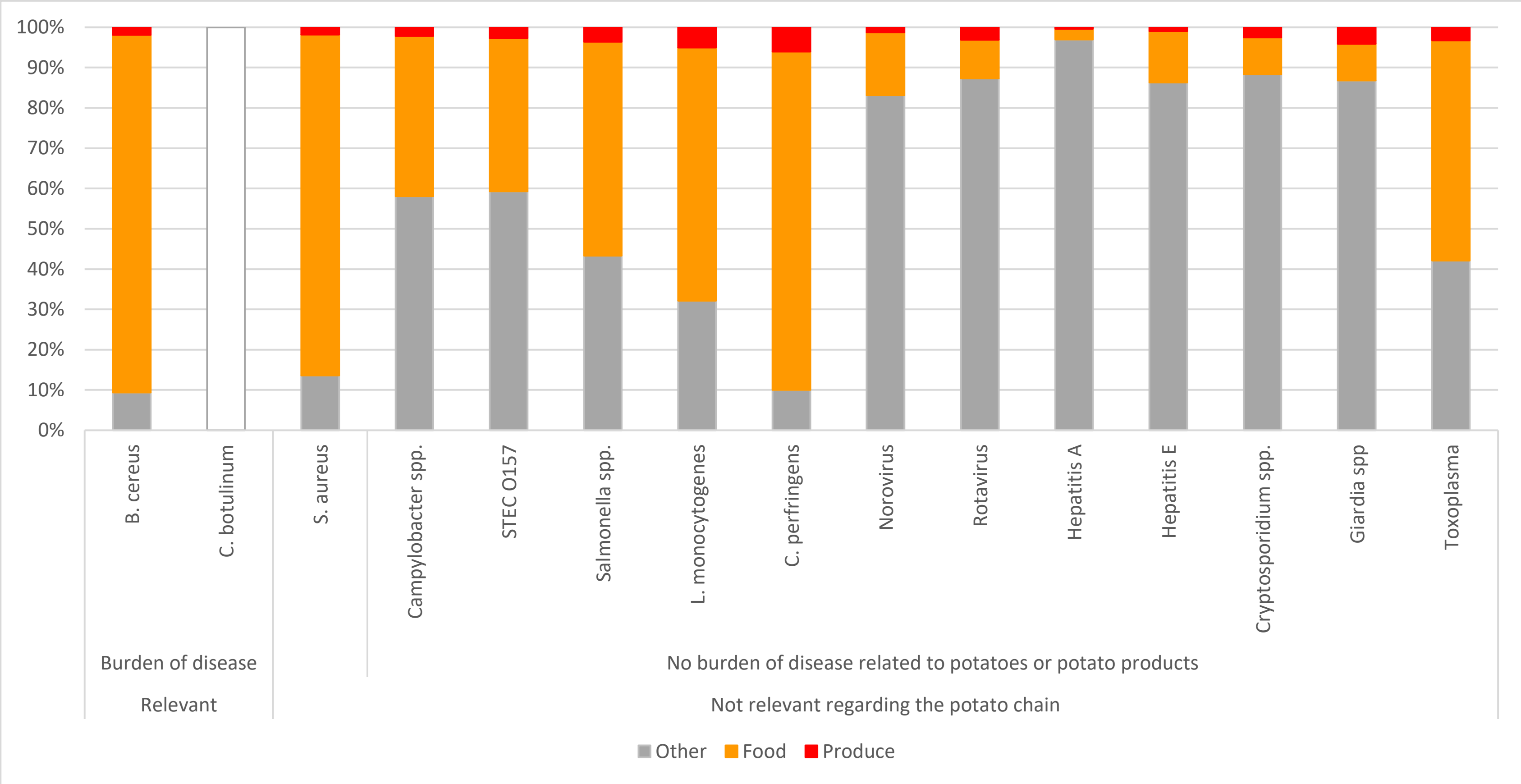

Figure 7.4 Overview of the share of produce in the estimated burden of disease caused by the 14 most relevant food-related microorganisms, with the addition of *C. botulinum*. It is indicated whether or not the pathogen is considered to be a relevant hazard in relation to the potato chain.

7.4.5. Control measures

Primary phase: Cultivation, harvest, transport and storage

An analysis of the risks arising from the microbiological hazards present in the potato chain shows that the naturally occurring pathogens in fresh potatoes (*B. cereus*, *C. botulinum*, *L. monocytogenes*) are the most relevant hazards that pose a risk emanating from the chain itself. These pathogens are inevitably introduced into the chain via fresh potatoes.

The pathogens associated with animal manure (*Salmonella*, pathogenic *E. coli* (STEC)) do not, in principle, pose a problem because they do not survive the cooking process of potatoes. However, two exceptional STEC outbreaks - in which fresh potatoes (and fresh leek) were identified as the cause and the adhering soil as a likely source of the STEC - demonstrate the need to prevent fresh potatoes from becoming contaminated with manure or manure-contaminated soil, in order to avoid cross-contamination to other prepared products in the kitchen.

- ➔ Care must be taken to ensure that table potatoes are clean.

Secondary and tertiary phase

Processing and storage activities play a role in both the secondary (industry) and tertiary (trade, food preparation) phases of the chain. Many of the control measures are therefore important for both phases of the chain.

B. cereus and *C. botulinum* survive the preparation process of processed potatoes as spore-formers. *L. monocytogenes* does not survive this process.

- ➔ *L. monocytogenes* is a well-known post-process contaminant and is primarily a hazard that needs to be controlled in chilled ready-to-eat products. Since this pathogen enters the processing environment of the potato-processing industry via the raw material (fresh potato), it is important to remain alert to ensure that this pathogen does not contaminate the ready-to-eat end product via this processing environment (biofilm).

B. cereus and *C. botulinum* can grow at lower temperatures and form toxins in food.

Further preparation (heating) of fresh (unprocessed) or pre-cooked (processed) chilled or unchilled products kills the vegetative cells of *B. cereus* and thus has an impact on the occurrence of *B. cereus* toxicoinfection. However, the toxin formed by *B. cereus* in food (food poisoning) is heat-stable and is not inactivated by further preparation (heating).

C. botulinum is primarily a hazard in chilled products that are vacuum-packed, due to the anaerobic conditions in the product. Although the botulinum toxin is heat-labile, it is also highly toxic. Therefore, it is important to prevent this toxin from forming in food under any circumstances.

- ➔ Heated products should be cooled down quickly or consumed immediately (WFBR, 2018).
- ➔ Potatoes that have been handled (unprocessed product) or processed in any way (peeled/cut, pre-cooked/fried or fully cooked) must be kept refrigerated (≤7°C, preferably ≤4°C) so that growth (and toxin formation) is slowed down or prevented. This also controls the growth of pathogens that have entered the product through post-process contamination.
- ➔ Often (in case of products with longer shelf-life) it is necessary to apply additional control measures besides cooling, such as reducing the pH level or water activity, packaging the product under modified atmosphere and/or adding preservatives (WFBR, 2018).

Additions to the cooked product (especially herb and spice mixes) present a risk of introducing pathogens (bacilli, clostridia and *Salmonella*).

- ➔ The risk of post-process contamination must be controlled. If applicable, post-packaging pasteurisation may be applied (WFBR, 2018).

Bacteria will not grow in dehydrated and frozen products, although any existing bacteria will survive.

- ➔ Post-process contamination of these products must be prevented (WFBR, 2018), especially if no further heating is required in the preparation.

Dehydrated products (incl. instant mashed potatoes) are not sterile (*B. cereus*).

- ➔ Prepared product should either be served immediately or kept refrigerated (WFBR, 2018). The responsibility for controlling these outbreaks lies with the food handler (mass caterer, consumer).

Almost all the outbreaks and cases of disease observed were caused by inadequate temperature control during storage (stored for too long outside the refrigerator) or inadequate cooling of the products (too slowly, usually outside the refrigerator) by the food handler (mass caterer, consumer), where contamination through hand contact (*S. aureus*) is also seen as an additional risk factor.

- ➔ The responsibility for controlling these outbreaks lies with the food handler (mass caterer, consumer).

7.5. Data

7.5.1. Obligation to report infectious diseases

Pursuant to the Public Health Act (*Wet publiek gezondheid, Wpg*[47]), doctors and laboratories are obliged to report certain infectious diseases to the Municipal Health Services (*Gemeentelijke Gezondheidsdienst, GGD*) if they come across these diseases in patients. This notification obligation helps in preventing the spread of infectious diseases. Some of these diseases can be transmitted via food (Table 7.2). In addition, institutions housing groups of people who are vulnerable to infectious diseases are required to report multiple cases of gastroenteritis occurring simultaneously. In all these situations, the GGD traces the source of the infection and checks whether the patient's contacts are at risk of infection. After that, the GGD can take the appropriate measures to protect the contacts and prevent the spread of the disease. If food is identified as the source of the infection, the GGD will work in collaboration with the NVWA. A report regarding this is published annually (Friesema et al., 2014; Friesema et al., 2015a;2016a; Friesema et al., 2017a; Friesema et al., 2018).

Table 7.2 Overview of notifiable infectious diseases under the Public Health Act where foodborne transmission is possible

Notifiable infection	Pathogen
Diphtheria	*Corynebacterium diphtheriae*
Tuberculosis	*Mycobacterium tuberculosis*complex (incl. *Mycobacterium bovis*)
Typhoid fever	*Salmonella typhi*
Cholera	*Vibrio cholerae*
Hepatitis A	Hepatitis E virus
Paratyphoid fever	*Salmonella paratyphi*
Shigellose	*Shigella* spp.
STEC/EHEC infection	Shiga toxin-producing *Escherichia coli* (STEC)/enterohemorrhagic *Escherichia coli* (EHEC)
Food infection with ≥2 patients*	
Anthrax	*Bacillus anthracis*
Botulism	*Clostridium botulinum*
Brucellosis	*Brucella* spp.
Variant Creutzfeldt–Jakob disease (vCJD)	Prion disease (presumed to be related to BSE)
Hantavirus infection	Hantavirus
Listeriosis	*Listeria monocytogenes*
Trichinellosis	*Trichinella* spp.
Tularaemia	*Francisella tularensis*
Gastroenteritis outbreak in institutions**	

* Refers to patients related to one another, indicating food as a source of infection

** Refers to an institution where populations vulnerable to infectious diseases stay or congregate for one or more parts of the day within a 24-hour period

[47] https://wetten.overheid.nl/BWBR0024705/2020-03-19

7.5.2. Information about potatoes and potato products and pathogenic microorganisms

Table 7.3 Overview of relevant properties of potatoes and various types of potato products

Product	pH	Aw[1]	Reference
Fresh potato	5.4–6.0	0.98	(Solomon et al., 1998; DiPersio et al., 2005; FDA, 2012)
Cooked potatoes	5.9–6.2	0.98	(Dodds, 1989; van Gerwen et al., 1997)
Mashed potatoes	5.7–5.9	0.99	(Carlin & Peck, 1996; Mahakarnchanakul & Beuchat, 1999; Thomas et al., 2002)
Dehydrated potato flakes		0.3	(WFBR, 2018)
Potato starch	6.7	0.64	(Park & Beuchat, 2000)
Crisps		0.3	(WFBR, 2018)
Gnocchi	5.0–5.3	0.96–0.98	(Del Torre et al., 2004)

[1] Aw refers to water activity

Table 7.4 Overview of relevant growth or other factors relating to pathogenic microorganisms occurring in the potato chain (source: (FDA, 2012))

Microorganism	**Gram**	**Min. Temp. (°C)**	**pH[1]**	**Min. Aw**	**O_2[2]**	**Growth required[3]**	**Min. ID[4]**	**Disease due to ingestion**	**Toxin**	**Supplementary ref.**
B. cereus	+	4	4.3/9.3	0.91	-/+	Yes	$>10^5$ cfu/g	Cells/spores[5]	[6]	(King et al., 2007)
						Yes	$>10^6$ cfu/g[7]	Toxin[8]	Heat-stable	(King et al., 2007)
C. jejuni	-	30	4.9/9.5	0.99	±	No	>500 cells	Cells	N/A	
C. botulinum	+									
Proteolytic: A,B,F		10	4.6/9	0.93	-	Yes		Toxin	Heat-labile	(Peck et al., 2011)
Non-proteolytic: B,E,F		2.5	5/9	0.93–0.97	-	Yes		Toxin	Heat-labile	(Peck et al., 2011)
C. perfringens	+	4–10	5/9	0.93	-/±	Yes	$>10^6$ cfu/g	Cells/spores	[6]	
E. coli (STEC)	-	±6.5	4/10	0.95	-/+	No	±10-100 cells	Cells	N/A	
L. monocytogenes	+	-0.4	4.4/9.4	0.92	-/+	No/Yes	$\pm 10^3$-10^4 cells	Cells	N/A	
Salmonella spp.	-	5.2	3.7/9.5	0.94	-/+	No	>1 cells	Cells	N/A	
S. aureus growth	+	7	4/10	0.83	-/+	Yes	$>10^5$ cfu/g[7]	Toxin	Heat-stable	(ICMSF, 1996)
Toxin production		10	4/9.8	0.85						
Viruses and parasites		Human-pathogenic viruses and parasites cannot grow and multiply outside their living host. Therefore, their numbers cannot increase in food.								

1 Minimum/maximum, the optimum usually lies between pH 6-7
2 O_2: oxygen needed for growth; -: strictly anaerobic, ±: microaerophilic, +: strictly aerobic: -/+: both aerobic and anaerobic growth (facultative anaerobe)
3 Growth in product required to reach minimum infectious dose or to produce toxin
4 Min. ID: minimum infectious dose. These are often estimates, where the values depend on the host, matrix and strain.
5 Diarrhoea-type symptoms
6 Formed in the intestines
7 Number of cells (cfu/g) in food that are related to toxin production
8 Vomit-type symptoms (cereulide)

7.5.3. Detection in the chain

Table 7.5 Overview of prevalence data for suspected presence of *B. cereus* in potatoes and potato products (based on references from (WFBR, 2018) indicated with a * and the cited references)

Microorganism	Product	Stage of the chain	Prevalence % (N)	Level (log cfu/g)	Country[1]	Reference
Table potato						
B. cereus	Table potato	Retail	78% (9)	2–2.8	AR	(41)*
B. cereus	Table potato	Retail	Demonstrated	endophyte	FI	(26)*
B. cereus	Table potato					(28)*
B. cereus	Hand-peeled	End user	<1%		AR	(75)*
B. cytotoxicus	Table potato	Retail	10% (10)		DE	(42)*
Ready-to-cook						
Bacillus spp.[2]	Potato slices (frozen)	Retail	16% (50)		BW	(90)*
Bacillus spp.[3]	Pre-cooked or cooked potatoes	End user	Demonstrated		NL	(98)*
B. cereus	Gnocchi (chilled)	Industry	33% (110)	1–2	IT	(99)*
Ready-to-eat						
B. cereus	Potato dishes	Catering	10% (38)		IT	(Bonerba et al., 2010)
B. cytotoxicus	Miscellaneous	Retail	0% (21)		DE	(42)*
B. cytotoxicus	Miscellaneous (fresh potato mash, gnocchi)		0% (3)		FR	(Koné et al., 2019)
B. cereus	Mashed potatoes	Food service industry	100% (10)		US	(96)*
B. cereus	Mashed potatoes	Industry	70% (10)		FR	(Choma et al., 2000)
B. cytotoxicus	Mashed potatoes (fresh)	Food service industry	100% (9)		DE	(42)*
B. cereus	Vacuum-packed potato mash	Industry	67% (6)	1.7–3.2	BE	(100)*
Dehydrated potato products						
B. cytotoxicus	Chips/crisps[4]	Retail	33% (6)		DE	(42)*
B. cytotoxicus	Chips/crisps[5]	Retail	0% (7)		DE	(42)*
B. cytotoxicus	Chrisps	Retail	67% (3)		FR	(Koné et al., 2019)

B. cereus	Dehydrated potato		40% (20)	2–3.6	US	(70)*
B. cereus	Dehydrated potato		10% (50)	1.7–2.3	AR	(63)*
B. cereus	Potato flakes		74% (50)	1–2.5	NZ	(67)*
B. cereus	Potato flakes	Retail	100% (20)	<2	FR	(Koné et al., 2019)
B. cereus	Mashed potatoes[6]		-	1–1.4	US	(Mahakarnchanakul & Beuchat, 1999)
B. cereus	Mashed potatoes (dehydrated)		92% (13)		CH	(Heini et al., 2018)
B. cytotoxicus	Mashed potatoes (dehydrated)	Retail	88% (17)		DE	(42)*
B. cytotoxicus	Potato powder/flakes/granules	Retail	67% (12)		DE	(42)*
B. cytotoxicus	Prepared product[6]	Retail	50% (24)		DE	(42)*
B. cytotoxicus	Miscellaneous (instant soup, etc.)	Retail	71% (7)		FR	(Koné et al., 2019)
Miscellaneous						
B. cytotoxicus	Other	Retail	5% (19)		DE	(42)*
B. cytotoxicus	Other	Retail	33% (15)		DE	(42)*
B. cytotoxicus	Peels	Retail	17% (6)		FR	(Koné et al., 2019)
B. cytotoxicus	Baby meals	Retail	0% (11)		DE	(42)*

[1] AR: Argentina, BE: Belgium, BW: Botswana; CH: Switzerland, DE: Germany, FI: Finland, FR: France, IT: Italy, NL: The Netherlands, NZ: New Zealand, US: United States of America
[2] No pathogenic species
[3] *B. cereus, B. polymyxa, B. licheniformis*
[4] Pre-shaped crisps, probably made from a dehydrated potato product
[5] Made from sliced potatoes
[6] Prepared product made from dehydrated potato products

Table 7.6 Overview of prevalence data for pathogens other than the *B. cereus* group in potatoes and potato products (based on references from (WFBR, 2018): * and the cited references)

Microorganism	Product	Stage of the chain	Prevalence % (N)	Levels	Country[1] (year)	Reference
Table potato						
Campylobacter		Retail	0% (10)		US (±2000)	(Thunberg et al., 2002)
Campylobacter		Farmers' market	1.6% (63)		CA (1990)	(Park & Sanders, 1992)
Campylobacter		Retail	0% (90)		CA (1990)	(Park & Sanders, 1992)
Campylobacter		Farmers' market	1.3% (75)		CA (1990)	(Park & Sanders, 1992)
C. botulinum (A)			Present			(43)*
C. botulinum (E)			68% (40)		SE	(25)*
C. botulinum (E)			100% (3)		IL	(Johannsen, 1963)
C. botulinum			0% (72)		DE	(van Leusden, 2000)
C. botulinum		Cultivation phase	0% (50)		ES	(34)*
C. perfringens		Cultivation phase	0% (50)		ES	(34)*
L. monocytogenes	Potato plant	Cultivation phase	12.2% (41)		DE (1972-1974)	(Weis & Seeliger, 1975)
L. monocytogenes		Retail	17% (12)		ES	(48)*
L. monocytogenes	Peeled and washed		10% (30)		PL	(49)*
L. monocytogenes		Retail	40% (10)		US (±2000)	(Thunberg et al., 2002)
Listeria spp.		Cultivation phase	? (50)	3 log cfu/g	ES	(34)*
L. monocytogenes		Retail	21% (132)		US (1987-1988)	(47)*
Salmonella		Retail	0% (10)		US (±2000)	(Thunberg et al., 2002)
Salmonella			1% (100)		MX (2004)	(Quiroz-Santiago et al., 2009)
Salmonella		Retail	100% (13)		US	(Wells & Butterfield, 1997)
S. aureus	Hand-peeled	End user	Present			(75)*
STEC O157:H7		Cultivation phase	0% (50)		ES	(34)*
Enterobacter cloacae	Hand-peeled	End user	Present			(75)*
Pseudomonas	Hand-peeled	End user	Present			(75)*
Klebsiella oxytoca	Hand-peeled	End user	Present			(75)*
Hafnia alvei	Hand-peeled	End user	Present			(75)*
Vibrio fluvialis	Peeled, sliced		Present			(76)*
Ready-to-cook						
C. botulinum	Cooked, vacuum		-	0.63 cfu/kg	NL	(van Leusden, 2000)

C. botulinum	Pasteurised, vacuum		0% (48)		DE	(van Leusden, 2000)
C. botulinum			0% (27)		RU	(van Leusden, 2000)
C. botulinum	Gnocchi		0% (80)		IT	(Del Torre et al., 2004)
E. coli	Rösti		0% (1562)	>2.2 log cfu/g	US (1980)	(69)*
E. coli	Chips		0% (1585)	>2.2 log cfu/g	US (1980)	(69)*
S. aureus	Rösti		1.3% (1562)	>2 log cfu/g	US (1980)	(69)*
S. aureus	Chips		0.1% (1585)	>2 log cfu/g	US (1980)	(69)*
S. aureus	Potato slices		2.0% (50)		BW	(90)*
Corynebacterium diphtheria	Potato slices		18.0% (50)		BW	(90)*
Pseudomonas aeruginosa	Potato slices		8.0% (50)		BW	(90)*
Vibrio spp.	Potato slices		12.0% (50)		BW	(90)*
Dehydrated potato products						
E. coli	Rösti		0% (1469)	>3 cfu/g	US (1980)	(69)*
E. coli	Mash		0% (1584)	>3 cfu/g	US (1980)	(69)*
L. monocytogenes	Crisps		0% (25)		EU	EFSA (2011-2018)
Salmonella	Potato starch		No data			
Salmonella	Crisps		0% (31)		EU	EFSA (2011-2018)
S. aureus	Rösti		0.1% (1409)	>2 log cfu/g	US (1980)	(69)*
S. aureus	Mash		0.3% (1584)	>2 log cfu/g	US (1980)	(69)*
Cronobacter spp.	Processing environment[2]	Industry	27% (15)			(66)*
Other						
E. coli	Potato salad		0.9% (1352)	>2.2 log cfu/g	US (1980)	(69)*
STEC	Potato dish		0% (5)		EU	EFSA (2011-2018)
S. aureus	Potato salad		0.1% (1352)	>2 log cfu/g	US (1980)	(69)*
S. aureus	Mashed potatoes	Food service industry	0% (21)		ES	(Soriano et al., 2002)
S. aureus	Potato dish		17% (12)		EU	EFSA (2011-2018)
S. aureus	Prepared products		Present			(71)*
L. monocytogenes	Potato dish		0.5% (211)		EU	EFSA (2011-2018)
Salmonella	Potato dish		1.1% (370)		EU	EFSA (2011-2018)

[1] BW: Botswana, CA: Canada, DE: Germany, ES: Spain, EU: European Union, incl. Norway, Liechtenstein, Iceland and Switzerland, IL: Israel, MX: Mexico, NL: The Netherlands, PL: Poland, RU: Russia, SE: Sweden, US: United States of America, ZA: South Africa

[2] Study conducted at one plant

Table 7.7 Overview of RASFF notifications relevant to the potato chain (1990-2018). Notifications involving potatoes and potato products, together with relevant information.

RASFF no.	Product category	Product	Hazard	Number of cfu/g
Pathogenic microorganisms				
2011.0259	Prepared dishes and snacks	Chilled gnocchi	*B. cereus*	1,800,000; 62,000; 1,400,000
2014.1402	Prepared dishes and snacks	Gnocchi	*B. cereus*	390,000
2018.0052	Prepared dishes and snacks	Chilled potato gratin	*Salmonella*	
2002.323	Fruits and vegetables	Potato crisps	*E. coli*	1,100; 0.3
Non-pathogenic microorganisms				
2002.323	Fruits and vegetables	Potato crisps	Coliforms	11,000; 2,300
2001.BHU	Fruits and vegetables	Potatoes	Fungi	
2012.ALU	Fruits and vegetables	Potatoes	Fungi	
2008.1595	Other food product/mixed	Potato salad	Yeast	

Table 7.8 Overview of the number of recall notifications, broken down by cause, recorded by the FDA in the US for the presence of pathogens in potatoes and potato products or products containing processed potatoes (2010-2018) (FDA, 2019b)

Pathogen **Cause**	**Potato slices**	**Potato product**	**Crisps**	**Miscellaneous /composite**	**Total**
Listeria monocytogenes	**1**			**3**	**4**
Contaminated environment/equipment	1			2	3
Unknown				1	1
Salmonella		**1**	**13**	**1**	**15**
Contaminated ingredient		1	13	1	15
Total	**1**	**1**	**13**	**4**	**19**

7.5.4. Growth

Table 7.9 Overview of growth possibilities of pathogens in potatoes and potato products (based on references from (WFBR, 2018) indicated with a * and the cited references)

Microorganism	Product Category	Product	T (°C)	Growth[1]	Time (days)[2]	Growth (log cfu/g)	Ref[6]
B. cereus	Prepared product	Mash	4	0			(100)*
B. cereus	Prepared product	Mash	4	0			a
B. cereus	Prepared product	Pre-cooked	5	1	>4 wks		(98)*
B. cereus	Prepared product	Mash	7	1	9	0.6–2.3	(100)*
B. cereus	Prepared product	Mash	8	1	12	2.5	(138)*
B. cereus	Prepared product	Gnocchi	8	1	50	<1	(99)*
B. cereus	Prepared product	Mash	10	1	20	5	a
B. cereus	Prepared product	Gnocchi	12	1	25	>3	(99)*
Bacillus spp.	Prepared product	Pre-cooked	14	1	1	3	(98)*
B. cereus	Prepared product	Pre-fried chips	21	1	9 hours	3	b
Bacillus spp.	Prepared product	Pre-cooked	22	1	1	4–5	(98)*
Bacillus spp.	Prepared product	Cooked	22	1	2	73	(98)*
C. botulinum toxin	Prepared product	Cooked	4	0			(79)*
C. botulinum toxin	Prepared product	Pre-cooked	5	0	15		(98)*
C. botulinum toxin	Prepared product	Mash	5	0	38		(131)*
C. botulinum	Prepared product	Gnocchi	8	0			(78)*
C. botulinum toxin	Prepared product	Mash	8	1	31		(131)*
C. botulinum toxin	Prepared product	Cooked	10	1	8		(79)*
C. botulinum toxin	Prepared product	Mash	10	0	27		(131)*
C. botulinum	Prepared product	Gnocchi	12	0			(78)*
C. botulinum toxin	Prepared product	Cooked	14	1	5		(98)*
C. botulinum toxin	Prepared product	Cooked	15	1	<4		(79)*
C. botulinum toxin	Prepared product	Mash	16	1	4.5		(131)*
C. botulinum	Prepared product	Gnocchi (-)[4]	20	1			(77)*
C. botulinum	Prepared product	Gnocchi (+)[4]	20	0			(77)*
C. botulinum toxin	Prepared product	Cooked	20	1	<4		(79)*
C. botulinum toxin	Fresh	Potato slices	22	1	4–5		(136)*
C. botulinum toxin	Prepared product	Oven-baked (foil)	22	1	6–7		(82)*
C. botulinum toxin	Prepared product	Cooked, wrapped (foil)	25	1	5–9		(80)*
C. botulinum	Prepared product	Jacket/baked potato (foil)	RT[5]	1	3–7		?
C. botulinum toxin		Cooked	RT	1	1		(81)*
L. monocytogenes	Fresh	Peeled	4	1	8	2	(117)*
L. monocytogenes	Fresh	Potato slices	8	1	12	2	(118)*
L. monocytogenes	Fresh	Potato slices	20	1	6	3–4	(118)*
Salmonella	Prepared product	Cooked	5	1	7	2	c
Salmonella	Prepared product	Salad	8	1			d
Salmonella	Prepared product	Cooked	14	1	1	5	c
Salmonella	Fresh	Potato slices	RT	1	1	1	e
S. aureus	Prepared product	Pre-cooked	5	1	7		(98)*
S. aureus	Prepared product	Cooked	8	0	42		(132)*
S. aureus	Prepared product	Cooked	10	1	1		(132)*
S. aureus	Prepared product	Salad	10	0	42		(132)*
S. aureus	Prepared product	Pre-cooked	14	1	3	3	(98)*
S. aureus	Prepared product	Salad	15	1	0.5		(132)*
S. aureus	Prepared product	Pre-cooked	22	1	1	5	(98)*

[1] 0: no growth, → Time = max. sample retention time in which no growth was observed; 1: growth was observed → Time = time to first measurement point with growth
[2] Time in days, unless stated otherwise
[3] Final concentration
[4] -: without preservative,+: with preservative
[5] RT: room temperature
[6] a: (Choma et al., 2000), b:(Doan & Davidson, 1999), c: (Tamminga et al., 1978), d: (Huang, 2016), e: (Wells & Butterfield, 1999)

7.5.5. Disease cases and outbreaks

Table 7.10 Outbreaks reported in the scientific literature relating to potatoes and potato products, supplemented with data from EFSA and CDC (based on references from (WFBR, 2018) indicated with a * and the cited references)

Pathogen	Product	Country[1], year	N[2]	Cases[3]	HA[4]	†[5]	Location	Cause	Reference
B. cereus	Mash/flakes	NL, 1967	1	-					(21)*
B. cereus		US, 1975	1	2			Home		(21)*
B. cereus	Mash/flakes	GB, 1977	1	49		1	Caterer	Improper storage	(68)*
B. cereus	Flakes	US, 1978	1	450			School	Improper storage	(21)*
B. cereus	Mash	SE, 1995-1997	5				Restaurant		(Lindqvist et al., 2000)
B. cereus	Potato and potato products	US, 1998-2017	2	51	0	0			(CDC, 2018b)
B. cereus	Mash	FI, 2008	1	5	0	0	Unknown		(18)*
B. cereus	Potatoes (in salad)	DK, 2016	1	50	1		Restaurant	Improper storage	EFSA (2011-2017)
B. cereus/B. cytotoxicus	Mash	FR, 2009	1	24			School		(Glasset et al., 2016)
B. cereus sensu lato	Mash	FR, 2013	1	12			Healthcare institution		(Glasset et al., 2016)
B. cereus sensu lato	Mash	FR, 2011	1	10			School		(Glasset et al., 2016)
B. cereus/B. cytotoxicus	Potatoes/mash	FR, 2008	1	28			Healthcare institution		(Glasset et al., 2016)
B. cytotoxicus	Mash	FR, 2003	1	-					(Guinebretière et al., 2013)
B. cytotoxicus	Mash	DE, 2007	1	-					(Guinebretière et al., 2013)
C. botulinum	Salad	US, 1992	1	2			Home		(21)*
C. botulinum A	Baked potatoes (in foil)	US, 1978	1	7	2		Restaurant	Improper storage	(103)*
C. botulinum A	Baked potatoes (in foil)	US, 1994	1	30	21	0	Restaurant	Improper storage	(105)*
C. botulinum A	Cooked potatoes	BE, 1996	0	1		1	Home	Improper storage	(102)*
C. botulinum A	Baked potatoes (in foil)	CA, 2002	0	1	0		Restaurant		(104)*
C. botulinum A	Potato and potato products	US, 1998-2017	1	29	28	2	Home	Canned at home	(CDC, 2018b;2018a), (113)*
C. botulinum A	Pruno	US, 1998-2017	1	8		0	Prison		(CDC, 2018b;2018a)
C. botulinum A	Pruno	US, 1998-2017	4	35		0	Prison		(CDC, 2018a)
C. botulinum A	Potato and potato products	US, 1998-2017	0	5				Improper storage	(CDC, 2018a)
C. botulinum A	Pruno	US, 1998-2017	0	1			Prison		(CDC, 2018a)
C. perfringens	Mash	US, 1996	1	34			Unknown		(106)*
C. perfringens	Potato and potato products	US, 1998-2017	3	131	0	0			(CDC, 2018b)*
E. coli O153:H45 (STEC)	Potato dish	US, 1994	1	372–645	35		Catering	Improper storage	(Roels et al., 1998)

E. coli O157 (STEC)	Fresh potato/leek	GB, 2011	1	250	79	1	Consumer	Soil	EFSA (2011-2017), (46)*
E. coli O157 (STEC)	Fresh potato	GB, 1985	1	≥24	11	1	Consumer	Soil	(44)*
L. monocytogenes	Mash	SE, 2018	1	7		4	Industry	Contaminated machine	(Smittskydd Västra Götaland, 2018)
Norovirus	Potato and potato products	US, 1998-2017	4	66	1	0			(CDC, 2018b)*
Norovirus	Potato	DE, 2010	1	41	0	0	Unknown		(18)*
Unknown	Potato and potato products	IE, 2014	1	4	2	0			EFSA (2011-2017)
S. aureus	Potato	GB, 1955	1	?				Food handler, improper storage	(Davies & Parry, 1958)
S. aureus	Potato	GB, 1957	1	8			Restaurant	Food handler, improper storage	(Davies & Parry, 1958)
S. aureus	Mash	US, 1975	1	12			Military base		(21)*
S. aureus	Mash	NO, 2005	1	8			Childcare	Raw milk, improper storage	(110)*
S. aureus	Mash	US, 1995	1	9			Restaurant		(115)*
S. aureus	Mashed potato product	IN, 2005	1	>100			Village festival		(Nema et al., 2007)
S. aureus	Potato and potato products	US, 1998-2017	1	19	0	0			(CDC, 2018b)*
S. aureus and *B. cereus*	Mash	AT, 2013	1	14	3		Restaurant	Raw milk, incorrectly stored	EFSA (2011-2017), (107)*
Salmonella spp.	Mash	LT, 2008	1	35	21	0	Unknown		(18)*
Salmonella spp.	Mash	JO, 1989	1	183	84		Restaurant	Food handler	(Khuri-Bulos et al., 1994)
Salmonella spp.	Potato	AT, 2005	1	85	14	0	Village festival	Raw eggs, incorrectly stored	(Schmid et al., 2006)
Salmonella spp.	Potato and potato products	US, 1998-2017	3	65	17	0			(CDC, 2018b)*
Salmonella spp.	Crisps	DE, 1993	1	±1000			Production plant	Spices	(108)*
Salmonella spp.	Mash	SG, 2007	1	55			Military base	Food handler, improper storage	(109)*

[1] AT: Austria, BE: Belgium, CA, Canada; GB: Great Britain, DE: Germany, DK: Denmark, FI: Finland, FR: France, IE: Ireland, IN: India, JO: Jordan, LT: Latvia, NL: The Netherlands, NO: Norway, SE: Sweden, SG: Singapore, US: United States
[2] N: number of outbreaks (0 = no outbreak, only sporadic cases of disease)
[3] Cases: number of patients involved
[4] HA: number of hospital admissions (if known)
[5] ✝: number of deaths (if known)

8. Chemical risks to food safety

8.1. Introduction

Chemical hazards to food safety are defined as chemical substances that may be intentionally or unintentionally introduced into food. Unintentional introduction refers not only to environmental contaminants that can be taken up by the crops during cultivation but also plant toxins that occur naturally in the plant or mycotoxins that are produced by fungi on the plant. This may also include substances that enter the food via the machines used or packaging materials. In addition, there are chemicals that can be formed during processing, for example, during the heating process.

