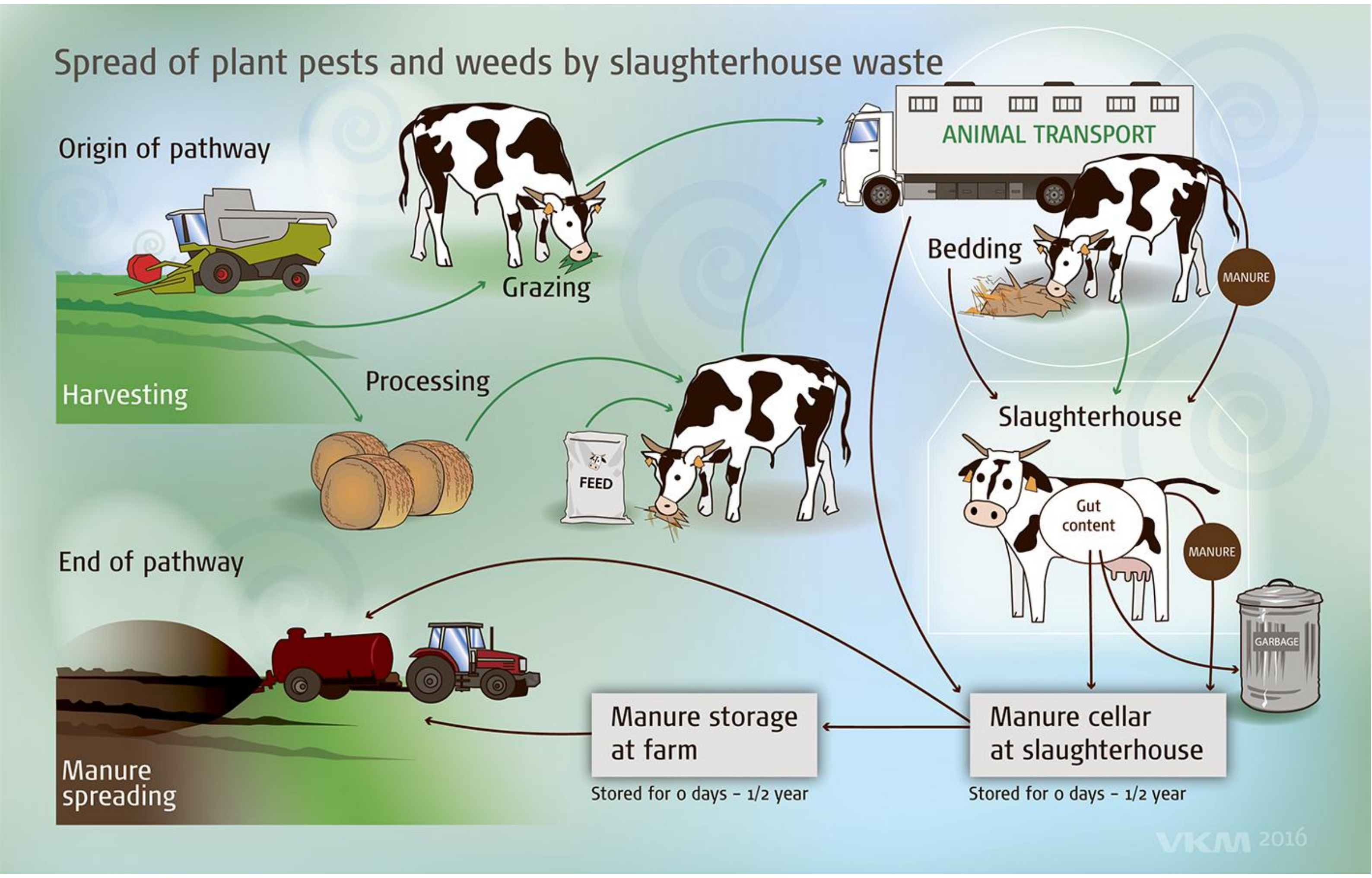
Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety



VKM Report 2016: 55

Assessment of manure and digestive tract content from slaughterhouses as a pathway for weeds and plant pests

Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety

Report from the Norwegian Scientific Committee for Food Safety (VKM) 2016: 55
Assessment of manure and digestive tract content from slaughterhouses as a pathway for weeds and plant pests

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Assessment of manure and digestive tract content from slaughterhouses as a pathway for weeds and plant pests

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Assessed and approved

The opinion has been assessed and approved by the Panel on Plant Health. Members of the panel are: Trond Rafoss (chair), Guro Brodal, Åshild Ergon, Christer Magnusson, Arild Sletten, Halvor Solheim, Leif Sundheim, May-Guri Sæthre, Anne Marte Tronsmo, Bjørn Økland.

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Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Summary

Key words: VKM, risk assessment, Norwegian Scientific Committee for Food Safety, Norwegian Environment Agency, plant health, plant pest, weed, manure, intestine tract content, digestive system, spread, cattle, sheep, goat, horse, pig, agricultural, slaughterhouse, economic consequences, bedding, feed, forage, pasture, vegetable waste, risk reduction options, crop

The Norwegian Food Safety Authority (NFSA) commissioned the Norwegian Scientific Committee for Food Safety (VKM) to assess if the current practice, that manure and digestive tract content from slaughterhouses are spread on adjacent farms, is a pathway for spread of plant pests to new agricultural areas. During the recent decades, the industry has rationalized and consolidated its activities by reducing the number of slaughterhouses and building larger and more mechanized plants. This has increased the transport distance from farms to slaughterhouses. That may elevate the risk of domestic spread of plant pests and weeds, which would otherwise be limited to specific regions in Norway.

The assessment deals with manure from ruminants (cows, sheep and goats), pigs and horses. Poultry is not considered in the assessment, as they are fed concentrate only. There is no import to Norway of animals for slaughter in domestic slaughterhouses. About half the ingredients used in concentrate production is imported. The import of hay and cereal straw is very limited.

Main conclusion

Cultivated and domesticated plants are threthend by several different plant pests. Among those, a limited number may survive the animal digestive tract and manure. Today just a few plant pests have a limited geographical occurrence. Nevertheless, those pests may be spread to new areas through spreading of manure and digestive tract content from slaughterhouses on adjacent farms. The plant pests that posseses the highest risk to be spread by manure and digestive tract content from slaughterhouses are; wild oat, potato wart fungus, potato cyst nematodes and cockspur grass. However, it is uncertainty related to the probability of cockspur grass to survive through the digestive tract and manure.

Plant pests evaluated

The weed flora in Norwegian agriculture is well mapped. The weed species evaluated were restricted to vigorous and competitive weed species, invasive alien species, and species with hard seeds that are known to be robust under anaerobic conditions. The wild oat (*Avena fatua*) is under phytosanitary regulation, and the cockspur grass (*Echinochloa grus-galli*) is spreading. A number of plant pathogenic fungi, viruses and bacteria were considered in the assessment. The potato wart fungus is under phytosanitary regulation and was last detected in 1994. Animals grazing on pastures may ingest plant parasitic nematodes that occur on above-ground plant parts, or on superficial roots and in adherent soil. The potato cyst

nematodes, PCNs (*Globodera rostochiensis, G. pallida*) have been monitored since their first recording in 1950s, and the PCNs are under phytosanitary regulation. Only phytophageous insects and mites that feed on plants that are likely to be eaten by grazing animals or harvested were considered.

Pest survival in feed and bedding material

The probability of survival of weed seeds increases, when harvesting grass at a late stage of maturity. The ensiling process reduces viability of many weed seeds, although not all. Species with hard seed coat might survive. Weed seed in bedding material is only expected to survive, when straw is used. Survival of weed seeds in concentrate is unlikely. When whole oat is used as horse feed, the survival of weed seed is likely. Survival of weed seed in other feed is moderately likely.

Plant pathogenic fungi, oomycetes and protozoa are unlikely to survive during the production of pelleted concentrate feed, but they are likely to survive in non-treated concentrates, such as whole oats, grain legumes, and rapeseed. These pathogens are likely to survive in hay, stored potatoes and root vegetables, food waste and in straw used as bedding material, and they are moderately likely to survive in silage.

Plant pathogenic bacteria and viruses are likely to survive in hay and straw used as feed and bedding material, but these pathogens are unlikely to survive ensiling, and the production of pelleted concentrate feed.

It is unlikely that plant parasitic nematodes would survive processing of concentrates. PCNs are moderately likely to survive ensiling for silage. Cyst nematodes are likely to survive storage of bedding material like haulm. Most nematodes are all likely to survive storage in hay. The potato rot nematode *Ditylenchus destructor*, root lesion nematodes (*Pratylenchus* spp.) and the root knot nematode *Meloidogyne hapla* are likely to survive storage of roots. PCNs are likely to survive in contaminated soil.

It is unlikely that insects and mites can survive processing of concentrates and silage due to mechanical destruction during grinding or packing, killing during heating or anaerobic conditions, and due to the relatively low pH. Hay is too dry for the insects and mites. Untreated root vegetable waste or potatoes may contain living insect larvae when fed to animals.

Pest survival in the digestive tract of animals

Seeds from broad-leaved *Rumex* weed species, *Chenopodium album* and *Fallopia convolvulus* are likely to survive passage through the digestive tract of animals. Seeds of *A. fatua, E. grus-galli* and *Thlaspi arvense* are moderately likely to survive. The mechanical process of chewing, together with enzymatic digestion and exposure to acidic conditions, especially in the abomasum, reduces the viability of seeds, but not all are killed. The probability of survival of weed seeds in faeces is highest in horses, followed by large ruminants, small ruminants, and then pigs. For ruminants, much of the digesta volume is in the rumen where the probability of survival of seeds is likely.

The plant pathogens *Plasmodiophora brassicae, Spongospora subterranea, Synchytrium endobioticum, Verticillium dahlia, V. albo-atrum, Sclerotinia spp.* and *Tilletia caries* are likely to survive passage through the digestive tracts of animals. Other fungal and oomycete plant pathogens are moderately likely to survive.

It is unlikely that pathogenic bacteria and viruses survive in the digestive tract of animals.

PCNs and the cereal and grass cyst nematodes are moderate likely to survive and remain infective after passage through the alimentary canals of cows and sheep. PCNs and the cereal and grass cyst nematodes are unlikely to survive after passage through the alimentary canals of pigs.

It is unlikely that phytophagous insects and mites will survive the processes of chewing and digestion if ingested by an animal.

Pest survival during manure storage

The temperature in manure storage is crucial for survival. It is likely that temperature varies both between and within manure storage. It is therefore moderately likely that weed seeds will lose their viability in manure storage. In manure storage in which temperature reaches 55°C, seed survival is unlikely.

The plant pathogens *P. brassicae, S. subterranea*, *S. endobioticum, V. dahlia and V. albo-atrum* are likely to survive in manure until it is applied on fields. *Bipolaris sorokiniana* is moderately likely to survive during manure storage. The survival of other fungal pathogens during manure storage is moderately likely.

It is unlikely that plant-pathogenic bacteria and viruses survive during manure storage.

The PCNs are moderately likely to survive and remain infective after storage in cattle manure. This is also expected to be true for sheep manure. The PCN, and the cereal and grass cyst nematodes are unlikely to survive and remain infective after storage in pig manure.

Phytophagous insects and mites are unlikely to survive during manure storage.

Pests with the potential for resulting in highly negative consequences

Wild oats reduce yield and is under phytosanitary regulations. On properties with wild oats farmers are obliged monitor their land each year and to control infestations. The regulation prohibits seed production on wild oats infested areas. The cockspur grass is expanding in South-East Norway, and the weed has been detected in Rogaland County.

The potato wart fungus is under phytosanitary regulation and was last detected in Norway more than 50 years ago. The potato fungus is a serious pathogen that reduces the yield and quality of the potato harvest.

The potato cyst nematodes (PCNs) represent a serious problem, as they can survive for up to 32 years in soil following an infestation. PCN have been detected on more than 6000 properties in Norway. PCN infestation reduces potato yield.

Risk reduction options

Storage of manure and digestive tract content.

If the temperature in the storage facility is sufficiently high, the viability of weed seeds will be reduced, decreasing their potential for spread. Manure storage is likely to reduce the risk of spread for most plant pathogens. *Plasmodiophora brassicae, S. subterranea* and *S. endobioticum* are likely to survive storage of manure. Manure storage is likely to reduce the risk of spread for most nematodes.

Separation of manure and digestive tract content.

Weed seeds often survive passage through the digestive tract of cattle and sheep. This implies that the documented seed-killing properties of windrow composting are also sufficient to destroy seeds contained in the washout of rumen content. Windrow composting is the production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows (windrows). Thus, there is no obvious reason to separate manure and rumen content, if they are properly composted. Separation of manure and digestive tract content is probably of no importance regarding plant pathogenic fungi, bacteria, viruses and phytophageous insects and mites.

Avoidance of specific types of feed for a defined period before transport to the slaughterhouse.

The plant health risk from spread of untreated slaughterhouse manure on the receiving farm can be reduced by avoiding use of animal feed potentially containing plant pests or weeds during the period prior to slaughter.

Choice of crop after application.

Avoidance of potato and vegetable crops the year of application of slaughterhouse manure will reduce the risk for spread of the plant pathogens and nematodes that survive in the digestive tract and in manure.

Composting of manure and digestive tract content.

Aerobic windrow composting is an effective method of reducing the viability of weed seeds. These rows are turned to improve porosity and oxygen content, to mix in or remove moisture, and to redistribute cooler and hotter portions of the pile. Data on any effect of composting of manure and digestive tract content on plant pathogens have not been found in the literature search.

Sammendrag på norsk

Vitenskapskomiteen for mattrygghet (VKM) har på oppdrag fra Mattilsynet vurdert om dagens praksis med å spre husdyrgjødsel og mageinnhold fra slakterier som gjødsel er en smittevei for spredning av planteskadegjørere. I de siste tiår har slakteriene blitt større og mer mekaniserte. Det har gitt lenger transportdistanse fra gård til slakteri, noe som kan gi økt risiko for at planteskadegjørere som i dag har begrenset utbredelse i Norge, blir spredd til et større område.

Rapporten vurderer gjødsel fra drøvtyggere (ku, sau og geit), svin og hester. Fjørfe er ikke vurdert fordi de bare fôres med kraftfôr. Norge importerer ikke dyr til slakterier. Om lag halvparten av råvarene som brukes i produksjon av kraftfôr er importerte. Importen av høy og halm er svært begrenset.