Chemicals that are intentionally used in the production of potatoes and potato products include, for example, plant protection products[48] used during cultivation or additives used during processing.

The following substantiation of the chemical food safety risks examines the chemical substances that can enter into potatoes and potato products and subsequently pose a risk to the food safety of potatoes in the Netherlands.

The assessment of chemical food safety in the potato chain is based on an extensive study by Wageningen Food Safety Research (WFSR[49]), with additional risk assessments prepared by the RIVM on behalf of NVWA-BuRO (Nijkamp et al., 2017). Additional scientific and other relevant literature has also been consulted. In addition to the datasets consulted by WFSR, data from the Quality Programme for Agricultural Products (KAP) database[50] (2016, 2017 and 2018) and the European RASFF system (1990 to 2018) have been used, supplemented with information and available chemical measurement data from NVWA inspections. Reports published by EFSA and the NVWA containing aggregated data from a number of years were also consulted. The available period may differ per source, which makes comparison between datasets difficult and as a result of which there may be an overlap between different datasets.

8.2. Approach to the chemical risk assessment

The assessment of the chemical risks relating to the food safety of potatoes and potato products has been carried out based on the four-step risk assessment process. This method is largely based on that of the Codex Alimentarius and the method followed by EFSA, and it is in line with the systematic risk assessment referred to in the General Food Law Regulation (Regulation (EC) 178/2002).

8.2.1. Hazard identification

The chemicals that could be introduced into potatoes during cultivation, harvesting, storage and transport and during the handling and processing of potatoes have been identified.

8.2.2. Hazard characterisation

This describes the toxic effects of the substances. These descriptions have usually been taken from toxicity studies conducted on laboratory animals (rats, mice, dogs) or from epidemiological studies. The legal limits for maximum permissible levels of the substance in potatoes and potato products as well as the established health-based limit values have also been collected.

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[48] The scope of the risk assessment is limited to the risks associated with active substances and does not take into consideration possible risks from adjuvants and basic substances. Biostimulants have also not been taken into consideration in the assessment.

[49] WFSR (till 1 June 2019, known as RIKILT, part of Wageningen University & Research)

[50] The KAP database contains data on the occurrence of residues and contaminants in food and feed, as measured by the government (NVWA, WFSR).

8.2.3. Exposure assessment

To gain an idea of whether, where, how often and in what concentrations chemical substances can occur in potatoes, data on the presence of chemical substances in potatoes and potato products has been collected. For this, databases containing results of chemical analyses in potatoes and potato products were consulted. The Food Consumption Survey (VCP), conducted by the RIVM, provides a picture of the Dutch consumption of potatoes and potato products.

8.2.4. Risk characterisation

The concentrations of substances in potatoes have been compared with the legal limits, if any. If the legal limits are not exceeded, it can generally be assumed that the public health risks are extremely low or negligible. If the legal limits are exceeded, it has been checked whether the intake of the substance via consumption exceeds the health-based limit value. For each substance or group of substances, it has been indicated whether there is a risk to the food safety of potatoes and potato products on the Dutch market or whether the information for determining this risk is unavailable.

To determine whether the presence of chemical substances in potatoes and potato products poses a risk to public health in the Netherlands, it is important to know the share of potatoes and potato products in the total amount of a substance taken in via food. Finally, the contribution of intake via routes other than food is important for assessing the contribution of chemical substances in food, and more specifically, in potatoes and potato products. If available, this information has been included in the risk assessment.

The present risk assessment examines the effect of individual substances. The risk assessment of cumulative effects, as a result of simultaneous exposure to multiple substances, is an area of that is currently under development. EFSA and the RIVM are jointly coordinating a research programme on the development of methods to assess cumulative effects. At present, Cumulative Assessment Groups of plant protection products have been defined for two known toxicological effects, i.e. neurotoxicity and effects on the thyroid gland (EFSA, 2020a), (EFSA, 2020b). The effects of different substances can be assessed cumulatively within these groups. For other effects as end-points, the necessary groups are currently being defined (EC, 2019).

8.2.5. Explanation of the risk assessment

For all the identified substances, three steps of the risk assessment - hazard characterisation, exposure assessment and risk characterisation - have been followed per substance or group of substances, with the hazard characterisation and exposure assessment steps often being combined. The last step - risk characterisation - describes BuRO's assessment of the risk posed by each substance or group of substances to food safety in relation to potatoes and potato products on the Dutch market. Available risk assessments by EFSA or RIVM for a specific substance or group of substances have been taken as a basis, unless BuRO had reason to arrive at a different assessment.

Health-based limit values

The basis for the risk assessment of chemicals is the dose that is considered safe for humans. This is calculated by extrapolating toxicity data using safety factors. The safe dose is the amount of a substance that can be ingested daily over a lifetime without an appreciable health risk (chronic exposure). This amount is usually referred to as the Acceptable Daily Intake (ADI) or the Tolerable Daily Intake (TDI). The ADI applies to permitted substances such as food additives and veterinary medicinal products. The TDI applies to substances that are not deliberately added to the food and that are therefore introduced into the food unintentionally, such as environmental contaminants. For substances that can accumulate in the body, the TWI (Tolerable Weekly Intake) measure is also used, instead of the TDI. The likelihood of an effect increases if the ADI or TDI is exceeded, but this does not automatically mean that there will always be an effect. Minor or incidental exceedance of the ADI or TDI is usually not regarded as a significantly increased public health risk, as the ADI and TDI values are determined based on lifelong exposure. If the values are exceeded by a large amount or for an extended period, the likelihood of health effects will increase. If no TDI or ADI values are available or any usable data from which they can be derived, EFSA recommends using the Margin of Exposure (MoE) for the risk assessment. This looks at whether the exposure dose is low enough compared to a dose for which a small effect has been observed.

The Acute Reference Dose (ARfD) is used for the assessment of acute health effects after short-term exposure. This is the maximum amount of a substance in food or drinking water that can be ingested within a 24-hour period without any appreciable health risk.

Legal limits

In European legislation, policy-based implementation of chemical food safety is based on the principle that consumer exposure to chemical substances must be as safe as possible. Policy enforcement therefore relies on legal limits that define the maximum permissible levels of substances in food. Product standards have been established for this at the European level, i.e. the MRL (Maximum Residue Limit) or ML (Maximum Limit). MRL relates to substances that can be found as residues in food, such as plant protection products. ML relates to substances that can be unintentionally introduced into food, such as environmental contaminants. For additives (E numbers), the product standard is defined in terms of maximum use levels. All three are legal limits that have been established for a specific substance-food combination. The Specific Migration Limit (SML) is the maximum permitted amount of a given substance released from a material or article into food or food simulants. This is expressed in mg of substance per kg of food.

MRLs for plant protection products in and on food[51] are established in line with Good Agricultural Practice (GAP)[52]. The expected MRL on the crop is calculated based on the prescribed use (for example, amount to be used per hectare, spraying conditions, number of applications). This value is compared to the health-based limit value by estimating the amount ingested (in other words, how much of a crop is consumed by the consumer). This also takes into account, as far as possible, the presence of residues in other sources (food and drinking water) and the amounts ingested by vulnerable groups and consumers who consume large quantities of the particular type of food. If the health-based limit values are not exceeded, the MRL is finalised and included in Regulation (EC) 396/2005. If the MRL leads to ingestion amounts that are far below the health-based limit values, the MRL is not adjusted upwards. If the calculated value for the MRL is such that it leads to the health-based limit values being exceeded, the plant protection product will not be authorised for that application. MRLs are established for a substance-product combination, where products are grouped together as far as possible so that a single common MRL can be set for them. This means that the MRL is not a toxicological limit value and therefore an exceedance of the MRL does not automatically imply a risk to food safety. Exceedances of the MRL may point towards a conflict with the conditions of use specified in the statutory instructions for use and an unnecessarily higher level of exposure of the consumer to plant protection products than desired.

MLs for contaminants are established at the European level if a risk assessment by EFSA shows that the level of exposure of the consumer to a contaminant is higher than the safe health-based limit value. These MLs for contaminants are based on the ALARA (As Low As Reasonably Achievable) principle. In this way, food business operators are forced to ensure that their products contain as few contaminants as possible. Exceedance of a legal limit does not necessarily imply that there is an acute health risk (NVWA, 2018c).

[51] Regulation (EC) No. 396/2005 of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EC.

[52] Regulation (EC) 396/2005, Art.3: Good Agricultural Practice (GAP): nationally recommended, authorised or registered safe use of plant protection products under actual conditions at any stage of production, storage, transport, distribution and processing of food and feed. It also implies the application, in conformity with Directive 91/414/EEC, of the principles of integrated pest control in a given climate zone, as well as using the minimum amount of pesticides and setting MRLs/temporary MRLs at the lowest level that allows the desired effect to be obtained.

The SML is the maximum amount of a chemical that is allowed to migrate from a food contact material to food. It is a safety limit based on toxicological data. SMLs have been legally established per material category for specific food contact materials. For most material categories, an Overall Migration Limit (OML) of 60 mg/kg food applies. This OML has been set because, in principle, food packaging must be inert and release as few substances as possible into the food.

Concentrations of the substances

Before using the results of measured concentrations of the substances, it is important to check whether the measurements give a representative picture of the presence of chemical substances in potatoes on the Dutch market. Samples taken in response to a suspected contamination, a calamity or an incident may not be representative of the average exposure level. However, the distinction between representative samples and ‘suspect’ samples is not always clear in reports and databases. The present risk assessment therefore uses these terms interchangeably, where it tends to overestimate rather than underestimate the risk.

For calculating the mean or median value of the concentrations, the values below the Limit of Detection (LOD) can be taken into account in three different ways: by calculating with the LOD (Upper Bound, UB), with half of the LOD (Medium Bound, MB) or with zero (Lower Bound, LB). The UB concentration is a high estimate of the exposure concentration and the LB is a low estimate of the exposure concentration. The assumed values will be indicated in this risk assessment. This often depends on the choice of the researcher reporting the value. In addition, the intake calculations (exposure concentration x consumption) are based on either high consumption (P95 or P99 of the consumption distribution curve representing high consumers) or median consumption (P50 of the consumption distribution curve). These data, combined with ADI/TDI values, are then used to calculate the risk posed by a chemical substance due to intake via food.

8.3. Risk assessment of chemical hazards

To draw up an inventory of the possible chemical hazards that can occur in the potato chain, the processes and actions taking place in the chain, as well as the chemical substances that could be introduced as a result, have been examined (see Figure 8.1, Table 8.1). The chemical substances described in scientific or other relevant reports as a possible risk to the food safety of potatoes and potato products, RASFF notifications and substances identified during monitoring and enforcement have been taken into account. In addition, relevant informational videos published by the potato sector have been viewed on YouTube.

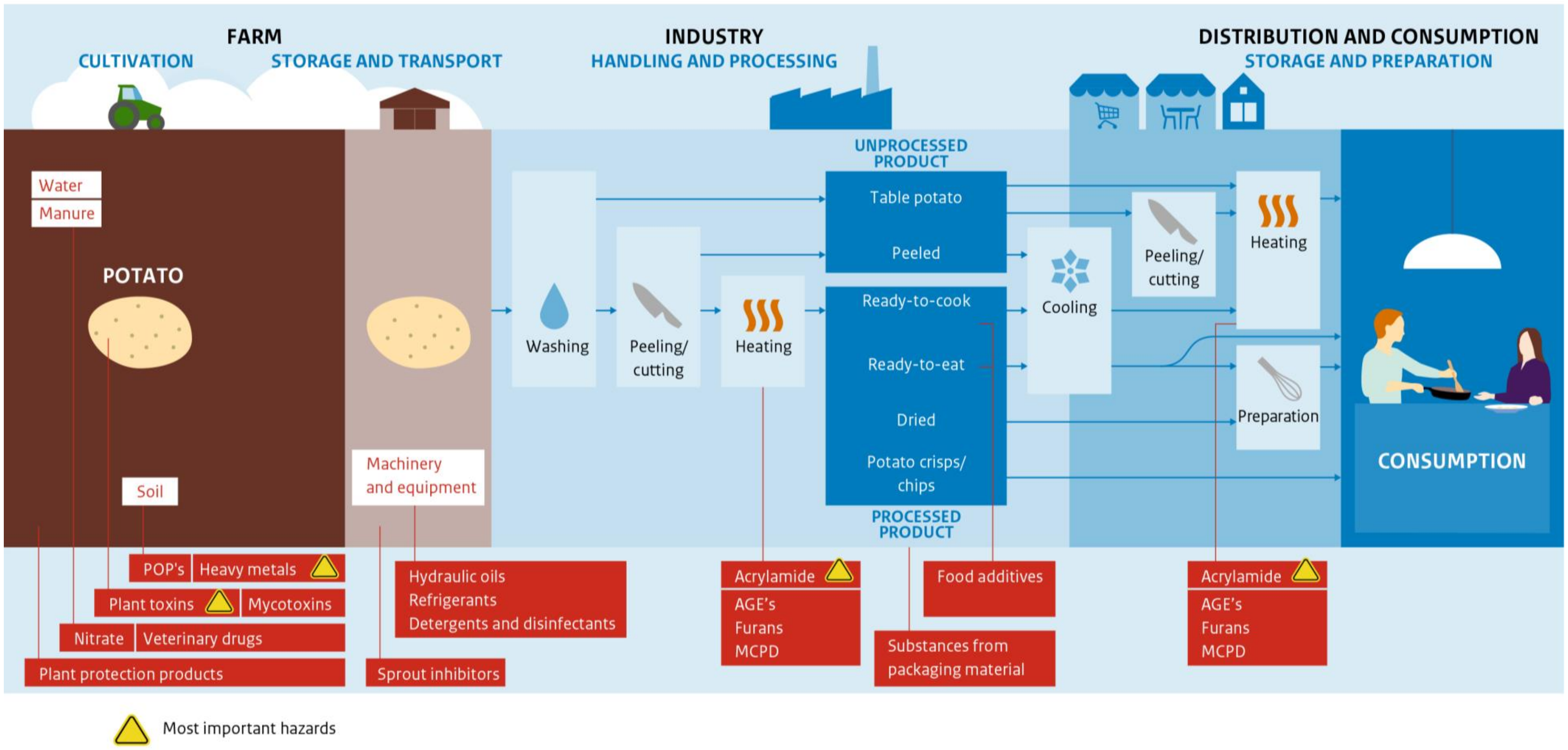

Figure 8.1. Chemical hazards in the various stages of the potato production chain

8.3.1. Cultivation phase

Natural toxins can be formed in and on potatoes during the growth of the plant. Plant toxins are substances that are formed by the plant (for example, solanine) to protect itself against pests (fungi and damage by insects). Fungi present on the plant can also form toxins (mycotoxins).

Environmental contaminants that accumulate in the soil, such as heavy metals, can be absorbed by the plant from the contaminated soil. Sprinkler irrigation with surface water and flooding during heavy rainfall can also transfer contaminants from surface water to the plants and the field. As a result of climate change, heavy rainfall is expected to increase, which will cause more flooding. Sprinkler irrigation with surface water is not expected to contribute significantly to the contamination of the field and plants, because a ban on using sprinkler irrigation for potatoes has been in effect for a large part of the Netherlands since the 1990s[53]. This ban has been imposed because of the risk of contamination with brown rot (caused by a bacterium present in surface water). For seed potatoes, sprinkler irrigation using surface water is prohibited throughout the Netherlands since 2005 (NVWA, 2020l).

Persistent organic pollutants can survive in the environment for a long time. This includes brominated flame retardants, dioxins and polychlorinated biphenyls (PCBs), perfluorinated compounds and organochlorine pesticides. Each of these groups of substances consists of a large number of individual substances.

Fertilisation of the field provides nutrients for potato cultivation. Excessively high concentrations of certain fertilising substances (e.g. nitrate) in potatoes could pose a threat to food safety. In addition, the manure itself may contain contaminants.

Finally, various plant protection products are used during cultivation, residues of which can remain on or in the potatoes.

8.3.2. Harvesting, storage and transport

During this phase, chemical hazards can be introduced as a result of contaminants from hydraulic or other machines used for lifting, transporting and storing the potatoes. Climate control systems are used to control the temperature during storage. Leaks from these systems can also cause contaminate the potatoes.

During storage, sprout inhibitors and fungicides are used to prevent the potatoes from sprouting and to control the formation of mould.

Cleaning and disinfecting agents are used for cleaning and disinfecting transport crates and the machines and materials used for lifting, sorting and processing potatoes. Disinfection procedures are carried out to prevent the spread of potato and plant diseases.

8.3.3. Handling and processing

During the handling and processing of potatoes, various substances can end up in or on the potatoes. These may be processing aids used for washing and sorting the potatoes or substances that are added to a potato product, for example, to preserve it. Cleaning agents and disinfectants are also used during these steps to clean and disinfect machines and equipment.

New substances can also be introduced when preparing and heating potatoes, for example, for the production of pre-fried chips. Finally, substances can migrate from packaging materials to the

[53] The areas subject to the sprinkler irrigation ban are extended after the detection of brown rot. It is also examined whether certain areas can be released from the ban. The areas that are currently subject to the sprinkler irrigation ban can be found at https://www.nvwa.nl/onderwerpen/plantenziekten-en-plagen/bruinrot/verbodsgebied-gebruik-ruimtetewater.

potato product. This may also apply to other food contact materials, such as cardboard containers for chips.

In addition, ignorance, incompetence or fraud on the part of producers or traders may lead to the introduction of chemical substances. Examples of this include the excessively high concentration of Sudan Red (a prohibited additive) in potato crisps from India (RASFF 2003) and the improper use of colouring agents (E104, E102 and E110; RASFF 2016, 2017). In 2008, there two reports of melamine found in crisps from China (RASFF period from 1990 to 2018).

Table 8.1 Chemical hazards in the potato chain.

Hazard category	**Substances**	**Source or pathway of introduction**
Stage 3: Production of ware potatoes		
Cultivation		
Plant toxins	Glycoalkaloids (incl. solanine, chaconine)	Naturally occurring in potato plant
	Tropane alkaloids (incl. calystegines)	
Mycotoxins	Trichothecenes (incl. deoxynivalenol (DON), diacetoxyscirpenol (DAS))	Produced by fungi in the potato (e.g. Fusarium)
Persistent Organic Pollutants (POPs)	Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF)	Contaminated arable land (persistent substances are mainly formed by combustion processes)
	Polycyclic aromatic hydrocarbons (PAHs)	
	Polychlorinated biphenyls (PCB)	Contaminated arable land (emission of these substances (from plastics, textiles, electronics, printed circuit boards, hydraulic fluids, Teflon, fire extinguishers) into the environment/accumulation in the soil)
	Brominated flame retardants	
	Perfluorinated compounds (PFAS)	
	Organochlorine pesticides	Persistent substances that are still present in the environment (accumulation in the soil) after earlier use
Radioactive substances	Radioactive caesium	Environmental contamination (after incident involving radioactive substances)
Heavy metals	Lead	• Contaminated arable land (through the use of fertilisers, including earlier use of sewage sludge or • atmospheric deposition (regional))
	Cadmium	
	Arsenic	
	Mercury	
Fertilisers and contaminated manure	Nitrate	Fertilisation of the soil

	Veterinary medicinal products	Spreading of manure
	Drug waste	Spreading of manure, after illegal dumping of drug waste in liquid-manure cellar
Plant protection products	Fungicides	• Use of plant protection products during potato cultivation • Plant protection products from previous crops • Irrigation/spraying with contaminated surface water
	Herbicides	
	Insecticides	
	Nematicides	
Harvesting, storage and transport of ware potatoes		
Sprout inhibitors	Chlorpropham	Use during storage
	1,4,-dimethylnaphthalene	
	Maleic hydrazide	
	Ethylene and green mint oil	
	Carvone	
Hydraulic oils and lubricants	Mineral oils (paraffin)	Leakage from hydraulic harvesters, conveyors, machines used for handling and processing potatoes
Refrigerants	Hydrochlorofluorocarbons	Leakage from cooling installations
	Hydrofluorocarbons	
Disinfectants	Benzoic acid	Disinfection of machines, tools (use in planting, harvesting, transporting, sorting, spraying) and surfaces (floors, tables, storage areas, crates)
	• Quaternary ammonium compounds (QUATs) • Didecylmethyl ammonium chloride (DDAC) • Benzalkonium chloride (BAC)	
	Peracetic acid/hydrogen peroxide	
	Sodium hypochlorite	
	Tosylchloramide-sodium	
Stage 4: Handling and processing of ware potatoes		
Processing aids	Clay (with possible contaminants)	Clay bath for sorting potatoes
	Antifoaming agents	• Removal of organic contamination from washing water (flocculation of colloid particles) • Reduction in sugar content

	Polymer flocculants	
Food additives	Preservatives	• Additives (E numbers) during the production of potato products •
	Acids	
	Antioxidants	
Substances that arise during preparation (heating)	Acrylamide	Substances that arise during preparation (heating) of potatoes (chips, crisps)
	Advanced glycation end products (AGEs) (e.g. CML, CEL and MG)	
	Furans	
	MCPD and MCPD esters	
Substances from packaging materials and other food contact materials	Precursors and additives	Migration from packaging materials and other food contact materials

8.3.4. Plant toxins

Glycoalkaloids

Plant toxins are toxins that can occur naturally in plants. Glycoalkaloids belong to a group of substances found in plants of the nightshade family, including the potato. The main glycoalkaloids specifically related to potatoes are α-solanine, α-chaconine and β-chaconine. Glycoalkaloids are produced as a defence mechanism to protect the plant against fungi, microorganisms and insects (Haasse, 2010). They are created and broken down in all parts of the potato plant, including the tuber, with the highest levels occurring during the flowering season. The amount of glycoalkaloids depends on the potato variety and the growing conditions (soil, climate, amount of light to which tubers are exposed). After the harvest, glycoalkaloid content can increase further under the influence of light and storage temperature and in case of damage to the potato. The highest concentrations of glycoalkaloids are found in and just below the skin and around the sprouts ('eyes') of the potato, as well as in the haulm and in damaged potatoes. Starch potatoes contain higher levels of glycoalkaloids than ware potatoes. Glycoalkaloids give the potato a bitter taste (Nijkamp et al., 2017).

Solanine and chaconine are chemically related substances (Rietjens et al., 2005). Toxic effects after ingestion of these substances include nausea, neurological effects (dizziness, drowsiness, confusion), cardiovascular effects (incl. increased heart rate), cell membrane disruptions resulting in internal bleeding and hepatotoxic effects. Solanine does not appear to be mutagenic but there is evidence of teratogenicity (Nijkamp et al., 2017),(Rietjens et al., 2005). Based on a limited number of available studies, EFSA concludes that there is no evidence of genotoxicity of α-solanine and α-chaconine (EFSA CONTAM Panel, 2020a). Due to the non-specific symptoms of glycoalkaloid poisoning, the relationship with this substance often goes unrecognised. Only a few cases of glycoalkaloid poisoning have been described. In the period 2014-2018, five reports were made to the National Poisons Information Centre (*Nationaal Vergiftigingen Informatie Centrum, NVIC*) relating to the intake of green potatoes followed by symptoms of poisoning (nausea, vomiting, abdominal pain, muscle spasms) (NVIC, 2019). In 2015, the Bundesinstitut für Risikobewertung (BfR) reported that an entire family in Germany fell ill after eating unpeeled potatoes. The glycoalkaloid content was 236 mg/kg potatoes (BfR, 2018a).

No legal limits have been established in the EU for the occurrence of glycoalkaloids in potatoes. Sweden and Finland have established a legal limit of 200 mg at the national level for the amount of glycoalkaloids per kg of fresh potatoes (Nijkamp et al., 2017). This standard is also used in the Netherlands but is not laid down by law (NVWA, 2018c). In new potato cultivars, the targeted limit is 100 mg/kg. The average content in the registered cultivars is 48.4 mg/kg (EFSA CONTAM Panel, 2020a). In Hungary, a maximum level of 100 mg/kg of fresh unpeeled potatoes is laid down via national legislation (EFSA CONTAM Panel, 2020a). In 2018, BfR derived a provisional NOAEL (No Observed Adverse Effect Level) of 0.5 mg glycoalkaloids/kg body weight per day. For this, they state that the glycoalkaloid content in potatoes must not exceed 100 mg/kg fresh weight, based on a consumption of 350 grams of potatoes and potato products per day (BfR, 2018b). This is in line with the findings of the WHO in 1992, i.e. that the customary glycoalkaloid levels (20-100 mg/kg) will not lead to health problems (Joint FAO/WHO Expert Committee on Food Additives, 1992).

For Europe, the reported measured concentrations in potatoes lie between 20 and 1560 mg total glycoalkaloids/kg (based on studies from 1997 and 2008-2014) (Nijkamp et al., 2017). For the sum of α-solanine and α-chaconine, EFSA reports an average content of 52.0 mg/kg (UB) and a maximum content of 550.3 mg/kg (UB). This has been calculated based on data from Germany, Sweden and the Netherlands (2005, 2007, 2015, 2016 and 2017). For the Dutch data (2015 and 2016), the average is 50.5 mg/kg (n = 133; range: 8.8-166.6 mg/kg fresh weight) (EFSA CONTAM Panel, 2020b). In a Dutch study conducted in 2015 on the optimisation of the analysis method for glycoalkaloids in potatoes, the average levels of α-solanine and α-chaconine in potatoes reported are approximately 25 mg/kg fresh weight (n = 69; range: 0.7-89.0 mg/kg fresh weight (α-solanine) and 0.6-66.2 mg/kg fresh weight (α-chaconine)) (López, 2016). A study on glycoalkaloids in potatoes was conducted by RIKILT[49] in 2016. For solanine, an average value of 28.3 mg/kg (n = 157, max: 95.9 mg/kg), and for α-chaconine, mean values of 24 mg/kg (n = 157, max: 97.1 mg/kg) are reported (NVWA, 2018c). In Dutch potatoes, these levels are below the applicable limit of 200 mg total glycoalkaloids/kg fresh potatoes, and in most cases, also below 100 mg/kg.

The levels of solanine and other glycoalkaloids in potatoes are lower after preparation than the measured concentrations in fresh potatoes. A large number of the glycoalkaloids are removed when the potatoes are peeled (25-75%) (EFSA CONTAM Panel, 2020a). Cooking, frying or deep-frying peeled potatoes also removes some of the glycoalkaloids (5-90%) (Nijkamp et al., 2017) (EFSA CONTAM Panel, 2020a). The storage conditions (dark and cool) and the removal of the parts of the potato with the highest amount of glycoalkaloids (the 'eyes', haulm and damaged potatoes) before preparation also help in lowering the glycoalkaloid content in potatoes (BfR, 2018c).

In a probabilistic exposure study carried out in 2009, the exposure to glycoalkaloids via potatoes for Dutch consumers was estimated to be 24 µg/kg body weight per day (P50) and 601 µg/kg body weight per day (P99) for an acute exposure. For chronic exposure, this was 154 µg/kg body weight per day (P50) and 374 µg/kg body weight per day (P99). This study used Dutch food consumption data from 1997/1998 (1-97 years) and concentration data of glycoalkaloids in potatoes from Sweden (1997) and the Czech Republic (2004-2005) (Nijkamp et al., 2017); range: 6.3 and 302.9 mg/kg fresh potato (n = 372; median: 64.0 mg/kg and average 70.4 mg/kg) (Ruprich et al., 2009).

The acute lethal dose for humans is estimated to be 3-6 mg glycoalkaloids per kg body weight (i.e. 180-360 mg for a person weighing 60 kg) (Nijkamp et al., 2017; EFSA CONTAM Panel, 2020a). For acute toxicity, EFSA uses a LOAEL (Lowest Observed Adverse Effect Level) of 1 mg/kg body weight per day as a reference point. Since the available data on acute toxicity is considered insufficient to derive a health-based limit value, EFSA uses a MoE approach to assess the health risks of ingesting glycoalkaloids. A minimum MoE of 10 has been established for this[54] (EFSA CONTAM Panel, 2020a).

Based on probabilistic calculations of the intake of glycoalkaloids via prepared, peeled potatoes, EFSA concludes that there is a risk for infants (average and P95 exposure) and for adults with the

[54] The MoE of 10 consists of a factor of 3 for extrapolation of LOAEL to NOAEL and a factor of 3 for variability between individuals.

highest exposure (P95). This is based on German, Dutch and Swedish data on α-solanine and α-chaconine in potatoes. It should be noted that uncertainties in the data can lead to both an overestimation and underestimation of the risk (EFSA CONTAM Panel, 2020a).

EFSA states that there is not enough data to establish a reference point for chronic exposure due to the lack of knowledge about the possible chronic health issues that may occur (EFSA CONTAM Panel, 2020a).

Based on the Dutch data only, the MoE for acute exposure was calculated for the various age categories (Table 8.2). For high exposure (P95), these are just below the limit of 10 for all age categories. This indicates that glycoalkaloids in potatoes gives rise to a potential food safety risk. With average exposure, the MoE remains above 10, except for children aged 7-14 (food consumption data for 2007-2010).

Table 8.2 Margin of Exposure (MoE) in case of acute exposure to the sum of α-solanine and α-chaconine for Dutch consumers. Exposure (µg/kg body weight per day) calculated by EFSA (EFSA CONTAM Panel, 2020b). MoE calculated with respect to reference point of 1 mg/kg body weight per day.

		Food consumption data	**Exposure (average)**		**Exposure (P95)**	
		Year	**µg/kg body weight per day**	**MoE**	**µg/kg body weight per day**	**MoE**
Young children	2 years	2006–2007	92.8	10.8	293.0	3.4
Children	3-7 years	2006–2007	74.4	13.4	227.6	4.4
Children	7-14 years	2007–2010	112.2	8.9	384.9	2.6
Adolescents	14-19 years	2007–2010	79.5	12.6	268.5	3.7
Adults	19-51 years	2007–2010	53.8	18.6	181.1	5.5
Parents	51-70 years	2007–2010	41.8	23.9	135.6	7.4
Parents	70-80 years	2010–2012	41.3	24.2	122.5	8.2
Elderly of advanced age	Over 80 years old	2010–2012	38.8	25.8	115.4	8.7

Summary

- Glycoalkaloids, including solanine and chaconine, occur naturally in potatoes.
- Potato variety, cultivation method and storage conditions influence glycoalkaloid levels in potatoes.
- No legal limits have been established at the EU level for glycoalkaloid levels in potatoes. In Sweden and Finland, a limit of 200 mg/kg for glycoalkaloids is laid down as a national legal limit. This standard is also used in the Netherlands but is not laid down by law.
- A study by BfR (2015) warns that concentrations of glycoalkaloids above 100 mg/kg fresh weight could lead to health problems.
- The total glycoalkaloid levels measured in Dutch potatoes lie below the applicable limit of 200 mg/kg fresh potatoes, and in a few cases, above 100 mg/kg.
- A large part of the glycoalkaloids can be removed by peeling, cooking, frying or deep-frying the potatoes.

➔ Based on acute exposure calculations for prepared, cooked potatoes, it is assessed that glycoalkaloids in potatoes give rise to a potential food safety risk in case of high intake levels. No statement can be made about food safety risks associated with chronic exposure.

Tropane alkaloids

Other plant toxins formed in potatoes include the calystegines, which belong to the group of tropane alkaloids. Calystegines A3, B2 and B4 are the most commonly found calystegines in potatoes (Mulder et al., 2016). The potato variety influences the calystegine content, which is associated with the amount of sucrose available in the potato. The highest concentrations are found in the skin and 'eyes' of the potato (Nijkamp et al., 2017). Unlike in the case of glycoalkaloids, damage to the potato or exposure to light does not affect the calystegine content in potatoes (Nijkamp et al., 2017).

Little is known about the toxic effects of calystegines. Calystegines are considered to be a potential glucosidase inhibitor (Mulder et al., 2016); (EFSA, 2019c).

No maximum product standards have been laid down by law in Europe for tropane alkaloids in potatoes. No health-based limit values have yet been derived for calystegines.

A study of the occurrence of tropane alkaloids in food in Europe shows that potatoes and eggplants are the main edible crops in which calystegines are found. Calystegines were found in all potatoes that were tested for this, with an average concentration of 161.6 mg/kg fresh weight and a maximum concentration of 507.3 mg/kg fresh weight (n = 297) (Mulder et al., 2016). The process of preparing the potatoes seems to lower the concentrations of calystegines (mean concentration in processed potatoes 95.6 mg/kg, maximum concentration 207.7 mg/kg; n = 11) (EFSA, 2019c).

Due to the lack of information about the toxicity of calystegines and the absence of health-based limit values and product standards, the food safety risk due to calystegines in potatoes cannot be determined.

Summary

- Calystegine occurs naturally in potatoes, especially in the skin and in the 'eyes'.
- The potato variety influences the levels of calystegines in the potatoes.
- No legal limits have been established for calystegines in potatoes.

➔ Due to the lack of information about the toxicity of calystegines and the absence of health-based limit values, the food safety risk due to calystegines in potatoes cannot be determined.

8.3.5. Mycotoxins

Mycotoxins are toxins produced by fungi that can occur in crops such as maize and grain and also potatoes. Moist, damp environments and higher temperatures promote the growth of fungi. With the more extreme weather conditions expected due to climate change (wetter, higher temperatures), we may need to pay additional attention to the potential contamination of food and feed crops by mycotoxins in future. Contaminations may occur more frequently and other countries may also be identified as risk areas.

Fungi species belonging to the genus *Fusarium*, known to cause rotting in potatoes, produces diacetoxyscirpenol (DAS) and deoxynivalenol (DON) during cultivation (Nijkamp et al., 2017). These are the most commonly reported mycotoxins for potatoes.

The main toxic effect of DAS is haematotoxicity (based on animal studies). Reprotoxicity has been reported in animal experiments. Too little toxicity data are available to make a statement about the genotoxicity and carcinogenicity of DAS (EFSA CONTAM Panel, 2018b). DON is reprotoxic in rats and affects the immune system (in laboratory animals). *In vitro*, DON was also found to be genotoxic. There is no evidence relating to the carcinogenicity of DON (EFSA CONTAM Panel, 2017b).

No MLs for mycotoxins in potatoes have been established. Hardly any data have been found about the levels of DAS or DON in potatoes. The highest concentration of DAS in potato products reported by EFSA is 21 µg/kg (n = 21, of which 5 are positive) (EFSA CONTAM Panel, 2018b). The 2017 EFSA study on DON contains data for potatoes derived from the study of composite foods containing potatoes (n = 4), where concentrations are around 120 µg/kg, and for the 'Starchy roots and tubers' category (n = 6), the concentrations are below the LOD (EFSA CONTAM Panel, 2017b). In a Dutch study, the concentration of DON and DAS is measured as being below the Limit of Quantification (LOQ) (2.5 µg/kg and 1.0 µg/kg respectively) in a combined potato sample (n = 1) (López Sánchez et al., 2016).

The ARfD for DAS derived by EFSA lies at 3.2 µg/kg body weight and the TDI at 0.65 µg/kg body weight. EFSA concludes that no chronic or acute health effects are to be expected as a result of the intake of DAS via food (EFSA CONTAM Panel, 2018b).

The ARfD for DON (including the metabolites Ac-DON, 15-Ac-DON and DON-3-glucoside) is 8 µg/kg body weight (EFSA CONTAM Panel, 2017b). For the intake of DON via food, EFSA concludes that there is no acute food safety risk (EFSA CONTAM Panel, 2017b).

For chronic exposure, the TDI for DON and metabolites is 1 µg/kg body weight per day. As calculated by EFSA, the average chronic exposure from food exceeds the TDI for DON in children, and at high levels of exposure, in adults as well, which may lead to a potential public health risk. On the other hand, EFSA concludes in the same study that, based on a qualitative uncertainty analysis, the risks for DON have been overestimated rather than underestimated (EFSA CONTAM Panel, 2017b).

For a number of mycotoxins, including DON and metabolites of DON, a Dutch total diet study (2013) concluded that the TDI is not exceeded (López Sánchez et al., 2016). The largest source of intake of DON and DAS from food is via grains and grain products (bread, pasta). Potatoes are a less significant source (EFSA CONTAM Panel, 2017b), (López Sánchez et al., 2016; EFSA CONTAM Panel, 2018b). Hence, DON and DAS do not constitute a food safety risk in potatoes.

Summary

- The most commonly reported mycotoxins for potatoes are DON and DAS that are formed when the potato tubers are affected by *Fusarium* spp.
- Grain products are the main source of exposure to DAS and DON (incl. metabolites), while the contribution of potatoes is much lower.
- Exposure to DAS from food does not entail a health risk.
- Exposure to DON from food entails a minor risk. The TDI can be exceeded in children and also in adults at high exposure levels.

➔ Mycotoxins in potatoes do not pose a risk to the food safety of potatoes and potato products since concentrations are low (below the LOD) and exposure calculations show that the contribution of potatoes is small.

8.3.6. Persistent organic pollutants

Persistent organic pollutants are widespread in the environment. This includes organic contaminants such as dioxins and PCBs, brominated flame retardants, polycyclic aromatic hydrocarbons (PAHs) and perfluorinated compounds. Each of these groups of substances consist of a large number of individual substances. Their persistent character means they can survive in the environment for a long time and accumulate in soil. From there, they can be absorbed by the plant.

Dioxins, dibenzofurans and polychlorinated biphenyls

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF)[55] are formed during combustion processes, if the burnt materials contain chlorinated components (e.g. PVC). The production of chlorinated pesticides and paper bleaching processes also produce dioxins and dibenzofurans. Polychlorinated biphenyls (PCBs) are highly stable and non-flammable substances, which is why they are added to hydraulic oils and liquids for electrical insulators and capacitors. Dioxins and PCBs attach to soil particles and dust in the environment and can be spread in this manner. They are found everywhere in the environment.

Dioxins, dibenzofurans and PCBs have acute and chronic toxic effects. The most significant effects are on the liver and its functions and on human reproduction and growth. Dioxins and dibenzofurans are carcinogenic.

Levels of dioxins, dibenzofurans and PCBs in potatoes are very low due to the low fat content of potatoes (Boon et al., 2014). Therefore, potatoes play a negligible role in the intake of these substances through food.

Based on calculations made in 2014 (Boon et al., 2014), the RIVM concluded that the calculated intake of dioxins and dioxin-like PCBs in the Dutch population did not exceed the health-based limit value (based on a TDI of 2 pg TEQ/kg body weight per day). At the end of 2018, EFSA published an opinion on the risks to human and animal health from dioxins and dioxin-like PCBs in food and feed (EFSA CONTAM Panel, 2018d). In this opinion, the newly derived TWI of 2 pg TEQ/kg body weight per week is lower than the previous TDI (2 pg TEQ/kg body weight per day (= 14 pg TEQ/kg body weight per week) by a factor of 7. Based on the intake of dioxins and dioxin-like PCBs by the Dutch population as calculated in 2014, this TWI is already exceeded. Once the TWI is exceeded, adverse health effects for the consumer cannot be ruled out.

Summary

- The newly derived TWI by EFSA for dioxins, dibenzofurans and PCBs is so low that the current intake of dioxins via food cannot be ruled out as a potential public health risk.
- ➔ Potatoes and potato products contribute little or nothing to the intake of dioxins and PCBs from food, so that it can be concluded that dioxins, dibenzofurans and PCBs do not pose a risk to the food safety of potatoes and potato products.

Brominated flame retardants

The two most well-known brominated flame retardants are polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecanes (HBCDDs). Both types are added to polymers such as foam plastics and have a very wide range of applications. These compounds occur everywhere, are emitted as fumes from the various applications into the ambient air and thus end up in food and animal feed. Though the use of HBCDDs is heavily restricted both in Europe as well as worldwide, these will continue to be released from existing materials over the coming decades.

The main toxic effects of brominated flame retardants are their adverse effects on neurological development.

[55] PCDFs are broadly similar to dioxins in terms of their properties.

Brominated flame retardants accumulate in the soil and from there can be taken up by plants belonging to the nightshade family, with the highest concentrations occurring in the above-ground parts of the plant (Nijkamp et al., 2017). Brominated flame retardants are substances that are highly soluble in fat. That is why they mainly occur in foods of animal origin and vegetable oils and fats. Therefore, potatoes and potato products will scarcely contribute to the intake of these compounds from food(Boon et al., 2016).

A risk assessment performed by the RIVM for three brominated diphenyl ethers (BDE-47, BDE-99 and BDE-153) indicates that the intake is so low that the risk of harmful health effects is negligible. For other brominated diphenyl ethers, there is not enough information (health-based limit values and/or concentration data) for evaluating their effects (Boon et al., 2016). Based on a risk estimate (MoE) of the current exposure to brominated flame retardants via food in Europe, EFSA concludes that no health effects are expected, with the exception of BDE-99, which could possibly pose a risk (EFSA CONTAM Panel, 2011b).

However, it is not currently possible to assess the risk of other brominated flame retardants, (such as *tris(2,3-dibromopropyl) phosphate (TDBPP)*), because the required occurrence, exposure and toxicity data are not yet available. The risks to the food safety of potatoes are expected to be negligible, because these bromine compounds are also readily soluble in fat and will therefore mainly occur in foods of animal origin and vegetable oils and fats.

Summary

- ➔ Intake of known brominated flame retardants via food is not expected to have any health effects, except possibly in the case of BDE-99.
- ➔ Potatoes and potato products make little or no contribution to the intake of brominated flame retardants via food, because these substances mainly occur in food of animal origin and vegetable oils and fats.

Perfluorinated compounds

Perfluorinated compounds (PFAS) are substances that are used in consumer products (for example, for making carpets, textiles, paper and cardboard water and dirt-repellent) and in industrial products (for example, in Teflon and fire extinguishing agents). They are highly persistent substances that are found everywhere in the environment. This group (PFAS) consists of a large number of substances, of which PFOS and PFOA are the best known. There is a shift towards the use of perfluorosulfonates and perfluorocarboxylic acids with shorter chains and perfluoroalkyl ether carboxylic acids (including GenX). These substances have been detected in surface water in the Netherlands (Gebbink et al., 2017).

Animal studies show that these substances can cause a wide variety of toxic effects, such as hepatotoxicity, immunotoxicity, and reproductive and developmental toxicity, and that they are potentially genotoxic and carcinogenic. For PFOS, the increase in serum cholesterol in adults and the decrease in antibody response to vaccination in children have been identified as the most critical effects (EFSA CONTAM Panel, 2018c). For PFOA, increase in serum cholesterol has been identified as a critical effect. There is also a negative effect on reproduction and the development of the foetus. However, the dose at which this effect occurs is higher than the dose required for the most critical effect (increase in cholesterol) (EFSA CONTAM Panel, 2018c).

PFAS can be taken up from the soil by potatoes, as demonstrated in studies with experimentally contaminated soil (Nijkamp et al., 2017). PFAS can also be released from packaging materials to food (see 8.3.15). Measurements in 250 samples of European potatoes and potato products yielded only one positive sample for PFOS (EFSA, 2011).

The TDIs for perfluorinated compounds are currently being re-evaluated. In February 2020, EFSA proposed a new TWI of 8 ng/kg body weight per week for the sum of four perfluorinated compounds (EFSA CONTAM Panel, 2020c).

Based on various studies that have examined the intake of perfluorinated compounds via food, it can be concluded that potatoes make little or no contribution to the total intake. The main contributors for the average chronic intake of PFOS and PFOA are animal products (PFOS: fish, meat and eggs; PFOA: dairy products and fish) (Noorlander et al., 2011; EFSA CONTAM Panel, 2018c). Perfluorinated compounds do not pose a risk to the food safety of potatoes.

Summary

- Perfluorinated compounds can be taken up from the soil by potatoes.
- ➔ The intake of PFOS and PFOA mainly comes from animal products and potatoes hardly contribute to this.
- ➔ Perfluorinated compounds do not pose a risk to the food safety of potatoes.

Organochlorine pesticides

Various organochlorine pesticides are still found in the soil, although the use of these pesticides has been banned for some time. These include the drins (aldrin, dieldrin, endrin) and DDT (4,4'-dichlorodiphenyltrichloroethane), an insecticide that has been banned in the Netherlands since the 1970s and in the EU since 1986. Since these substances are poorly biodegradable (persistent), their levels in the soil decrease very slowly.

Regular analyses conducted by the NVWA of plant protection products in samples of fruit and vegetables, including potatoes, apply multi-residue methods in which hundreds of plant protection products are simultaneously analysed. DDT (incl. DDDs and DDEs[56]) and the drins were also included in these analyses. These substances were not detected in potatoes in the Netherlands in the period from January 2010 to February 2018. In one sample of potato salad, DDT was found in a concentration (0.006 mg/kg) that was well below the ML (0.05 mg/kg) (n = 360) (NVWA, 2018f).

Summary

- The use of DDT/DDE and related organochlorine pesticides have been banned for decades in the Netherlands and in the EU but these are still found in the soil.
- ➔ Organochlorine pesticides are not found in potatoes and potato products and do not pose a risk to the food safety of potatoes and potato products.

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) belong to a large group of substances that are formed during combustion processes (via heaters, traffic) and can subsequently end up in the environment. Smoking food (e.g. meat), heating vegetable oil or barbecuing also gives rise to PAHs.

A number of PAHs are carcinogenic. Benzo[a]pyrene (BaP) is the best known and most carcinogenic PAH. However, BaP is a poor indicator of the total amount of PAHs in food. A number of PAHs considered together provides a better indication, for example, PAH-4 (the sum of benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene and chrysene) (EFSA CONTAM Panel, 2008). Legal limits in food have been laid down for both benzo[a]pyrene and PAH-4 (Regulation (EU) 835/2011[57]).

[56] DDD (4,4'-dichlorodiphenyldichloroethane) and DDE (4.4'-dichlorodiphenyldichloroethylene) are substances related to DDT that are found as impurities or degradation products in DDT.

[57] Commission Regulation (EU) 835/2011 of 19 August 2011 amending Regulation (EC) 1881/2006 as regards maximum levels of polycyclic aromatic hydrocarbons in foodstuffs.

EFSA concludes, based on MoE calculations, that the average exposure to PAHs from food is not a cause for concern. The contribution from potatoes is minimal in this respect. Grain and grain products and fish and fish products play the largest role in terms of the exposure to PAHs from food (EFSA CONTAM Panel, 2008).

Summary

- The average exposure to PAHs from food is not a cause for concern.
- ➔ The contribution of potatoes to the intake of PAHs from food is minimal, which means that PAHs do not pose a risk to the food safety of potatoes and potato products.

8.3.7. Radioactive substances

Radioactive substances can be introduced into the environment and food as a result of a radiation accident.

Maximum permitted levels of radioactive contamination in food have been laid down at the European level (Regulation 733/2008[58]). For caesium-134 and caesium-137, this is 600 Bq/kg (excluding milk and milk products and infant formula).

In the Netherlands, measurements of caesium-134, caesium-137 and potassium-40 are carried out for potatoes and potato products. In the period 2010-2017, caesium-134 and caesium-137 levels were between 3 and 10 Bq[59]/kg (n = 43) and potassium-40 levels between 78 and 312 Bq/kg (n = 33) (NVWA, 2018f). Therefore, the measured radiation level in Dutch potatoes is well below the applicable EU standard. In the absence of a radiation incident, there is no risk to the food safety of potatoes on account of radioactive substances.

Summary

- ➔ Without a radiation accident, radioactivity does not pose a risk to the food safety of potatoes.

8.3.8. Heavy metals

Heavy metals occur naturally in the soil. In addition, heavy metals can occur as contamination in the soil after the use of fertilisers (animal manure, chemical fertilisers and the earlier use of sewage sludge) or as a result of regional atmospheric deposition due to industrial activities. In this context, the most important heavy metals are lead, cadmium, arsenic and mercury (Nijkamp et al., 2017). To prevent contamination with heavy metals, the use of sewage sludge as a fertiliser is not permitted in potato cultivation (Regulation 86/278/EEC[60]). The use of leaded petrol has historically been a major source of lead contamination in the environment.

Heavy metals can be taken up by potatoes from the soil and groundwater via the roots. The accumulation mainly occurs in the parts that are not consumed, such as roots (especially inorganic arsenic) and leaves (cadmium, lead). For cadmium and lead, the concentrations in the skin are higher than in the tuber (Nijkamp et al., 2017). For arsenic, it appears that the concentration in vegetables, including potatoes, does not show a clear relationship with the concentrations of arsenic in the soil. This makes the concentration in potatoes difficult to predict (Swartjes et al., 2018).

The availability for uptake in potatoes depends on the soil properties, such as the amount of organic matter and clay contained in the soil and the composition of the soil moisture. In acidified soil, heavy metals are more readily available for uptake in potatoes (de Vries et al., 2008).

[58] Council Regulation (EC) 733/2008 of 15 July 2008 concerning the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station.

[59] Becquerel (Bq) is a measure of radioactivity.

[60] Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture.

Improper fertilisation and tillage of the soil can cause it to acidify. This may happen in private vegetable gardens. In addition, private vegetable gardens are often located next to motorways or railways and therefore have elevated concentrations of heavy metals in the soil (Otte et al., 2011). In addition, potatoes from private vegetable gardens are often intended for personal consumption and the growers/consumers often consume all the potatoes they grow, as a result of which these persons may be exposed to high concentrations of heavy metals.

Lead

Chronic exposure to lead can lead to neurotoxic effects and an increase in blood pressure.

For lead, the ML has been established as 0.10 mg/kg fresh weight (peeled potatoes)[61]. European data aggregated by EFSA show that there are occasional exceedances of the ML for lead (2012) (n = 1370; P95/MB of ca 0.06 mg/kg for potato products, with an outlier of 0.182 mg/kg for mashed potatoes) (Nijkamp et al., 2017). For 2017, the RIVM reports an average value for lead in potatoes in EU Member States of 0.02 mg/kg (n = 1028) (Boon et al., 2017). In 2018, a lead content of 0.032 mg/kg fresh weight was found in one potato sample (n = 4; from Malta) (KAP, 2020). In 2018, RASFF reported the presence of lead in Greek potatoes (0.118 mg/kg). The ML values for lead can be exceeded in potatoes growing on contaminated soil. Lead concentrations between 100 and 425 mg/kg have been found in Canadian potatoes grown on contaminated soil (Nijkamp et al., 2017).

Food is the main source of lead exposure (EFSA CONTAM Panel, 2010;2012a). The EFSA (2010) risk assessment of exposure to lead via food, based on the MoE approach, concluded that the effects of lead cannot be ruled out for adults, children and infants. It also noted that, in terms of the exposure of infants, young children and pregnant women, the neurotoxic effect of lead is a matter of concern. Potatoes and potato products contribute approximately 5% -15% to the total intake of lead from food (EFSA CONTAM Panel, 2012a; Boon et al., 2017). The food safety risk of lead in potatoes in the Netherlands is therefore assessed as low (low concentrations below the ML).

Cadmium

Long-term exposure to cadmium can cause kidney damage. Cadmium has been classified by the WHO's International Agency for Research on Cancer (IARC) as a human carcinogen (Category 1) (Nijkamp et al., 2017). The European Commission's Joint Research Centre (JRC) concludes that there is no evidence that cadmium is carcinogenic after oral exposure, but that there is strong evidence that cadmium oxide is carcinogenic after inhalation (Nijkamp et al., 2017).

The ML for cadmium is 0.10 mg/kg fresh weight (peeled potatoes)[61]. Data aggregated by EFSA from European Member States show that there are occasional exceedances of the ML in potatoes for cadmium (2009) (from <LOD to 0.1420 mg/kg, n = 2116, P95 of 0.07 mg/kg). For 2017, the RIVM reports an average value of 0.022 mg/kg (n = 2280) for cadmium in potatoes in EU Member States (Boon et al., 2017). Measurements in potatoes from potentially contaminated areas in the Netherlands (De Kempen) showed no exceedances of the ML for cadmium (Nijkamp et al., 2017).

The TWI for cadmium is 2.5 µg/kg body weight (EFSA CONTAM Panel, 2011a). The RIVM has made a risk assessment for cadmium for the Dutch population, based on Dutch food consumption data and the aggregated EFSA data. It concludes, based on TDI calculations , that only children (up to about ten years of age) consume, on average, more cadmium from food than desirable. The lifetime risk of cadmium intake through food is negligible. The contribution of potatoes to the

[61] Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs.

intake of cadmium from food is around 15-20% (Sprong & Boon, 2015; Boon et al., 2017). The food safety risk of cadmium in potatoes in the Netherlands is therefore assessed as low (low concentrations below the ML).

Arsenic

Arsenic has a high degree of acute toxicity in its inorganic form. Lung, skin and bladder cancer are the main toxic effects of long-term exposure (EFSA CONTAM Panel, 2009).

No ML has been established for arsenic in potatoes (Nijkamp et al., 2017). EFSA has found reported mean concentrations of inorganic arsenic in potatoes and potato products between 1.6 µg/kg (LB) and 7.2 µg/kg (UB) (n = 1065) (EFSA, 2014a). Reported mean concentrations of total arsenic in potatoes from a field study in the United Kingdom (2001) lie between 0.10 mg/kg dry weight (peeled potato tuber) and 0.35 mg/kg dry weight (peel) (Nijkamp et al., 2017). There is limited data on arsenic levels in potatoes grown in the Netherlands. Reported mean concentrations (inorganic arsenic) are between 0.01 and 0.06 mg/kg dry weight and high concentrations (P95) are 0.135 mg/kg dry weight and 0.023 mg/kg wet weight (Swartjes et al., 2018).

No health-based limit value has been established for arsenic. The 1989 PWTI (Provisional Tolerable Weekly Intake) was withdrawn by EFSA in 2009 and by JECFA (Joint FAO/WHO Expert Committee on Food Additives) in 2011 after a re-assessment of the epidemiological data. In 2011, JECFA derived a $BMDL_{0.5}$[62] of 3 µg/kg body weight per day (inorganic arsenic) (Swartjes et al., 2018). Subsequently, in 2015, EFSA defined the lower confidence limit of the benchmark dose ($BMDL_{01}$[63]) as 0.3 to 8 µg/kg body weight per day based on lung, urinary bladder and skin cancer and skin lesions[64].

EFSA concludes that the estimated intake of inorganic arsenic via food in Europe for average consumers and high consumers is close to the established $BMDL_{01}$. Hence, a risk for some consumers cannot be ruled out (Regulation 2015/1006).

A Dutch study of the intake of contaminants via food shows that the intake of arsenic is close to the $BMDL_{0.5}$ (Boon et al., 2017). From this, it can be concluded from this that there are potential health risks for the Dutch situation (if the consumption pattern is in accordance with the five recommended food groups in the 'Wheel of Five' (*Schijf van Vijf*). Exposure to inorganic arsenic arises mainly from the consumption of fish, rice and drinking water and not from the consumption of potatoes (Boon et al., 2017). The food safety risk of arsenic in potatoes is therefore assessed as negligible.

Mercury

Methylmercury is the most toxic and also the most commonly occurring form of mercury in food (especially fish). Long-term exposure to methylmercury can lead to adverse effects on neurodevelopment.

No ML has been established for mercury in potatoes. For the Netherlands, no data are available regarding the presence of mercury in potatoes.

EFSA has established a TWI of 1.3 µg/kg body weight per week for methylmercury, expressed as mercury. The intake of inorganic mercury from food does not exceed the TWI. However, intake of

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[62] Benchmark dose lower confidence limit: dose at which an additional 0.5% risk of lung cancer may occur.

[63] Benchmark dose lower confidence limit; dose at which an additional 0.1% risk of lung cancer may occur.

[64] Commission Regulation (EU) 2015/1006 of 25 June 2015 amending Regulation (EC) 1881/2006 as regards maximum levels for inorganic arsenic in foodstuffs.

methylmercury can lead to an exceedance of the TWI, which mainly occurs via the consumption of fish. Potatoes rarely contribute to this (EFSA CONTAM Panel, 2012b). The food safety risk of mercury in potatoes is therefore assessed as negligible.

Summary

- Heavy metals (cadmium, lead, arsenic and mercury) mainly accumulate in parts of the potato plant that are not intended for consumption (roots, leaves).
- Occasional exceedances of the ML have been reported for cadmium and lead in potatoes in the EU.
- ➔ The total intake via food (especially for children) is higher than desirable for both lead and cadmium. Potatoes are a significant contributor (5-10% for lead and 15-20% for cadmium) but concentrations usually remain below the ML. The risk is assessed as low.
- ➔ As far as the Netherlands is concerned, there are possible health risks relating to the intake of arsenic. However, the risks of arsenic in potatoes are considered to be negligible because potatoes contribute minimally to the intake of arsenic.
- ➔ Intake of methylmercury via food can lead to exceedance of the TWI. This mainly arises from the consumption of fish; potatoes rarely contribute to this. The risks of methylmercury in potatoes are therefore assessed as negligible
- Consumption of potatoes grown in private vegetable gardens increases the risk of exposure to heavy metals. The risk factors involved are: contaminated soil along the railway or motorway, incorrect treatment of the soil with the risk of acidification and long-term consumption of private cultivation.

8.3.9. Fertilisers and contaminants

Fertilising the field mainly involves the application of nitrogen, phosphorus, potassium and magnesium, sulphur and calcium to the soil. Regulations for the use of fertilisers are mainly aimed at protecting the environment. Dutch legislation for the use of nitrogenous fertilisers is based on the EU Nitrates Directive[65]. The amount of nitrogen that may be applied via fertilisers depends on the type of potato and the soil type (Nijkamp et al., 2017).

A Dutch study from 2017 shows that fertilisers can also become contaminated with veterinary medicinal products and hormones. About 30 substances were present in slurry (from pig and calf farms) and were subsequently also found in the soil, groundwater and surrounding surface water. The persistent substances (various antibiotics) were mainly found in the soil (Lahr et al., 2018). It is unknown whether residues of veterinary medicinal products in the soil and groundwater are also taken up by the potato plant.

In recent years, drug waste (residues from the production of XTC) has been found in slurry pits on a number of occasions. If this slurry is then spread on the land, these substances could be taken up by the potatoes, as was previously observed with maize. MDMA was found in maize cultivated in a field contaminated with MDMA. In this particular case, it was concluded that no public health risks were involved if consumers consumed this maize or meat or milk derived from farm animals that had been fed with MDMA-contaminated maize (NVWA BuRO, 2018). In potato cultivation, slurry is regularly applied in the spring, prior to or shortly after planting the potatoes (Van Geel, 2015). The percentage of the plots where slurry is used for potato cultivation is unknown. Since 2019, requirements have been laid down for the low-emission application of animal manure (RVO, 2020). It is not known whether MDMA and residues from the production of XTC also enter the potatoes and in what quantities. Hence, the risk for the food safety of potatoes cannot be assessed.