Hovedkonklusjon

Kulturplanter er utsatt for mange ulike skadegjørere. Bare et lite antall skadegjørere overlever i husdyrmagen og i husdyrgjødsel. Blant disse er det noen få som har begrenset geografisk utbredelse i dag, og de kan utvide sitt område gjennom spredning av mageinnhold og gjødsel fra slakterier på jordbruksareal. De alvorligste skadegjørerne som kan spres med slakteriavfall er floghavre, potetkreft, potetcystenematoder og hønsehirse. Det er imidlertid usikkerhet rundt sannsynligheten for at hønsehirse kan overleve i dyremagen og i gjødsla.

Skadegjørere som er vurdert

Ugrasartene som er vurdert i rapporten, er begrenset til sterkt konkurrerende arter, invaderende arter og arter med hardt frøskall. Blant disse er floghavre (*Avena fatua)* og hønsehirse (*Echinocloa crus-galli)*. Floghavre reguleres av floghavreforeskriften. Hønsehirse mangler regulering og sprer seg fortsatt i landet.

Et stort antall sykdomsfremkallende sopper, virus og bakterier er vurdert, deriblant potetkreft. Potetkreft omfattes av regelverket for plantehelse, og ble sist funnet i Norge i 1994. Beitedyr kan få i seg nematoder som finnes på plantedeler over jordoverflaten. Potetcystenematodene (PCN) (*Globodera rostochiensis, G. pallida*) omfattes av regelverket for plantehelse, og er blitt overvåket siden 1950 tallet da de ble funnet i Norge for første gang. Bare planteskadende insekter og midd som lever på beiteplanter, høstet gras og høy er vurdert.

Overlevelse av skadegjørere i fôr og strø

Sannsynligheten for at ugrasfrø skal overleve, øker ved sen høsting. Ensilering, det vil si konservering av fôr i tårnsilo, plansilo eller rundballer, fører til at mange ugrasarter dør, men ikke alle. Arter med hardt frøskall kan overleve. Ugras i strø forventes bare å overleve når halm blir brukt som strømiddel. Når hel havre blir brukt til hestefôr, er det sannsynlig at ugrasfrø overlever. Det er middels sannsynlighet for at ugrasfrø overlever i annet fôr. Det er ikke sannsynlig at ugrasfrø overlever i kraftfôr.

Det er ikke sannsynlig at sykdomsfremkallende sopper, oomyceter og protozoer overlever i pelletert kraftfôr, men det er sannsynlig at de kan overleve i ubehandlet fôr, som hel havre, belgvekstfrø og oljevekstfrø. Det også er sannsynlig at disse sykdomsfremkallende soppene overlever i høy, lagrede poteter, rotvekster, matavfall og i halm og strø, og middels sannsynlig at de overlever i ensilert fôr.

Det er sannsynlig at plantepatogene bakterier og virus overlever i høy og halm til fôr og strø, men det er ikke sannsynlig at de overlever ensilering og i produksjon av kraftfôr.

Det er ikke sannsynlig at nematoder vil overleve produksjon av kraftfôr. Det er middels sannsynlig at potetcystenematodene overlever ensilering. Det er sannsynlig at cystedannende nematoder overlever lagring av halm og annet strø. Det er sannsynlig at nematoder overlever lagring av høy. Det er sannsynlig at rotråtenematode (*Ditylenchus destructor*), rotsårnematoder (*Pratylenchus* spp.) og rotgallnematode (*Meloidogyne hapla*) overlever i lagrede rotvekster. Det er sannsynlig at potetcystenematodene overlever i smittet jord.

Det er ikke sannsynlig at insekter og midd overlever i produksjon av kraftfôr eller ensilering, fordi de blir ødelagt av mekanisk skade ved maling, varme, anaerobe forhold og lav pH. Høy er for tørt for insekter og midd. Ubehandlede rotvekster og potet til dyrefôr kan inneholde insektlarver.

Overlevelse av skadegjørere gjennom dyrenes mage- og tarmsystem

Det er sannsynlig at frø av breiblada *Rumex*-arter, meldestokk (*Chenopodium album*) og vindelslirekne (*Fallopia convolvulus*) overlever gjennom dyremagen. Frø av floghavre, hønsehirse og pengeurt (*Thlaspi arvense*) har middels sannsynlighet for å overleve gjennom dyremagen. Mekanisk skade ved tygging, enzymatisk nedbryting og surt miljø i løypemagen (abomasum) hos drøvtyggere reduserer overlevelsen av ugrasfrø. Men ikke alt frø blir drept. Sannsynligheten for at ugrasfrø lever i avføring er i rekkefølge: hest (størst), storfe, småfe og svin (minst). Hos drøvtyggere har ugrasfrø størst sannsynlighet for å overleve i vommen (rumen).

Sykdomsfremkallende organismer og virus som er årsak til klumprot (*Plasmodiophora brassicae*), vorteskurv (*Spongospora subterranea*), potetkreft (*Synchytrium endobioticum*), visnesjuke (*Verticillium dahli* og *V. albo-atrum*), storknolla råtesopp og stinksot (*Tilletia* *caries*) har stor sannsynlighet for å overleve i dyremagen. Andre plantepatogene sopper og oomyceter har middels sannsynlighet for å overleve gjennom dyremagen.

Det er ikke sannsynlig at plantepatogene bakterier og virus overlever gjennom dyremagen.

Det er middels sannsynlig at potetcystenematodene, korncystenematoder (*Heterodera avenae*, *H. filipjevi*) og grascystenematode (*Punctodera punctata*) overlever og er smittedyktige gjennom dyremagen hos storfe og sau. Det er ikke sannsynlig at potetcystenematodene og korncystenematode og grascystenematode overlever gjennom magen hos svin.

Det er ikke sannsynlig at planteparasittære insekter og midd overlever tygging og fordøyelsen gjennom dyremagen.

Overlevelse av skadegjørere i husdyrgjødsel

Temperaturen er avgjørende for overlevelse av planteskadegjørere i husdyrgjødsel. Det er sannsynlig at temperaturen varierer både mellom og innen forskjellige gjødsellagre. Det er derfor middels sannsynlig at ugrasfrø vil miste spireevnen i gjødsellager. Det er ikke sannsynlig at ugrasfrø overlever i husdyrgjødsel om temperaturen kommer opp i 55ºC.

Det er sannsynlig at sykdomsfremkallende organismer og virus som er årsak til klumprot, vorteskurv, potekreft og verticillium- visnesjuke overlever i husdyrgjødsel til den blir spredd i åkeren. Det er middels sannsynlig at andre plantepatogene sopper overlever i husdyrgjødsel.

Det er ikke sannsynlig at plantepatogene bakterier og virus overlever i husdyrgjødsel.

Det er middels sannsynlig at potetcystenematodene overlever og beholder smitteevnen etter lagring i storfegjødsel og småfegjødsel. Det ikke sannsynlig at potetcystenematodene, korncystenematode og grascystenematoder overlever i svinegjødsel.

Det er ikke sannsynlig at planteparasittære insekter og midd overlever i husdyrgjødsel.

Skadegjørere som kan resultere i svært negative konsekvenser

Floghavre reduserer avlingene og omfattes av regelverket for plantehelse. På eiendommer med floghavre er bruker pålagt årlig inspeksjon av arealene og bekjempelse av ugraset. Regelverket forbyr såvaredyrking på arealer med forekomst av floghavre. Utbredelsen av hønsehirse er raskt økende på Østlandet, og ugraset er funnet i Rogaland.

Potetkreft omfattes av regelverket for plantehelse og ble sist funnet i Norge for over femti år siden. Potetkreft er et alvorlig patogen som reduserer avling og kvalitet i potet.

Potetcystenematodene er et alvorlig problem siden de kan overleve opp til 32 år i smitta jord. Potetcystenematodene reduserer poteavlingene. De er funnet på over 6000 eiendommer i Norge.

Risikoreduserende tiltak

Lagring av gjødsel og vominnhold

Om temperaturen er tilstrekkelig høy reduseres spireevnen hos ugras og deres potensiale for spredning. Gjødsellagring reduserer risikoen for spredning av de fleste plantepatogener. Men det er sannsynlig at klumprot, vorteskurv og potetkreft overlever gjødsellagring. Risikoen for spredning av planteparasittære nematoder blir redusert ved lagring av husdyrgjødsel.

Separering av husdyrgjødsel og vominnhold

Ugrasfrø overlever ofte gjennom dyremagen hos storfe og sau. Kompostering ved å legge husdyrgjødsel sammen med annet bionedbrytbart materiale i ranker (windrow composting) ødelegger spireevnen hos ugras. Dersom komposteringen er godt gjennomført, er det ingen grunn til å skille husdyrgjødsel og vominnhold. Separering har trolig ingen virkning på sykdomsfremkallende organismer og virus, insekt og midd.

Unngå visse typer av fôr i en periode før transport til slakteriet

Risikoen for spredning av planteskadegjørere kan reduseres ved å unngå fôr som kan inneholde planteskadegjørere de siste dagene før slakting.

Valg av kultur etter tilførsel av slakterigjødsel

Risikoen for spredning av sykdomsfremkallende organismer og virus og nematoder som overlever i dyremagen, kan reduseres ved å unngå å dyrke potet og rotvekster på arealer hvor man sprer gjødsel fra slakterier.

Kompostering av husdyrgjødsel og vominnhold

Windrow kompostering i ranker er en effektiv metode for å redusere spireevnen til ugrasfrø. Vending av radene for å blande og sørge for oksygentilgang og oppvarming av alt materialet er viktig. I litteratursøket er det ikke funnet noen data om virkning av kompostering av husdyrgjødsel og vominnhold på organismer og virus som kan forårsake sykdom hos planter.

Abbreviations and/or glossary

Abbreviations

EFSA: European Food Safety Authority

EPPO: The European and Mediterranean Plant Protection Organization

LMD: Ministry of Agriculture and Food

PCN: Potato cyst nematode

PMR: Partial mixed rations

PRA: Pest Risk Assessment

SSB: Statistics Norway (Statistisk sentralbyrå)

TMR: Total mixed rations.

Glossary

Concentrate ("kraftfôr" in Norwegian)

Feed ingredient with a high energy and/or protein content.

Concentrate mixture ("kraftfôrblanding" in Norwegian)

A mixture of different concentrate feed ingredients. Concentrate mixture is also called compound feed.

Ensiling

The process of making silage or haylage from forage. The ensiling process consists of a short aerobic phase (< 1 day in which aerobic respiration depletes any oxygen present), and a longer fermentation phase (approx. 1-4 weeks), in which anaerobic microorganisms, mainly lactic acid bacteria, multiply and produce lactic acid that conserves the mass at a pH around 4 (Barnes et al., 2003).

Feed

Ingredients in the diet of animals.

Forage

Edible above-ground parts of plants, other than separated grain, that can provide feed for grazing animals or that can be harvested for feeding animals. Also called roughage, herbage or fodder.

<u>Green forage</u>

Forage like turnip, rape, marrow stem kale (fornepe, forraps, formargkål).

<u>Hay</u>

Forage preserved by drying to moisture levels low enough to prevent microbial activity that leads to spoilage.

<u>Haylage</u>

Product resulting from ensiling forage. Haylage is preserved like silage, but has higher dry matter content (typically 50-60 %).

<u>Heifer ("kvige" in Norwegian)</u>

A young cow before she has had her first calf.

<u>Other feed</u>

Potatoes and other root vegetables cultivated for the use as animal feed, as well as food waste (e.g. bread, groceries, fruits) and residues from the food industry (e.g. brewer's grain, vegetable waste).

<u>PMR</u> - <u>Partial mixed rations</u>

Mixed rations of forages and concentrates for feeding to dairy cows that needs to be supplemented with additional ingredients, usually a concentrate mixture.

<u>Pasture</u>

A field of forage plants that can be grazed by animals.

<u>Pathway</u>

Any means that allows the entry or spread of a pest (IPPC FAO, 2016a).

<u>Pest (Plant pest)</u>

Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (IPPC FAO, 2016a).

Sclerotium

A compact mass of fungal hyphae, with or without host tissue, capable of surviving under unfavourable conditions.

Silage

Product resulting from ensiling forage. Silage is preserved like haylage, but has lower dry matter content (typically around 30 %).

Silo

The location where ensiling takes place and silage is stored. The three main types are: tower silo, bunker silo and big bales wrapped in plastic.

TMR - Total Mixed Rations

Mixed rations of forage and concentrates for feeding to dairy cows containing all the main feed ingredients so that additional feed ingredients are not needed.

Vector

Any biological or non-biological agent which may transmit a pest

Background as provided by the Norwegian Food Safety Authority

Manure and digestive tract content originating from slaughterhouses are commonly delivered to nearby farmers and applied on land in unprocessed form. As these materials are potential carriers of animal- and plant pests, their handling and use are regulated by several regulations:

- Regulation on organic fertilizers (FOR-2003-07-04-951) (LMD et al., 2003)
- Regulation on animal by-products (FOR-2016-09-14-1064) (NFD and LMD, 2016)
- Regulation on plant health (FOR-2000-12-01-1333) (LMD, 2000)
- Regulation on wild oats (FOR-2015-06-22-752) (LMD, 2015)

The Animal by-product Regulation accepts the application of untreated manure and digestive tract content on agricultural land. However, according to the Fertilizer Regulation there is a general requirement for sanitation if there is any risk of transmission of plant pests (including wild oats). In the Fertilizer Regulation, plant pests are not restricted to quarantine pests but also include other pests that can have practical or economic consequences for the farmer if they are introduced on the farm (for example *Plasmodiophora brassicae*).

The past years, several exemptions have been granted to apply untreated manure directly on agricultural land. The reasons for giving exemptions are partly the tradition to dispose slaughterhouse waste in this way, partly that the plant health risk has been regarded as acceptable. Nearby treatment facilities have also been unavailable in several cases. In contrast to manure originating and applied on the same farm, slaughterhouse waste is collected from animals originating from many farms and a large geographical area. The potential of spreading plant pests can therefore be different from traditional application of untreated manure on farm of origin. The Norwegian Food Safety Authority find that there is a need for an assessment considering manure and digestive tract content from slaughterhouses as a pathway for spread of plant pests to new agricultural areas.

Terms of reference as provided by the Norwegian Food Safety Authority

The Norwegian Food Safety Authority requests VKM to give their opinion on the probability of spread of plant pests and weeds to new agricultural areas when digestive tract content and manure originating from slaughterhouses are applied on agricultural fields untreated.

We also ask VKM to specify which plant pests and weeds can pose practical and/or economic consequences if spread.

Specified questions:

1. Sources of plant pests and weeds

   To what extent are feedstuffs, bedding materials, pasture etc. possible sources to plant pests and weeds in slaughterhouse manure?