[65] Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

Nitrogen compounds present in manure are converted in the soil into nitrate and can be taken up in this form by the potato plant. The leaf contains more nitrate than the tuber. In the tuber, the nitrate concentration is highest just below the skin. This nitrate can be partially converted into nitrite by the human body after consuming potatoes. Nitrite can combine with proteins to form N-nitroso compounds, which cause methemoglobinemia (oxygen deficiency) and which are possibly carcinogenic (EFSA, 2008). On the other hand, nitrate metabolites are also essential for various physiological processes such as vascular regulation and are associated with positive health effects such as lower blood pressure and a reduced risk of cancer and cardiovascular disease (EFSA, 2008; NVWA BuRO, 2014).

No ML for nitrate has been determined for potatoes. However, the ML for nitrate has been derived for various green leafy vegetables and for baby food (Regulation (EC) 1881/2006[61]): from 200 mg/kg in baby food to 5000 mg/kg in fresh lettuce and 7000 mg/kg in rucola.

The average nitrate concentrations in potatoes in EU Member States are approximately 168 mg/kg (n = 2795; P5 = 10 (UB); P95 = 340 (UB); period 2000-2007). Here it is should be noted that a relatively greater number of samples with high concentrations came from the Netherlands than expected based on all the tested samples (EFSA, 2008). In the Netherlands, measurements in potatoes from 1990 to 2011 (KAP database[50]) show nitrate concentrations ranging from below the LOQ to 2750 mg/kg (maximum concentration measured in 1990) (n = 375). The annual averages are around 200 mg/kg, as is the median (see Table 8.3). No data from after 2011 was found in the KAP database.

Table 8.3 Nitrate concentrations in Dutch potatoes (KAP, 2018)

Year	Total number of samples	Number of samples <LOQ*	Average per year (LB**) mg/kg	Median per year (LB**) mg/kg
1990	48	0	245	180
1991	43	0	152	130
1992	27	0	133	140
1994	31	0	146	134
1995	17	0	452	387
1996	47	0	280	250
1997	61	0	245	210
1998	60	1	220	200
2006	27	0	257	230
2010	9	1	172	160
2011	5	1	78	100

*LOQ: Limit of Quantification
** LB: calculated with zero concentration for the samples below the LOQ (lower-bound concentration)

Washing, peeling, and then cooking the potatoes results in an 18-40% decrease in nitrate concentrations, depending on the potato variety. A decrease of approximately 25% was also observed when potatoes were cooked unpeeled. The nitrate concentration decreases by about 95% during the preparation of chips (Nijkamp et al., 2017). The RIVM reports nitrate concentrations of 39 mg/kg in cooked potatoes and 29 mg/kg in mashed potatoes (Boon et al., 2017).

The ADI for nitrate is 3.7 mg/kg body weight per day. In 2017, EFSA decided that there is no reason to adjust this previously derived ADI (EFSA, 2017a). EFSA concludes, based on European data, that the intake of nitrate from food exceeds the ADI (with medium and high exposure). For small children (infants and children up to 9 years), starchy tubers are[66] the main source (4-35%), while for adolescents and adults, leafy vegetables (0.4 -47%) and salads (0-44%) are the most important sources (EFSA, 2017a).

Summary

- No ML has been established for nitrate in potatoes.
- ➔ For small children, starchy tubers are the main source (4-35%) of nitrate intake.
- ➔ The total nitrate intake from food exceeds the ADI (with medium and high exposure), whereby health risks cannot be ruled out.
- There are examples of illegal dumping of drug waste into manure. The extent to which slurry is used in potato cultivation is unknown. It is also unknown whether MDMA and residues from the production of XTC are introduced into potatoes via manure. Hence, the risk for the food safety of potatoes cannot be assessed.

8.3.10. Plant protection products

Plant protection products are used in potato cultivation to prevent potatoes from being adversely affected by diseases, pests and weeds. The tubers are treated against fungal diseases and insects before and during planting. The soil may be treated with granular nematicides before planting. This is mainly done on starch potato plots because these are often grown on the same plot, which may lead to build up of large populations of harmful soil-borne organisms. Around the time of crop emergence, herbicides are used to fight weeds. This is an important measure not just because weeds can contain viruses that can also infect the potato plant but also because the weeds compete with the potato plant for light. After the crop has emerged, it is sprayed with insecticides against aphids (a known vector for certain viruses) and with fungicides against fungi and particularly potato blight *(Phytophtora infestans)*. In seed potato cultivation, paraffin oil is also used as a plant protection product against the transmission of viruses by aphids. The haulm can be destroyed with a herbicide prior to harvest. The active substances from the plant protection products can be absorbed directly by the plant via the leaves or taken up via the roots from the soil. There are also certain products that are used to treat the seed potatoes. In addition, fungicides and sprout inhibitors are used during the storage of potatoes.

MRLs have been established for residues of plant protection products on food. An exceedance of the MRL implies that the food fails to meet the legal requirements and may therefore no longer be marketed as food (although it can be sold as animal feed). However, this does not necessarily mean that there is a health risk for the consumer.

The MRL for plant protection products is established based on GAP. The MRL lays down the maximum concentration that can be found in the product when using the prescribed minimum amount of plant protection product sufficient for the purpose for which this product is used. If the MRL leads to intake amounts that are far below the health-based limit values, the MRL is not adjusted upwards. If the MRL is such that it leads to the health-based limit value being exceeded, the plant protection product will not be authorised for that application.

The NVWA monitors compliance with the European legal requirements concerning residues of plant protection products on fruit and vegetables in accordance with Regulation (EC) 396/2005. This European Regulation requires Member States to implement two control programmes: the EU-coordinated control programme (EUCP) and a National Control Programme.

Under the EUCP, random and representative sampling of a product or product group on the market (for example, potatoes) should be carried out in order to get an idea of the residues of plant protection products in the products. Every year, the EUCP indicates about ten products (for example, potatoes) that have to be sampled. In the Netherlands, samples for the EUCP are collected from retail chains, wholesalers, auctions, the processing industry and distribution centres.

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[66] In addition to potato, this may also include sweet potatoes and/or cassava.

The choice of products for sampling takes into consideration the amount of the product consumed in the Netherlands and results from previous studies (NVWA, 2017c).

The National Control Programme should be risk-oriented. This is based on RASFF notifications and country-product combinations where regular exceedances have been found in the past (NVWA, 2017c). In addition, each EU Member State is obliged to carry out mandatory controls on the import of food of non-animal origin at the external borders of the EU (Regulation (EC) 669/2009[67]). For this purpose, a list of countries and products is drawn up every six months based on previous results[68]. A fixed percentage of the imported consignments are checked. Consignments that do not meet the legal requirements are not allowed to enter the EU. In the event of a potential health risk, i.e. an exceedance of the health-based limit value (acute), the consignment must be destroyed (Regulation (EC) 882/2004[69]).

The samples taken via the different sampling operations are analysed using multi-residue methods, where the presence of hundreds of different active substances of plant protection products is simultaneously analysed.

'Unknown' chemicals and situations (other than those included in the measurement and control programmes) are only examined if there are clear signs that a production process or a contaminant may potentially result in a contamination.

The results of these controls carried out by the EU Member States on residues of active substances of plant protection products found in fruit and vegetables are published annually in an overview report by EFSA. In 2011, 2014 and 2017, potatoes were one of the products required to be subjected to the annual representative sampling by the EUCP (EFSA, 2014b;2016b;2019a).

A total of 1440, 1456 and 1389 potato samples were analysed in 2011, 2014 and 2017 respectively by the EU Member States. Thirty different active substances of plant protection products were detected in 2011, 40 in 2014 and 25 in 2017. No residues of active substances from plant protection products were found in 76.2% (2011), 70.9% (2014) and 66.9% (2017) of the samples. Residue concentrations above the MRL were found in 0.6% (n = 9) (2011), 1.1% (n = 16) (2014) and 1.2% (n = 16) (2017) of the samples (EFSA, 2014b;2016b;2019a).

In 2018, the MRL was exceeded for one active substance in 5.8% of the potatoes tested (n = 34) in the Netherlands. In 2017, this was 5.4% (n = 37) and no exceedances of the MRL were found in 2016 (n = 40) (KAP, 2020).

In the Netherlands, more than 250 plant protection products, based on 80 different active substances, are authorised for use[70] in potato cultivation (Ctgb, 2020e)[71].

Fifteen of these products (based on seven active substances[72]) are only authorised for use for seed potato cultivation, of which five products based on three active substances (thiabendazole, carvone, imazalil) are used during the post-harvest phase. As a result of cross-contamination (due to the use of tools for sorting and transport) among farmers who grow both ware and seed

[67] Commission Regulation (EC) 669/2009 of 24 July 2009 implementing Regulation (EC) 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin and amending Decision 2006/504/EC.

[68] The most recent list can be found in: Commission Implementing Regulation (EU) 2017/2298 of 12 December 2017 amending Regulation (EC) No 669/2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin.

[69] Control Regulation (EC) No. 882/2004 of the European Parliament and of the Council of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules**.**

[70] See Chapter 10.1 (Plant protection products - other public health risks) for a description of the authorisation procedure.

[71] Status as of 1 January 2020

[72] Carvone, fluoxastrobin, imazalil, metam sodium, paraffin oil, thiabendazole, thiophanate-methyl (section 10.1.3.)

potatoes (approximately 40% of the companies (see section 3.3)), ware potatoes could be contaminated with substances that are not authorised for ware potatoes. Another route by which ware potatoes could become contaminated with the active substances of plant protection products that are only authorised for seed potatoes is when these seed potatoes are ultimately used as ware potatoes. On the one hand, this is authorised, and is also customary, in the case of undersized and oversized seed potatoes that are often used for producing chips or crisps (see section 3.3). But on the other hand, the use instructions of products containing carvone and imazalil as active substances indicate that seed potatoes treated with these products may not be used for animal feed or human consumption. The VVAK Food and Feed Safety Guide states that, if seed potatoes are certified as consumption or starch potatoes, they must also meet the requirements applicable to ware and/or starch potatoes (Akkerbouw Certificeringsoverleg, 2019).

A potato plot is sprayed 10 to 15 times a year and different products may be used simultaneously or consecutively (Nijkamp et al., 2017; Luttik, 2018). Seed potatoes may be sprayed up to more than 20 times, where fungicides are often combined with insecticides (Luttik, 2018). About twice as many plant protection products are used per hectare for seed potatoes as for starch and ware potatoes (see Annex 10.1).

In the assessment of active substances for the authorisation of plant protection products, the substances and products are assessed individually, and the simultaneous use of products and the use of different products one after the other is only included if such use is explicitly indicated on the product label. As part of the evaluation of the European Plant Protection Products Regulation (Regulation (EC) 1107/2009[73]), EFSA has assessed the current practice of authorisation and risk assessment of plant protection products. One of the recommendations made by EFSA is to include, as soon as possible, new scientific methodologies for assessing of the cumulative use of plant protection products (EFSA, 2018c). However, no widely accepted methodology for assessing the cumulative risks of plant protection products is available as yet. This is why the present risk assessment of the potato chain also assesses the plant protection products individually. However, research shows that the effects of simultaneous or consecutive use of plant protection products can be greater than the effects after exposure to a single substance (for aquatic ecosystems (Luttik et al., 2017) and for bees (Willow et al., 2019).

This risk assessment of the potato chain looks more specifically at the risk posed to the consumer by substances that, based on an initial selection, are most relevant in terms of the assessment of food safety risks. Sprout inhibitors have not been included in this selection; they are described and assessed separately (see section 8.3.11).

The selection is based on two criteria. The first criterion concerns the detection of the active substance, where only those substances are selected for which an exceedance of the MRL has been reported in fresh potatoes. For this, monitoring data from the Netherlands (2016 to 2018) (KAP, 2020) and the EU (2017) (EFSA, 2019a) as well as all RASFF notifications (1990 to 2018) have been used. The second criterion is based on the risk classification prepared by the independent consultancy CLM[74]. CLM has divided all the active substances authorised in the Netherlands into three classes (high, medium, low) based on the risks to humans, aquatic life, drinking water supply, soil life and beneficial organisms (Hoogendoorn M. et al., 2019). Of all these active substances authorised for use in potato cultivation (1 January 2020), only those substances with a CLM classification of ‘High’ for humans have been selected. However, no exposure data have been taken into account for determining this risk class, which means that it is actually a classification based on hazard rather than risk. In accordance with the above criteria based on the occurrence and toxicity of the substances, a total of 31 active substances have been selected (Table 8.4).

Active substances that are not included in the chemical analyses and not classified by CLM are missing from this selection[75]. These include Bacillus amyloliquefaciens, carfentrazone-ethyl, and

[73] Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC.

[74] CLM Research and Advice Ltd, part of CLM

[75] The CLM list “contains all 271 pesticides (active substances) that are authorised in the Netherlands in 2018.”

paraffin oil. The selection also excludes active substances that are not authorised in the Netherlands but authorised in countries from which potatoes are imported[76] and that are not included in the chemical analyses. It is not known which substances this involves because there is no overview of the active substances authorised in the countries that export to the Netherlands.

Table 8.4 Selection of 31 active substances for the risk assessment[77].

Active substance	**Selection criterion**			**Effect of active substance**	**Use**	**Authorisation**
	>MRL[1]	RASFF[2]	Toxicity classification 'High'[3]			
2-phenylphenol	X			Fungicide		Authorised in the EU, not authorised in NL
Aclonifen			X	Herbicide	Seed potato Ware potato Starch potato	
Chlorpyrifos	X			Insecticide		Not authorised in NL since 31/12/2019, no longer authorised in the EU since 16/2/2020
Lambda-cyhalothrin	X 2018 NL		x	Insecticide	Seed potato Ware potato Starch potato	
Cyromazine	X			Insecticide		Not authorised in NL since 31/12/2019, not authorised in the EU
Difenoconazole			X	Fungicide	Seed potato Ware potato Starch potato	
Diflufenican			X	Herbicide	Ware potato Starch potato	
Esfenvalerate			X	Insecticide	Seed potato Ware potato Starch potato	
Fenamiphos		2015		Nematicide		Not authorised in NL since 31/01/2008, no longer authorised in the EU since 31/07/2020
Flonicamid	X			Insecticide	Seed potato Ware potato Starch potato	

[76] Imports from EU Member States and imports from third countries that do not fall (via a derogation) under the import ban (Switzerland and some Mediterranean countries).

[77] Based on the products authorised for use in potato cultivation as on 1 January 2020

Fluazifop-p-butyl	x	2012		Herbicide	Seed potato Ware potato Starch potato	
Fluazinam		2011		Fungicide	Seed potato Ware potato Starch potato	
Fludioxonil	X		X	Fungicide	Seed potato Ware potato Starch potato	
Flufenacet			X	Herbicide	Seed potato Ware potato Starch potato	
Fluopicolide			X	Fungicide	Seed potato Ware potato Starch potato	
Fosthiazate	X	2011 2012 2014 2016 2017		Nematicid e	Seed potato Ware potato Starch potato	
Iprodione	X			Fungicide		Not authorised in NL since 30/1/2018, not authorised in the EU
Linuron	X 2017 NL			Herbicide		Not authorised in NL since 01/05/2017, not authorised in the EU
Metalaxyl	X 2018 NL		X	Herbicide	Seed potato Ware potato Starch potato	
Metam sodium			X	Nematicid e	Seed potato	
Metribuzin			X	Fungicide	Seed potato Ware potato Starch potato	
Oxamyl			X	Nematicid e	Seed potato Ware potato Starch potato	
Pencycuron	X			Fungicide	Seed potato Ware potato Starch potato	
Pendimethalin			X	Herbicide	Ware potato Starch potato	
Pirimicarb			X	Insecticide	Seed potato Ware potato Starch potato	
Pirimiphos-methyl	X 2017 NL			Insecticide		No longer authorised in NL for use in potato cultivation
Pyrimethanil	X			Fungicide		No longer authorised in NL

						for use in potato cultivation, no longer authorised in the EU since 30/4/2020
Quizalofop-p-ethyl			X	Herbicide	Ware potato Starch potato	
Spirotetramat			X	Insecticide	Seed potato Ware potato Starch potato	
Tefluthrin			X	Insecticide	Seed potato Ware potato Starch potato	
Thiacloprid			X	Insecticide	Seed potato Ware potato Starch potato	

[1] Exceedance of the MRL reported in the Netherlands (KAP database; 2016 to 2018) or in the EU 2017 (EFSA, 2019a).
[2] An exceedance of the MRL reported in the RASFF (1990 to 2018). Fluazifop-p-butyl: a report from Belgium in 2012 about Dutch potatoes. Fluazinam: a report from Luxembourg in 2011 about Dutch potatoes. Fosthiazate: a Greek report (2016) and a Belgian report (2017) about potatoes from Cyprus, 2016; a report from the UK (2012) about potatoes from the UK; a report from Belgium in 2011 about Spanish potatoes and a Dutch report about Dutch potatoes from 2014. Fenamifos: a report from the Czech Republic in 2015 about Greek potatoes.
[3] Classification 'High' for humans. Substances classified as 'High' solely based on the list of the Ministry of Social Affairs and Employment (Hoogendoorn M. et al., 2019)have not been taken into account.

The selected substances include a number of active substances that are no longer authorised for use in the Netherlands (2-phenylphenol, chlorpyrifos, cyromazine, fenamiphos iprodione, linuron and pyrimethanil). Pirimifos-methyl is not authorised in the Netherlands for use in the potato chain but is authorised for a different application (storage of grain). In case of both linuron and pirimiphos-methyl, levels higher than the MRL have been found in potatoes (KAP, 2020) (Table 8.5).

Three of the selected substances (2-phenylphenol, cyromazine and metam sodium) are not measured regularly because they are not included in the multi-residue methods used in the Netherlands[78] for the analysis of plant protection products. Metam sodium is only authorised for use for seed potatoes.

This risk assessment analyses the food safety risk of the selected active substances from plant protection products by using the ratio between the ARfD and the MRL. Since the MRL is not a toxicological limit value, exceeding the MRL does not automatically imply a risk to food safety. It is possible that, even at concentrations above the MRL, the intake will remain below or even far below the ARfD and ADI. How far below is different for each active substance and depends on the ratio between the MRL and ARfD or ADI and the amount of potatoes consumed. The smaller the servings at which the health-based limit value (ARfD) is exceeded, the greater the risk of exceeding of the MRL. For the selected substances, the ratio between ARfD and MRL for each substance is used to calculate the amount of potatoes - if the contamination of these potatoes with the plant protection product is equal to the MRL - a person would have to consume in order to exceed the health-based limit value (Table 8.5). The calculations are made for a child of 4-6 years (20 kg) and for an adult of 60 kg: ARfD/MRL x kg body weight. The ARfD has been chosen for these calculations instead of the ADI because the measurements show that the plant protection products are only found sporadically, which means that there is no chronic exposure (Table 8.5).

[78] NVWA method in 2018.

The results show that the minimum amount of potatoes that a person has to consume in a day to exceed the health-based limit value (ARfD) varies from 6 (for oxamyl) to 1500 kg (for metalaxyl-m) for an adult of 60 kg (Table 8.5). For a child of 20 kg, this intake varies from 2 kg (for oxamyl) to 500 kg (for metalaxyl-m). This shows that there is still a large margin before the health-based limit value (ARfD) is exceeded. In addition, after the potatoes are prepared, the concentrations of the plant protection products will be even lower because some of the products will have been removed by washing, peeling and cooking/frying/deep-frying the potatoes. The peeling process, in particular, leads to a significant reduction (Nijkamp et al., 2017).

For some plant protection products, measured concentrations in fresh unpeeled potatoes have been found to be higher than the MRL. These are occasional minor exceedances. For fluazinam, it was reported in 2011 (RASFF) that the MRL (0.02 mg/kg potato) was exceeded by a factor of 33 (0.65 mg/kg potato) in a batch of Dutch potatoes. Based on this high concentration, calculations show that an adult (60 kg) would have had to eat more than 6.5 kg of these contaminated potatoes in one day to exceed the ARfD of 0.07 mg/kg body weight (0.07/0.65 x 60). For a child weighing 20 kg, this would have to be more than 2 kg of potatoes in a single day. Here too, these calculations do not take into account either the further reduction in the concentrations of the plant protection product due to the preparation of the potatoes (peeling, washing, cooking) or the possible intake from other foodstuffs.

Based on the above calculations, it can be concluded that plant protection products do not pose a risk to the food safety of potatoes.

Table 8.5 Estimated amount of potatoes (kg) with plant protection product at MRL level that a person may eat (per day) without exceeding the ARfD.

Active substance	MRL[1] Mg/kg potato	Max. concentration measured in NL Mg/kg potato NL (2016-2018)[2] RASFF (2006-2018)	EU report on plant protection products (2017) (EFSA, 2019a)	ARfD Mg/kg body weight per day	ADI Mg/kg body weight per day	Amount of potatoes (kg) with plant protection product at MRL level that a person would have to eat (per day) to reach the ARfD[4] (ARfD/MRL x kg body weight)	
						Child 20 kg	Adult 60 kg
2-phenylphenol	0.01		n = 977; 1>MRL	n/a[3]	0.4		
Aclonifen	0.02			n/a[3]	0.7		
Chlorpyrifos	0.01		n = 1352; 4>MRL	0.005	0.001	10	30
Lambda-cyhalothrin	0.01	0.011 (NL 2018)		0.005	0.0025	10	30
Cyromazine	0.05		n = 778; 1>MRL	0.1	0.06	40	120
Difenoconazole	0.1	0.0052 (NL 2016)		0.16	0.01	32	96
Diflufenican	0.01			n/a[3]	0.2		
Esfenvalerate	0.02			0.0175	0.0175	17.5	52.5
Fenamiphos	0.02	0.23 (RASFF 2015)		0.0025	0.0008	2.5	7.5
Flonicamid	0.09		n = 685; 2>MRL	0.025	0.025	5.6	16, 7
Fluazifop-p-butyl	0.15	0.22 (RASFF 2012)	n = 707; 2>MRL	0.017	0.01	2.23	6.8
Fluazinam	0.02	0.65 (RASFF 2011)		0.07	0.01	70	210
Fludioxonil	5	0.55 (NL 2017)		n/a[3]	0.37		
Flufenacet	0.15			0.17	0.005	22.7	68

Fluopicolide	0.03	0.0074 (NL 2017)		0.18	0.08	120	360
Fosthiazate	0.02	0.0081 (NL 2018) 0.062 (RASFF 2014; 2017)	n = 1048; 1>MRL	0.005	0.004	5	15
Iprodione	0.01		n = 1293; 1>MRL	0.06	0.02	120	360
Linuron	0.01	0.039 (NL2017)		0.03	0.003	60	180
Metalaxyl-m	0.02	0.024 (NL 2018)		0.5	0.08	500	1500
Metam sodium	0.02			0.1	0.001	100	300
Metribuzin	0.1	0.0072 (NL 2018)		0.02	0.013	4	12
Oxamyl	0.01			0.001	0.001	2	6
Pencycuron	0.1	0.034 (NL 2016)	n = 1268; 1>MRL	n/a(3)	0.2		
Pendimethalin	0.05			0.3	0.125	120	360
Pirimicarb	0.05			0.1	0.035	40	120
Pirimiphos-methyl	0.01	0.025 (NL 2017)	n = 1344; 1>MRL	0.15	0.004	300	900
Pyrimethanil	0.05		n = 1346; 2>MRL	n/a(3)	0.17		
Quizalofop-p-ethyl	0.1			Unknown	Unknown		
Tefluthrin	0.01			0.005	0.005	10	30
Thiacloprid	0.02			0.02	0.01	20	60

(1) MRL from the EU Pesticides Database (consulted on 7/2/2020)
(2) Data for the Netherlands from the KAP database (2016 to 2018)
(3) No ARfD value because substance is not acutely toxic
(4) This calculation does not take into account the decrease in concentration as a result of the preparation (washing/peeling, cooking/deep-frying/frying) of the potatoes

There are two active substances from plant protection products that have received a great deal of attention recently. The first of these is copper oxychloride that came to the forefront when it started being used in organic potato cultivation. In the Netherlands, copper oxychloride is no longer authorised for use as a plant protection product (fungicide) since 2000. However, it may be used as a foliar fertiliser in low concentrations (6 g/ha per year). In the summer of 2016, questions were posed in parliament regarding the use of copper oxychloride by several growers as a remedy for potato blight in organic cultivation (Tweede Kamer der Staten-Generaal, 2016). In organic potato cultivation, there is a strict restriction on the use of plant protection products (Regulation (EC) 889/2008[79]) (SKAL, 2018a). However, copper oxychloride was being used by several growers in greater quantities than was authorised for use as a fertiliser. But research showed that, despite the higher use, the concentrations of copper oxychloride in organic potatoes did not exceed the MRL (5 mg/kg potatoes) (Nijkamp et al., 2017).

In addition, there is extensive discussion about glyphosate, the active substance used in a large number of products as a herbicide and haulm destructor. The main point of discussion is whether or not this substance is carcinogenic. Glyphosate has been classified by the IARC as 'Probably carcinogenic to humans' (Group 2A) (IARC, 2015). However, EFSA has arrived at the opposite conclusion, i.e. that glyphosate is unlikely to cause cancer (EFSA, 2015). The approval of the active substance glyphosate in the EU was extended for five years on November 2017 and is due for a reassessment by December 2022. This assessment will be carried out by a group of four Member States (including the Netherlands) (Ctgb, 2020c).

There are almost 40 products containing glyphosate as an active substance that are authorised in the Netherlands for use in potato cultivation. Pursuant to EU Implementing Regulation 2017/2324[80] (renewal of the approval of the active substance glyphosate), glyphosate may only be used as a herbicide.

Glyphosate has not been reported in potatoes in the EU. In 2011, 2014 and 2017, further studies were conducted on the occurrence of plant protection products in potatoes in the EU (EFSA, 2014b;2016b;2019a). Only in 2011 was it mandatory to include glyphosate in the analysis[81]. For the other two years (2014 and 2017), there was no obligation to analyse glyphosate in potatoes and it is not clear whether glyphosate was also included in the analyses. Glyphosate is not included in the multi-residue methods used by the NVWA. Dutch reports on plant protection products in fruit and vegetables do not report any glyphosate in potatoes (2015 and 2016) (NVWA, 2017c) (2016 to 2018) (KAP, 2020). It is unknown whether glyphosate in potatoes poses a food safety risk.

[79] Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control.

[80] Commission Implementing Regulation (EU) 2017/2324 of 12 December 2017 renewing the approval of the active substance glyphosate in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market, and amending the Annex to Commission Implementing Regulation (EU) No 540/2011.

[81] Commission Regulation (EC) 1213/2008 of 5 December 2008 concerning a coordinated multiannual Community control programme for 2009, 2010 and 2011 to ensure compliance with maximum levels of and to assess the consumer exposure to pesticide residues in and on food of plant and animal origin.

Summary

- Plant protection products are found very sporadically in potatoes in quantities above the MRL.
- Exceedances of MRLs in potatoes are minimal and do not lead to exceedance of the health-based limit value for acute exposure (ARfD).
- ➔ Due to cross-contamination or the marketing of seed potatoes as ware potatoes, plant protection products that are only authorised for seed potatoes may also be present in ware potatoes.
- ➔ Not all plant protection products authorised in the Netherlands for use in potato cultivation are included in the multi-residue methods[78] that are usually used for the detection of active substances of plant protection products. The same may apply to active substances authorised in countries from where potatoes are imported but for which there is no authorisation in the Netherlands.
- ➔ The risks to food safety due to the use of plant protection products in potato cultivation are assessed as negligible.

8.3.11. Sprout inhibitors

Sprout inhibitors are used to prevent potatoes from sprouting. In the Netherlands, about 20 products are authorised for this purpose, the vast majority of which are based on the active substance chlorpropham. The authorisation of products based on the active substance chlorpropham ended on 8 January 2020, with a grace period for use until 31 July 2020 (Ctgb, 2020e). In addition, a few products based on the active substances carvone, maleic hydrazide, 1,4-dimethylnaphthalene, ethylene and green mint oil are authorised[82]. Of these active substances, only chlorpropham is included in the multi-residue methods[78] used for analysing the active substances.

Chlorpropham is only authorised for use for ware and starch potatoes, just like maleic hydrazide, green mint oil and 1,4-dimethylnaphthalene. Carvone is only authorised for use for seed potatoes. Ethylene (made from ethanol) can be used for all potatoes (Ctgb, 2020e).

Chlorpropham

Chlorpropham is applied to the potatoes as dusting powder during the storage process, via the conveyor. It can also be sprayed as a liquid for follow-up treatment during storage. During storage, the treatment is repeated at a daily or four-weekly frequency, depending on the technique used. The final residue on the potatoes depends on the length of storage and the temperature in the storage facility. Storage in crates or in a heap results in an uneven distribution of chlorpropham over the potatoes (Nijkamp et al., 2017). The substance remains traceable in the storage shed for years to come and the shed releases chlorpropham for up to 10 years (Knuivers, 2019). When the potatoes are processed, the remaining soil along with the chlorpropham is removed. The soil tare is reused in various soil applications via a soil bank (Nijkamp et al., 2017). The requirements for the use of soil tare from potatoes treated with chlorpropham are set out in the Soil Quality Regulations (*Regeling bodemkwaliteit*) (2014)[83].

The acute toxic effects of chlorpropham are vomiting and reduced activity (observed based on experiments on rats). Chronic exposure to chlorpropham leads to effects on the thyroid gland and haematopoietic system (morphological changes of red blood cells, methaemoglobinemia, changes in liver and spleen due to haemolysis) (Nijkamp et al., 2017). No genotoxic effects have been reported for either chlorpropham or its main metabolite 3-chloroaniline. Chlorpropham is classified as a Category 2 carcinogen (EFSA, 2017b).

[82] As of 5 June 2020, a new sprout inhibitor based on orange oil has been authorised.

[83] Regulation of the State Secretary for Infrastructure and the Environment, of 26 November 2014, no IENM/BSK-2014/255553, amending the Soil Quality Regulations (updating references to normative documents 2015.1).

In the period from 1990 to 2018, there is one RASFF notification of MRL exceedance (where the MRL is 10 mg/kg (EC, 2020b), the notified amount was 47 mg/kg) in the UK in 2006.

In EFSA's annual plant protection product report, potatoes were reported separately in 2014 and 2017. For 2014, the annual EU overview of residues of plant protection products in food reveals only one potato sample with chlorpropham content above the MRL of 10 mg/kg (n = 1057), while in 256 potato samples, chlorpropham was found but in levels below the MRL (EFSA, 2016b). No exceedance of the MRL is reported for the year 2017 (n = 918), with levels remaining below the MRL in 290 samples (EFSA, 2019a).

No exceedances of the MRL were found in the Netherlands in the period 2016 to 2018 (n = 111) (KAP, 2020). The highest concentration found in this period is in a potato sample from 2017. But at 4.3 mg/kg, this is well below the MRL (10 mg/kg) (KAP, 2020). Although the concentrations are low, chlorpropham was found in a large proportion of the samples: it was found in 25 of the 40 samples in 2016, in 18 of the 37 samples in 2017 and in 18 of the 34 samples in 2018 (KAP, 2020). In potatoes, the levels lie between 0.005 and 1.7 mg/kg in 2016, between 0.071 and 4.3 mg/kg in 2017 and between 0.005 and 1.2 mg/kg in 2018 (KAP, 2020).