2. Spread

- To what extent can digestive tract content and manure from slaughterhouses contribute to spread of plant pests and weeds to new agricultural areas? Will the risk depend on species (cattle, sheep/goat, horses, and pigs)?

3. Effect of risk reduction options

- To what extent will storage of digestive tracts content and manure from slaughterhouses reduce the risk of spread of plant pests and weeds?
- To what extent will source-separation of manure and digestive tract content reduce the risk of spread of plant pests and weeds if only the manure fraction is applied untreated on agricultural land?
- Can the risk of spread be reduced if vegetable waste potentially containing plant pests or weeds is avoided as feed during the last period before slaughter (specify for different animal species and time period before planned transport to slaughtering)?
- Does the risk of spread vary with the type of crop grown the following years after application?

Assessment

1 Introduction

1.1 Purpose and scope

This Opinion was prepared by the VKM Panel on Plant Health (hereafter referred to as the Panel), in response to a request from the Norwegian Food Safety Authority. The Opinion is an assessment of the probability of slaughterhouses manure and digestive tract content acting as pathways for spread of weeds and plant pests to new agricultural areas within Norway. The assessment also specifies which of the identified plant pests and weeds can pose highly negative consequences (practical and/or economic) if spread. Furthermore, the Opinion answers some questions on risk reduction options in terms of their effectiveness in reducing the plant health risk posed by this pathway. The initiation point of this Opinion is therefore the identification of pathways that pose potential risks to plant health in Norway.

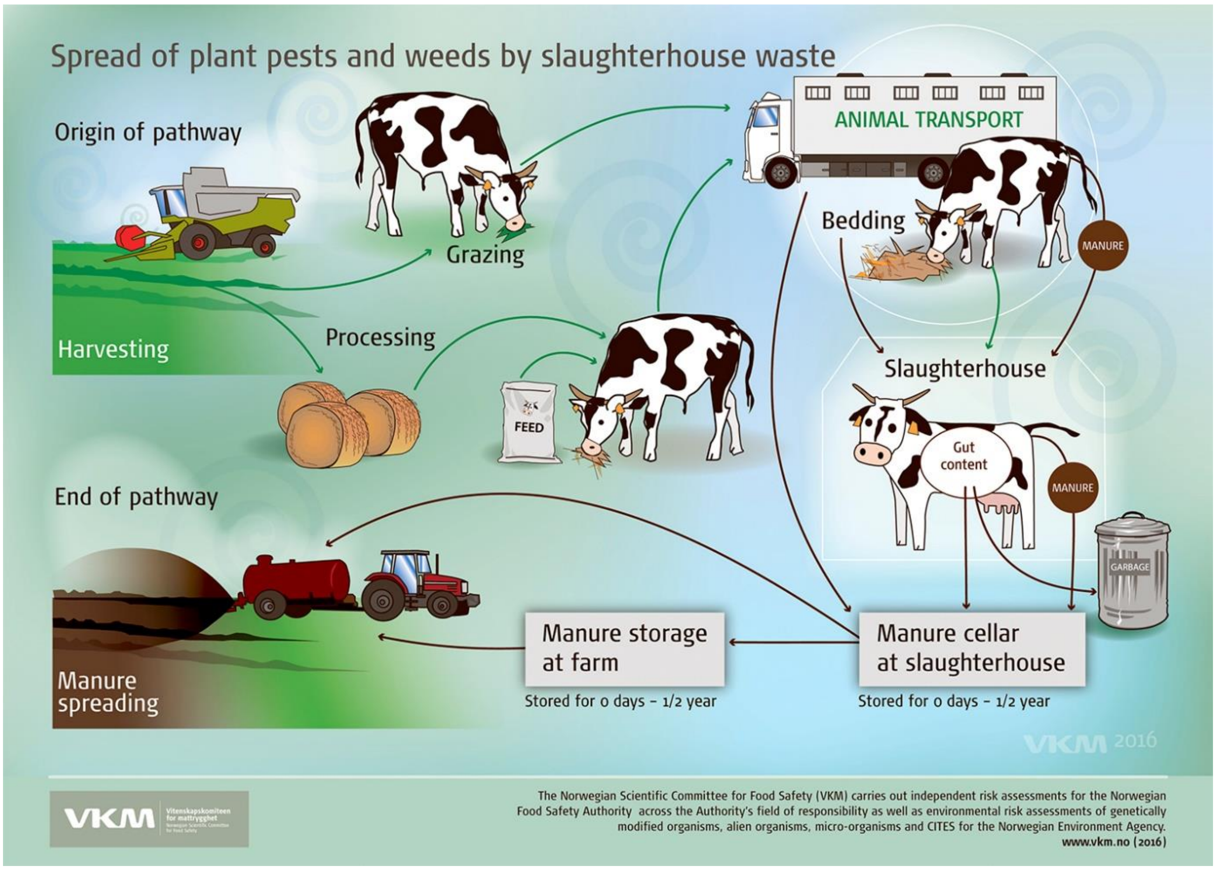
Hereafter in this Opinion, weeds and plant pests will collectively be referred to as plant pests or pests. This is in accordance with the definition of pests in ISPM No. 11 (IPPC FAO, 2016b), (see definition in glossary).

According to the terms of reference, the following domestic animals are included in the opinion: Large ruminants (cattle), small ruminants (sheep and goats), horses, and pigs.

Poultry is not included in terms of reference or in the Opinion. Poultry diets are mixtures of concentrates. It is assumed that no other feed is given and that grazing does not occur. Untreated manure and digestive tract contents from poultry are therefore not considered by the Norwegian Food Safety Authority and by the Panel to present any plant health risk when applied onto agricultural fields.

1.2 Methodology

Figure 1 illustrates the different steps, inputs and outputs of the pathway that is assessed in the current Opinion. The Panel has attempted to obtain and present information on the probabilities of plant pests being associated with plant material at the origin of the pathway (at the time of harvest or grazing, and before any processing of the feed or bedding), and on the probabilities of plant pests surviving in the processing and storage of feed and bedding, in the animal digestive tract, and during storage of manure. This Opinion concludes with an evaluation of the probability of spread of plant pests to new agricultural areas, when digestive tract content and manure originating from slaughterhouses are applied untreated to the land.



Figur 1. Different steps, inputs and outputs of the pathway that is assessed in the current Opinion

1.2.1 Ratings of probabilities and uncertainties

All probabilities on pest survival in the different steps of the pathway and on spread to new agricultural areas were rated separately. The ratings were qualitative and followed a fixed scale: unlikely, moderately likely, likely.

For the conclusions on probabilities (as described above), the levels of uncertainty were rated separately. The ratings were qualitative following a fixed scale: low, medium, high.

The description of each rating is given in Appendix I of the current opinion.

1.2.2 Literature search strategy

This section describes the literature search conducted for retrieving the scientific documentation available for this opinion:

Literature searches were conducted by the members of the project group in a number of literature bases, including ISI Web of Knowledge, AGRIS, Science Direct, CAB Abstracts (1984-2015), Google Scholar. Searches were performed separately for the different types of plant pests included in the assessment: insects, mites, nematodes, weeds and plant pathogens: fungi, Oomycetes, protozoa, bacteria and viruses. The searches were conducted during the period February – September 2015. Articles were not excluded on the basis on their date of publication. The main focus of the literature searches was information on survival of the different types of pests in processing of feed and bedding, in animal digestion systems, and in manure.

If relevant references were identified (e.g. in article reference lists) that had not been previously found in the main search, these were also included. Literature was also retrieved by individual members of the project group that they were aware about, due to their expertise on the subject.

1.2.3 Data collection

Information on the companies operating slaughterhouses in Norway was obtained from their homepages on the Internet. Data on the turnover for the companies were obtained from The Brønnøysund Register Centre (2015).

Data on the import of hay and oats were obtained from Statistics Norway (SSB, 2015), and data from the sale and ingredients of concentrate feed were obtained from the Norwegian Agriculture Agency (Landbruksdirektoratet, 2015).

Information on the production area and yields for legumes in Norway was obtained from the Norwegian Agricultural Extension Service (John Ingar Øverland, personal communication).

1.2.4 Previous risk assessments

No previous risk assessments on the use of manure and digestive tract content from slaughterhouses as a pathway for introduction or spread of weeds and plant pests were identified in the literature search (described in section 1.2.2).

Following a request from the European Commission, the EFSA Panel on Plant Health delivered a scientific opinion on the risk of entry into the EU of harmful organisms associated with soil or growing media attached to plants for planting, as commodities, and as contaminants on imported consignments. The assessment was published in June 2015 (EFSA Panel on Plant Health, 2015). The EFSA Plant Health Panel defined eight groups of soil and growing media with contrasting ratings of probability of association with harmful organisms. The association of plant pests with animal manure was rated as moderately likely. Because the probability of association depends on several factors, such as place of origin, type of animals, animal feeds and processing method, the uncertainty was considered high.

2 Pest identity and probability of association with the pathway at origin

In Section 2.1, the different plant materials and plant species in the diet of the domestic animals (2.1.1) and in the bedding at the farm and during transport (2.1.2), are identified. The different plant pest species that could be associated with this material at the origin of the pathway (at the time of harvest or grazing, and before any processing of the feed or bedding) are identified in Section 2.2. The probabilities of the plant pests being associated with the material at origin are evaluated in Section 2.3.

The probabilities of the plant pests surviving different processing procedures of the materials identified in Section 2.1 are discussed in Chapter 3.

2.1 Identification of pest sources in animal feed and bedding

2.1.1 Composition of the feed

The word feed refers to ingredients in the diet of animals. In the current Opinion, feed is classified as either concentrate, forage or other feed. Concentrate is used to describe feeds with a high energy and/or protein content, and includes single raw materials (e.g. barley, oats, wheat and maize), protein feeds (e.g., soybean meal and rapeseed meal), various supplements (e.g., minerals or vitamins), and mixes thereof (usually named compound feed or concentrate mixtures). Forage is used as a collective term for all edible above-ground parts of plants, other than separated grain, that can provide feed for grazing animals or that can be harvested for feeding of animals. Forage plants includes natural vegetation (e.g., grasses, legumes, shrubs, herbs, trees, mosses) and cultivated plants (e.g., grasses, legumes, cereals) grazed, harvested and fed fresh, or harvested and fed conserved (e.g., hay, silage, haylage, straw). Forages usually have high fibre content. Other feed is used as a collective term for potatoes and root vegetables cultivated for the use as animal feed, food waste (e.g. bread, groceries, fruits), and residues from the food industry (e.g., brewer's grain, vegetable waste).

The diet used depends on type of animal and the production system. Table 1 shows the approximate proportion (%) of concentrate and forage in the diets of different groups of domestic animals. Except for dairy cows and dairy goats, where good statistics exist (Tine rådgivning, 2014), the figures are approximate averages.

Table 1. Approximate average proportion (%) of concentrate, forage (silage, hay, straw, pasture) and other types of feedstuff in the diet of different domestic animals. (Numbers for dairy cows, and

partly for dairy goats, were obtained from Tine Rådgivning Tine rådgivning (2014). Numbers for other animals are rough estimates based on the judgement of the project group and the Panel on Plant Health).

	Concentrate	Forage	Main forages				Other[2]
			Silage[1]	Hay	Straw	Pasture	
Dairy cows	40-45	55-60	45	<1	<1	10	0-2
Beef production bulls	25-35	65-75	70	<1	<1	0	0-5
Beef production steers	10-20	80-90	70	<1	0-5	10	0-5
Suckler cows	10-20	80-90	50	<1	20	20	0-5
Beef production suckler cows	20-25	75-80	45		10	15	0-5
Dairy goats	35-40	60-65	35	<1	<1	30	
Sheep	15-20	80-85	40			45	
Lambs	5-10	90-100	10			80	
Horses	20-25[3]	75-80	25	40	0	10	0-5
Pigs for slaughter	95-100	0-5					0-5
Sows	90-100	0-5					0-5

[1]Average proportion of silage to horses also include haylage
[2]Other feed comprise potatoes and root vegetables cultivated for the use as animal feed, food waste (e.g. bread, groceries, fruits), and residues from the food industry (e.g. brewer's grain, vegetable waste).
[3] Concentrate to horses comprise also whole or crushed oats.

Table 1 shows that in ruminants (cattle, sheep, and goats) and horses, the diet usually consists of forage and a concentrate mixture. For pigs, the diet usually consists of a concentrate mixture only, although some forage is usually given, especially to breeding sows. Table 1 does not include all possible production systems. For example, free-ranging pigs and pigs in ecological farming, whose diet is usually a combination of forage and a concentrate, are not included. However, free-range and ecological production is limited compared with commercial indoor production of pigs. In table 1, the concentrate fed to horses also includes whole or crushed oats, of which approximately 2500 tonnes are sold for this use annually.

For ruminants, feeding of forage as hay was common some decades ago. Table 1 shows that today, the annual forage fed to ruminants is dominated by the crop preserved as silage. For indoor feeding of dairy cows, the diet is silage and a concentrate mixture. However, although grazed forage contributes only 10 % of the annual feed, it contributes up to 100% of the forage during the grazing period. For dairy cows, hay, straw, and other feed contribute in total less than 2% of the annual diet. Hay is the main forage in the diet of horses, followed by silage. In recent years, haylage has achieved some use as horse feed, but hay and silage still dominate. Silage and concentrate mixture predominate by far in the annual diet within beef production also, but some untreated or treated straw (halm) is also used.

Raw potatoes and root vegetables were commonly used to feed ruminants previously. However, the use of these feeds has strongly diminished in recent years, and is now almost negligible, although they are still used on some farms. In addition, by-products from food production and food wastes from retailers, bakeries and grocery stores locally may be a significant part of the diet in milk and meat production. As described by the Norwegian Food Safety Authority in their terms of reference, some vegetable waste is delivered to farms as animal feed. Examples of such vegetable waste are waste from potato and vegetable packing/packers, from both domestic and imported goods. Statistics on the volume of by-products from food production and food wastes that is used as feed are not available.

2.1.1.1 Plant species and ingredients in concentrates

Concentrates fed to domestic animals consist mainly of various concentrated feed ingredients combined into a mixture (compound feed). Table 2 gives the Norwegian sale of concentrate mixtures (tonnes) for ruminants, pigs, poultry, and other animals in the period 2010 to 2014. In 2014, the sale was 996 448 tonnes ruminant feed and 481 269 tonnes pig feed. Horse feed is included within the 25 052 tonnes (2014) of other feed.

Table 2. Total Norwegian sale of concentrate mixtures (tonnes) for ruminants, pigs and other domestic animals in the period 2010 to 2014 (Landbruksdirektoratet, 2015).