In 2003, the ARfD for chlorpropham was established by the European Commission at 0.50 mg/kg body weight and the ADI at 0.05 mg/kg body weight per day. These ARfD and ADI values were reconfirmed during the reassessment carried out for the renewal of the authorisation (EFSA, 2017b). Calculations of the minimum amount of potatoes (kg) with chloorprofam contamination level equal to the MRL that would have to be eaten in order to exceed the health-based limit value for acute toxicity (ARfD) show that a substantial serving of potatoes would have to be consumed per meal (3 kg of potatoes for an adult weighing 60 kg, and 1 kg for a child weighing 20 kg) (Table 8.6).

Chlorpropham is regularly detected on potatoes. Moreover, since the potatoes are repeatedly treated with sprout inhibitors throughout the storage period, chronic exposure of the consumer is a realistic scenario. As in the case of acute toxicity, an estimation can be made of the possible exceedance of the health-based limit value for chronic toxicity (ADI). These calculations show that, with chlorpropham concentrations at the level of the MRL, the ADI can be exceeded. A minimum daily average intake of 300 grams of potatoes (with chlorpropham at MRL level) for an adult weighing 60 kg or of 100 grams for a child weighing 20 kg (4-6 years) exceeds the ADI. These are quantities for large eaters. On average, potatoes are eaten three to four times a week in the Netherlands. That works out to an average consumption of 75.1 grams of potatoes per day (from 0 grams per day (P5) to 223 grams per day (P95, large eaters)) for adults in the Netherlands. For children aged 4-8 years, this is an average of 46.4 grams per day (from 0 grams (P5) to 124 grams (P95, large eaters)) (RIVM).

The above calculations do not take into account a decrease in the concentration of chlorpropham as a result of preparing the potatoes (washing, peeling and cooking/frying/deep-frying), which removes a significant part (up to 95%) of the chlorpropham. Most of the residues are on the skin, which means that unpeeled potatoes contribute the most to chlorpropham intake. In a worst-case estimate where a person consumes a large serving of unpeeled potatoes daily and the MRL for potatoes is exceeded on a regular basis, chlorpropham on potatoes can pose a risk to food safety.

Table 8.6 Estimated amount of potatoes with chlorpropham at MRL-level that a person may eat (kg/day) without exceeding the health-based limit value.

	MRL **Mg/kg potato**	**Max. concentration in NL** **Mg/kg potato**	**ARfD** **mg/kg body weight per day**	**ADI** **mg/kg body weight per day**	**Amount of potatoes with chlorpropham at MRL-level that a person would have to eat (kg/day) to reach the health-based limit value(1)** **(Limit value/MRL x kg body weight)**			
					Calculation with ARfD		Calculation with ADI	
					Child 20 kg	Adult 60 kg	Child 20 kg	Adult 60 kg
Chlorpropham	10	4.3(3)	0.50	0.05	1.0	3.0	0.1	0.3
	0.01(2)				1000	3000	100	300
3-chloroaniline	0.5(4)		0.03	0.007	1.2	3.6	0.28	0.84
	0.0005(4)				1200	3600	280	840

(1) This calculation does not take into account the decrease in concentration as a result of the preparation (washing/peeling, cooking/deep-frying/frying) of the potatoes
(2) Since the European authorisation of chlorpropham has expired, the MRL has been made equal to the LOD (0.01 mg/kg)
(3) Detected in one sample in 2017 (KAP, 2020)
(4) Five percent of the MRL of chlorpropham (DAR, 2016)

Chlorpropham is converted within the body, with 3-chloroaniline being produced as the main metabolite. This metabolite has a higher toxicity than chlorpropham itself. The ARfD for 3-chloroaniline has been established as 0.03 mg/kg body weight and the ADI as 0.007 mg/kg body weight per day (EFSA, 2017b). The 3-chloroaniline level is estimated to be 5% of the chlorpropham content (DAR, 2016). At a concentration of 10 mg/kg chlorpropham (MRL level), the concentration of 3-chloroaniline is estimated to be 0.5 mg/kg. Assuming the level of concentration, an estimation has been made of the minimum amount of potatoes (kg) that would have to be consumed to exceed the health-based limit values (ARfD and ADI) for 3-chloroaniline (see Table 8.6). These estimated servings are larger than those calculated for chlorpropham. Subsequently, it was estimated that, in case of consumption of the calculated chlorpropham-servings, the intake of 3-chloroaniline is about 35% of the ADI and over 80% of the ARfD for 3-chloroaniline[84].

In the Netherlands, products based on the active substance chlorpropham have a grace period for use until 31 July 2020. This means that chlorpropham may continue to be used for treating the 2019 potato harvest but may not be used for the 2020 harvest. Once banned from use, the MRL of chlorpropham for potatoes will be lowered to the LOD (0.01 mg/kg) (Knuivers, 2020). Based on this lower MRL, further calculations have been made of the minimum amount of potatoes (kg) that would have to be consumed in order to exceed the health-based limit values (Table 8.6). These calculated servings are extremely large and hence it can be concluded that, if this low MRL is maintained, chlorpropham does not pose a risk to the food safety of potatoes.

To achieve these low levels of chlorpropham in the new potato harvest, the storage facilities and sheds must be thoroughly cleaned. A sufficiently thorough cleaning appears to be difficult in practice and hence chlorpropham remains detectable in the sheds for a long time. The sector expects that the levels in the stored potatoes will almost always exceed 0.01 mg/kg. The European potato sector has therefore requested a temporary MRL that is higher than the LOD. This dossier has been submitted to the Dutch Board for the Authorisation of Plant Protection Products and

[84] Calculation for an adult: ADI: ((0.3 x 0.5)/60)/0.007 x 100% = 35.7% and ARfD: ((3 x 0.5)/60)/0.03 x 100% = 83%.

Biocides (*College voor de toelating van gewasbeschermingsmiddelen en biociden, Ctgb*) and is currently being assessed by EFSA (Knuivers, 2020). EFSA will submit its opinion to the European Commission. Until such a decision is taken, the existing MRL (10 mg/kg) will remain in force (Ctgb, 2020b).

Maleic hydrazide

Besides being used as a sprouting inhibitor during the storage of the potatoes, maleic hydrazide is also used as a sprouting inhibitor in the field three to five weeks prior to the harvest to prevent the ground-keeper potatoes ('volunteer potatoes') from sprouting among the subsequent crop (Nijkamp et al., 2017; Ctgb, 2018b). The substance accumulates in and around the 'eyes' of the potato. It is recommended as an effective alternative to chlorpropham (Knuivers, 2019).

Maleic hydrazide cannot be classified either as a genotoxic carcinogen or as reprotoxic or neurotoxic. Potential endocrine-disrupting effects seem unlikely. A reduction in body weight is the only toxic effect observed in animal studies. However, there is still too little information about the main metabolite of maleic hydrazide (3-pyridazinone) to estimate the risk for consumers (EFSA, 2016a).

The MRL for maleic hydrazide in potatoes has been established as 60 mg/kg potato and the ADI as 0.25 mg/kg body weight per day (EC, 2020b). No ARfD has been established (EFSA, 2016a; EC, 2020b). Levels found in potatoes (in the Netherlands in 2012, n = 1) were below the MRL (Nijkamp et al., 2017). Maleic hydrazide is not included in any of the multi-residue methods for plant protection product analysis[78] (KAP, 2020).

Just as in the case of chlorpropham, the minimum serving of potatoes (kg) that would have to be consumed daily to exceed the ADI can also be calculated for maleic hydrazide. This has been estimated as a serving of 300 grams for an adult (60 kg) and 100 grams for children (20 kg)[85]. These are quantities for large eaters. Average serving sizes are 75.1 grams for adults and 46.4 grams for children between 4 and 8 years (RIVM, 2020b). The above calculations do not take into account a possible decrease in the concentration of maleic hydrazide as a result of preparing the potatoes (washing, peeling and cooking/frying/deep-frying). The risk posed by the use of maleic hydrazide for the food safety of potatoes cannot be determined because there is hardly any information available about maleic hydrazide levels in or on potatoes in the Netherlands. More information on the main metabolite of maleic hydrazide (3-pyridazinone) is also lacking.

Ethylene and green mint oil

Products based on ethylene or green mint oil are used for the post-harvest treatment of crops in treatment rooms. These two products are not widely used because it is difficult to disperse them properly over the entire lot of potatoes (NVWA, 2018i).

Ethylene (ethene) is authorised for use in eight products to encourage the faster ripening of fruits (bananas) or as a sprout inhibitor for potatoes. Two of these products may be used for potatoes[86].

It is not considered necessary to derive health-based limit values (ARfD, ADI) or MRL (fruit or potatoes) for this substance (EC, 2020b).

[85] ADI/MRL x weight. For an adult weighing 60 kg: 0.25/50 * 60 kg = 0.3 kg. For child weighing 20 kg, this is 0.25/50 x 20 = 0.1 kg.

[86] Biofresh Safestore and Restrain

One product[87] based on green mint oil is authorised for use as a sprout inhibitor for potatoes during storage. This product is also authorised for use in organic farming (SKAL, 2019). No MRL for potatoes has been derived for green mint oil either.

Since it has not been considered necessary to derive any health-based limit values for these substances, no risks are expected in terms of the food safety of potatoes due to these two active substances.

1,4-Dimethylnaphthalene

1,4-Dimethylnaphthalene is a growth regulator and is used as a so-called dormancy enhancer to slow down the sprouting process.

It is neither genotoxic nor carcinogenic. In animal studies, the observed critical effect relates to histopathological changes in kidneys (rats; NOAEL of 10 mg/kg). Based on this, an ADI of 0.1 mg/kg body weight per day has been derived. An ARfD is not necessary for this substance, given its low acute toxicity (EFSA, 2013a).

The MRL for 1,4-dimethylnaphthalene has been established as 15 mg/kg (EC, 2020b). There are no known concentrations of 1,4-dimethylnaphthalene in potatoes. 1,4-Dimethylnaphthalene is not included in any of the multi-residue methods for plant protection product analysis[78] (KAP, 2020).

The risk of the use of 1,4-dimethylnaphthalene for the food safety of potatoes cannot be determined because there is no information on the levels of 1,4-dimethylnaphthalene in potatoes.

Carvone

Carvone-based sprout inhibitors are used for the post-harvest treatment of crops in treatment rooms. Carvone is a natural constituent of caraway and is also used as a fragrance and flavouring agent in food and personal care products (toothpaste, mouthwash).

Use as a sprout inhibitor is only authorised for seed potatoes, but seed potatoes treated with this product may not be used for consumption or placed on the market (Ctgb, 2020d). Carvone only inhibits the sprouting of the potatoes during the use of the product and is therefore less suitable for use for ware and starch potatoes (personal communication, NVWA HH). Chlorpropham, on the other hand, stops the sprouting process entirely and is therefore not suitable for use for seed potatoes since these, of course, need to sprout again later.

Carvone occurs in two forms: d-carvone (or S-carvone) and l-carvone (or R-carvone) (enantiomers). d-Carvone is used in the sprout inhibitor product Talent (EFSA, 2018a). In 2014, EFSA issued an opinion concerning the safety of carvone intake by consumers. The opinion made a specific distinction between d-carvone and l-carvone.

Liver toxicity is the most critical effect of d-carvone.

An ADI of 0.6 mg/kg body weight has been derived for d-carvone and EFSA estimates the intake of d-carvone from the total diet to be just below the ADI (EFSA Scientific Committee, 2014). However, the exposure of consumers to d-carvone as a result of its use for seed potatoes will be far below the intake from food. That is why no MRL has been derived for carvone (listed in Annex IV of Regulation (EC) 396/2005).

No monitoring data for carvone in potatoes are available (Nijkamp et al., 2017; KAP, 2020).

The likelihood of ware potatoes being contaminated with carvone is estimated to be very low. Firstly, not just because carvone is not authorised for use for ware potatoes but also since it is less suitable for ware potatoes. Secondly, because it is not allowed to offer carvone-treated seed potatoes for sale as ware potatoes. The food safety risk of carvone for potatoes is assessed as negligible based on this low likelihood. However, it is unknown whether these regulations are always complied with and whether carvone is present in ware potatoes.

[87] Biox M

Summary

- ➔ Ethylene and green mint oil are not expected to pose any risk to the food safety of potatoes.
- Chlorpropham, the most commonly used active substance in potato sprout inhibitors, almost never exceeds the MRL.
- Due to the ban on the use of chlorpropham since 31 July 2020, chlorpropham may continue to be used for treating the 2019 potato harvest, but not the 2020 harvest.
- The current MRL of chlorpropham is so high that even a small exceedance of the MRL will lead to a risk of the ADI being exceeded (worst case: daily consumption of large servings of unpeeled potatoes and a regular exceedance of the MRL on potatoes).
- ➔ Once the ban is in effect, the MRL will be lowered to the LOD (0.01 mg/kg). With the enforcement of this low MRL, chlorpropham will not pose a risk to the food safety of potatoes.
- ➔ The alternatives to chlorpropham (following the ban on 31 July 2020), i.e. maleic hydrazide and 1,4-dimethylnaphthalene, are not yet included in any of the multi-residue methods[78] for the analysis of plant protection products.
- ➔ The risk posed by the use of maleic hydrazide and 1,4-dimethylnaphthalene for the food safety of potatoes cannot be determined because there is no, or hardly any, information available about the levels of these active substances in potatoes in or on potatoes the Netherlands. More information on the main metabolite of maleic hydrazide (3-pyridazinone) is also lacking.
- Carvone may only be used for seed potatoes, but seed potatoes treated with this product may not be used for consumption or placed on the market.
- It is unlikely that carvone will be used for ware potatoes because its effect (inhibiting sprouting instead of stopping it) makes it less suitable for ware potatoes.
- ➔ The likelihood of ware potatoes being contaminated with carvone is estimated to be very low.
- ➔ The food safety risk of carvone for potatoes is assessed as negligible based on this low likelihood. However, it is unknown whether these regulations are always complied with and whether carvone is present in ware potatoes.

8.3.12. Hydraulic oils and lubricants

Hydraulic oils used in harvesters for the harvesting and storage of potatoes are made of refined mineral oils and additives. Leaks from these machines can contaminate potatoes and potato products (Nijkamp et al., 2017). It has been stipulated that the lubricants used in machines in the food industry may only contain liquid paraffin. A maximum level of 50 mg/kg may be present in food (Commodities Act Decree[88]). Lubricants that meet the food safety system requirements applicable to liquids with incidental food contact, based on the HACCP principles[6], are classified as 'H1' (food-grade lubricant). Residues of lubricants with this classification do not pose any health risk up to a maximum of 10 ppm (mg/kg) (Nijkamp et al., 2017). The VVAK Food and Feed Safety Guide (Akkerbouw Certificeringsoverleg, 2019) refers to the use of food grade oil in machines where there is a risk that the lubricant could come into contact with the product through lubrication or leakage. It is not known whether this is regularly monitored.

In the Netherlands, potatoes contaminated with hydraulic oils have been found in the potato processing industry (2015). However, no information is available about the detected levels (Nijkamp et al., 2017).

The risk of using hydraulic oils in potato cultivation cannot be assessed because no information is available with regard to the detected levels.

Summary

[88] Preparation and Processing of Foodstuffs (Commodities Act) Decree (Art. 7).

- Hydraulic oils can leak from harvesters and from machines used in the potato processing industry.
- ➔ There is no information on the use of lubricants within the potato chain that meet food safety system requirements for liquids with incidental food contact (H1 classification) or information on the levels detected on potatoes. Therefore, it is not possible to assess the risk of the use of hydraulic oils in potato cultivation.

8.3.13. Refrigerants

During the storage of potatoes, fans and heating or cooling equipment may be used for air conditioning in the storage sheds. The use of refrigerants is regulated by European legislation. Hydrochlorofluorocarbons are now banned (Ozone Policy Regulation (EC) 1005/2009[89]) and hydrofluorocarbons will be phased out from 2020 (F-Gasses Regulation (EC) 517/2014[90]). Commonly used refrigerants are penta/tetra/trifluoroethane. Mechanical cooling is expected to be used more in the future since it is seen as a good alternative to the use of sprout inhibitors (Vos P, 2020).

Substitutes that are less harmful to the environment are propane CO_2 or ammonia CO_2. Cooling systems containing hydrofluorocarbons are subject to mandatory semi-annual or annual leak tightness testing (Nijkamp et al., 2017). In addition, the VVAK advises that a cover plate should be placed over the potatoes when using cooling equipment (Akkerbouw Certificeringsoverleg, 2019). Research by NL Agency (*Agentschap NL*)[91] in 2012 revealed an average hydrofluorocarbon leakage rate of 7.8%, calculated based on data on the refilling of installations. This involved a random sampling within the food industry, with the exception of the meat and dairy sectors (Nijkamp et al., 2017). There are no known studies on the occurrence of refrigerants in potatoes. Since refrigerants are volatile substances, the amount that ends up in food or potatoes will be much lower than the actual leaked amount (in other words, a certain part will evaporate).

Refrigerants are unlikely to pose a risk to the food safety of potatoes given the volatile properties of the substances and the stipulated precautions.

Summary

- ➔ The used refrigerants are volatile substances and therefore the amount that ends up in the food or potatoes from air conditioning equipment will be much lower than the actual amount leaked (Akkerbouw Certificeringsoverleg, 2019). Refrigerants are unlikely to pose a risk to the food safety of potatoes given the volatile properties of the substances and the stipulated precautions.

8.3.14. Cleaning agents and disinfectants

Cleaning agents and disinfectants are used to clean and disinfect the machines and materials used for harvesting, sorting and processing potatoes and for cleaning the crates used for storage and transport. For better disinfection results, it is recommended that the materials are thoroughly cleaned in advance. It is not known which cleaning agents are used for this. Disinfectants are used to prevent the spread of plant diseases (Nijkamp et al., 2017).

The Ctgb defines biocides as products that are used to destroy or prevent the occurrence of harmful or undesirable organisms. There are four main groups of biocides: disinfectants,

[89] Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer.

[90] Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.

[91] NL Agency was a former agency of the Ministry of Economic Affairs. Since 1 January 2014, it has merged with the National Service for the Implementation of Regulations (*Dienst Regelingen*) to form the Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*).

preservatives, pesticides and other biocides. Most of the biocides used in the potato chain will fall under the category of disinfectants or pesticides. In 2017, the Ctgb further harmonised its biocide authorisation policy to align it with the European directives, as a result of which the use of biocides may no longer be specifically aimed at the protection of plants or plant products; products used for this purpose are designated as 'plant protection products'. This only applies to new registrations or re-registrations to ensure that this change can be gradually implemented (Ctgb, 2018d).

Excessive or incorrect use of disinfectants can contribute to the development of resistance to disinfectants as well as antibiotics (Gezondheidsraad, 2016). However, it is unknown whether disinfectants are always used in the correct manner in potato cultivation and the processing industry. The main sectors where disinfectants are used are the healthcare sector, livestock farming, agricultural, food and water treatment sectors (Gezondheidsraad, 2016). Disinfectants have not been used for as long in the primary sector as compared to, for example, the food service industry. Knowledge on how to use them effectively is still limited (NVWA, 2018i).

The Ctgb authorisation database contains a number of products used in potato cultivation. Active substances in these products include quaternary ammonium compounds (alkyldimethylbenzylammonium chloride (BAC) and didecyldimethylammonium chloride (DDAC)), tosylchloramide-sodium and hydrogen peroxide (Ctgb, 2020f). However, this does not provide a complete picture because the search results of the authorisation database do not include biocides with a Union authorisation or those subject to a simplified authorisation procedure [92](Ctgb, 2020f). Other active substances from disinfectants used in potato cultivation include benzoic acid and sodium hypochlorite (Nijkamp et al., 2017). It is not known whether this list is exhaustive. Generically authorised disinfectants, i.e. those not specific to potato cultivation, might also be used.

Quaternary ammonium compounds

Quaternary ammonium compounds (QUATs), including DDAC and BAC, are only authorised for use for the disinfection of equipment and tools used for seed potatoes (Nijkamp et al., 2017). These could enter the food chain if seed potatoes are used as ware potatoes or if materials used for the cultivation of seed potatoes are subsequently used in the cultivation of ware potatoes. In addition, these substances are also generically authorised for use for the disinfection of cultivation materials and/or tools. In practice, it appears that rejected seed potatoes are partly sold in the Netherlands as ware potatoes (see section 3.3).

BAC is classified as a possible carcinogen, mutagen (Category 1A or 1B) and is toxic to reproduction. DDAC is toxic to reproduction. There is no information on the genotoxicity, carcinogenicity, immunotoxicity, neurotoxicity or endocrine disrupting effects of DDAC (Banach et al., 2020).

The MRL for DDAC and BAC is 0.1 mg/kg (Banach et al., 2020). In 2013, EFSA published an inventory of the presence of DDAC in food. In 2012/2013, DDAC was found in nine potato samples (n = 1167) from different Member States (incl. Netherlands). DDAC was most commonly found in milk and milk products (EFSA, 2013a). In 2018, the NVWA took five samples of potatoes from distribution centres and wholesalers and analysed them for disinfectants. In all five samples, the concentration of BAC and DDAC was lower than the LOQ (0.005 mg/kg) (KAP, 2020). Therefore, BAC and DDAC do not pose a risk to the food safety of potatoes.

[92] With a Union authorisation, an authorisation for the entire EU can be obtained in one go. A simplified authorisation is possible for products that meet specific requirements (for example, the absence of substances of concern).

Tosylchloramide-sodium

An MRL of 0.1 mg/kg has been established for tosylchloramide-sodium in potatoes. Tosylchloramide-sodium may only be used in the cultivation of seed potatoes (Nijkamp et al., 2017). No data are available on measured levels in potatoes. It is not possible to assess the risk of tosylchloramide-sodium for the food safety of potatoes.

Hydrogen peroxide and benzoic acid

Bezoic acid is a volatile substance, while hydrogen peroxide is a moderately volatile substance that is reactive and is converted relatively quickly when it comes in contact with air. So it is hardly likely that residues of these substances will be present on potatoes (Nijkamp et al., 2017)and hence there is no expected risk to the food safety of potatoes. It is not necessary to establish an MRL for these two substances (EC, 2020b).

Sodium hypochlorite

Sodium hypochlorite is a highly reactive substance and is rapidly converted, forming chlorate and perchlorate (Banach et al., 2020).

The acute toxic effect of chlorate is the formation of methaemoglobin (oxygen deficiency). The main chronic effect is the inhibition of iodine absorption (EFSA CONTAM Panel, 2015a). Perchlorate can also inhibit the uptake of iodine by the thyroid gland in case of chronic exposure. A single exposure to perchlorate can have adverse effects on unborn babies and infants (EFSA CONTAM Panel, 2014).

The MRL for chlorate is 0.01 mg/kg and for perchlorate 0.1 mg/kg, both of which apply to fruit and vegetables[93], (Banach et al., 2020). In 2015, EFSA made an inventory of the presence of chlorate in food, including in potatoes from 19 Member States (including the Netherlands) and reported average concentrations of 5 µg/kg (LB) to 11 µg/kg (UB) (n = 103) (EFSA CONTAM Panel, 2015a). For perchlorate, average concentrations in potatoes are reported from 1.8 µg/kg (LB) to 5.8 µg/kg (UB) (n = 191; without suspect samples) and from 3.8 µg/kg (LB) to 8.0 µg/kg (UB) (n = 204; including suspect samples) (EFSA CONTAM Panel, 2014). In 2018, the NVWA analysed five samples of potatoes for the presence of disinfectants, including chlorate and perchlorate. In all five samples, the concentration of both substances was lower than the LOQ (0.01 mg/kg) (KAP, 2020). In addition to the use of disinfectants, chlorate and perchlorate can also end up in food as a result of the use of chlorinated water or contaminated processing aids. Moreover, perchlorate can also originate from artificial fertilisers (Banach et al., 2020).

EFSA has concluded that acute exposure to chlorate from food and drinking water does not entail any risk (ARfD of 36 µg/kg body weight). With chronic exposure to chlorate, the TDI (3 µg/kg body weight per day) is exceeded for children with high exposure (P95). For adults, chronic exposure does not lead to exceedances of the TDI. A major source of chlorate intake is chlorinated drinking water (EFSA CONTAM Panel, 2015a). Since drinking water is almost no longer chlorinated in the Netherlands, it is unlikely that the TDI for chlorate will be exceeded, assuming that drinking water is the main source.

EFSA indicates that chronic exposure to perchlorate may pose a risk to young children with thyroid dysfunction who are large eaters (fruits and vegetables) and to infants who are being fed by mothers with thyroid dysfunction (EFSA CONTAM Panel, 2014).

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[93] As of 1 July 2020, the MRL for chlorate (potatoes) and perchlorate (fruit and vegetables) has been changed to 0.05 mg/kg.

(Commission Regulation (EU) 2020/749 of 4 June 2020 amending Annex III to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for chlorate in or on certain products and Commission Regulation (EU) 2020/685 of 20 May 2020 amending Regulation (EC) No 1881/2006 as regards maximum levels of perchlorate in certain foods)

Based on the brief information provided above, neither DDAC or BAC (not present or only found to a negligible extent in ware potatoes) nor hydrogen peroxide or benzoic acid (volatile compounds) appear to pose any risk to the food safety of potatoes. Chronic exposure to chlorate and perchlorate (sodium hypochlorite) is a risk to infants and people with thyroid dysfunction. It is not clear to what extent potatoes contribute to this because there is too little information about the occurrence of these substances in potatoes. There is no information about the occurrence of tosylchloramide-sodium in potatoes and potato products and therefore the risk cannot be assessed.

Summary

- Cleaning agents and disinfectants are used to clean and disinfect machines and materials used for harvesting, sorting and processing of potatoes and for cleaning and disinfecting the crates used for storage and transport. The specific products used for this are not known.
- Quaternary ammonium compounds (QUATs), including DDAC and BAC, and tosylchloramide-sodium are only authorised for seed potatoes.
- ➔ No risks for the food safety of potatoes are expected for DDAC, BAC, hydrogen peroxide and benzoic acid.
- ➔ The food safety risk due to the use of tosylchloramide-sodium in potato cultivation cannot be assessed because of the lack of occurrence and toxicity data.
- ➔ Chronic exposure to chlorate and perchlorate (sodium hypochlorite) is a risk to infants and people with thyroid dysfunction. It is not clear to what extent potatoes contribute to this because there is too little information about the occurrence of these substances in potatoes.
- Incorrect and excessive use of disinfectants can contribute to the development of resistance to disinfectants as well as antibiotics.

8.3.15. Processing aids

Processing aids are substances that are used during the production process. These include, for example, antifoaming agents and polymer flocculants for washing and rinsing potatoes and substances (clay) that help in sorting the potatoes (Akkerbouw Certificeringsoverleg, 2017). No authorisation procedure exists for these processing aids, but Regulation (EC) 1333/2008[94] indicates that these substances must be such that they do not pose a risk to food safety. Companies must themselves demonstrate, on the basis of a hazard analysis, that the use of these processing aids does not endanger human health (Nijkamp et al., 2017).

Before the potatoes are processed, any poor-quality potatoes - selected based on density - are separated from the starchy (heavier) potatoes by means of a salt or clay bath. In 2004, a potato processing company used kaolinite clay (marl) for this purpose, which turned out to be contaminated with dioxins. The dioxins remained on the potato skins, which were processed into animal feed intended for dairy cattle. When dioxins were found in the milk, this could be traced back to the location of the potato processing company. No dioxins above the action level (0.30 pg/g WHO-TEQ for fruit and vegetables) were found in the potatoes themselves, because the clay had been removed during the washing and peeling of the potatoes in the production process (Nijkamp et al., 2017). The VVAK Food and Feed Safety Guide (Akkerbouw Certificeringsoverleg, 2019) focuses explicitly on this. Clay that is used for washing and rinsing the potatoes must be free of dioxins (based on a declaration from the supplier) (Akkerbouw Certificeringsoverleg, 2019).

Summary

- ➔ No data have been found about the levels of processing aids in potatoes and potato products.
- Following an incident (2004) with contaminated clay, the VVAK has stipulated that the clay used in washing and rinsing the potatoes must be free from dioxins.

[94] Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives.

8.3.16. Food additives

Food additives such as acids, preservatives and antioxidants can be intentionally added during the handling and processing of potatoes. The use of food additives, the so-called E numbers, is regulated via European regulations on the use of additives and maximum levels of use (Regulation (EC) 1333/2008; Regulation (EU) 1129/2011[95]; Regulation (EU) 601/2014[96]). By 2020, all food additives authorised for use in the EU prior to 20 January 2009 will need to be re-evaluated (Regulation (EU) 257/2010[97]). EFSA will carry out these re-evaluations.

Acids (e.g. citric acid (E330), sorbic acids (E200-E203)) or sulphites (E220-E228) (e.g. sodium metabisulfite (E223)) are added to prevent peeled potatoes from browning. Sulphites also have an antimicrobial effect. EFSA has carried out an evaluation of the toxicity and use of, and exposure to, sulphites (E220-E228) from food (EFSA ANS Panel, 2016).

Based on the evaluated toxicity studies, it was concluded that the sulphites are neither genotoxic nor carcinogenic. There was too little information to reach a conclusion on reproductive toxicity. Sulphites can cause urticaria (hives) and angioedema (swelling of the face and throat) and trigger an asthma attack in asthmatic patients (EFSA ANS Panel, 2016).

The use of sulphites is prohibited in the US due to the adverse effects on people with asthma. An exception is made for potatoes (WFBR, 2018). The use of sulphites is permitted in Europe, with a maximum level of 50 mg/kg for peeled potatoes, 100 mg/kg for frozen potatoes and 400 mg/kg for dehydrated potato products (Regulation (EU) 1333/2008 and Regulation (EU) 1129/2011).

EFSA's estimates of exposure from food show that the ADI for sulphite (0.7 mg SO_2 equivalent[98]/kg body weight per day) is exceeded, but it should be noted that the ADI needs to be re-evaluated as soon as new data (toxicity) become available. Potato products appear to be an important source (more than 5%) of exposure to sulphites (EFSA ANS Panel, 2016).

No data were found on the presence of food additives in potatoes and potato products in the Netherlands. It is therefore not known whether the additives are always being used in the right manner or whether the established maximum use levels in potato products are being exceeded.

Summary

- ➔ The addition of sulphites to food leads to exceedance of the ADI, with potato products contributing more than 5% to this.

8.3.17. Substances formed by heating

Acrylamide

Acrylamide may be formed when starchy products such as potatoes and potato products are heated. When heated above 120ºC , acrylamide is formed via the Maillard reaction (non-enzymatic

[95] Commission Regulation (EU) No 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives.

[96] Commission Regulation (EU) No 601/2014 of 4 June 2014 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council as regards the food categories of meat and the use of certain food additives in meat preparations.

[97] Commission Regulation (EU) 257/2010 of 25 March 2010 setting up a programme for the re-evaluation of approved food additives in accordance with Regulation (EC) No 1333/2008 of the European Parliament and of the Council on food additives.

[98] SO_2 equivalent: the sum of the measured concentrations of sulphur compounds H_2S, COS, CS_2, (..), expressed in SO_2 equivalents.

browning) between amino acids, especially asparagine, and reducing sugars such as glucose and fructose. Consumers mainly ingest acrylamide via chips, although this can also occur via crisps, biscuits, gingerbread and coffee. This was first described by the Swedish National Food Agency (NFA) at the beginning of this century (2002) (Nijkamp et al., 2017). EFSA concluded that deep-fried potatoes are the main source of intake of acrylamide from food (EFSA CONTAM Panel, 2015b).