Total sales per year	Ruminants	Pigs	Other
2014*	996 448	481 269	25 052
2013**	992 145	479 026	27 779
2012	985 585	490 740	29 647
2011	913 124	491 335	32 056
2010	907 352	486 507	32 537

* The Directorate of Agriculture has adjusted the values after new information, for ruminants in 1st, 3rd and 4th quarter, and for pigs in 4th quarter. ** The Directorate of Agriculture has adjusted the values after new information, for all feed types in 1st quarter, and for pigs in 2nd quarter.

The ingredients used in production of the concentrate mixtures originate from domestic and imported feed ingredients. Table 3 gives the amount of different feed ingredients used in 2014. The import amount of cereals (barley, oats, wheat, rye) varies from year to year, depending on the domestic production of feed-grade cereals and the total compound feed production of the year. In the period 2010-2014, the import of carbohydrates averaged approximately 420 000 tonnes per year, whereas the import of protein feeds constituted around 220 000 tonnes. In addition, approximately 155 000 tonnes soybean meal are produced from imported beans extracted in Norway. In recent years, the import of both carbohydrates and protein feeds has increased, partly due to high production of concentrate mixtures and partly due to reduced domestic production of cereal grains.

The amount of grain legumes used in production of the concentrates is included in “other carbohydrates” or in “other proteins” (not consistently reported) in table 3. According to the Norwegian Agricultural Extension Service (John Ingar Øverland, personal communication), the production area of legumes varies as a result of different challenges in their cultivation. Numbers from the last 12 years show a variation for grain peas and broad beans from 2800 hectares in 2007 to 1000 hectares in 2013. In a normal year the area for cultivation of legumes is estimated to be 2000 – 3000 hectares, with an annual total yield in the range

10 000 tonnes. If new cultivars currently being tested are successful, this area might increase in the years to come.

Within the group, "Other carbohydrates" in table 3, imported beet pulp for ruminants is the main ingredient. Other ingredients in this group are pea starch, pea hulls, pelleted lucerne meal and potato starch. Within "Other proteins", in addition to Norwegian peas and broad beans, some imported sunflower meal and potato protein are included.

Table 3. Total amounts of ingredients used in production of concentrate mixtures (tonnes) for domestic animals in 2014 (Landbruksdirektoratet, 2015).

Ingredients	Total (tonnes)	Source (tonnes)		
		Imported	Norwegian	% Norwegian
Maize	104 834	104 834	0	0
Maize grits	34 436	34 436	0	0
Wheat	265 718	152 373	113 345	43
Rye/Triticale	1 249	0	1 249	100
Barley	529 605	42 142	487 463	92
Oat	209 671	18 579	191 092	91
Bran [1]	73 425	23 409	50 016	68
Molasses	72 697	72 697	0	0
Other carbohydrate	138 015	116 028	21 987	16
SUM carbohydrate	**1 429 650**	**564 498**	**865 152**	**61**
Destruction fat	14 792	0	14 792	100
Other fat	36 823	28 373	8 450	23
SUM fat	**51 615**	**28 373**	**23 242**	**45**
Maize gluten	35 088	35 088	0	0
Soybean flour	194 901	59 182	135 719 [2]	70 [2]
Rape pellets	140 482	139 987	495	0.4
Oil seeds	13 810	8 431	5 379	39
Fishmeal	6 437	73	6 364	99
Fish silage	5 042	0	5 042	100
Urea	3 768	3 768	0	0
Other protein	20 237	11 590	8 647	43
SUM protein	**419 765**	**258 119**	**161 646**	**39**
Vitamins/Minerals	90 217	90 217	0	0
TOTAL SUM	**1 991 247**	**941 207**	**1 050 040**	**53**

[1] Bran from cereals [2] Flour produced in Norway by imported soybeans.

Imported oats for animal feed originate mainly in Nordic and Baltic countries. Protein, other carbohydrates and lipid ingredients used in concentrate production are imported from a global market. Concentrate mixtures are seldom imported.

Destruction fat, a by-product from of meat- and bone meal production (fat from ruminants, pork and poultry) is allowed for use in concentrate production.

2.1.1.2 Plant species and plant materials in forage

Typical forages are perennial grasses and legumes that may be grazed fresh or fed conserved. Timothy is the most common forage species, followed by meadow fescue. Other commonly used species are perennial ryegrass, *Festulolium* hybrids, and smooth meadow grass. Perennial legumes, mainly red and white clover, are commonly included in grasslands. Other frequently used species include cocksfoot, smooth bromegrass, red fescue, tall fescue, common bent, reed canarygrass, alsike clover, and lucerne. In pasture and unmanaged rangeland in particular, a large number of other plant species from many plant families may be eaten by animals. Animals may also graze on trees and shrubs. Annual or biannual species are also grazed, fed without a conservation process, or conserved as silage, but this occurs to a relatively minor extent. This includes above-ground biomass of annual ryegrass, cereals, maize, peas, vetch, beans, rape, marrow stem kale, turnip, and radishes. Cereal straw is also used as forage to a limited extent.

The hay import in 2014 represented only 0.8 % of the domestic production, originated from neighbouring countries: Sweden (18 600 tonnes), Denmark (1 500 tonnes), Finland (400 tonnes), and Lithuania (400 tonnes) according to Statistics Norway (SSB, 2015). There was also limited import from the Netherlands and Germany (SSB, 2015).The import of cereal straw in 2014 was minor and originated exclusively from neighbouring countries: Denmark (500 tonnes), Sweden (200 tonnes), and Finland (200 tonnes) (SSB, 2015).

2.1.1.3 Plant species and plant materials in other feed

Feed other than concentrates and forage includes by-products like food waste (e.g. bread, groceries, fruits), residues from the food industry (e.g. brewer's grain, vegetable waste), and potatoes and root vegetables cultivated for use as feed.

According to the Norwegian Food Safety Authority, vegetable waste and residues from the food industry can be used as animal feed (Randi Knudsen, personal communication). This waste can include potatoes and vegetables such as carrot, turnip, onion, leek, celery, beetroot, etc., which may be imported from other countries, or grown locally or in other parts of Norway. The waste can comprise peel waste, rejected and discarded goods, or rasp from potato flour production.

2.1.2 Composition of bedding

Bedding material at the farm (before transport to the slaughterhouse), is most commonly sawdust and wood shavings originating from sawmills and the lumber industry. This material is considered by the Panel to present no plant health risk to the crops that are within the scope of this opinion. Forests pests that might be present in the sawdust or shavings will not be a hazard to crops grown in the agricultural fields treated with manure from slaughterhouses.

Another commonly used bedding material at the farm, especially in beef production, is chopped or whole straw. More rarely, sand is used as bedding material. The Panel considers dry peat to present no plant health risk in the pathway of slaughterhouse manure, due to the limited use as bedding. The panel also assumes that sand is free from pests and therefore presents no plant health risk to the pathway.

The Panel assumes that bedding material used in transport vehicles and slaughterhouses is mainly sawdust and wood shavings. It is assumed that chopped or whole straw is used to a limited extent for this purpose. Thus, the Panel considers bedding material from the transport vehicles and slaughterhouses to present no plant health risk in the assessed pathway of slaughterhouse manure.

In conclusion, the Panel considers that only chopped or whole straw used as bedding material at the farm might present a plant health risk if the bedding is eaten by the animal before transport to the slaughterhouse.

2.2 Identity of pests associated with the pathway at origin

In Section 2.1 the different materials used in the diet and bedding of the domestic animals were identified. In this section, the different plant pest species that could be associated with this material at the origin of the pathway (at the time of harvest or grazing and before any processing of the feed or bedding) are identified. In Section 2.3 their probabilities of association with the material at the origin of the pathway are evaluated.

Soil borne plant pests of crops or pasture could attach to the hooves of grazing animals and thus end up in the manure. However, this is considered unlikely and therefore this pathway is not considered any further in the current assessment.

In this section we will consider plant pests of forage grasses, forage legumes, cereals, grain legumes, vegetable crops, and potatoes. Use of other plants as feed is limited. The only bedding material considered in the current opinion is chopped or whole straw.

2.2.1 Weeds

In principle, seeds from a wide range of weed species may be ingested, but some are more harmful to agriculture than others. The species to be evaluated have therefore been restricted to vigorous and competitive weed species, invasive alien species, and species with hard seeds that are known to be robust under anaerobic conditions; see table 4 for categories of seed-propagated weeds. All these species are likely to be associated with the pathway at origin.

Table 4. Categories of vigorous and competitive seed-propagated weeds that are considered in the current opinion.

Categories	Latin name	Norwegian name	English name
Vigorous, competitive species	*Avena fatua* Broad-leaved *Rumex* spp. *Tripleurospermum inodorum*	Floghavre Høymole Vanlig balderbrå	Wild oats Docks Scentless mayweed
Invasive alien species	*Echinochloa crus-galli* *Solanum nigrum*	Hønsehirse Svartsøtvier	Cockspur grass Black nightshade
Species with hard seed coat	*Fallopia convolvulus* *Chenopodium album* *Thlaspi arvense*	Vindeslirekne Meldestokk Pengeurt	Wild buckwheat Lamb´s quarters Field pennycress

Livestock may ingest weed seeds when grazing, consuming silage, haylage, or whole grain (Blackshaw and Rode, 1991). The latter is particularly relevant for horses fed with whole oat grain that may be harvested from fields that are infested with wild oats (*Avena fatua*), the only weed listed as a quarantine pest by EPPO (2010). However, according to the Regulation on wild oats, feed should be free from *A. fatua* before sales (LMD, 2015). One way to achieve this is to use oat from farms that are not infested with wild oats. Hay, silage/haylage and pasture may contain seeds from perennial weeds: broad-leaved *Rumex* species, *Taraxacum officinale*, *Ranunculus repens*, *Anthriscus sylvestris,* and *Urtica dioica*. Bedding material originating from cereal straw, vegetable waste as animal feed and green forage may contain seeds from several annual weed species: *Fallopia convolvulus, Chenopodium album, Thlapsi arvense, Echinochloa crus-galli, Solanum nigrum, Tripleurospermum inodorum* (syn. *Matricaria inodora*) and *Galium aparine*.

The distribution of *A. fatua* is scattered and rather limited in Norway. *Eschinochloa crus-galli* is widely distributed in the counties of Østfold and Vestfold, and some scattered occurrences in other locations in the South East of Norway, including Hedmark (VKM, 2016) are confirmed. Recently the weed was also observed in a field used for depositing broiler manure at Jæren (Jan Netland, NIBIO, personal communication). *E. crus-galli* is spreading, whereas *A. fatua* is regulated (LMD, 2015). The weeds *C. album, F. convolvulus, Rumex obustifolius, T. inodorum*, and *T. arvense* are widely distributed in agricultural areas. *Solanum nigrum* is commonly distributed in South East Norway and scattered along the coast up to Nordland.

In forages, the harvesting time in relation to the stage of plant maturity affects the viability of the weed seeds. Grass for production of high-quality silage and haylage is usually harvested at an early stage of maturity, and probably before viable seeds have developed. Although hay is also harvested at an early stage, the probability of it containing viable seeds is higher than for silage, because more weeds have set seed at the time of hay harvest than at the silage harvest. Late-harvested grass, and, in particular, straw from grain production, are harvested at a stage of maturity when it is probable that there will be viable weed seeds in the crop. The maturity and viability of weed seeds in pastures will increase throughout the summer.

Table 5. Norwegian occurrence of some weeds

Weed	Habitat	Occurrence
Avena fatua	Cereals	Limited, under phytosanitary regulation
Chenopodium album	Cereals, potato, vegetables	Common
Echinochloa crus-galli	Cereals, potato, vegetables	Coastal areas, expanding
Fallopia convolvulus	Cereals, vegetables	Common
Rumex obtusifolius	Pasture, cereals	Coastal areas
Rumex longifolius	Pasture, cereals	Common
Thlaspi arvense	Potato, vegetables	Common

2.2.2 Plant pathogenic fungi, oomycetes and protozoa

A number of plant pathogenic fungi, oomycetes and protozoa occur in cereal, potato, vegetable fields, pastures and grasslands. The geographical distributions of most of these pathogens have not been characterised systematically in Norway.

Plant pathogenic fungi that infect leaves and inflorescences of grassland crops and that are regarded as broadly present and occasionally problematic include: *Microdochium* spp., *Typhula ishikariensis, T. incarnata, Sclerotinia borealis, S. trifoliorum, Fusarium* spp., *Claviceps purpurea, Drechslera* spp., *Mastigosporium* spp., *Rhynchosporium* spp., *Puccinia* spp., *Uromyces dactylidis, Cladosporium phlei, Blumeria graminis,* and *Pseudopeziza trifolii* (Sundheim, 1982). Most plant species growing in grasslands are also present in the local flora, and their pathogens are generally assumed also to be present in all areas with a suitable climate. For example, the distribution of different species of snow moulds appears to be defined by environmental conditions, such as the duration of snow and ice cover (Årsvoll, 1973). In general, pathogens infecting leaves and inflorescences during the growing season increase in prevalence as the shoot tissue ages. Fungi infecting above-ground plant parts during the growing season can produce various survival structures, including the cleistothecia of *B. graminis* and the sclerotia of *C. purpurea*. Because these structures are produced in older plant tissue at the end of the growing season, large amounts are unlikely to be present in forage (Plantevernleksikonet).

Leaves and inflorescences of cereal crops are susceptible to a number of pathogenic fungi, such as *B. graminis, Fusarium* spp., *Microdochium* spp., *Leptosphaeria* spp., *Puccinia* spp., *Pyrenophora spp.,* and *Rhynchosporium* spp., all of which are widely distributed in Norway (Plantevernleksikonet).The prevalence of mycotoxin-producing *Fusarium* spp. in Norway has recently been assessed by VKM (VKM, 2013). As for grassland species, leaf pathogens of cereals are not present in large amounts at the time of harvesting cereal shoot biomass as forage.

Smut and bunt fungi produce large quantities of spores in infected cereal kernels. Smut fungi in the genus *Ustilago* and the wheat bunt fungus, *Tilletia caries*, infect cereals in Norway (Plantevernleksikonet). Cereal kernels may also be infected with *Fusarium* spp. and *Microdochium* spp. Rye is susceptible to ergot, *C. purpurea*. The sclerotia produced by the fungus in the inflorescence of rye may drop to the ground or be harvested with the grain.