Acrylamide is the same substance that is being used in the chemical industry since around 1950 for the production of polyacrylamide. The polymer is not carcinogenic but the monomer acrylamide is classified by the IARC as 'Probably carcinogenic to humans' (Group 2A) (Nijkamp et al., 2017). In addition, acrylamide can cause potentially adverse effects to the nervous system and has a negative effect on reproduction (especially in men) and the development of children (EFSA CONTAM Panel, 2015b).

No legal MLs (maximum permissible levels) have yet been established for acrylamide in food. However, the European Commission has indicated certain benchmark levels based on the ALARA principle[99]. When a benchmark level is exceeded, food business operators must take corrective action to bring the levels below the benchmark levels. The measures taken must be evaluated based on sampling and analysis. For ready-to-eat chips, the benchmark level is 500 µg/kg, and for potato crisps, potato-based crackers and other potato products based on potato dough, the benchmark level is 750 µg/kg (Regulation (EU) 2017/2158[100]). Until 2017, this was 600 µg/kg for chips and 1000 µg/kg for crisps (Recommendation 2013/647/EU[101]).

Between 1990 and 2019, there were three notifications in the RASFF database of high acrylamide concentrations in chips (1418-5900 µg/kg). Average concentrations of acrylamide in food (2010-2014) reported by EFSA are: 308 µg/kg (MB) (n = 1,694) for deep-fried potato products and 389 µg/kg (MB) (n = 34,501) for crisps (EFSA CONTAM Panel, 2015b). The Swedish NFA demonstrated that concentrations of acrylamide in chips (16%) and crisps (34%) were above the indicative values[102] (Nijkamp et al., 2017).

In the Netherlands, the NVWA has been monitoring acrylamide levels in chips (cafeterias and restaurants, Table 8.7) and potato crisps (Table 8.8) for a number of years now. The highest concentration measured in chips made from fresh potatoes is 2643 µg/kg (2017), which exceeds the benchmark level by more than a factor of five (500 µg/kg). In chips made from potato dough, the concentrations are higher than in fresh potato chips, and in 10 of the 14 samples, the benchmark level is exceeded. The benchmark level is also exceeded by a large margin in crisps (Table 8.8).

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[99] ALARA: As Low As Reasonably Achievable (section 8.2)

[100] Commission Regulation (EU) 2017/2158 of 20 November 2017 establishing mitigation measures and benchmark levels for the reduction of the presence of acrylamide in food.

[101] Commission Recommendation of 8 November 2013 on investigations into the levels of acrylamide in food.

[102] The indicative values from Recommendation 2013/647/EU.

Table 8.7 Acrylamide in chips (KAP, 2020).

	Chips made from fresh potatoes				Chips made from potato dough			
	Number(1)	Average µg/kg	Minimum µg/kg	Maximum µg/kg	Number(1)	Average µg/kg	Minimum µg/kg	Maximum µg/kg
2016	5/1	380	123	545	14/10	1675	114	5228
2017	50/32	932	50	2643	-			
2018	-				-			

(1) Number of samples/number of samples above the benchmark level (compared to the current benchmark level of 500 µg/kg)

Table 8.8 Acrylamide in crisps (KAP, 2020).

	Crisps made from fresh potatoes				Crisps made from potato dough			
	Number(1)	Average µg/kg	Minimum µg/kg	Maximum µg/kg	Number(1)	Average µg/kg	Minimum µg/kg	Maximum µg/kg
2016	33/20	1046	223	3675		-		
2017	-					-		
2018	48/11	488	0	1140	7/0	309	0	568

(1) Number of samples/number of samples above the benchmark level (compared to the current benchmark level of 750 µg/kg)

Several factors influence the concentration of acrylamide in deep-fried or fried potato products. An important factor is the level of reducing sugars in the potatoes, which mainly depends on the potato variety and the conditions during the harvest. Special cultivars for potatoes intended for chips usually have a lower sugar content than cultivars for regular ware potatoes (see Annex 3.2). Low sugar levels are preferable, because less acrylamide is formed during the production process of deep-fried or fried potatoes and potato products. In addition, the amount of nitrogen, potassium and calcium in the soil influences the sugar content in the potatoes. The sugar content also appears to increase in case of lower temperatures during storage and a longer storage period. During processing, the level of reducing sugars can be lowered by blanching the potatoes before heating or by adding acidifying agents (citric acid, E330). However, if the potatoes are blanched, the disadvantage is that they absorb more oil during deep-frying and acidification with citric acid gives them an undesirable aftertaste. Finally, the frying time and temperature have a strong effect on the formation of acrylamide. EFSA's advice is to avoid heating potatoes and potato products at temperatures above 170-175ºC (Nijkamp et al., 2017). EU Member States are expected to monitor and enforce requirements for acrylamides in certain foods, such as potato products (Regulation (EU) 2017/2158 and Recommendation (EU) 2019/1888[103]). If acrylamide levels are significantly higher than benchmark levels, food business operators are required to examine acrylamide levels and take corrective action to minimise them.

[103] Commission Recommendation (EU) 2019/1888 of 7 November 2019 on the monitoring of the presence of acrylamide in certain foods.

In the updated version of the Hygiene Code for the food service industry (KHN, 2016), it is stated that the temperature of frying oil may not exceed 175°C.

No health-based limit value (TDI) can be derived for acrylamide since it is a suspected genotoxic carcinogen. For genotoxic substances, EFSA has recommended the use of a MoE and has indicated that an MoE of 10,000 or higher does not give cause for concern for public health. For the exposure of different age groups to acrylamide from food, EFSA has calculated MoEs ranging from 425 (adults; LB concentration) to 89 (toddlers; UB concentration) (P50) and from 283 (elderly; LB concentration) to 50 (pre-schoolers; UB concentration) (P95). The $BMDL_{10}$[104] (neoplastic effects) of 0.17 mg/kg body weight per day was used as a reference point.

Exposure studies of the Dutch population (2009 and 2014) also show that the MoE for acrylamide (based on the $BMDL_{10}$ for neoplastic effects) is many times lower than the desired 10,000. The MoE (P50 intake) ranges from 242 (young children) to 566 (adults) and the MoE (P95 intake) ranges from 121 (children) to 189 (adults). Therefore, there is cause for concern for public health with respect to acrylamide intake from food. Deep-fried potatoes and crisps are the largest contributors to acrylamide intake: 35% for young children (2-6 years), 56% for children (7-15 years) and 43% for adults (Nijkamp et al., 2017).

Summary

- Acrylamide is formed when potatoes are heated at high temperatures (>120°C).
- Acrylamide is a suspected carcinogen (genotoxic) and is also potentially harmful to the nervous system and has a negative effect on reproduction and on the development of children.
- Deep-fried potato products (chips, crisps) contain considerable levels of acrylamide, which regularly exceed European benchmark levels.
- Deep-fried potatoes are the main contributor to acrylamide intake from food.
- Legal MLs for acrylamide in food have not been established, but food business operators are required to carry out further investigations if established benchmark levels are exceeded (chips: 500 µg/kg; crisps, crackers and other potato products: 750 µg/kg).

➔ There is cause for a public health concern with regard to the intake of acrylamide from food. Deep-fried potatoes and crisps are the largest contributors to this, with a contribution of up to more than 50% for children.

Advanced glycation end products (AGEs)

In addition to acrylamide, other substances can also be formed when foods rich in sugars are heated. A group of substances that inevitably arises via the Maillard reaction are called 'advanced glycation end products' (AGEs). Known substances from this group found in food include Nε-carboxymethyl-lysine (CML), Nε-carboxyethyl-lysine (CEL), methylglyoxal-lysine dimers (MOLD), methylglyoxal (MG), pentosidine and pyrraline (Van der Lugt et al., 2020). [

These substances seem to play a role in age-related diseases such as diabetes (Type 2), inflammatory responses and cardiovascular disease (Scheijen et al., 2016; Van der Lugt et al., 2018).

Various studies have been conducted on AGEs but only a few of these have examined potatoes and potato products. The levels of three substances from the group of AGEs have been measured in potatoes and potato products. For CML, these range from 0.1 mg/kg in cooked potatoes from the supermarket (Scheijen et al., 2016) to 22 mg/kg in deep-fried and oven-baked potato crisps, (Nijkamp et al., 2017)and for CEL, from 0.9 mg/kg in frozen chips from the supermarket (Scheijen et al., 2016) to 7.1 mg/kg in deep-fried and oven-baked crisps (Nijkamp et al., 2017). For MG, the only known content is 94 mg/kg in deep-fried potato products (Nijkamp et al., 2017). It is likely

[104] Benchmark dose lower confidence limit: dose at which there may be an additional 10% risk of tumor formation.

that AGEs can also develop during the preparation of potatoes by consumers at home but the extent to which this can happen is unknown.

No legal MLs have been established for AGEs in food. EFSA has also not issued any opinion for this group of substances.

Summary

- AGEs are formed when foods rich in sugars are heated.
- No legal MLs have been established for AGEs in food.
- ➔ AGEs have also been found in potatoes and potato products. There is not enough occurrence data to assess the food safety risk of AGEs in potatoes and potato products. Health-based limit values are also lacking.

Furans

Furan and methylfurans are formed in food when the food is heated (also during cooking). They can be formed in various ways from, for example, amino acids, unsaturated fats and carbohydrates/sugars (EFSA CONTAM Panel, 2017a). Therefore, furans have always been present in heated food. However, they are volatile substances, so reheating food can help reduce the level of furans (EFSA CONTAM Panel, 2017a). Until 2014, 2-methylfuran and 2,5-dimethylfuran were used as flavouring agents in foodstuffs. Since the industry stopped using these substances, they have also been removed from the European list of permitted flavourings and food ingredients (Regulation (EC) 1334/2008[105]) (EFSA CONTAM Panel, 2017a).

Furans and related methylfurans are also used as intermediates in the chemical and pharmaceutical industries and are potential biofuels. Furans have been found in the air (from combustion processes), in industrial effluents and in rivers (EFSA CONTAM Panel, 2017a).

Furan has been classified by the IARC as 'Probably carcinogenic to humans' (Group 2A) (Nijkamp et al., 2017). Furan and methylfurans can cause long-term liver damage (EFSA CONTAM Panel, 2017a).

In industrially processed potatoes (n = 4), the following concentrations have been measured: for furan, between 20 and 114 µg/kg; for 2-methylfuran, between <1 (LOD) and 2.7 µg/kg; and for 3-methylfuran, between <1 (LOD) and 1.5 µg/kg. Concentrations between 3 and 15 µg/kg have been measured for furan in a number of different types of potato products (n = 1 per product) (EFSA CONTAM Panel, 2017a).

No legal MLs have been established for furans in foodstuffs ((EC) 1881/2006[61]).

EFSA concludes that the highest exposure to furans arises from coffee and grain-based foods. Although there is no health concern for the average consumer, EFSA refers to a public health concern (based on MoE) for consumers with a high consumption levels (a lot of coffee, grains and grain products). Moreover, EFSA concludes that the exposure is significantly higher when methylfurans are also included in the exposure calculations (EFSA CONTAM Panel, 2017a).

In a Belgian study, it is estimated that, for children, potatoes contribute 9% of the total exposure to furans (Scholl et al., 2012). Potatoes and potato products are not mentioned in the EFSA study because they make a negligible contribution to the intake of furans from food. This conclusion is based on the minimal information available about the levels of furans in potatoes and potato products. EFSA indicates that additional data is needed concerning methylfuran levels (EFSA CONTAM Panel, 2017a).

Summary

- Furans are formed in foods on heating.
- No legal MLs have been established for furans in food.

[105] Regulation (EC) 1334/2008 of the European Parliament and of the Council of 16 December 2008 on flavourings and certain food ingredients with flavouring properties for use in and on foods.

- Coffee, grain and grain products are by far the most significant contributors to the intake of furans from food. The contribution of potatoes appears to be much smaller.
- ➔ The risk of furans in potatoes and potato products for food safety cannot be properly determined due to insufficient data on the occurrence of furan and related methylfurans in prepared potato products.

MCPD

MCPD (3-chloro-1,2-propanediol) is a substance formed during the refining of vegetable oils and fats (high temperature).

This substance can be harmful to the kidneys and is classified as a possible carcinogen. Male infertility is an identified chronic effect (Boon & te Biesebeek, 2015).

No MLs have been established for MCPD in potatoes. EFSA has reported values of 870 and 1100 µg/kg in chips (EFSA CONTAM Panel, 2018a). In 2018, 33 crisps samples were analysed in the Netherlands for MCPD, where the substance was measured in the fat fraction of the product. MCPD was found in 16 samples, at concentrations of 100 to 320 µg/kg (average of 177 µg/kg) (KAP, 2020).

In 2018, EFSA evaluated the TDI. A TDI of 2 µg/kg body weight per day offers protection against male infertility (EFSA CONTAM Panel, 2018a). In 2015, RIVM studied the intake of MCPD from food. The chemical analysis techniques for MCPD are still under development, but the RIVM has provided an initial estimate of the MCPD intake. Especially among younger children (2 to 7 years), the intake was higher than the TDI for 18-35% of the children. Thereafter, the percentage decreases; from the age of 17, the TDI is exceeded among less than 5% of the children (Boon & te Biesebeek, 2015). Main contributors to the intake are margarine, biscuits and vegetable oils (Boon & te Biesebeek, 2015). Potato products, such as crisps and chips, make a relatively small contribution (less than 5%) to the total intake of MCPD from food. The risk of MCPD for the food safety of potato products is assessed as negligible.

Summary

- MCPD is a substance formed during the production of vegetable oils and fats (high temperature).
- No legal MLs have been established for MCPD in potatoes.
- MCPD has also been found in potatoes and potato products.
- ➔ The risk of MCPD for the food safety of potatoes is assessed as negligible because potato products, such as crisps and chips, make a relatively small contribution (less than 5%) to the total intake of MCPD from food.

8.3.18. Substances from packaging materials and other food contact materials

A large number of chemical substances are used in the production of plastic packaging materials (Food Contact Materials, FCM): monomers, catalysts, printing inks, antioxidants, plasticisers, fillers, etc. New substances are often created during the production process, both intentionally (polymers) and unintentionally; the last group is referred to in legislation as NIAS (non-intentionally added substances).

In European legislation regarding FCMs (Regulation EC 1935/2004[106] and Regulation EC 2023/2006[107]), it is stated that these materials must be manufactured in accordance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities that:

a) endanger human health;

b) bring about an unacceptable change in the composition of the food; or

c) cause a deterioration in the organoleptic properties of the food.

A special regulation has been drafted for plastic FCMs (Regulation EU 10/2011[108]) with lists of precursors and additives that have received a positive evaluation. Only the substances on these lists may be used, provided they comply with the imposed restrictions. Such a restriction could be, for example, the imposition of an SML. Requirements are also defined for the end product, including the migration of a number of heavy metals and primary aromatic amines.

A 2016 inventory of chemicals that can migrate from food packaging to food yielded a list of approximately 6,000 unique chemicals, 77% of which have not been assessed for their hazard properties (Van Bossuyt et al., 2016). Based on the physico-chemical properties of these substances, the authors conclude that these substances can migrate to food and thus become available for human intake. It is not clear which substances are relevant to potatoes and potato products because the study did not focus on the occurrence in different types of food.

An overview (Groh et al. (2019)) of substances known to occur in plastic packaging was published in 2019. The accompanying database contains 906 substances that are likely to occur and 3377 substances that may occur. The authors have also created a hazard classification for the 906 substances: 63 substances received the highest classification for human health and 68 for the environment. In addition, 7 substances are classified as persistent, bioaccumulative and toxic (PBT) or as very persistent, very bioaccumulative (vPvB) and 15 as endocrine disruptors. The substances are used in plastics as monomers, intermediates, solvents, surfactants, plasticisers, stabilisers, biocides, fire retardants, accelerators and dyes.

Potato products, such as pre-fried chips, potato slices and cooked baby potatoes, are sold in the shop packed in plastic. These packaged products are usually kept in the refrigerated or frozen foods section. No information is available about the type of plastic used for packaging potato products. As a result, there is also no insight into the substances that may be present in these packaging materials and their possible migration to the potato product.

Perfluorinated compounds (PFAS) can migrate from packaging materials to food. The RIVM has conducted a literature search on PFAS in FCMs (Bokkers et al., 2019). PFAS are used for making paper and cardboard grease and water-repellent. This type of packaging can be used for serving chips, whereby PFAS can migrate to the chips. In 2020, the NVWA conducted a study on the presence of PFAS in paper and cardboard in relation to food contact.

Equipment used in the food industry must also comply with FCM legislation if they come into contact with food. The RASFF database (1990 to 2018) contains about 10 notifications concerning the migration of substances from potato masher machines. These substances include a number of

[106] Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC.

[107] Commission Regulation (EC) No 2023/2006 of 22 December 2006 on good manufacturing practice for materials and articles intended to come into contact with food.

[108] Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food.

heavy metals (chromium, nickel and manganese) and various aromatic amines (4,4-diaminodiphenylmethane, aniline). In several cases, this involved machines from China.

Summary

- ➔ It is not known which substances from food packaging are relevant to potato products.

9. Physical risks to food safety in the potato chain

9.1. Introduction

Physical hazards in the potato chain are contaminants present in a product that can pose a threat to the health of the consumer when the product is used or consumed. These are foreign objects that can be unintentionally introduced into the food and cause choking, cuts and other physical injury. These physical hazards are essentially harmful substances that are present in food and are referred to as *foreign objects* in relation to food safety. Physical hazards that are inherent to the product itself or the method of preparation are not included in this category as these are generally part of the hazards of consuming food, for example, when the high temperature, shape or consistency of food is such that intake leads to a risk of choking or injury. Examples of contaminants that often occur in the potato chain are stones, glass, animal material (such as bone residues), material of plant origin (including wood), metal, golf balls and plastics.

To assess the physical hazards, information was sought and collected in a number of ways. Firstly, scientific literature was consulted with the help of search engines such as Scopus and PubMed, using keywords such as 'potato', 'potatoes', 'Solanum tuberosum', 'gnocchi', 'physical', 'accidents' and 'hazards' in various combinations. In addition, relevant notifications were looked up in the RASFF, the European Union's system for food and feed safety alerts intended for the rapid exchange of notifications regarding a direct or indirect risk to human health in relation to food or animal feed. The Recalls, Market Withdrawals, & Safety Alerts of the Food and Drugs Administration were also examined (FDA, 2019b). An additional source of information was the report entitled 'Chemical and physical hazards in the Dutch potato chain' (*Chemische en fysische gevaren in de Nederlandse aardappelketen*) (Nijkamp et al., 2017), drawn up on the instructions of the NVWA for the chain analysis. In addition, industry documents, supply requirements within the chain and news reports were consulted using the Google search engine. These searches focused on the situation in the Netherlands.

9.2. Approach

The assessment of the physical risks relating to the food safety of potatoes and potato products has been carried out based on the four-step risk assessment process.

9.2.1. Hazard identification

An inventory has been made of the contaminants or foreign objects that could end up among or in the potatoes during cultivation, harvesting, storage and transport as well as during the handling and processing of the potatoes.

9.2.2. Hazard characterisation

The hazard characterisation deals with the consequences of foreign objects in the potato chain for humans, such as choking, cuts and other physical injuries. As part of this step, it was established that there are no health-based limit values for food in relation to physical hazards.

9.2.3. Exposure assessment

Data on the occurrence of foreign objects in potatoes and potato products has been collected to gain an idea of whether, where and how often such objects could occur in potatoes and potato products. For this, databases with reports of foreign objects in potatoes and potato products have been consulted. In addition, relevant scientific literature and verifiable media reports have been viewed.

9.2.4. Risk characterisation

The occurrence of foreign objects in potatoes cannot be linked to a legal health-based limit value. The basic assumption is that the potatoes and potato products must be free from physical hazards by the time they reach the consumer. Therefore, the technical and organisational measures taken within the potato chain to prevent consumer exposure to these hazards have been taken into consideration for determining the risk.

9.2.5. Explanation of the risk assessment

To assess the risk of foreign objects, three of the risk assessment steps, i.e. hazard characterisation, exposure assessment and risk characterisation, have essentially been followed, where the hazard characterisation and exposure assessment steps are combined. The last step - the risk characterisation - describes BuRO's assessment of the risk of foreign objects for food safety in relation to potatoes and/or potato products on the Dutch market.

The basic assumption for the risk assessment is that there is no safe limit of exposure for physical hazards in potato products. In other words, this means that the products must be free from physical hazards by the time they reach the consumer. However, this does not mean that the mere presence of a physical hazard immediately implies a risk to the consumer. In case of a choking hazard, for example, this depends on the size of the object, and in case of a cutting hazard, the edges and points of an object.

9.3. Risk assessment of physical hazards

To identify the possible hazards that may occur in the potato chain, the various processes and actions carried out in the chain, as well as the foreign objects that can be introduced as a result, have been examined (see Figure 9.1). Scientific or other relevant literature has been searched for descriptions of the physical hazards considered to be a possible risk to the food safety of potatoes and potato products. In addition, notifications in the RASFF and FDA databases and supervision and enforcement case histories have also been consulted.

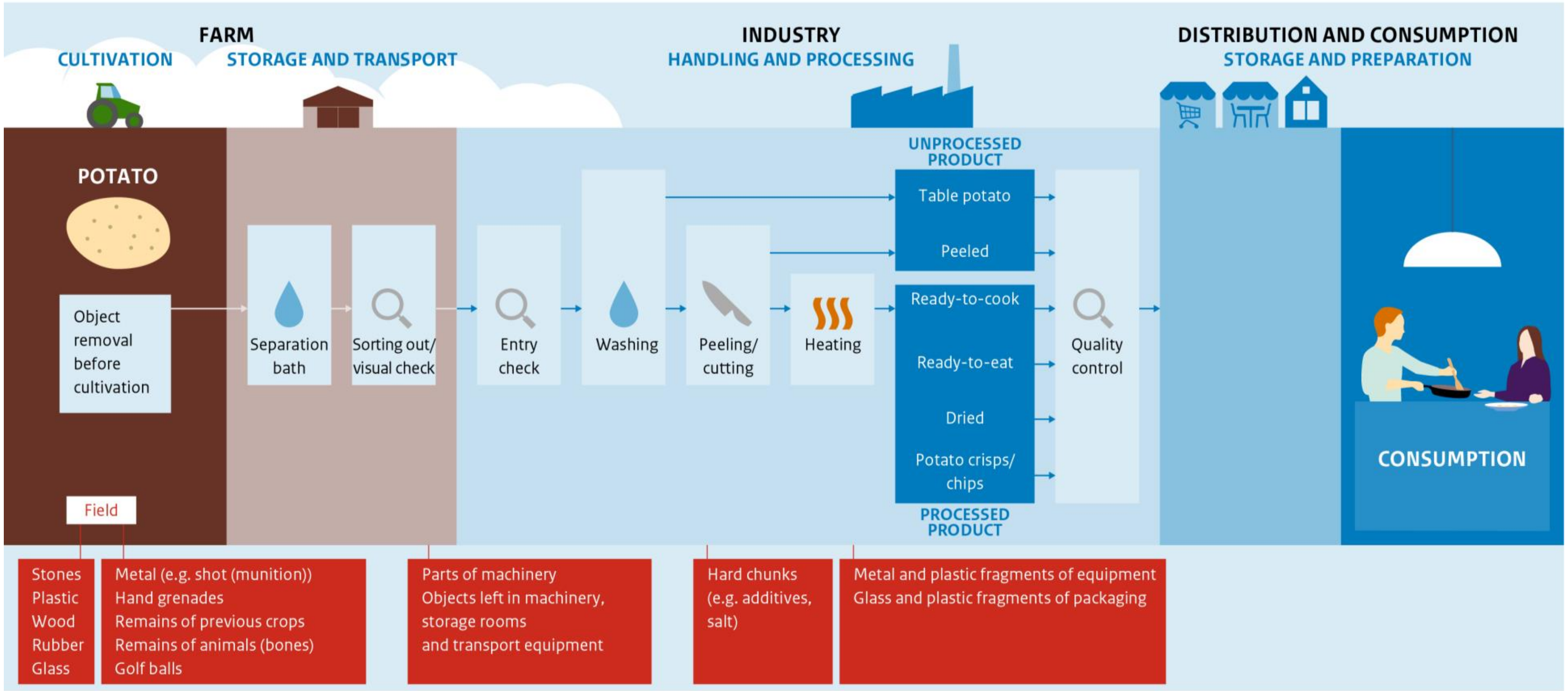


Figure 9.1. Physical hazards in the various stages of the potato production chain

9.3.1. Cultivation phase

Physical hazards introduced in the cultivation phase include those already present on the plot where the cultivation takes place or that are introduced into the plot during cultivation. It is not possible to compile a complete list of the physical hazards that may be present on a plot. Such hazards may include remains of crops that have been grown on the plot prior to the potato cultivation, stones, bones and other remains of animals, metals, ammunition, golf balls, wood and plastics. During cultivation, further objects from public roads, agricultural machines or due to other uses of the plot, such as hunting, may also end up in the plot.

Special attention must be paid to foreign objects with a specific weight similar to that of the potato, for example, golf balls and maize stumps saturated with moisture.

9.3.2. Harvesting, storage and transport

In addition to the physical hazards that may be transferred from the plot during the harvest, new hazards may also be introduced during this phase.

During the harvest, parts of machines and transport equipment can get transferred to the potato lots. In addition, objects left behind in the machines and transport equipment during earlier use or cleaning may be carried along with the harvested potatoes. This also applies to the storage facilities. This may introduce physical risks similar to those listed under the cultivation phase.

9.3.3. Handling and processing

Foreign objects can be introduced in a number of ways during the handling and processing of potatoes. This includes glass and plastic from packaging material, metal particles and plastics from machines and conveyors and objects used in cleaning and maintenance that are unintentionally left behind in the process. In addition, improperly processed additives, such as aromas and flavourings that remain in chunks, may create hard, sharp sections in the end product.

9.3.4. Results of the search for sources

No scientific literature could be found via the PubMed and Scopus search engines that addressed the physical hazards in the potato chain.

The RASFF database was searched using the keywords ‘potato’ and ‘gnocchi’. Subsequently, the results were specifically examined for notifications involving foreign objects. The search yielded 21 notifications. Apart from a notification about a hand grenade, the remaining notifications dealt with handled or processed potato products (‘Prepared dishes and snacks’ category, such as fried potatoes, mashed potatoes, potato salad and crisps). The notifications about composite products, i.e. products with another ingredient besides potato, are also a part of this.

Of the 21 RASFF notifications - the first of which relates to foreign objects and dates from 2007 - the majority (11) are from 2017 and 2018. The precise origin of the foreign objects is only specifically indicated in the notification about the plastic fragments from a conveyor.

In the FDA’s Recalls, Market Withdrawals, & Safety Alerts, the keywords ‘potato’ or ‘gnocchi’ does not yield any reports involving physical hazards. The keyword ‘hash browns’ (fried grated potato) produces two related reports. These two products, from the same manufacturer, involved golf ball material that ended up in the end product. Consumption of this material may result in choking or injury due to cuts or abrasion (FDA, 2018a), (FDA, 2018b).

In a study commissioned by the NVWA, Nijkamp (Nijkamp et al., 2017) has concluded that glass and golf balls are physical hazards for consumers. For golf balls, it is specifically noted that they have the same specific weight as potatoes and therefore cannot be separated from the potatoes through the use of conventional separation methods (such as the use of a clay bath).

Potato processing company Aviko has recently published certain news items about physical hazards (Aviko, 2013;2014;2015;2019). These news items have subsequently been taken up by various media. Aviko regularly finds contaminants in the supplied lots, such as those from the above-mentioned sources. In addition, it is mentioned that maize stumps, which have a similar specific weight as potatoes when saturated with water, are often found if the plot from which the potatoes originate had previously been used for maize cultivation.

To summarise, the following list of physical hazards in the potato chain has been drawn up based on reports:

- Metal particles, including lead shot (hunting ammunition)
- Plastic
- Glass
- Wood
- Rubber
- Stones
- Hand grenades
- Golf balls
- Residues of earlier crops, especially the crown roots of the maize plant
- Bones and other remains of animals
- Chunks of flavouring agents (in chips)

The hazards listed here can lead to various physical consequences, such as cuts (due to presence of metal, plastic and glass) and choking (plastic, rubber). Other effects may also include damage to the teeth or more serious injuries if explosives are involved.

Besides the absolute number of notifications in the RASFF and FDA databases, i.e. 21 and 2 respectively, no further exposure data are available. Reports from other sources about the detected physical contaminants are not quantifiable and no reports of injuries have been found. Exposure is estimated to be low.

9.3.5. Control measures

To ensure that products are free from physical hazards when they reach the consumer, organisational and technical measures are taken within the potato chain.

The physical hazards in the potato chain are mainly controlled via the requirements imposed on the various parties within the chain based on Regulation (EU) 852/2004 (see Annex 2.2.3) and the requirements imposed by these parties on one another (see Annex 2.3.2). Moreover, the elimination and prevention of physical hazards during cultivation, storage and transport is an important criterion for the certification schemes.

In the cultivation phase, a commonly used method to remove contaminants from lots of harvested potatoes is to pass the potatoes through a salt or clay bath. But this does not separate the foreign objects with the same specific weight as the potatoes from the lot. As a result, these objects may be carried along with the lot when the potatoes are washed. To prevent this, the lot can be inspected or visually checked. This can be done using inspection tables or a conveyor. This process is labour intensive. Aviko (Aviko, 2019) observes that the increase in scale has led to a decrease in the manpower available for inspection and cleaning, and consequently more foreign objects are being introduced in the processing phase. The Grower's Handbook (*Telerhandleiding*) based on the Food Safety Certificate for the Potato Processing Industry (*Voedselveiligheid certificaat aardappelen verwerkende industrie, VVA-Certificaat*) (VAVI, 2019) requires the "mandatory removal of contaminants (pieces of glass, plastic, etc., especially along public roads)" from the cultivation plot and does not permit hunting activities on the plot if there is a chance of lead shot (hunting ammunition) being introduced into the product.

In the harvesting, storage and transport phase, the visual inspection and cleaning of the potato lot, when it is removed from the storage facility and prepared for delivery, is explicitly stated in the VVA Grower's Handbook(VAVI, 2019) as a condition for preventing physical hazards.

When handling and processing potatoes, processing companies must take measures based on the HACCP guidelines to prevent the occurrence of physical hazards in the product. The industry may fulfil this requirement in various ways. Potato lots are sieved and washed upon entering the factory, and infrared detection facilities are present. In the event that a contamination introduced with a potato lot is noticed late in the production process, the production line is shut down and cleaned. To ensure that adequate attention is paid to the removal of foreign objects, the general terms and conditions of the processing industry stipulate that the costs of any damage caused by foreign objects will be recovered from the grower or supplier (NAO, 2012; VAVI-LTO, 2012; Aviko, 2020). The HACCP guidelines also require companies to take into account the hazards introduced during processing and to take appropriate measures.

9.3.6. Conclusion

No physical hazards must be present in a potato product when it reaches the consumer. Control measures are implemented in the chain to prevent consumers from being exposed to physical hazards. Although the number of RASFF notifications in 2017 and 2018 about foreign objects in potato products was higher than in previous years, this effectively concerns a small number of notifications. The observation that more contaminants enter the production process of the potato processing industry cannot be further substantiated. The risk posed by physical hazards to food safety is estimated to be low.