Fungal root and foot diseases of peas and/or broad beans are commonly caused by the oomycetes *Aphanomyces euteiches* and *Pythium* spp., and the fungal pathogens *Rhizoctonia solani, Fusarium* spp., *Cylindrocarpon* spp., and *Thielaviopsis basicola* (Biddle and Cattlin, 2007; Persson et al., 1997). *Ascochyta fabae, Botrytis cinerea, B. fabae, Perenospora viciae*, and *Sclerotinia sclerotiorum* are pathogens that commonly infect leaves, stems, and flowers (Biddle and Cattlin, 2007). *Ascochyta pisi, Phoma medicaginis,* and *Mycosphaerella pinodes* can infect all plant parts, including seeds (Biddle and Cattlin, 2007). *A. euteiches* and *Pythium* spp. can produce resistant, long-lived oospores, but these are not likely to be associated with harvested grain as these pathogens mainly infect the root and stem base. Sclerotia produced by *S. sclerotiorum* and *Botrytis* spp. may contaminate the harvested grain. The white mould fungus (*S. sclerotiorum*) is widely distributed in Norway.

Club root of Brassicaceae, caused by the protozoan *Plasmodiophora brassicae*, is a disease of about 3700 species in 330 genera of cultivated and wild Brassicaceae (Hwang et al., 2013). Oilseed rape, radish, rutabaga, and turnip are some of the important host plants for club root, and the pathogen produces root galls that release resting spores that may survive up to 20 years in the soil (Wallenhammar, 1996). The pathways for dispersal of *P. brassicae* spores are movement of infested soil, soil erosion by wind and water, and in livestock manure (Chai et al., 2014).

The club root pathogen (*P. brassicae*) is widely distributed in Norway, with the exception of Finnmark County (Hansen, 1989; Plantevernleksikonet). *S. sclerotiorum, B. cinerea, Alternaria brassica* and *A. brassicicola* are common and widespread pathogens of cruciferous crops, and the fungi may contaminate rapeseed and soil on the surface of root vegetables.

Powdery scab of potato is caused by the protozoan *Spongospora subterranea.* In surface wounds on infected potato tubers resting spores are produced as spore balls (Harrison et al., 1997). The host range of the pathogen includes potato, other *Solanum* spp. including tomato, and some species in Chenopodiacae (Merz and Falloon, 2009). Powdery scab of potato is most severe in wet climates, but the pathogen is distributed throughout Norway. In a Norwegian survey of 247 potato lots, powdery scab was found on 65 % of the samples in 2008 and on 82 % of the samples in 2009. The disease was most prevalent in South East Norway in 2008, but there was no difference between districts in 2009 (Nærstad et al., 2012).

Potato wart, caused by the fungus *Synchytrium endobioticum*, is a quarantine pest that was introduced to Norway early in the 20th century (Plantevernleksikonet). Potato and some other *Solanum* spp. are susceptible. The epidemics were most severe in coastal counties up to Trøndelag. The fungus produces resting spores that may survive up to 20-30 years in soil (EPPO, 1990). The last case detected in Norway was in 1994 (Hermansen et al., 2012). The important potato producing counties, Oppland and Hedmark, have never experienced any case of potato wart (Jørstad, 1946).

The oomycete *Phytophthora infestans* causing potato foliar blight and tuber rot, and the fungi *Fusarium* spp. and *Phoma* spp. are common in potato tubers (Plantevernleksikonet).

Table 6. Norwegian occurrence, habitat and host plants of some fungi, oomycetes and protozoa

Pathogen	Host plant	Habitat	Occurence
Tilletia caries	Cereals	Head	Common
***Ustilago* spp.**	Cereals	Head	Common
***Fusarium* spp. in cereals**	Cereals	Foliage and/ or head	Very common
Foliar fungi of cereals	Cereals	Foliage and/ or head	Very common
Foliar fungi of grasses	Grasses	Foliage and/ or head	Very common
Plasmodiophora brassicae	Crucifers	Root	Very common
Synchytrium endobioticum	Potato	Tuber, stem	Under phytosanitary regulation, last detection in 1994
Spongospora subterranea	Potato	Tuber	Most common in humid climate
Phytophthora infestans	Potato	Foliage and tuber	Very common, except at high altitudes and latitudes
***Fusarium* spp. in other crops**	Potato, vegetables	Tuber, root	Very common

2.2.3 Plant pathogenic bacteria

Relatively few plant pathogenic bacteria cause problems in agricultural crops grown in Norway, and in cereals, oilseed crops and forage legumes there are only minor bacterial diseases (Sletten, 1999).

In potato, *Clavibacter michiganensis* ssp. *sepedonicus*, causing ring rot, *Pectobacterium carotovorum*, causing blackleg and soft rot, and *Streptomyces scabies*, causing common scab, may all cause damage and rotting of tubers in potato-growing areas in Norway. *S. scabies* is common in most of the country (Dees et al., 2013; Sletten, 1999), whereas *C. michiganensis* ssp. *sepedonicus* has a restricted distribution in Norway and is under official control by the Norwegian Food Safety Authority (Mattilsynet). Among the control measures, use of contaminated potatoes for animal feed is not recommended unless the tubers have been boiled. Contaminated tubers are usually destroyed, minimizing the risk of spread of the disease (Mattilsynet, 2012). The bacterium is only known to survive in the vessels of the tuber, not in the peel (Dees et al., 2013; Sletten, 1999).

In vegetables, *P. carotovorum* may cause considerable rotting in plant parts above and below ground. The bacterium is common in most of Norway (Sletten, 1999). *Xanthomonas campestris* pv. *campestris*, which may cause rotting of cabbage and root vegetables, is rarely a problem for growers because the seed lots are seldom contaminated.

X. translucens pv.*graminis* may cause serious wilting of forage grasses. It can be dispersed by seed, but the pathogen usually spreads during grass cutting with harvesters. It is widespread in Norway on *Phleum pratense,* but may also attack several other grass species. The damage is usually of minor importance (Sletten, 1999).

2.2.4 Plant pathogenic viruses and their vectors

Plant-pathogenic viruses infecting grasses, legumes and cereals may cause some damage in Norway. They are spread by aphids and leaf hoppers (Blystad and Munthe, 1997).

Plant viruses that damage root vegetables have been only of minor importance in Norway to date (Blystad and Munthe, 1997).

Most potato viruses are transmitted by insects or by physical contact between potato foliage (Blystad and Munthe, 1997). Potato mop-top virus, which is transmitted by the soil-dwelling powdery scab protozoan *S. subterranea*, and the tobacco rattle virus, which is transmitted by soil-dwelling nematodes, can only be spread if their vectors are present (Blystad and Munthe, 1997). The mop-top virus is common throughout most of Norway (Blystad and Munthe, 1997).

Table 7 Norwegian occurrence, habitat and host plants of some plant pathogenic bacteria and viruses

Pathogen	Host plant	Habitat	Occurence
Clavibacter michiganensis ssp. sepedonicus	Potato	Tubers	Restricted, under Phytosanitary regulation
Pectobacterium carotovorum	Potato, vegetables	Tubers, stem	Very common
Streptomyces scabies	Potato, vegetables	Tubers, root vegetables	Very common
Xanthomonas campestris pv. campestris	Crucifers	Foliage, roots	Not common
Xanthomonas translucens pv. graminis	Grasses	Foliage	Common

Pathogen	Host plant	Habitat	Occurence
Cereal viruses	Cereals, grasses	Foliage/aphid vectors	Common
Potato viruses	Potato	Potato tubers/vectors	Very common

2.2.5 Plant parasitic nematodes

Animals grazing on pastures may ingest plant parasitic nematodes that occur as endoparasites (*ie*. living in plant tissue) in above-ground plant parts, or on superficial roots and in adhearant soil. According to Decker (1969), species of the endoparasitic leaf gall nematodes (*Anguina* spp.) occur in bentgrass (*Agrostis* spp.), couch grass (*Elymus repens*), timothy (*Phleum pratense*), red fescue (*Festuca rubra*), sheep fescue (*F. ovina*), and cock´s foot (*Dactylis glomerata*). The leaf gall nematodes *Anguina agrostis*, *A. graminophila* and *Paranguina agropyri* have been reported from Sweden (Decker, 1969), and it is plausible that these species also occur in Norway.

The stem nematode (*Ditylenchus dipsaci*) is an endoparasite of stems and petioles of clovers (*Trifolium* spp.). The stem nematode was previously locally important, but it seems to be of less concern today.

Potato tubers and carrots may be infested by the endoparasitic potato rot nematode (*Ditylenchus destructor*), the root lesion nematode (*Pratylenchus penetrans*), and the root knot nematode (*Meloidogyne hapla*). Potato rot nematode (*D. destructor*) is of little concern in field crops. As weed hosts seem to be important for maintaining nematode soil infestations, both inside and outside crop fields, this may relate to good weed control (Andersson, 1967).

Host plants of the grass cyst nematode (*Punctodera punctata*) include *Agrostis stolonifera*, *Poa annua* and *P. pratensis (Commonwealth Agricultural Bureaux, 1997)*. Red clover (*Trifolium pratense*) and white clover (*T. repens*) are host plants of the clover cyst nematode (*Heterodera trifolii*). The cereal cyst nematode (*Heterodera avenae*) is a parasite of cereals, but may also occur on a number of wild grasses like *Agrostis tenuis*, *A. stolonifera*, *F. rubra*, *F. ovina* and *D. glomerata*. It may also attack *P. pratense*, *Lolium perenne*, *P. pratensis* and *Bromus inermis* (Decker, 1969; Holgado et al., 2003). The rye cyst nematode (*Heterodera filipjevi*) may be locally abundant in cereals. Potential host plants among wild grasses are not well known. The cereal cyst nematode and the rye cyst nematode often occur in mixed populations, and they are common throughout Norway. The population densities depend on the cultivar grown.

The potato cyst nematodes (PCN), *Globodera rostochiensis* and *G. pallida*, are parasites of potato and black nightshade (*Solanum nigrum*). The root gall nematode (*Subanguina radicicola*) is an endoparasite in the roots of *P. pratense* and *P. annua*.

Root lesion nematodes (*Pratylenchus* spp.) are very common in many crops. The root gall nematode (*S. radicicola*) is common throughout Norway. This is also the case for the cereal cyst nematode (*H. avenae*) and the rye cyst nematode (*H. filipjevi*), which often occur in mixed populations which densities depend on the cultivar grown.

In Norway, the PCNs have been monitored more or less since their first recording in 1955 (Holgado et al., 2015). Analysis of more than 100 000 samples demonstrated the frequent occurrence of *G. rostochiensis* from Rogaland to Trøndelag, with *G. pallida* especially frequent in Rogaland (Holgado et al., 2011; Holgado et al., 2012; Holgado et al., 2013; Holgado et al., 2014; Holgado et al., 2015; Magnusson et al., 2011). PCNs have been detected in 6181 properties, including private gardens and farmland (Mattilsynet, 2014).

Table 8. Occurrence, habitat and host plants of some nematodes in Norway

Nematode	Host plants	Occurrence	Habitat
Anguina spp.	Grass	Probably whole country	Leaf and stem
Ditylenchus dipsaci	Clover	Not common	Stem basis and petioles
Ditylenchus destructor	Potato, carrot & weeds	Not common	Tubers, roots & soil
Pratylenchus spp.	Potato & carrot	Very common	Tubers, roots & soil
Subanguina radicicola	Grass (*Poa* spp.)	Common	Roots (galls)
Punctodera punctata	Grass	Common	Roots & soil
Heterodera avenae	Cereals & grass	Very common	Roots & soil
Heterodera filipjevi	Cereals & grass	Common	Roots & soil
Globodera rostochiensis	Potato	Common in southern Norway	Roots, tubers & soil
Globodera pallida	Potato	Common in Rogaland	Roots, tubers & soil
Meloidogyne hapla	Carrot	Not common	Roots

2.2.6 Phytophagous insects and mites

A number of phytophagous insect species belonging to several different orders, and some mite species, are found on grasslands. Of these, only species regarded as plant pests are considered in this assessment. The insect and mite fauna occurring at a specific location depend on the plant species present as well as other biotic and abiotic factors. Particularly important are the local climatic conditions, which together with availability of suitable host plants, largely determines the distribution of phytophagous insects and mites. The dominating plant species with respect to forages grazed fresh or fed conserved are perennial grasses (such as timothy and meadow fescue) and perennial legumes (mainly red and white clover). Only phytophagous insects and mites that feed on the part(s) of the plant that are likely to be eaten by grazing animals or harvested, i.e. the above-ground parts of their respective host plant, are considered.

Three aphid species, *Rhopalosiphum padi* (bird cherry/oats aphid), *Sitobion avenae* (grain aphid), and *Metopolophium dirhodum* (rose/grain aphid) (Insecta: Hemiptera: Heteroptera: Aphididae), are the most important aphid species commonly feeding on cereal crops and on several grasses in Norway. *Rhopalosiphum padi* and *S. avenae* are distributed in all parts of Norway, while *M. dirhodum* probably has a more limited distribution with occasional outbreaks only, particularly in Østlandet.

The meadow plant bug, *Leptopterna dolabrata,* (Insecta: Hemiptera: Heteroptera: Miridae) commonly feeds on cereal crops and grasses, and is distributed throughout most of Norway, except for Troms and Finnmark counties.

A number of phytophagous species in the order Diptera (Insecta) are found in grasslands. In the family Agromyzidae several fly species belonging to the genera *Chromatomyia, Agromyza* and *Phytomyza* attack cereal crops and grasses. The most important species is *C. fuscula*, the oat leafminer, which is distributed throughout Norway. The most severe damage due to this species has been observed on cereals and grasses in the eastern parts of Østlandet and Trøndelag. In the family Ephydridae, the most important species is *Hydrellia griseola,* the barley leafminer (also known as rice leafminer). This species shares host plants with the oat leafminer, but it prefers a more humid climate and is very common in the coastal areas of Norway, causing serious damage in Vestlandet.

Several flies in the genus *Oscinella* (Diptera: Chloropidae) cause damage in cereal crops and grasses. The most common species is *Oscinella frit* (frit fly), which is distributed all over Norway. In addition, two fly species in the family Scatophagidae (Diptera), *Nanna flavis* and *N. armillata*, both have timothy as their host plant. Both species are distributed in all parts of Norway, up to 1000 m.a.s.l.

One mite species, *Siteroptes graminum* (Arachnida: Acari: Pygmephoridae), grass and cereal mite/silvertop, has been reported from Østlandet. The species is known to be sedentary, and therefore damage is more severe in older meadows than in newly established ones.

Several species of clover seed weevils belonging to the genus *Apion* (Insecta: Coleoptera: Curculionoidea) are pests of clover. *Apion* spp. are distributed throughout Norway.

Animals may also be fed with potatoes, turnips and beets. The main insect pests related to this type of fodder include larvae of click beetles belonging to the family Elateridae (Insecta: Coleoptera) that might be inside the potatoes and thereby eaten by the animals. Similarly, larvae of the cabbage root fly, *Delia radicum*, and the turnip root fly, *Delia floralis* (both Insecta: Diptera: Anthomyiidae), feed inside the root of turnips and beets, and might thereby be consumed by animals.

Adult winged insects are easily disturbed by the movements of grazing animals, and therefore many escape being eaten by animals. This is particularly relevant for dipteras that are exceptionally fast and very good flyers. Other life cycle stages with less or no mobility compared with winged adults, such as eggs, nymphs/larvae and pupae may be eaten by grazing animals. Aphids (unwinged) and mites are at risk of being eaten in all stages due to their limited mobility. Aphids live in colonies, and this may lower the risk of being eaten, if they are avoided by animal due to their unpleasant taste, smell or changes caused to the plant.

Table 9. Norwegian occurrence, habitat and host plants of some phytophagous insects and mites

Pest	Host plant	Habitat	Occurence
Rhopalosiphum padi	Cereals, grasses	Foliage	Very common
Sitobion avenae	Cereals, grasses	Foliage	Very common
Metopolophium dirhodum	Cereals, grasses	Foliage	Common
Hydrellia griseola	Barley	Foliage	Common in Western Norway
Oscinella frit	Cereals, grasses	Base of tillers	Very common
Siteroptes graminum	Cereals, grasses	Silvertop	Very common

2.3 Probability of pest association with the pathway at origin

Tables 10A-F, give the assessment of the probabilities of the different types of plant pests (weed seeds, fungi, Oomycetes, protozoa, bacteria, viruses, nematodes, insects and mites) being associated with the pathway at origin, along with the uncertainties associated with the probability. "At origin" means at the time of harvest or grazing, and before any processing of the feed or bedding. The ratings of probability and uncertainty are described in Appendix I.

Table 10A. The probabilities of weed seeds being associated with the pathway at origin

Scientific name	English name	Norwegian name	Probability	Uncertainty	Comment
Avena fatua	Wild oats	Floghavre	Moderately likely	Medium	Seeds in whole grain for horse feed
Chenopodium album	Lambsquarters	Meldestokk	Likely	Low	Seeds in green forage, vegetable waste, and strawbased bedding material
Echinochloa crus-gallii	cockspur grass	Hønsehirse	Moderately likely	Medium	Seeds in green forage, vegetable waste, and strawbased bedding material

Scientific name	English name	Norwegian name	Probability	Uncertainty	Comment
Fallopia convolvulus	Wild buckwheat	Vindeslirekne	Likely	Low	Seeds in green forage, vegetable waste, and strawbased bedding material
Rumex longifolius and R. obtusifolius	Broad-leaved docks	Høymole og byhøymole	Likely	Low	Seeds in pasture
Thlaspi arvense	Field penny-cress	Pengerurt	Likely	Low	Seeds in green forage, vegetable waste, and strawbased bedding material

Table 10B. The probabilities of plant pathogenic fungi, oomycetes and protozoa being associated with the pathway at origin. Pathogens infecting only non-harvested plant parts are unlikely to be associated with the pathway at origin with low uncertainty, and are not included in the table.

Feed type	Fungal plant pathogen	Scientific name	Norwegian name	Probability	Uncertainty
Concentrate	Cereal bunt and smuts	*Tilletia caries* *Ustilago* spp.	Stinksot, naken sot, dekka sot	Moderatly likely	Low
	Other seed borne fungi in cereals	See text	Andre frøoverførte sopper i korn	Likely	Low
	Fungi infecting seeds of legumes and oilseed crops	See text	Frøoverførte sopper i belg- og olje-vekster	Likely	Low
Forage	Fungi infecting above ground forage plants	See text	Sopper som infiserer overjordiske deler av fôrvekster	Likely	Low
Cruciferous root vegetables	Club root pathogen	*Plasmodiophora brassicae*	Klumprot	Moderately likely	Low
	Other fungal pathogens infecting roots	See text	Andre rotråtesopper i rotvekster	Moderately likely	Medium
Potato tubers	Potato wart	*Synchytrium endobioticum*	Potetkreft	Unlikely	Low
	Powdery scab pathogen	*Spongospora subterranea*	Vorteskurv	Moderately likely	Low
	Potato late blight pathogen	*Phytophthora infestans*	Potet-tørråte	Likely	Low
	Other fungal pathogens infecting tubers	*Fusarium* spp. *Phoma* spp.	Andre soppsjuk-dommer på potetknoller	Likely	Low
Food waste	Other fungal pathogens infecting fruits and vegetables. e.g. Verticillium wilt	*E.g. Verticillium dahlia* and *V. albo-atrum*	Andre patogene sopper f.eks. krans-skimmel	Moderately likely	High

Table 10C. The probabilities of plant pathogenic bacteria being associated with the pathway at origin

Scientific name	English name for disease	Norwegian name for disease	Probability	Uncertainty	Comment
Clavibacter michiganensis* pv.*sepedonicus	Potato ring rot	Lys ringråte på potet	Unlikely	Low	Bacterial cells survive in vessels of the tuber, not in the peel
Pectobacterium carotovorum	Blackleg and soft rot of potatoes and vegetables	Stengelråte og bløtråte på potet og grønnsaker	Likely	Low	Bacterial cells
Streptomyces scabies	Common scab on potatoes and vegetables	Flatskurv på potet og grønsaker	Likely	Low	Bacterial cells
Xanthomonas campestris* pv. *campestris	Black rot of crucifers	Svartnerve på kålvekster	Unlikely	Low	Bacterial cells
Xanthomonas translucens* pv. *graminis	Bacterial wilt of forage grasses	Gras visnesjuke	Likely	Low	Bacterial cells spread by grass seed or harvester

Table 10D. The probabilities of plant pathogenic viruses being associated with the pathway at origin. Plant pathogenic viruses damaging vegetables have so far been only of minor importance (Blystad & Munthe 1997), and are thus not included in the table.

Crop	English name	Norwegian name	Probability	Uncertainty	Comment
Cereals and grasses	Viruses on cereals, grasses and forage legumes	Virus på korn, gras og engbelgvekster	Likely	Low	Virus particles transmitted by contact, i.e.insects and harvesting
Potato	Mop-top virus	Mop-top virus	Likely	Low	Virus particles transmitted by soil-dwelling *Spongospora subterranea*
Potato	Tobacco rattle virus	Rattle virus	Likely	Low	Virus particles transmitted by soil-dwelling nematodes

Crop	English name	Norwegian name	Probability	Uncertainty	Comment
Potato	Other potato viruses	Andre potetvirus	Likely	Low	Virus particles transmitted by contact, i.e.insects and harvesting

Table 10E. The probabilities of plant parasitic nematodes being associated with the pathway at origin

Scientific name	English name	Norwegian name	Probability	Uncertainty	Comment
***Anguina* spp.**	Leaf gall nematodes	Bladgall-nematoder	Moderately Likely	Medium	Leafgalls
Ditylenchus dipsaci	Stem nematode	Stengel-nematode	Unlikely	Low	Nematodes in plant tissue
Ditylenchus destructor	Potato rot nematode	Potetråte-nematode	Unlikely	Low	Nematodes in tubers and carrot
***Pratylenchus* spp.**	Root lesion nematode	Rotsår-nematode	Unlikely	Low	Tubersl
Subanguina radicicola	Root gall nematode	Krok-nematode	Unlikely	Low	Root galls
Heterodera avenae	Cereal cyst nematodes	Korncyste-nematoder	Moderately likely	Medium	Cysts
Heterodera filipjevi	Rye cyst nematode	Rugcyste-nenmatode	Moderately likely	Medium	Cysts
Heterodera trifolii	Clover cyst nematode	Kløvercyste-nematode	Moderately likely	Medium	Cysts
Globodera rostochiensis	Yellow potato cyst nematode	Gul potetcyste-nematode	Moderately likely	Medium	Cysts on vegetation and tubers
Globodera pallida	White potato cyst nematode	Hvit potetcyste-nematode	Unlikely	Low	Cysts on vegetation and tubers
Punctodera punctata	Grass cyst nematode	Grascyste-nematode	Moderately likely	Medium	Cysts on vegetation
Meloidogyne hapla	Nothern root knot nematode	Nordlig rotgall-nematode	Unlikely	Low	Galls on tubers

Table 10F. The probabilities of phytophagous insects and mites being associated with the pathway at origin

Plant pest	Probability	Uncertainty	Comment
Insects	Likely	Low	Imago, larva/nymph, egg
Mites	Likely	Low	Imago, nymph, egg

3 Probabilities of pest survival

The various plant materials in the diet and bedding of the domestic animals were identified in Section 2, along with different plant pest species that could be associated with this material at the origin of the pathway (at harvest, feeding or grazing, before any processing). An evaluation of their probabilities of association was also provided.

In this Chapter, the probabilities of the identified plant pests surviving the different processing procedures of the identified material are discussed.

In Section 3.1 the probabilities of the pest surviving processing and storage of feed and bedding material before use are assessed. In Section 3.2 the probabilities of the pest surviving exposure to different degrees of digestion in the intestinal tracts of the domestic animals are assessed. In Section 3.3 the probabilities of the pest surviving storage of manure before application to fields are evaluated.

As pointed out in section 2.2, pests of forage grasses, forage legumes, cereals, grain legumes, Brassicaceae crops and potato are considered. Use of other plants is limited. Among bedding materials only straw is considered to present a plant health risk in the current opinion.

3.1 Survival in feed and bedding material

3.1.1 Conditions during processing of feed and bedding material

3.1.1.1 Concentrates

With the exception of whole oats for horse feed, concentrate ingredients are ground on hammer mills using a 3 or 4 mm screen. After grinding and mixing, the concentrate mixture is either steam-conditioned and pelleted directly (steam pelleting), or expander-conditioned before pelleting (expander pelleting). In both processes, the moisture content usually is in the range 15 to 18%. According to the Regulation on animal feed (Fôrvareforskriften, LMD 2015), the temperatures used in steam pelleting should be at least 81ºC, whereas the temperature used in expander pelleting normally exceeds 100ºC. In both processes, the peak temperature lasts for only a few seconds (usually less than 10 seconds). However, as the temperature usually exceeds 100ºC, the period above 81ºC will be considerably longer for expander pelleting than steam pelleting.

Both processes also results in the development of pressure and shear forces, but pressure and shear forces are higher in expander pelleting than in steam pelleting. Thus, the relative effect of heat treatment is considerably higher for expander pelleting than for steam pelleting. Expander pelleting is mainly used for ruminants feed. The amount of feed produced by expander pelleting has declined in recent years, but although reliable data are unavailable, probably as much as 50 % of concentrate mixtures for ruminants are produced by expander pelleting. The remaining 50%, and in practice all concentrate mixtures for pigs, are produced by steam pelleting. In addition, several of the feed ingredients, like soybean meal and the various imported rapeseed products, are heat-treated during production. Any imported concentrate ingredients to be included in mixed rations should be certified and free of salmonella (Forskrift om fôrvarer (NFD and LMD, 2002)). In addition to concentrates treated as described, whole, untreated oat is used as feed for horses. However, whole, untreated oats for feed must be certified as beeing free from wild oats (Forskrift om floghavre (LMD, 2015)). This is also the case for home-grown concentrates from other cereals, seed legumes and rapeseed.

3.1.1.2 Silage, haylage and hay

Whereas some decades ago grasses and legumes usually were conserved by drying to hay, the dominant conservation process today is production of silage or haylage.

Silage can be produced in tower siloes, in bunker siloes or as large bales. In Norway, tower siloes were previously predominant, but today more than half of the ensiled mass is conserved as large bales. Irrespective of type, the ensiling process consists of a short aerobic phase (< 1 day), in which aerobic respiration depletes the oxygen present, and a longer fermentation phase (approx. 1-4 weeks), in which anaerobic microorganisms, mainly lactic acid bacteria, multiply and produce lactic acid that conserve the mass at a pH around 4 (Barnes et al., 2003). Heat can develop during the aerobic phase, but when the biomass is well packed the increase in temperature rarely exceeds 40˚C (McDonald et al., 1991). In order to assist with the fermentation process, an additive (in Norway usually a formic acid-based additive) is commonly used, but it is not essential. The dry matter content of silage is typically around 30 %, but ranges from below 20 % to over 50 %.

Haylage is preserved like silage, but has higher dry matter content (typically 50-60 %). Less water is present during ensiling, thereby restricting the lactic acid fermentation and giving a higher pH (typically > 5) in the conserved feed mass compared with ordinary silage (Barnes et al., 2003; Müller, 2005).

In making silage, and in particular in making haylage, strict anaerobic conditions during fermentation are important to ensure that high quality feed is obtained. An additive containing propionic acid in addition to formic acid prevents development of moulds.

3.1.1.3 Other feed

Vegetable waste does not need to be heat treated before being fed to animals. According to the Norwegian Food Safety Authority (Randi Knudsen, personal communication), domestic goods are usually unwashed before processing, whereas most import consignments containing potatoes are washed.

3.1.1.4 Bedding material

As stated in section 2.1.2, the panel assumes that bedding material from the transport vehicles and slaughterhouses do not present any plant health risk in the assessed pathway of slaughterhouse manure. The Panel considers that among materials used as bedding at the farm, only untreated whole or chopped straw might present a plant health risk if eaten by the animal before transport to the slaughterhouse.

3.1.2 Probabilities of pest survival during processing and storage of feed and bedding material

The probabilities of survival of different plant pests during the processing and storage of different types of feed (concentrates, forage, and other feed) and straw as bedding are considered in the following sections.

3.1.2.1 Weed

Several studies on survival of weed seeds during processing of feed have been published.

Stanton et al. (2012) found that viability of a variety of Australian weeds including wild oats was reduced by ensiling. In another study (Blackshaw and Rode, 1991), ensiling completely destroyed *Echinochloa crus-galli* seeds and reduced viability of *Chenopodium album*, *Fallopia convolvulus*, *Avena fatua*, and *Thlaspi arvense* seeds to 3 %, 30 %, 0 %, and 10 %, respectively. Westerman et al. (2012) found that ensiling also reduced viability of *C. album*, *E. crus-galli* and *F. convolvulus* seeds to 0.02 %, 0.15 %, and 0.02 %, respectively. Both *C. album* and *F. convolvulus* are hard-seeded. Several other hard-seeded species that are not common in Norway were also shown to be resistant to ensiling. In the same experiment, the viability of *Rumex obtusifolius* was destroyed after ensiling and after anaerobic digestion in a batch reactor, which to some extent resembles rumen digestion (Westerman et al., 2012).