10. Other risks in the potato chain: public health, environment and nature

Apart from food safety risks, the cultivation and production of potatoes and potato products may also pose risks to public health. The use of plant protection products can have adverse effects on the health of product users or people living near the potato fields. Adverse effects on the environment as a result of the use of plant protection products, such as contamination of surface water or soil, can also have consequences for public health. During the processing of potatoes and the production of potato products, the machines used can pose a danger to the users.

10.1. Risks of plant protection products

10.1.1. Legislation

Dutch plant protection and biocides policies are based on European regulations and guidelines. The Plant Protection Products Regulation ((EC) 1107/2009) sets out rules for the authorisation and placing of plant protection products on the market and for their use and control within the EU. For biocides, this is the European Biocides Regulation ((EU) 528/2012)[109]. In addition, there is the Sustainable Use Directive (2009/128 / EC)[110] that provides for a framework for the sustainable use of plant protection products, which includes the promotion of Integrated Pest Management (IPM). Other European regulations that determine the plant protection policy include the Residues Regulation ((EC) 396/2005), which contains harmonised maximum levels of plant protection product residues for food and feed. Also of importance is the Water Framework Directive (2000/60/EC[111]) containing the framework for water policy in the Member States, which was later supplemented by Directive 2013/39/EU[112] concerning priority substances. Furthermore, the Official Controls Regulation (EU) 2017/625 outlines the official controls performed to ensure the application of rules on the use of plant protection products.

The most important national regulations are the Wgb and its underlying decree and rules. In 2011, the Wgb was adapted based on European Regulation (EC) 1107/2009[73]. The Wgb contains rules for the authorisation, placement on the market and use of plant protection products and biocides. In addition, the Environmental Management Act (*Wet milieubeheer*) and the Activities (Environmental Management) Decree (*Activiteitenbesluit milieubeheer*) contain regulations for the sustainable use of plant protection products, in relation to the storage of plant protection products or the protection of surface water. The Plant Protection Product Residues (Commodities Act) Regulations (*Warenwetregeling residuen van gewasbeschermingsmiddelen*) applies to residues of plant protection products that do not fall under the scope of the Residues Regulation.

Dutch plant protection policy is outlined in the Second Memorandum on Sustainable Plant Protection for 2013-2023 entitled '*Healthy Growth, Sustainable Harvest'* (*Gezonde Groei, Duurzame Oogst*) (EZ, 2013). This describes the ambition of making plant protection more sustainable, while at the same time, strengthening the economic perspective for agriculture and horticulture. IPM is an important approach in this respect that focuses on a combination of measures such as the prevention of harmful organisms, mechanical or biological control and the use of low-risk products. The aim is to reduce agricultural dependence on the use of chemical plant protection products. In April 2019, the Minister endorsed this approach in the Future Vision for Plant Protection 2030

[109] Regulation (EU) 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products (Text with EEA relevance).

[110] Directive 2009/128 / EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (Text with EEA relevance).

[111] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

[112] Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy.

(*Toekomstvisie gewasbescherming 2030*)[113]. The interim evaluation of the Second Memorandum on Sustainable Plant Protection by the Netherlands Environmental Assessment Agency (*Planbureau voor de Leefomgeving, PBL*) was published in June 2019 (PBL, 2019).

10.1.2. Authorisation

The safety of active substances of plant protection products for humans, animals and the environment is assessed at the European level by EFSA, based on a harmonised European assessment framework. For biocides, the European Chemicals Agency (ECHA) is responsible for the assessment of active substances. Approval of an active substance is only possible if the substance has at least one safe application. After approval of an active substance by the European Commission, it is determined at the national level whether a product based on the approved active substance may be used.

For the purposes of the authorisation of plant protection products, Europe is divided into three zones (north, central and south). The Netherlands, along with twelve other Member States, falls in the central zone. For each zone, the assessment for authorisation is carried out by one of the Member States, based on the European assessment framework[114]. Therefore, the assessment also applies to the other Member States from the same zone, which may accept the authorisation (within 120 days) (based on mutual recognition). Member States may also adopt additional risk mitigation measures if nationally specific conditions so warrant, for example, in connection with the leaching of contaminants to groundwater, wind speed and drinking water abstraction from surface water. In the Netherlands, for example, there are additional measures for various products in the form of cultivation-free zones to protect the surface water from these products. For greenhouse cultivation, treatment of storage areas, post-harvest treatments and products for seed treatment, the EU is considered as a single zone, and a single Member State will carry out the assessment for the entire EU.

For biocides, the individual Member States may assess the products and their applications. If a product is authorised by one of the Member States, other Member States may also authorise it (mutual recognition principle). Alternatively, it is also possible to apply for a Union authorisation, with which an authorisation for the entire EU can be obtained at one go. A simplified authorisation procedure is possible for products that meet specific requirements (for example, the absence of substances of concern). In the Netherlands, the Ctgb is responsible for the authorisation of plant protection products and biocides.

The authorisation of a plant protection product applies to a specific use for a crop in a Member State and is based on the assessment of whether the product is effective and safe for humans, animals and the environment. For plant protection products, the Defined List of Areas of Application of Plant Protection Products (*Definitielijst toepassingsgebieden gewasbeschermingsmiddelen, DTG*) is used. An earlier granted authorisation of a substance can be further extended to a 'minor use'. The holder of the authorisation of the plant protection product in question or a third party such as the Netherlands Agriculture and Horticulture Organisation can submit an application for this.

Each Member State is free to define the European criteria for minor uses. In the Netherlands, minor uses have been defined for crops that are grown on a small scale. A minor use may also be included as part of a large-scale cultivation, for example, special soil types or in case of a rare pest. At a national level, under specific circumstances in emergency situations when control by any other means is not possible, an exemption for an unauthorised product may be granted for a maximum period of 120 days[115].

[113] Letter from the Minister of Agriculture, Nature And Food Quality. Future vision for plant protection 2030 for developing resilient plants and cultivation systems and a package of emission-reduction measures for plant protection in open-field cultivation – Plant Protection Policy. 18 April 2019, KST27858449

[114] After Brexit comes into effect, the United Kingdom can no longer be a zonal rapporteur and the EU shall no longer recognise the decisions taken earlier by the United Kingdom as a basis for mutual recognition.

[115] Regulation (EC) 1107/2009 (Section 38 of the Wgb), Article 53

The Ctgb sets out the legal instructions for use of a product, which must be stated on the label. This specifies the crops for which the product may be used and how often it can be used during the cultivation cycle, how it should be applied, the dosage, the frequency and, if necessary, any personal protection measures to be taken. Approved active substances (EU level) and authorised products (zonal level) are reassessed after 10 years[116]. For low-risk plant protection products, the reassessment takes place after 15 years. There are certain plant protection products authorised under the old Directive (91/414/EC) that are still on the market. These products have not yet been assessed at the European (zonal) level but fall under Regulation (EC) 1107/2009. Ultimately, all products will be assessed at least at the zonal level.

For biocides as well, it is stipulated that existing national legislation shall apply to those products whose active substance has not yet been assessed in a European context (Regulation EU 528/2012[117]). The use of biocides in agriculture is only authorised for general hygiene purposes. In 2017, the Ctgb has harmonised its biocide authorisation policy to bring it further in line with European directives, as a result of which the use of biocides in agriculture can no longer be specifically aimed at the protection of plants or plant products. Products that claim to control plant pathogens are classified as plant protection products. This only applies to new registrations or re-registrations to ensure that this change can be gradually implemented (Ctgb, 2018d).

Basic substances are substances that are already on the market for use for another purpose (for example, in cosmetics or food). Therefore, any associated risks have already been determined. Authorised basic substances (on the list of authorised basic substances) may be used for plant protection but cannot be sold as plant protection products, and they have an unlimited authorisation period (Ctgb, 2020a). The assessment of basic substances is beyond the scope of this chain analysis.

10.1.3. Application, products and active substances

More than 250 plant protection products are authorised for potatoes, with a total of approximately 680 different applications (adverse effect-crop combination). The more than 250 authorised plant protection products contain 80 different types of active substances (Ctgb, 2020e). Usually a plant protection product contains only one active substance, but some products contain a combination of two or three active substances. Three products, that are approved as fungicides, contain microorganisms (*Bacillus amyloliquefaciens* (formerly subtilis) str. QST 713, *Coniothyrium minitans* strain CON/M/91-8 and *Pseudomonas* spp. strain DSMZ 13134) as their active substance.

There are a number of products that are authorised for use in the cultivation of seed potatoes but not for the cultivation of ware and starch potatoes. These include the fungicides fluoxastrobin, imazalil, thiabendazole and thiophanate-methyl, the sprout inhibitor carvone and the nematicide metam sodium. In addition, paraffin oil may only be used as an insecticide/virucide for the cultivation of seed potatoes.

The largest group of active substances for potato cultivation is the group of fungicides (over 40%), followed by herbicides (25%). In addition, a smaller number of active substances, such as insecticides, nematicides, growth regulators or sprout inhibitors, are authorised.

Compared to other arable crops, the amount of plant protection products used in potato cultivation per hectare (kg of active substance per hectare) is relatively large (Figure 10.1).

The highest amount of active substance per hectare is used for seed potatoes (kg/ha) (Figure 10.2 a, b, c.).

[116] Depending on the EU classification, a product may also be assessed after seven years.

[117] Regulation (EU) 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products.

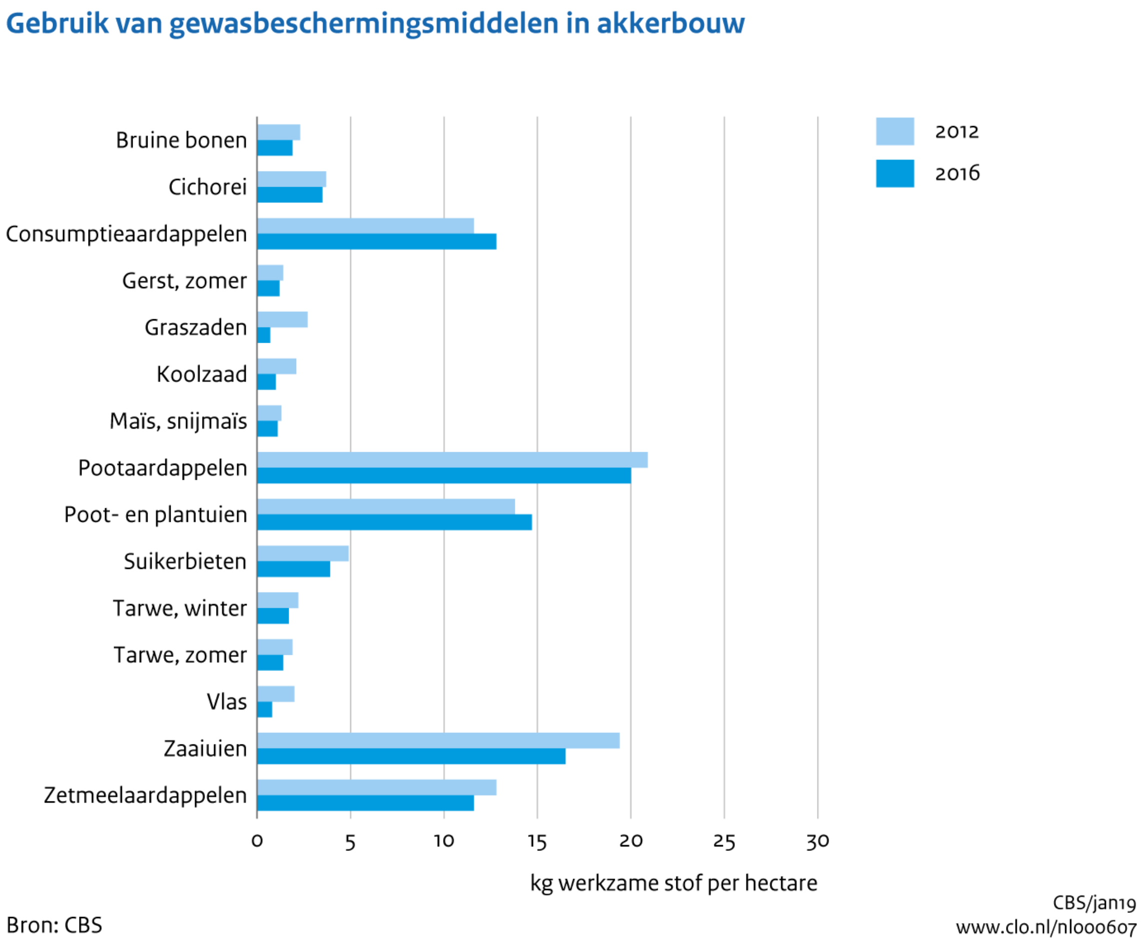


Figure 10.1 Use of plant protection products in the Netherlands in potato cultivation and other arable crops in 2012 and 2016 in kg/ha (2012) (CLO, 2020).

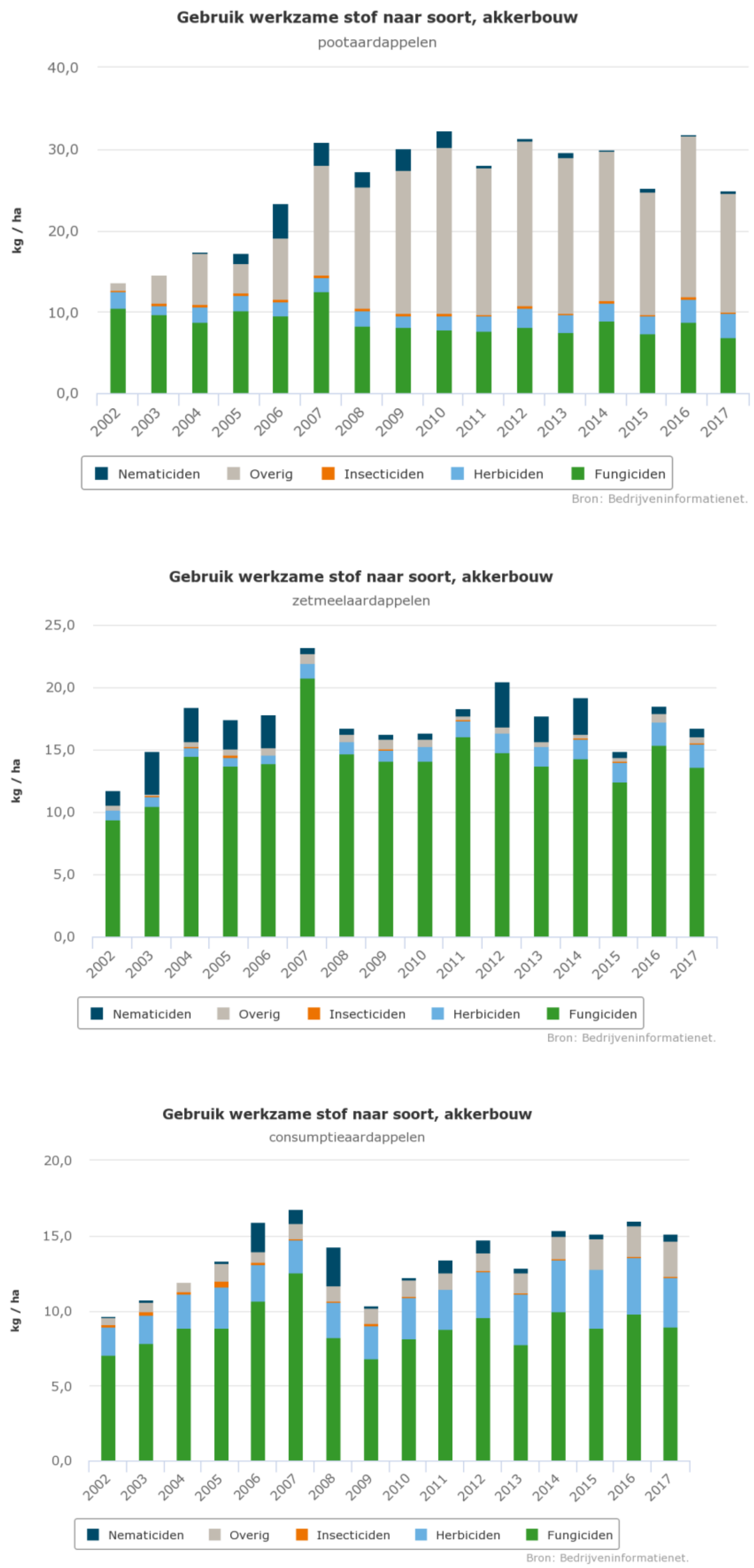


Figure 10.2 a, b, c. Amount of active substance (kg) per hectare used in the Netherlands between 2002 and 2017 for seed potatoes, starch potatoes and ware potatoes (source: (Agrimatie, 2020)).

In addition to the intended effect (for example, the destruction of nematodes, fungi, insects or weeds), the active substance of a plant protection product can also have undesirable or harmful effects. Although these effects are taken into account in the authorisation procedure, exceedances of environmental quality standards are still detected and adequate occupational safety standards are not yet applied (EZ, 2013; Gezondheidsraad, 2014). This is partly due to careless use by growers and non-compliance with the regulations, and also partly because the simultaneous use of various plant protection products with the same active substance is not taken into account in the authorisation (Gezondheidsraad, 2014; PBL, 2019). In potato cultivation as well, various products are applied in close succession and simultaneously (as a tank mix). For seed potatoes, the spray schedule shows that fungicides and insecticides are applied simultaneously, with weekly application in the summer (see Figure 10.3).

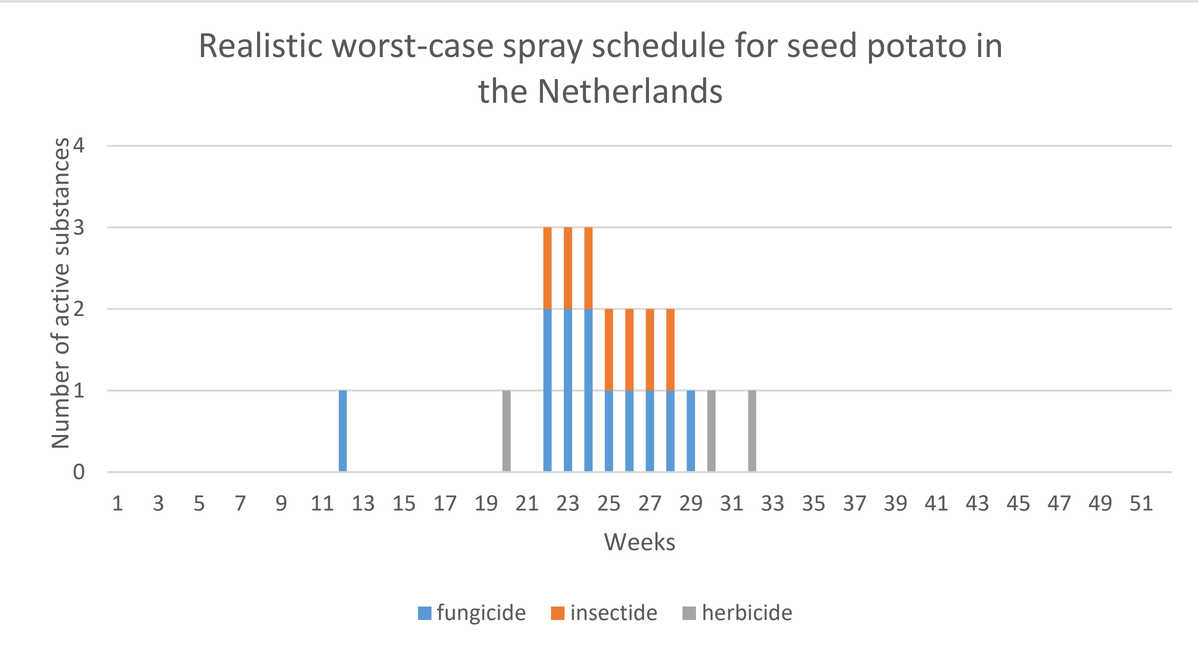


Figure 10.3 Realistic worst-case spray schedule for seed potatoes in the Netherlands (information taken from (Luttik, 2018))

To mitigate the risks of plant protection products, IPM pilots have been set up, as part of a collaboration between the government and the sector. In this cultivation system approach (IPM) the use of plant protection products across the entire chain is assessed, instead of merely performing an assessment of separate applications. This is a way of controlling pests and diseases through a combination of measures and products. The European Directive on the sustainable use of pesticides (Regulation 2009/128/EC[110]) states that Member States should promote IPM in practice.

In potato cultivation, the control of *Phytohthora infestans* takes into account the weather conditions. Preventive spraying is less frequent in dry periods than in wet periods. Apart from this, the IPM concept has hardly been applied in potato cultivation (NVWA, 2018i). A 2016 study by CLM revealed that potato cultivation with a special environmental label ('Ecolabel' (*Milieukeur*) or 'Clean Water' (*Schoon Water*)) uses half the amount of plant protection products (approx. 5 kg/ha) compared to conventional cultivation (CLM, 2016).

In organic cultivation, there is a strict limitation on the use of plant protection products (SKAL, 2019). Only a small part of potato cultivation in the Netherlands involves organic cultivation: over 2% of the farms and about 1% of the agricultural area used for potatoes (2015-2018) (see Annex 3.9).

Summary

- The assessment of active substances and products has been done based on the European Plant Protection Products Regulation (Regulation 1107/2009) and the European Biocides

Regulation (Regulation 528/2012). Active substances are assessed at the European level and the products containing those active substances at the Member State level.

- In potato cultivation, a relatively large number of plant protection products are used per hectare compared to other arable crops (in kg/ha).
- More than 250 plant protection products with 80 different active substances are authorised for use in potato cultivation.
- Fungicides are the largest group of active substances in plant protection products for potato cultivation (over 40%), followed by the group of herbicides at 25%.
- The highest amount of active substance (in kilogram per hectare) is used for seed potatoes. Only a small part of potato cultivation in the Netherlands is organic (a few percent), and this mainly involves ware potatoes.

10.1.4. Risks to public health

Local residents

The policy on plant protection products in relation to local residents falls under the purview of the Ministry of Infrastructure and Water Management. Therefore, this chain assessment touches briefly on this aspect and describes the risks but does not assess them in the same way as in the chapter on food safety.

Until 2014, the risk to local residents was not assessed separately as part of the Ctgb's authorisation assessment, with the exception of people living near greenhouses. It was implicitly assumed that the assessment of the risk for occupational exposure is sufficient to also protect the local residents. Nevertheless, there was concern among local residents about agricultural plots involving a heavy use of plant protection products. The Health Council of the Netherlands (*Gezondheidsraad*) issued a report in 2014 recommending further research on the exposure to plant protection products of people living near agricultural plots (Gezondheidsraad, 2014). The report indicates that people living near agricultural plots are concerned about their health. The Health Council has advised that the authorisation procedure for plant protection products should include a risk assessment not just for workers but also for local residents. This is because of the unique character of local residents as a risk group. There may be differences between the exposure of local residents and workers, for example, due to the duration of exposure, level of exposure (peak load versus longer exposure to lower concentrations) and the presence of sensitive groups such as children or pregnant women, and whether or not personal protective equipment is used.

In response to this report, the Ctgb has started explicitly assessing the exposure of local residents since 2014. It has also carried out, based on a new EFSA model, a reassessment of existing authorisations to identify the risk to local residents and any bystanders, including children. For this reassessment, the preliminary EFSA model (EFSA, 2014c) was used at the time for the exposure calculations. Based on intensity and method of application (upward spraying), 116 products were included in the reassessment. The Ctgb concluded that the assessed products are safe and that the assessments did not need to be reviewed. Since 1 January 2016, the EFSA model has been used as the basis for the risk assessment with respect to local residents and the public (Ctgb, 2018c).

In response to the Health Council report, the RIVM coordinated a research study on the exposure and health risks of residents living in the vicinity of agricultural plots (RIVM, 2018b). This study initially focused on flower bulb and fruit plots since these crops involve a relatively intensive use of plant protection products. The exploratory health study was published in July 2018 and it concludes that there is no clear link between health and the proximity of agricultural plots (RIVM, 2018d).

The Local Residents Exposure Study (*Onderzoek blootstelling omwonenden, OBO*) focused on measuring urine samples, outdoor air, indoor surface samples and the soil and vegetation around flower bulb plots. A small number of hand-wipe samples and indoor air samples were also taken. Residues of used plant protection products were found in samples of outdoor air around houses, dust on the doormat and in household dust. Such residues were also found in urine samples taken from local residents (adults and children), even in cases where the residents lived at a distance of more than 500 metres from the plot. The OBO shows that the current authorisation frameworks do not underestimate the exposure of local residents since the measured exposure lies below the health-based limit values. However, a further refinement of the model is possible, for example, by assessing the combined effects of substances. The studies provide various leads for further follow-up studies, for example, with regard to vulnerable groups or other health-related effects such as cognitive development (RIVM, 2019a).

Product users and workers

The policy and supervision of plant protection products and biocides with regard to safety for product users and workers falls under the purview of the Ministry of Social Affairs and Employment. This chain assessment briefly touches on this aspect and describes the risks but does not assess them in the same way as in the chapter on food safety.

Occupational exposure to plant protection products occurs during the use of the products (product user) and among workers who come into contact with the treated plants. Generally speaking, the exposure of these groups is the highest. The risks for product users and workers are also assessed as part of the Ctgb's authorisation process for plant protection products and biocides. Nevertheless, the Health Council has concluded that the level of safety related to occupational exposure is not always sufficient in practice (Gezondheidsraad, 2014). A possible cause for this may be inadequate compliance with the regulations or the fact that specific substance properties are not adequately addressed in the authorisation procedure. In addition, the possible cumulative effects (addition or synergy) of products are not yet being systematically taken into account in the authorisation assessment. In the interim evaluation of the *Healthy Growth, Sustainable Harvest* memorandum, the PBL concludes that growers and the government continue to pay insufficient attention to the occupational risks of working with plant protection products (PBL, 2019). The Health Council refers to national and international literature in which links between exposure to plant protection products and diseases such as skin disorders, effects on fertility, cancer (also in offspring) and Parkinson's disease have been described.

In the potato chain, occupational exposure to plant protection products occurs during the pre-treatment of the tubers, the spraying of the plots containing the potato crops and the storage period.

Summary

- Since 2014, the risk for local residents is explicitly included in the authorisation assessment. Following a 2014 report by the Health Council, a follow-up study - coordinated by the RIVM - has been initiated into the health risks of local residents.
- The exploratory health study of local residents concludes that there is no clear link between health and the proximity of agricultural plots.
- Occupational safety levels with regard to the use of plant protection products and biocides by growers and product users are not yet sufficient, partly due to inadequate compliance with regulations.

Resistance to azoles

Aspergillus fumigatus is a fungus commonly found on decaying planting material that produces a high number of spores. These spores are present everywhere in indoor and outdoor air and are inhaled by humans. It is a pathogen that can cause a serious burden of disease in patients with weakened immune systems, leading to death in some cases (Verweij et al., 2009). People become infected by inhaling spores that then continue to grow in the respiratory tract. Infections can be controlled with azole-based antimycotics (triazoles, imidazoles). However, just as bacteria can become resistant to antibiotics when exposed to non-lethal concentrations, similarly *A. fumigatus* can become resistant to azoles (Handel et al., 2015). Azoles are used not only as a medicinal antimycotic but also as a fungicide in agriculture and wood preservation. It has been shown that the azole resistance of the isolates of *A. fumigatus* that cause human infections was, in many cases, due to exposure to azoles used in the preservation and processing of plant material (Rietveld et al., 2017). Resistance due to exposure to azole fungicides is an important source of resistance of *A. fumigatus* in healthcare settings because cross-resistance between the different azoles is common (Azevedo et al., 2015).

Although *A. fumigatus* is often not the target organism of the control in agricultural applications of azoles, use of azoles against phytopathogenic species leads to resistance in *A. fumigatus* (Meis et al., 2016). Second-choice products against invasive aspergillosis are not always useful because of resistance in agriculture (Howard & Arendrup, 2011).

Of the fungicides authorised for use in potato cultivation, 10 are azole-based products (difenoconazole, prothioconazole, thiabendazole). In addition, there are three other products based on the active substance imazalil - a fungicide with a similar mode of action - which may also play a role in the development of resistance (NVWA, 2015d; Ctgb, 2020e). These products are used against fungi such as *Alternaria*, silver scurf, *Rhizoctonia*, dry rot and *Phoma* (NVWA, 2015d).

In 2015, the NVWA, on behalf of the then Ministry of Economic Affairs, studied the impact of the unavailability of azole-based plant protection products for professional agriculture and horticulture. For potatoes, it was found that the range of chemical products is so broad that the unavailability of azoles-based products has little or no effect on the extent to which fungi can be controlled (NVWA, 2015d). The picture has changed somewhat in 2020 because there are now indications that other products that are authorised for the control of Alternaria in potatoes have a reduced efficacy, in connection with a possible development of resistance (NVWA, 2020m). At the end of 2019, the Minister of Agriculture, Nature and Food Quality announced in a letter to the House of Representatives the intention to reduce the use of non-medical azoles as far as possible and tackling the main sources of resistance development (composting of flower bulbs, processing of preserved wood) (LNV, 2019).

Summary

- The use of azole-based fungicides in agriculture and horticulture contributes to azole resistance.
- For potatoes, a number of fungicides are authorised based on three different azoles (difenoconazole, prothioconazole, thiabendazole) and one substance (imazalil) with a similar mode of action. In 2015, the range of chemical products was assessed as sufficiently broad, such that the unavailability of azole-based products at the time would have little or no effect on the extent to which fungi in potato cultivation could be controlled.

10.1.5. Risks to the environment and nature

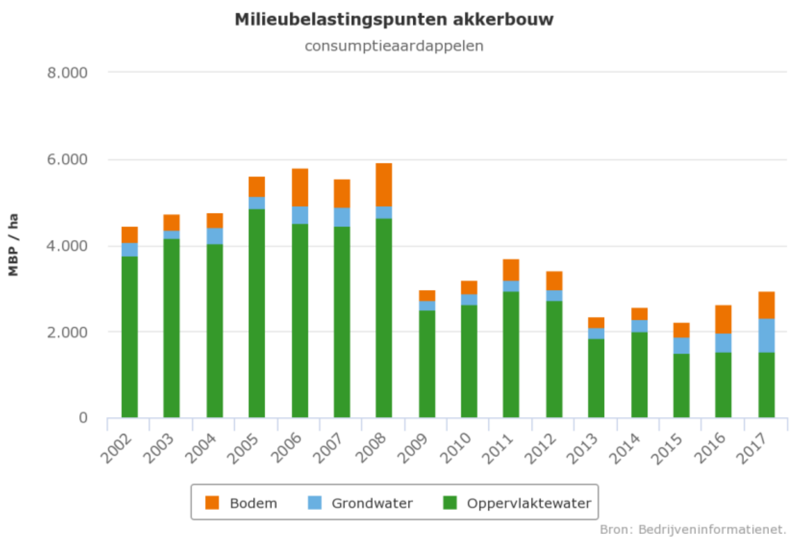
Environment

The policy on plant protection products in relation to the environment falls under the purview of the Ministry of Infrastructure and Water Management. This chain assessment briefly touches on this aspect and describes the risks but does not assess them in the same way as in the chapter on food safety.

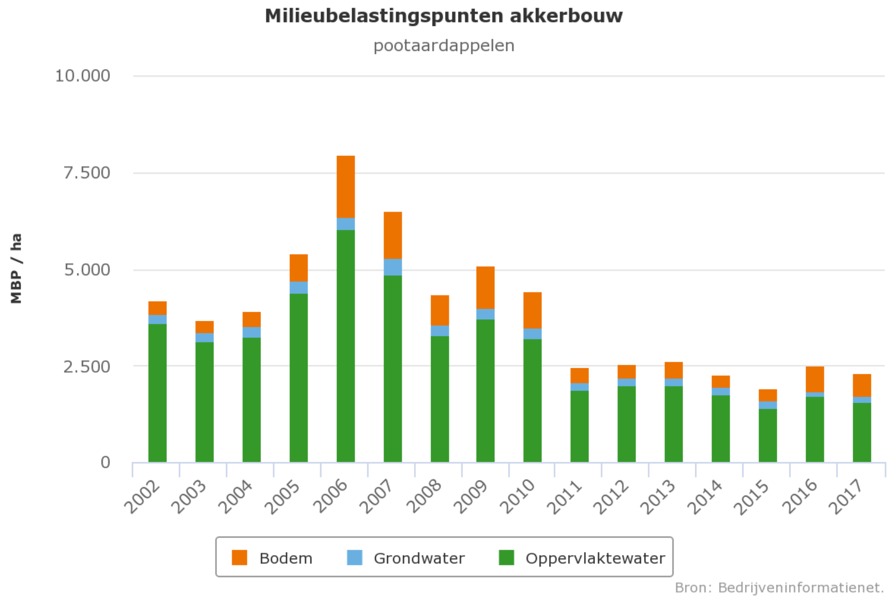
The use of plant protection products releases these products into the environment, for example, via build-up in the soil, wind-borne spread, leaching or run-off from the plot into surface water and groundwater (PBL, 2019). Groundwater mainly contains substances that are no longer authorised but residues of which are still present in the soil from earlier use (EZ, 2013; RIVM, 2016b). Residues of plant protection products can give rise to environmental problems, such as problems relating to drinking water supplies (CML, 2012; RIVM, 2016b). In order to limit emissions to the environment, requirements are set for the use of plant protection products. In addition to the instructions for use, there are requirements for the use of drift-reducing nozzles and cultivation-free zones along the water’s edge. Despite these defined requirements, by far the greatest impact on the environment is caused by the contamination of surface water. Plant protection products in surface water and groundwater can, in addition to possible effects on the ecosystem, also cause problems for drinking water extraction (CML, 2012; RIWA, 2016; Swartjes et al., 2016; VEWIN, 2019).

Products used in arable farming are found in surface water in excessively high concentrations, i.e. above the prevalent water quality standards (Deltares, 2018). A number of these products (fluoxastrobin, azoxystrobin, esfenvalerate, pendimethalin, acetamiprid and thiacloprid) are also authorised for use in potato cultivation. It is not known whether the use of such products in potato cultivation makes a major contribution.

The environmental impact of potato cultivation has been lower in recent years, with the exception of starch potato cultivation, which has seen an increased impact in 2012, 2013 and 2104 (Figure 10.4 a, b, c). In 2016 and 2017, all three potato groups (ware, seed and starch potatoes) showed a slight increase compared to 2015, which is due to the increasing use of fungicides. The decrease in 2015 compared to 2014 is the result of the temporary ban on metam-sodium-based soil disinfectants. The substitutes used since then contain fewer active substances and have fewer environmental impact points[118] per hectare (Agrimatie, 2016).



[118] The Environmental Yardstick for Pesticides, developed by the Centre for Agriculture and Environment Foundation (CLM), assigns environmental impact points to plant protection products. For this, the effects on aquatic life and soil organisms are considered as well as the risk of leaching (in connection with groundwater contamination).



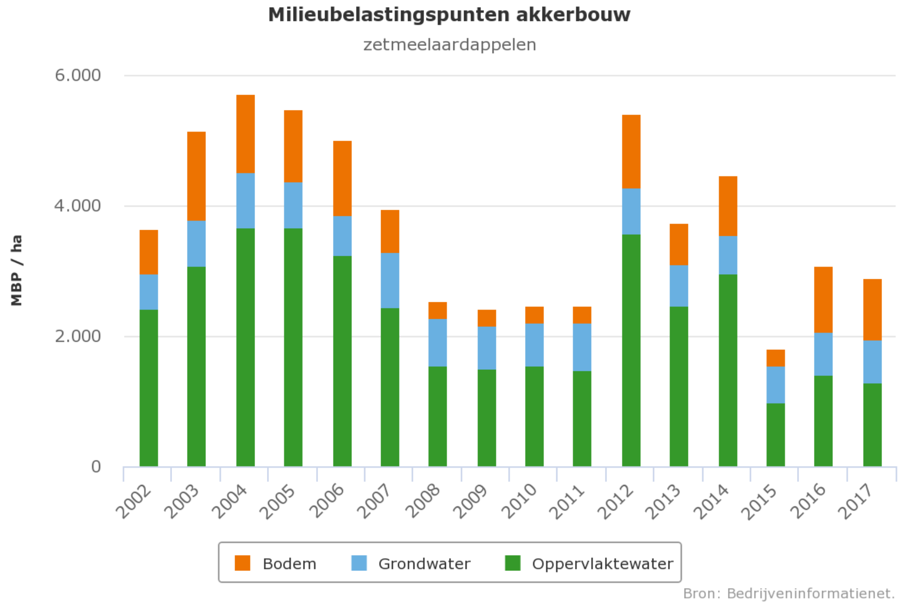


Figure 10.4 a, b, c. Environmental impact points for the use of plant protection products in the cultivation of starch potatoes in 2002 - 2017 (information taken from the Dutch agro & food portal Agrimatie, 11/2/2020)

In 2013, the government set a target of virtually no exceedances of the standards for surface water by 2023, with an interim target of a 50% reduction by 2018. In order to achieve these targets, additional measures must be taken so that the emissions in covered cultivation can be reduced almost completely via decontamination techniques. For open-field cultivation, the spray drift of plant protection products must be further limited and cultivation-free zones expanded. Point source emissions must also be reduced (EZ, 2013).

A different target applies to groundwater, i.e. the quality of groundwater must not deteriorate in the period 2013-2023. The interim evaluation of the Memorandum by the PBL shows that, despite an improvement in water quality, the intermediate target set for the ecological quality of surface water (50% reduction in exceedances of standards in surface water in 2018) has not been achieved (PBL, 2019).

Most residues found in groundwater come from products that are no longer authorised. However, there are three active substances found in groundwater that form an exception to this and that are still authorised: these include bentazone and glyphosate, which are also authorised for use for potatoes (Ctgb, 2018a; PBL, 2019).

A complicating factor in determining water quality and exceedances of standards based on measurements is the uncertainty arising as a result of substances that are difficult to measure. If the reporting threshold of a substance is higher than the standard, the measurement is not verifiable. There are an increasing number of such measurements that cannot be verified, which means that statements about the development of water quality and exceedances of standards based on these measurements are uncertain (PBL, 2019).

Exceedances of standards may occur as a result of incorrect use of products (non-compliance with instructions for use). However, the PBL also indicates that the national approval procedure does not take specific emission routes sufficiently into account, due to which environmental emissions may be underestimated and exceedances of standards may occur even in case of use according to the instructions (PBL, 2019). This means that the emission models used for the authorisation procedure for products and the water quality standards are not sufficiently aligned with one another (RIVM, 2019b).

Since 2018, stricter requirements have been applied to the implementation of emission-reducing measures. This has led to the widespread use of nozzles (at least 75% reduction in spray drift). Since the strict requirements only entered into force in 2018, any impact on water quality is not yet measurable. The Memorandum also encouraged making the field borders wider to support the population of natural enemies. This voluntary approach has not yielded the desired result because the area of field borders in the Netherlands has decreased slightly between 2013 and 2017 (PBL, 2019).

Nature

In view of the recent strong interest in the effects of plant protection products on bees - and particularly the impact of neonicotinoids - these effects are briefly discussed below.

Neonicotinoids are used against harmful insects but they also have adverse consequences on beneficial insects such as bees (EFSA, 2018b;2018e;2018d). In 2013, EFSA issued a specific guideline for the risk assessment of plant protection products with respect to bees (EFSA, 2013b). These guidelines were updated in 2018 with the evaluations of three neonicotinoids: clothianidin, imidacloprid and thiamethoxam (CIT). This guideline has not yet been adopted in Europe. Some sections of this draft guideline are currently being updated. In April 2018, the EU Member States approved the European Commission's proposal to completely ban the outdoor use of the three above-mentioned neonicotinoids ((EU) Implementing Regulation 2018/783[119], 2018/784[120] and 2018/785[121]). The use of these three neonicotinoids is no longer authorised, although thiamethoxam was still approved for use in potato cultivation until 19/9/2018. As the PBL concludes in its interim evaluation of the Second Memorandum, any beneficial effects such as

[119] Commission Implementing Regulation (EU) 2018/783 of 29 May 2018 amending Implementing Regulation (EU) 540/2011 as regards the conditions for the approval of the active substance imidacloprid.

[120] Commission Implementing Regulation (EU) 2018/784 of 29 May 2018 amending Implementing Regulation (EU) 540/2011 as regards the conditions for the approval of the active substance clothianidin.

[121] Commission Implementing Regulation (EU) 2018/785 of 29 May 2018 amending Implementing Regulation (EU) 540/2011 as regards the conditions for the approval of the active substance thiamethoxam.

reduced bee mortality will not yet be visible because the latest restrictions on use have only recently been introduced. However, there is an observable shift towards the use of alternative products, although these do not usually have a lower risk profile (PBL, 2019).

In addition to taking containment measures relating to the use of neonicotinoids, informing growers and encouraging non-chemical control, the government proposes additional measures in its Second Memorandum on Sustainable Plant Protection, such as encouraging the creation of more extensive cultivation-free zones that can be set up for functional agro-biodiversity (EZ, 2013). Furthermore, scientific research shows that, to understand the harmful effects on insects (using Ichneumon wasps as a model in the study), it is important to look at cumulative effects of mixtures of plant protection products because there may be a synergy between these effects (Willow et al., 2019).

Summary

- Although the risks to the environment are taken into account in the authorisation procedure, the environmental quality standards for plant protection products continue to be exceeded.
- The environmental impact, measured from 2002 to 2017, appears to be lower for ware potatoes from 2009 onwards, compared to the preceding period. For seed potatoes, there has been a decrease in the impact since 2011. For starch potatoes, a decrease in impact was observed from 2008 onwards, but this was followed by an increased impact in the period 2012–2014.
- The interim evaluation of the Memorandum by the PBL shows that, despite an improvement in water quality, the intermediate target defined for the ecological quality of surface water has not been achieved.
- Measures to reduce the use of neonicotinoids have not yet led to reduced bee mortality.

10.2. Physical risks to public health

Apart from food safety, there are other physical hazards in the chain that can have an impact on public health. This refers to the hazards faced by employees working within the chain. The potato chain extends over various sectors: the agricultural sector, food industry, transport sector and even the chemical industry. Occupational hazards may be related to, for example, machines, means of transport, confined spaces and working at heights. Choking hazards, fall hazards, cutting hazards, electrocution hazards and many other type of physical hazards may be present. Protection against these hazards is enforced via legislation on working conditions (Working Conditions Act (*Arbeidsomstandighedenwet*), underlying decisions and regulations). The reliability of the products for professional use is ensured based on various decisions under the Commodities Act. There are also a number of companies that fall under the Major Accidents (Risks) Decree (*Besluit Risico's Zware Ongevallen, BRZO* 2015), which stipulates that employee safety must be guaranteed. In the Netherlands, these regulations aimed at controlling the risks of physical hazards for the employee are regulated by the Social Affairs and Employment Inspectorate (*Inspectie SZW*). That is why a risk assessment of the physical hazards for employees has not been carried out as part of this chain assessment.

11. Abbreviations and terms relating to the risk assessment of the potato chain

11.1. Abbreviations

Abbreviation	Full name (for definitions, see following tables)
Institutes and organisations	
BfR	Bundesinstituut für Risikobewertung (Germany)
BuRO	Risk Assessment & Research Office (*Bureau Risicobeoordeling & onderzoek*) of the Netherlands Food and Consumer Product Safety Authority
CDC	Centers for Disease Control and Prevention (United States)
CFIA	Canadian Food Inspection Agency
CLO	Environmental Data Compendium (*Compendium voor de Leefomgeving*)
CML	Institute of Environmental Sciences (*Centrum voor Milieuwetenschappen*) - Leiden University
Ctgb	Board for the Authorisation of Plant Protection Products and Biocides (*College voor de toelating van gewasbeschermingsmiddelen en biociden*)
DEFRA	Department for Environment, Food and Rural Affairs - UK
EC	European Commission
ECDC	European Centre for Disease Prevention and Control
EFSA	European Food Safety Authority
EPPO	European and Mediterranean Plant Protection Organization
EZ(K)	Ministry of Economic Affairs (and Climate Policy) (*Ministerie van Economische Zaken (en Klimaat)*)
FAO	Food and Agriculture Organization of the United Nations
FDA	United States Food and Drug Administration
FSANZ	Food Standards Australia New Zealand
IARC	International Agency for Research on Cancer (part of WHO)
ICMSF	International Commission on Microbiological Specifications for Foods
IPPC	International Plant Protection Convention. International treaty deposited with the Food and Agriculture Organization of the United Nations to secure international cooperation to prevent and control the introduction and spread of pests.
ISHS	International Society for Horticultural Science
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JRC	Joint Research Centre. The Joint Research Centre is the European Commission's science and knowledge service.
KHN	Koninklijke Horeca Nederland, organisation representing hospitality businesses in the Netherlands
LNV	Ministry of Agriculture, Nature and Food Quality (*Ministerie van Landbouw, Natuur en Voedselkwaliteit*)
NAK	Dutch General Inspection Service for Agricultural Seeds and Seed Potatoes (*Nederlandse Algemene Keuringsdienst voor zaaizaad en pootgoed van landbouwgewassen*)
NAO	Dutch Potato Organisation (*Nederlandse Aardappel Organisatie*)
NPPO	National Plant Protection Organization

NVIC	National Poisons Information Centre (*Nationaal Vergiftigingen Informatie Centrum*) located at Utrecht University Medical Centre
NVWA	Netherlands Food and Consumer Product Safety Authority (*Nederlandse Voedsel- en Warenautoriteit*)
PBL	Netherlands Environmental Assessment Agency (*Planbureau voor de Leefomgeving*)
PD	Plant Protection Service (*Plantenziektenkundige Dienst*)
RIVM	National Institute for Public Health and the Environment (*Rijksinstituut voor Volksgezondheid en Milieu*)
RIWA	Association of River Waterworks (*Vereniging van Rivierwaterbedrijven*)
RVO	Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*)
TBM	Foundation for Crop Protection Measures for Starch Potatoes (*Stichting Teeltbeschermingsmaatregelen Zetmeelaardappelen*)
UN	United Nations
USDA-APHIS	United States Department of Agriculture – Animal and Plant Health Inspection Service
VAVI	Dutch Potato Processing Industry Association (*Vereniging voor de Aardappelverwerkende Industrie*)
VVAK	Arable Farming Food and Feed Safety (*Voedsel- en Voederkwaliteit Akkerbouw*)
WFBR	Wageningen Food & Biobased Research
WFSR	Wageningen Food Safety Research
WHO	World Health Organization
WUR	Wageningen University and Research
Chemical substances	
AGE	Advanced glycation end product
BAC	Benzalkonium chloride
DAS	Diacetoxyscirpenol
DDAC	Didecylmethyl ammonium chloride
DDT	4,4'-Dichlorodiphenyltrichloroethane
DON	Deoxynivalenol
HBCDD	Hexabromocyclododecane
MCPD	3-Chloro-1,2-propanediol
PAH	Polycyclic aromatic hydrocarbon
PBDEs	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyl
PCDDs	Polychloordibenzo-p-dioxins
PCDFs	Polychlorinated dibenzofurans
PFAS	Per- and polyfluoroalkyl substances
QUAT	Quaternary ammonium compound
Technical terms	
ADI	Acceptable Daily Intake
ARfD	Acute Reference Dose
BMDL	Benchmark dose: dose at which a substance causes a certain effect (benchmark effect)
Cfu	Colony-forming unit
FCM	Food Contact Materials
GAP	Good Agricultural Practice
GAP	Good Agricultural Practice

IPM	Integrated Pest Management
KAP	Quality Programme for Agricultural Products (*Kwaliteitsprogramma Agrarische Producten*)
LB	Lower Bound
LOD	Limit of Detection
MB	Medium Bound
ML	Maximum Limit
MoE	Margin of Exposure
MRL	Maximum Residue Limit
RASFF	Rapid Alert System for Food and Feed
SML	Specific Migration Limit
TDI	Tolerable Daily Intake
TWI	Tolerable Weekly Intake [PTWI = Provisional TWI]
UB	Upper Bound
VCP	Food Consumption Survey (*Voedselconsumptiepeiling*)

11.2. Plant health

Term	**Definition**
Active substance	Component or components in a plant protection product that is or are responsible for the effect of the product (Ctgb, 2015).
Containment	The application of phytosanitary measures in and around an infested area to prevent the spread of a harmful organism (FAO, 2016a).
Cultivar	Unit within a cultivated plant species. A cultivar can be a variety but not all varieties are cultivars. A cultivar, as a taxon, is an assemblage of plants that (a) has been selected for a particular character or combination of characters, and (b) remains distinct, uniform, and stable in these characters when propagated by appropriate means ((ISHS, 2016)).
Damage	Reduction in quantity and/or quality of the harvested product due to the presence of a harmful organism in the crop. Damage is synonymous with yield loss (Zadoks & Schein, 1979).
Designated area (*Meloidogyne*)	Area where there has been an official finding of *Meloidogyne chitwoodi* or *M. fallax*, designated (demarcated) by the NVWA (NVWA, 2020j).
Effective package of products and measures	An effective package of resources and measures means that sufficient measures and resources are available to control diseases, pests and weeds on a cultivated site in a way that is effective from an agricultural technology standpoint (which also means it must be cost-effective), including responsible resistance management (NVWA, 2018d).
Export control	Official procedure for export of consignments to countries outside the European Union to establish that the requirements of the importing country have been met.
Export loss	Economic value of reduced export of products due to the presence of a harmful organism within the territory of the exporting country.

Term	**Definition**
Fungicide	A chemical that kills fungi, an anti-fungal agent (Ctgb, 2015).
Genetic resources	Genetic resources are genetic material of actual or potential value. Genetic material means any material of plant, animal, microbial or other origin that contains functional units of heredity (UN, 1992).
Genus-origin-combination	A criterion for classifying plant lots of the same taxonomic genus imported from the same country or region.
Harmful	An organism is harmful if its presence gives rise to any damage and/or export loss of plants or plant products.
Harmful organism	Any species, strain or biotype of plants, animals or pathogens injurious to plants or plant products (Regulation 2016/2031); (FAO, 2016a).
Herbicide	A product to kill or control weed (Ctgb, 2015).
Hitchhiking	The movement of a harmful organism via means or materials other than host plants or natural spread.
Host	An organism (individual or species) in or on which another organism or virus finds the components and conditions necessary for its growth (and reproduction). If the host is a plant, it is referred to as a 'host plant' (Bos et al., 1985).
Host plant	See: Host.
Host Plant List	List of known host plants for an organism.
Import control	Official procedure for import of consignments from countries outside the European Union to establish that the requirements of Regulation 2016/2031 are met. The procedure comprises physical inspections, document checks and identity checks.
Incidence	The percentage or number of units of a lot, area or sample infested by a harmful organism (FAO, 2016a).
Infect/infest	The establishment and spreading of a parasite or phytophagous organism in or on the host (Bos et al., 1985).
Infestation/infection	Infesting/infecting or being infested/infected. Infestation by a pathogen is known as 'infection' and does not necessarily result in damage or disease symptoms (Bos et al., 1985).
Insecticide	A substance that kills insects and arthropods - a chemical or non-chemical product for the control of insects (Ctgb, 2015).
Inspection	Official visual assessment of plants, plant products or other objects to determine whether harmful organisms are present (FAO, 2016a). During an inspection, samples may also be taken for a test to determine the presence of one or more harmful organisms.
Integrated Pest Management (IPM)	The careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms, keep the use of plant protection products and other forms of intervention at levels that are economically and ecologically justified, and reduce or minimise risks to human health and the environment (Directive 2009/128/EC and the Plant Protection Products and Biocides Act (Wgb)). The definition in Directive 2009/128/EC continues: "Integrated pest management emphasises the

Term	Definition
	growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.”
Integrated Plant Protection	See: Integrated Pest Management.
Interception	The detection of a harmful organism in a consignment during import control (FAO, 2016a).
Introduction	The entry of a harmful organism in an area, resulting in the long-term presence of the organism in the area (FAO, 2016a). Introduction refers to both the entry and establishment of a harmful organism in an area (FAO, 2017).
Laboratory test	A test performed in a laboratory.
Loss	The economic value of damage (Zadoks & Schein, 1979).
Metabolite	Chemical conversion product created by the metabolic degradation of the parent substance (Ctgb, 2015).
Nematicide	Substance that kills nematodes - a nematode control product (Ctgb, 2015).
Neonicotinoid	A group of active substances (insecticides) related to nicotine.
NL-provisional Q-pest	A harmful organism not listed in Annex II of Implementing Act 2019/2072 and for which no temporary measures apply under any implementing act adopted by the Commission but for which, in the Netherlands, official phytosanitary measures are taken, usually in response to a previous detection or interception of the organism or a request from a company or institution to be allowed to work with an organism from outside the European Union.
Notification of interception	A ‘notification of interception’ is sent by an importing country to an exporting country if an exported consignment does not comply with the requirements set out in the phytosanitary certificate, for example, if the consignment proves to be infested by harmful organisms (FAO, 2016b).
Official	Established, authorised or performed by a national plant protection organisation (FAO, 2016a). The NVWA is the national plant protection organisation of the Netherlands.
Organism-crop combination	Specific combination of a species of harmful organism and a species of host plant, for example, to create a tolerance limit for the degree of infestation of that host plant lot.
Package of plant protection products	The set of plant protection products authorised by the Ctgb for the Netherlands for a defined activity (such as the cultivation of lilies, the cultivation of floristry plants (protected cultivation) or the Dutch agriculture and horticulture industries).
Pathotype	A unit within a species (mainly used for fungi) that is distinguished not on the basis of morphological characteristics, but on the formation of symptoms in a set of plant cultivars of one or more host plant species (see (Bos et al., 1985)).
Pest	See: Harmful organism.
Phytophagous organism	Organism that feeds on living plant tissue (Bos et al., 1985).

Term	**Definition**
Phytosanitary certificate	An official paper document or its official electronic equivalent, consistent with the model certificates of the IPPC (International Plant Protection Convention), attesting that a consignment meets phytosanitary import requirements (FAO, 2016a).
Phytosanitary measure	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2016a).
Plant passport	An official label indicating that the phytosanitary standards and the special requirements for the movement of plants within the EU, laid down in Regulation 2016/2031, have been met and which, to that end, is: - standardised at the Community level for different types of plants or plant products; and - prepared by the responsible official body of a Member State and issued in accordance with the implementing rules governing the details of the procedure for issuing plant passports (Regulation 2016/2031).
Plant pathogen	A harmful organism that is not an animal.
Plant protection product	Product, in the form in which it is supplied to the user, consisting of or containing active substances, safeners or synergists, and intended for one of the following uses: a) Protecting plants or plant products against all harmful organisms or preventing the action of such organisms, unless the main purpose of these products is considered to be for reasons of hygiene rather than for the protection of plants or plant products; b) Influencing the life processes of plants, such as substances influencing their growth, other than as a nutrient; c) Preserving plant products, in so far as such substances or products are not subject to special Community provisions on preservatives; d) Destroying undesired plants or parts of plants, except algae unless the products are applied on soil or water to protect plants; e) Checking or preventing undesired growth of plants, except algae unless the products are applied on soil or water to protect plants (Regulation (EC) No 1107/2009).
Potato Cultivation Prohibition Area	Demarcated area in the Netherlands where large amounts of propagating material are grown and where the cultivation of potatoes is prohibited (NVWA, 2018b).
Regulated Non-Quarantine Pest (RNQP)	A non-quarantine pest whose presence is regulated in the propagating material (and other plants for planting) of certain plant species that is placed on the market (FAO, 2016a).
Regulated organism	A quarantine pest, NL-provisional Q-pest or regulated non-quarantine pest (FAO, 2016a).
Residue	Residual amount of the active substance of a plant protection product or a harmful metabolite thereof, which is found on or in a product, plant, water or the soil after application of the plant protection product (Ctgb, 2015).
Resistance (against harmful organisms)	Genetically determined reduced susceptibility of a population of plants to damage by a harmful organism.
Resistance (against plant protection products)	Genetically determined reduced sensitivity of a population of a harmful organism to a plant protection product.

Term	Definition
Soil disinfectant	A plant protection product for soil or soil treatment specifically intended to control the harmful organisms in the soil. This product is often primarily aimed at controlling nematodes (Ctgb, 2015).
Spread	Expansion of the geographic distribution of a harmful organism in an area (FAO, 2016a).
Symptom	A sign indicating the presence of a harmful organism.
Test	An official assessment, other than a visual assessment, of plants, plant products or other objects to determine whether harmful organisms are present (FAO, 2016a).
Tolerance level	Incidence of a pest specified as a threshold for action to control that pest or to prevent its spread or introduction (FAO, 2016a).
Union Quarantine Pest	A harmful organism with an established identity that is not present or present only to a limited extent in the EU, which is capable of establishing itself in the EU and has unacceptable consequences after entry, and which is listed in Annex II of Implementing Regulation (EU) 2019/2072 (Implementing Regulation 2016/2031, Article 4) or subject to temporary measures under an implementing act adopted by the Commission (Implementing Regulation 2016/2031, Article 30). NB According to Regulation 2016/2031, only the organisms listed in Annex II of Implementing Regulation 2019/2072 are designated as Union Quarantine Pests.
Variety	See: Cultivar.
Visual assessment	Physical inspection of plants, plant products or other objects with the naked eye, magnifying glass, stereoscope or microscope to detect harmful organisms without carrying out tests (FAO, 2016a).
Yield loss	See: Damage.
Zero tolerance	For a harmful organism or a residue: the requirement indicating that the organism or substance must not be found in a lot or sample.

11.3. Food safety

Term	Definition
Acute exposure	Short-term, one-time exposure.
Carcinogen	Substance capable of causing cancer.
Chronic exposure	Long-term, lifelong exposure.
Colony-forming unit (CFU)	Unit used for determining the number of bacteria in a matrix. This quantity is expressed in the number of cfu per ml or gram, i.e. the number of colonies formed from 1 ml or 1 gram of product. Since one colony may be created from multiple cells, this unit is used rather than the number of cells per ml or gram.

Term	**Definition**
Cumulative effect	Total impact of the combined effects of different substances
Environmental contaminant	Contaminants in the environment.
Food poisoning	Poisoning caused by eating food containing toxins that have been formed by bacteria or fungi in that food.
Foodborne infection	Infection caused by eating food containing pathogenic microorganisms. The disease itself develops after the microorganisms have entered the body.
Fresh weight	Weight of the raw potatoes (also referred to as 'wet weight').
Genotoxic	Can cause hereditary changes via damage to DNA
Germicidal treatment	Treatment of a product to reduce the microbial contamination of the product.
Health-based limit value	Maximum amount of a substance that a human can ingest without risk to health (mg or µg of substance per kg of body weight) [RIVM, https://rvs.rivm.nl/normen/consumenten].
Hepatotoxicity	Toxic to the liver.
Legal limit	Maximum value laid down by law.
Multi-residue method	Chemical analytical method by which several plant protection products can be analysed simultaneously.
Mutagen	Genotoxic substance.
Neurotoxic	Toxic to the nervous system.
Nosocomial infection/transmission	Infection/transmission of microorganisms contracted in a hospital.
Product standard	Maximum content of a substance in food, determined per substance-food combination.
Teratogenic	Substance that can cause birth defects.
Toxico-infection	Poisoning that results from eating foods containing pathogenic bacteria that form one or more toxins in the intestines.

11.4. Cultivation, handling and processing

Term	**Definition**
Breeding	All actions that lead to improvement of the genetic characteristics of cultivated plants.

Term	**Definition**
Composite product	Products containing ingredients besides potatoes from production chains other than the potato chain.
Consumer	End user of an end product. The final stage in a production chain.
Consumption	End use of the product in various forms: feeding, placing plants in a private garden or private covered space, processing plants into decorative items, etc.
Crop rotation	The chronological order in which crops in a growing plan are grown on a single plot based.
End product	Harvested product of a crop, intended for consumption.
End use	See: Consumption.
Food handler	Consumer in private households or professional food handlers working for mass caterers.
Growing plan	The distribution of crops over the available plots of a farm.
Handling	Handling of the product without significantly altering it, such as washing, packaging and peeling.
Mass caterers	Companies or institutions (including vehicles and fixed or mobile stalls), such as restaurants, canteens, schools, hospitals and catering enterprises in which, in the course of a business, food is prepared to be ready for consumption by the final consumer.
Mini tubers	Mini tubers are small potato tubers that have grown in the greenhouse. They grow on plants that have been obtained from a single plant through rapid propagation. These plants are cultivated disease-free and subsequently planted in clean potting soil. The tubers harvested from such plants are called 'mini tubers'.
Plant reproductive material	See: Propagating material.
Planting material or seed potato	See: Propagating material.
Processing	Any action that substantially alters the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes. Source: Regulation (EU) 852/2004
Produce	Potatoes, vegetables and fruit
Propagating material	Plants or planting material intended for use as seeds, seed potatoes or planting material. Synonymous with starting material and plant reproductive material.
Propagation	Production of new propagating material (seeds, seed potatoes or planting material) for the cultivation of end products. Propagation techniques include seed cultivation, production of cuttings and grafts, in vitro culture and tissue culture.
Residual flow	By-products and waste generated at a stage in a production chain.

Term	**Definition**
Soil tare	Adhering soil that is released when processing harvested potatoes.
Subsequent crop	The next crop to be grown on a particular plot after the current crop has been harvested.
Tissue culture	Tissue culture is a method of propagating plants under sterile conditions and is often used to produce clones of a plant.

11.5. Medical

Term	**Definition**
Burden of disease	The burden of disease is the extent of the loss of health within a population caused by disease. The burden of disease is expressed in DALYs (Disability-Adjusted Life Years). DALYs quantify the loss of health and are made up of two components: the years of life lost due to premature mortality and the years lived with a disease.
Opportunistic pathogen	A microorganism present on or in a human body without causing any harm and that presents no health risk unless the body's immune system fails (O'Toole, 2017).

11.6. Other

Term	**Definition**
Environmental quality standard	Environmental quality standards are aimed at protecting the general environmental quality based on legal frameworks. There are environmental quality standards for substances in surface water, groundwater, sediment, soil and air.
Third country	A country that is not a member of the European Union.
Third-country requirement	Requirements imposed by third countries on consignments from other countries, for example, the Netherlands.

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