In conclusion, the stage of maturity and the conservation methods used affect germination of weed seeds. The process of ensiling considerably reduces viability of several grass weed seeds (Blackshaw and Rode, 1991), but in many cases viability was not completely destroyed. Dicotyledonous weed seeds are more persistent, and those with hard seed coats, in particular, are moderately likely to survive ensiling. *Rumex* species are not likely to survive in silage due to their soft seed and early harvesting. Hay, late harvested grass and pasture are likely to contain viable *Rumex* seeds.

Whole or chopped straw used as bedding has been dried without any other treatment, and it has the potential to contain mature, viable weed seeds.

3.1.2.2 Plant pathogenic fungi, oomycetes and protozoa

<u>Concentrates</u>

Most plant pathogenic fungi are killed after 30 minutes at 60-72˚C (Agrios, 2005). The temperature tolerance increases with decreasing moisture level (Noble et al., 2009). During composting of plant-based waste, a temperature of 64˚C for 7 days is sufficient for eradication of *Microdochium nivale,* while 58˚C for 7 days was not sufficient (Noble et al., 2009). There is less information available for survival at higher temperatures for shorter periods of time. Production of concentrate feed will probably kill most plant pathogens present in the raw material.

Unpublished results, referred to by Bonde et al. (1997), indicate that teliospores of the karnal bunt fungus (*Tilletia indica*) can be killed with dry heat if the product reaches temperatures of 84°C for 12 minutes, 101°C for five minutes, or 110°C for 12 two minutes. *Tilletia indica* has not been detected in Norway, but the patogen could be introduced with imported wheat grain and seed.

Seed-borne pathogens in whole oats and homegrown, untreated concentrates are likely to survive during storage.

<u>Silage, haylage and hay</u>

In successfully ensiled forage, the anaerobic conditions will inhibit growth of fungi. However, a number of species have been shown to survive in silage, and may proliferate during deterioration of silage upon exposure to air (McDonald et al., 1991). These include genera with plant-pathogenic members, such as *Aspergillus, Cladosporium, Fusarium, Geotrichum, Mucor, Monilia, Paecilomyces* and *Penicillium*. Species in the genera *Aspergillus* and *Penicillium* are the most common in Norwegian grass silage bales (Skaar et al., 1996). Plant-pathogenic *Fusarium* species, including *F. culmorum* and F*. avenaceum*, have been isolated from grass silage bales in Ireland (O'Brien et al., 2005; O'Brien et al., 2007a; O'Brien et al., 2007b). In a study of maize silage, Potkański Potkański et al. (2010) found that although *Ustilago maydis* and some other plant pathogens in the original maize biomass (such as several *Fusarium* species, and *C. cladosporoides*) were not found after ensiling, other fungi of genera that include plant pathogens (*Aspergillus, Oidium, Acremonium, Penicillium*) had survived. There are few studies of microbial composition in haylage, but haylage may be more prone to mould contamination than silage due to a lower degree of fermentation (Müller et al., 2011; O'Brien et al., 2008). Species in the genera *Aspergillus, Penicillium, Fusarium, Mucor, Cladosporium, Phoma and Rhizopus* have been isolated from haylage fed to horses in Sweden (Müller et al., 2011).

No studies of survival of plant pathogenic fungi in hay were found in the literature search. Most plant pathogenic fungi are moderately likely to survive in dry hay during storage.

<u>Other feed</u>

All plant-pathogenic fungi infecting roots used as forage are likely to survive during storage. Soil-borne pathogens of other plant species may attach to the surface (low probability) and survive during storage (high probability). Fungal plant pathogens in food waste are likely to survive until being fed to animals.

<u>Bedding material</u>

It is considered that fungal pathogens will survive preparation and storage of straw as bedding material.

3.1.2.3 Plant pathogenic bacteria and viruses

The literature search gave no information on the survival of plant pathogenic bacteria and viruses in feed and bedding material. It seems unlikely that they could survive the processing of concentrate, particularly because of the high temperatures used in the process. No information is available on the potential for survival of *Xanthomonas translucens* pv. *graminis* in silage, haylage and hay. However, the Panel considers this pest to be of little concern. The pest is of minor importance, and most likely common in grass fields in many parts of the country.

3.1.2.4 Plant parasitic nematodes

It is reasonable to assume that PCN could survive the ensiling process (with temperatures of 40°C), as wet cysts of *G. rostochiensis* are killed in 30 minutes at 58-59°C (Evans, 1991). The influence of the low pH and the lack of oxygen occurring during the processes on the survival of PCN and other cyst nematodes is unknown. However, the lack of cryptobiotic ability in *Heterodera avenae* and *H. trifolii* may render these species more vulnerable to ensiling.

3.1.2.5 Phytophagous insects and mites

Information on the survival of phytophagous insects and mites in feed and bedding material was not identified during the literature search. However, it seems unlikely that they would be able to survive during processing of feed when exposed to the conditions described in Section 3.1.1. Grinding, steaming or expander-conditioning and pelleting of concentrates are likely to kill all stages of insects and mites. Anaerobic conditions, close packing and relatively low pH in silage and haylage are conditions that are unsuitable for survival of insects and mites trapped in the forage during harvesting. Hay is too dry for the insects and mites listed in Section 2.2.6 to thrive in. As hay is usually dried outdoors, the adults will move away to feed on living plants, while larvae and nymphs will die due to lack of moisture in the material.

Grazed forage and other feed, such as untreated vegetable waste or potatoes, may contain living insect larvae when fed to animals.

3.1.3 Conclusions on survival of pests in feed and bedding material

In table 13 A-D in section 3.4, conclusions on plant pest survival in processing and storage of feed and bedding are summarized. In this section, the evaluations behind these conclusions are elaborated.

In production of concentrate ingredients, except for whole oat for horses, the combination of hammer milling, high temperature and mechanical workload created during the heat-treatment processes (steam pelleting or expander pelleting) is likely to kill most microorganisms, insects, mites and nematodes and destroy the germination abilities of seeds. Whole oats are used untreated in horse feed, and plant pests might survive in this concentrate. This is also the case for home-grown concentrates from other cereals, seed legumes and rapeseed.

Weeds: In forages, harvesting of grass at early stages of maturity reduces the probability for viable weed seeds in the grass forage. The probability of survival of seeds increases when harvesting is at a later stage of maturity. The ensiling process reduces viability of many weed seeds, although not all. Survival of weed seeds in bedding material is only expected when straw is used. Survival of weed seeds in concentrates is unlikely. When whole oat is used as horse feed, the survival is likely, but the uncertainty is medium. Survival in other feed is moderately likely. Species with hard seed coat might survive, but systematic comparable data between seeds with different level of seed hardiness are lacking. Therefore, uncertainty in these probability assessments is high.

Plant pathogenic fungi, oomycetes and protozoa: Plant pathogenic fungi are unlikely to survive during the production of pelleted concentrate feed. The uncertainty of this assessment is medium. Plant pathogenic fungi are likely to survive in non-treated concentrates, such as whole oat and homegrown cereals, grain legumes, and rapeseed. Plant pathogenic fungi, oomycetes and protzoa are likely to survive in stored potatoes and root vegetables, food waste, hay and straw. Plant pathogenic fungi are moderately likely to survive in silage and haylage. The uncertainty of these probability assessments is medium to high.

Bacteria and viruses: Plant pathogenic bacteria and plant pathogenic viruses are unlikely to survive ensiling and haylage, and production of pelleted concentrate feed. The uncertainty of these probability assessments is high. Plant pathogenic bacteria and plant pathogenic viruses are likely to survive in hay and straw used as bedding material. The uncertainty of these probability assessments is high.

Nematodes: PCN is moderately likely to survive ensiling for silage and haylage. The uncertainty of these probability assessments is medium. All cyst nematodes are likely to survive storage of bedding material like haulm. The uncertainty of these probability assessments is high. *Anguina* spp, *Ditylenchus dipsaci*, *Punctodera punctata*, *H. avenae, H. filipjevi*, *G. rostochiensis* and *G. pallida* are all likely to survive storage in hay. The uncertainty of these probability assessments is low. Potato rot nematode (*D. destructor*), root lesion nematode (*Pratylenchus* spp) and root knot nematode *Meloidogyne hapla* are likely to survive storage of tubers. The uncertainty of these probability assessments is low. PCN is likely to survive in contaminating soil. The uncertainty of these probability assessments is low. The processing conditions of compound feed are likely to kill all types of nematodes. The uncertainty of these probability assessments is low.

Insects and mites: It is unlikely that insects and mites can survive processing of concentrates, silage and haylage due to mechanical destruction during grinding or packing, killing during heating or anaerobic conditions, and due to the relatively low pH (each process is described in Section3.1.1). Hay is too dry for the insects and mites listed in Section 2.2.6, and they will either escape from the harvested material or die as the material dries. Untreated root vegetable waste or potatoes may contain living insect larvae when fed to animals. The uncertainty of these probability assessments is high due to lack of relevant data and subjective judgement without supporting evidence.

3.2 Survival of pests in the digestive tract of domestic animals

3.2.1 Conditions in the digestive tracts of domestic animals

Digestion includes both mechanical and chemical processes. Mechanical digestion includes chewing and breaking the feed into smaller particles that then pass through the digestive tracts of the animals. The digestive tract also performs some mechanical digestion as the muscles expand and contract to move the feed around and through the system.

Chemical digestion is the breaking down of food particles through fermentation and enzymatic digestion in the digestive tract. Figure 2 gives an overview of the digestive tract of ruminants (pre-gastric fermenters), and horses and pigs (hind-gut fermenters). In ruminants, the rumen and the reticulum act as fermentation chambers where the feed nutrients are digested by various species of microorganisms. In horses, and to a minor extent in pigs, comparable fermentation occurs in the cecum and large intestine. The abomasum of ruminants is comparable with the stomach of horses and pigs, and here the enzymatic digestion process of nutrients begins. The small intestine does not differ greatly between species and is the main compartment for enzymatic digestion and absorption of nutrients.

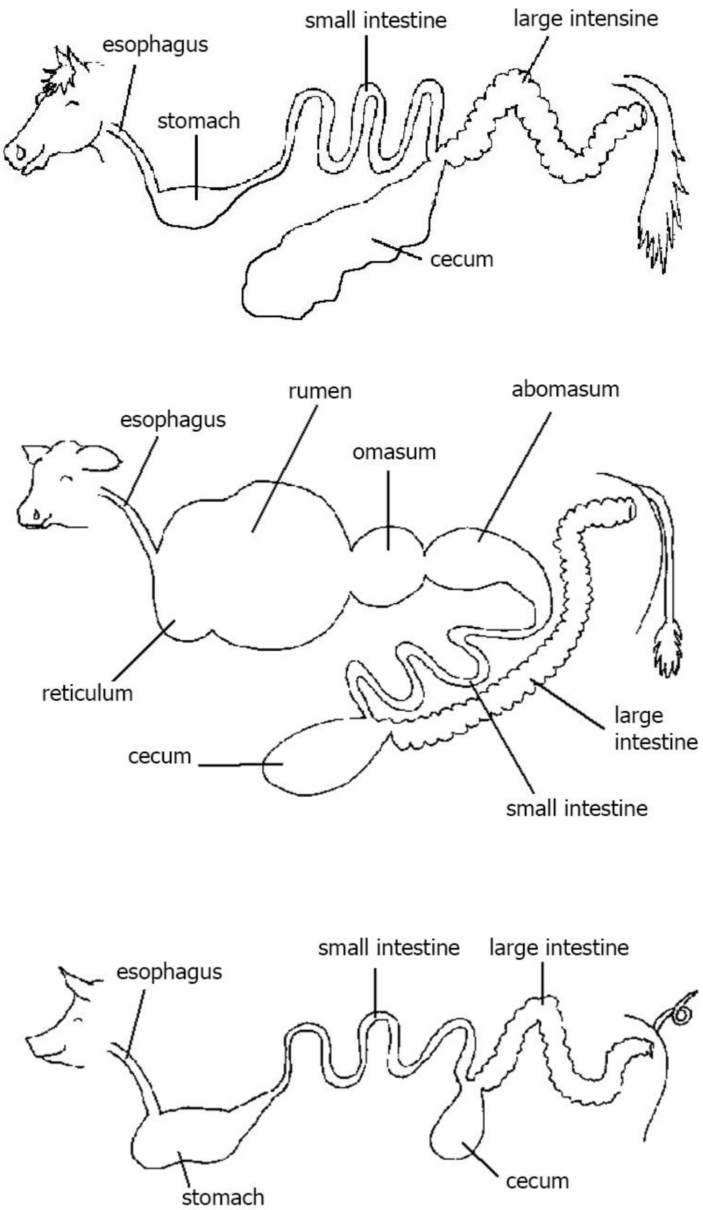


Figure 2. Description of the gastrointestinal tract of the ruminant, the horse and the pig (Copyright 1996-2010 by Jeannette A. Moore. Permission is granted for anyone to use these images for educational purposes, provided that this copyright statement is kept with the images and provided that the images are given, not sold. http://www.ncsu.edu/project/ansci_feeds/gi_tract/gi_tract.htm)

The digestion capacity of the digestive tract differs between animal species. The approximate capacities of the different digestive compartments of cattle, sheep, horses and slaughter pigs are listed in table 11. In relation to body size, the volumes constitute approximately 40%, approximately 20%, and approximately 25% in ruminants (cattle, sheep, and goats), horses and pigs, respectively. Feeding of animals directly prior to slaughter is restricted, and therefore the volume of digesta in the gut at slaughter will probably be lower than indicated in table 11.

Table 11. Approximate capacity (liters) of the different digestive compartments of cattle, sheep, horses and pigs (adapted from Bondi and Drori (1987) and Fuller (2004).

	Fore-stomach Rumen/reticulum/ omasum	**Stomach/ Abomasum**	**Small intestine**	**Cecum**	**Large intestine**	**Total**
Cattle	130	15	50	5	20	220
Sheep	15	2	5	1	2	30
Horses		10	30	15	45	100
Pigs		8	10	2	10	32

The dry matter content of digesta varies. It is usually is in the range 10-15 % in the rumen, but as water is added in the stomach and small intestine, dry matter may be less than 5 %. Throughout the small intestine and large intestine, water is absorbed and dry matter increases. In dairy cows, faecal dry matter content is usually in the range 10-15 %. Dry matter in faeces from horses and pigs is usually in the range 15-20%. Dry matter in faeces from small ruminants (sheep and goats) may exceed 50 % and is usually higher than 30%.

The approximate pH ranges in different segments of the gastrointestinal tracts of ruminants (cattle, sheep goats), horses, and pigs are shown in table 12.

Table 12. Approximate pH range in digesta in different compartments of the digestive tracts of ruminants (pre-gastric fermenters), and horses and pigs (hindgut fermenters).

	Fermentative digestion		**Enzymatic digestion**		**Fermentative digestion**	
	Reticuelo-Rumen	Omasum	Stomach/ Abomasum	Small intestine	Large intestine	Cecum
Ruminants	5.5-7.0	6.5-7.0	3.0-4.0	7.0-8.0	7.0-8.0	6.5-7.5
Horses			2.5-3.5	7.0-8.0	5.5-7.0	5.5-7.5
Pigs			2.0-2.5	7.0-8.0	6.5-7.5	6.5-8.0

In the fermentative chambers of ruminants and horses, the pH is usually in the range 5.5 to 7.0. Acidity below pH 5.5 occurs rarely. Fermentative digestion also occurs in the hindguts (cecum and large intestines) of ruminants and pigs, but not as intensively as in horses. The secretory cells in the stomach (abomasum) of the animals listed in table 12 have the potential to lower the pH to below 1.0, which is almost five million times more acidic than that of blood (Sjaastad et al., 2010). However, because digesta contains various buffering materials, the pH usually is higher, especially in ruminants where the flow of pH regulating material into the abomasum is high (Sjaastad et al., 2010). In pigs, horses and ruminants, the pH in the abomasum is usually in the in the range 2.0 to 2.5, 2.5 to 3.5 and 3.0 to 4.0, respectively. In the small intestine, digesta is efficiently buffered by bile and pancreatic juices back to a pH of around 7 to 8 in all animals. In the hindgut, microbial activity and fermentation of nutrients occurs that is comparable to that which occurs in the rumen, but except for in horses, the pH does not usually drop below approximately 6.5.

Retention time in the entire digestive tract, and in the different segments of the tract vary between species, between nutrients and between physical properties of the feed. In ruminants, the retention time in the rumen has a considerable impact on retention time in the entire digestive tract. Retention time in the rumen may vary from 4 to 5 hours for material following the liquid phase to more than 70 hours for fiber particles. In pigs and ruminants post-rumen, retention time through the digestive tract is in the range 8 to 24 hours, with 1 to 3 hours in the stomach. In horses, retention time in the digestive tract is somewhat prolonged compared with pigs, but more similar to pigs than ruminants.

According to the Norwegian Food Safety Authority, at many slaughterhouses the content of the intestine tract is collected in the manure cellar, together with manure and bedding from the transport vehicle and manure produced by the animals after transport. In some slaughterhouses, only the contents of the fore-stomachs (rumen, reticulum and omasum) and stomach of ruminants, and the stomach of monogastric animals is collected, whereas the content of the intestine/bowel is managed separately. Thus, the term «content of intestinal tract» may be comprised of material that has undergone diverse degrees of digestion.

3.2.2 Probabilities of pest survival in the digestive tracts of the animals

3.2.2.1 Weeds

Several studies have been published on the survival of weed seeds in the digestive tracts of domestic animals.

Incubation of intact *Chenopodium album* seeds for 2 hours in a cattle rumen, followed by a post-ruminal digestion *in vitro*, resulted in a small reduction in viability (Aper et al., 2014; Blackshaw and Rode, 1991). When a sheep rumen was used, the viability of seeds from the same species was reduced to 17 % (Haidar et al., 2010). The viability of *Fallopia convolvulus* seed was reduced to 63 % in cattle rumen (Blackshaw and Rode, 1991). Rumen digestion alone reduced the viability of *C. album* to 52 %, *F. convolvulus* to 63 %, and *Thlaspi arvense* to 68 %, respectively. When silage was combined with digestion in the rumen, only a minor change in viability was observed, indicating that rumen digestion had little additional effect on viability. A significant year-by-treatment interaction has been observed for *Avena fatua* and *T. arvense*, with no reduction in viability one year for wild oats seeds and complete kill the next year. Viability of *Echinochloa crus-galli* seeds was completely destroyed in the rumen in this trial, and viability was also very much reduced in a Czech trial (Sarapatka et al., 1993). However, Schröder and Baart (1982) found that *E. crus-galli* seeds remained viable after passing through the cattle intestine and Mt.Pleasant and Schlather (1994) found viable cockspur seed in cow manure from five out of 20 farms in upstate New York *T. arvense* germination was reduced to 35 % in rumen during the same trial. Seeds from *Rumex obtusifolius* were almost unharmed (91 % germinated) after passing through a cattle digestive tract (Sarapatka et al., 1993). However, seeds from this species were destroyed in a mesophilic, anaerobic digestion reactor, which can be considered comparable with rumen digestion. Rumen fermentation considerably reduces viability of several grass weed seeds (Blackshaw and Rode, 1991).

A Norwegian experiment from the late 1980s demonstrated that only 0.07% of whole *A. fatua* seeds that had been ingested by a horse survived the digestion process (Austbø, 1990). For grounded or crushed *A. fatua*, there was apparently no survival post digestion.

Based on scientific reports, weed seeds pass more or less unharmed through sheep and cattle rumens. *E. crus-galli* seeds*,* however, appear to be destroyed in the rumen. Several weed species are reported to survive post-ruminal digestion, both *in vitro* and *in vivo*.

Pigs are usually fed only grounded and heat-treated concentrates. In addition, pigs usually chew their feed well and have a low pH in the abomasum. Ruminants are usually fed a diet consisting of both concentrate and forage. As in pigs, the concentrate is usually ground and heat-treated, whereas the forage is usually fresh pasture grass or a grass silage.

The feeding characteristics of ruminants constitutes two phases: a first phase where feed is ingested and a second phase where fibrous forage is ruminated. In the first phase, chewing activity is limited especially in large ruminants (cattle), whereas in small ruminants (sheep and goats) usually chewing is more complete before swallowing. During the rumination phase, rumination mainly involves the fibrous part of the forage. Small particles like seeds, thus may escape chewing and rumination.

Horses, like ruminantes, are usually fed a diet consisting of concentrate and forage. Horses do not ruminate, and they compensate for the lower digestibility of forages with higher feed intake and increased rate of passage through the gut (Van Soest, 1994). In addition, horses are fed whole oats that can survive the digestive tract.

Thus, probability of survival of seeds in the digestive tract is probably highest in horses, followed by large ruminants, small ruminants and pigs. However, in ruminants, much of the digesta volume is in the rumen, which is in the early stage of digestion and prior to the acidic abomasum. It is likely that seeds survive passage through rumen. The uncertainty associated with this probability is medium. Undigested rumen content removed at slaughtering is likely to contain viable seed with low uncertainty.

3.2.2.2 Plant pathogenic fungi, oomycetes and protozoa

There is only limited information available on the survival of plant pathogenic fungi in the digestive tract of animals. However, some fungi belonging to different taxonomic groups have been found to survive passage through the digestive tract.

The resting spores of the protozoan that causes club root (*Plasmodiophora brassicae*) survive passage through the digestive tract of livestock (Howard et al., 2010). A Chinese dissertation (Li, JP. 2013, in Chinese), cited in Chai et al. (2014), found that 70 % of the *P. brassicae* spores in pig manure were viable.

Merz and Falloon (2009) reported that the protozoan *Spongospora subterranea* spores fed to cows and goats survived digestion and remained infective in the manure.

The resting spores of the potato wart-causing fungus *Synchytrium endobioticum* survive in the digestive tract of animals (EPPO, 1990; Franc, 2007).

Verticillium dahliae and *V. albo-atrum*, can infect a large number of plant species, including vegetables, potato and lucerne.These fungi produce microsclerotia that can survive for at least 20 years in soil. The microsclerotia can survive passage through the digestive tract of sheep and retain pathogenicity (Huang et al., 1986; Markakis et al., 2014). Huang et al. (1986) found that no viable *V. albo-atrum* spores were present in feces two days after the sheep returned to non-infected forage. Markakis et al. (2014) detected DNA of *V. dahlia* in the feces for up to five days after infected plants had been fed to the sheep.

Melouk et al. (1989) showed that sclerotia of *Sclerotinia minor* survived passage through the digestive tract of heifers and retained their pathogenicity.

The common bunt fungus, *Tilletia caries*, produces large amounts of spores in wheat grains. Johnsson (1990) and Smilanick (1986) tested the infectivity of spores that had passed through the digestive tracts of animals. They found that spores in cattle and sheep manure remained infective and caused infection in winter wheat, whereas spores in pig manure or in poultry manure did not survive.

In Russia, the manure of animals fed on infected potatoes acts as a source of inoculum for the fungus that cause potato skin spot *Polyscytalum pustulans* (syn. *Oospora pustulans*) (Khar´kova, 1961).

Wang et al. (2008) found that *Fusarium graminearum* in barley grain lost viability after being placed in a cow rumen for 12 hours.

In conclusion, these published results indicate that some plant pathogenic fungi and protozoa can survive passage through animal digestive tracts despite the acidic environment. The probability of survival in slaughterhouse manure is greater, as slaughterhouse manure may include only partially digested feed. There is insufficient available information to reach conclusions for specific animal species.

3.2.2.3 Plant pathogenic bacteria and viruses

Studies on the fate of plant pathogenic bacteria and viruses in the digestive systems of domestic animals were not found in the literature search. Potato mop-top viruses transmitted inside fungi and nematodes would probably survive passage through the digestive system, provided that their hosts survived. However, published studies on such pathways were not found.

However, the survival of human pathogenic bacteria and viruses in manure is better documented. Several human pathogens may survive and present a risk to human health if manure is applied onto fields where food crops are grown (Mawdsley et al., 1995). Human and plant pathogenic bacteria have many common traits, and they may be in the same bacterial genera. However, most human pathogens are well adapted to temparatures of 37°C, while plant pathogens have a temperature optimum around 25°C.

As noted in Section 3.2.1, the conditions for microorganisms in the digestive systems of cattle, sheep, and pigs would be very harsh for plant bacteria and viruses. This is due to unfavourable pH, various digestive enzymes, and the presence of microflora. For plant pathogenic bacteria, the relatively high temperature in the digestive system is also very unfavourable.

3.2.2.4 Plant parasitic nematodes

Only limited literature was identified on this subject, but it is clear that already in the late 1800 there was concern regarding the spread of nematodes with cattle (Goffart, 1933).

Nematode species that are protected in galls on plants or in cysts, are of special relevance regarding dispersal through use of slaughterhouse manure.

The spread of the cyst nematodes (*Heterodera* spp. and *Globodera* spp.) with cattle dung has been of concern to agronomists, with the suspicion that the eggs and juveniles, which are protected in cysts, could survive passage through the digestive tract of cattle (Kemper, 1958). The beet cyst nematode, *Heterodera schachtii*, was reported to survive and remain infective after passage through the digestive tracts of cattle (Kontaxis et al., 1976).

A Swedish study by Ländell (1988) reports the survival and infectivity of PCN (*Globodera rostochiensis* and *G. pallida*) in the digestive tracts of cattle, and the persistence of nematodes in the dung. In that study, the infectivity of nematodes was tested on the potato cultivar Bintje. Cysts of *G. rostochiensis* in soil were mixed with concentrated feed or silage and fed to cows. The eggs and juveniles were not damaged after passage through the digestive tract, but the infectivity of *G. rostochiensis* was reduced by 95 % or more. *In situ* exposure of *G. rostochiensis* to ruminal fluid for 9 hours resulted in loss of infectivity, while some nematodes (3 %) of *G. pallida* still were infective after 27 hours. Both species remained infective after 8 hours *in vitro* exposur
e to duodenal fluid, and also after the exposure to ruminal fluid for 1 hour, followed by exposure to duodenal fluid for 2 hours.

In 1887 Gillard (cited in Goffart (1933)) used sugar beet roots parasitized by the sugar beet cyst nematode (*H. schachtii*) as feed for sheep. The experiments demonstrated that the nematode could survive passage through the alimentary canal and remain infective on sugar beet exposed to the sheep dung.

A few studies have been published on the survival of cyst nematodes after passage through the digestive tracts of pigs. Smart Jr. (1963) fed cysts of the soybean cyst nematode *Heterodera glycines* to pigs, and reported a low hatch of juveniles from cysts recovered from the feces. However, the nematodes did not reproduce on soybeans in a pot experiment. Ländell (1988) studied the survival of *G. rostochiensis* in the alimentary canal of pigs, and reported very low survival of nematodes after passage through the pigs. Nematodes in 6 % of the test units produced a low number of new females in pot tests on potato.

3.2.2.5 Phytophagous insects and mites

Studies on the fate of phytophagous insects and mites in the digestive systems of grazing animals were not found in the literature search. The following comments are therefore based on the conditions in the digestive tracts of domestic animals described in Section 3.2.1, and on general knowledge of insects and mites, especially their respective life-cycles, and particularly considering life-cycle stages that are most likely to be ingested by grazing animals, based on the species and genera listed in Section 2.2.6.

If ingested by a grazing animal, it seems unlikely that insects and mites will survive the process of chewing and digestion. This assumption is based on the following factors: the pests that are most likely to be eaten (listed in Section 2.2.6) are rather soft bodied, with a thin exoskeleton. This will mean that they are easily destroyed if caught between the teeth of an animal. As a consequence the organism will die. Eggs and young nymphs/larvae probably have a slightly better chance than adults, older nymphs/larvae and pupae, of escaping the teeth or not being squeezed in the animals' mouth, due to their smaller size. Should an egg, larva/nymph, pupae or adult survive the mouth of the animal and enter the digestive tract undamaged, it is unlikely that the organism will survive the digestion process. This is due to lack of oxygen during fermentation, mechanical digestion (especially chewing), and the low pH in some parts of the gut (see Section 3.2.1). Lack of oxygen is deadly to all stages of insects and mites.

3.2.3 Conclusions on pest survival in the digestive tract of animals

Weed: Seeds from broad-leaved *Rumex* species, *C. album and F. convolvulus* are likely to survive passage through the digestive tract of animals. Seeds of *A. fatua* and *T. arvense* are moderately likely to survive, but the uncertainties in these assessments are high. The mechanical process of chewing, together with enzymatic digestion and exposure to acidic conditions, especially in the abomasum, reduces the viability of seeds, but not all are killed. If the pericarp of a seed is not damaged during processing of the feed or chewing, it may survive and germinate post-passage through the digestive tract. The probability of survival of weed seeds in faeces is highest in horses, followed by large ruminants, small ruminants, and then pigs. For ruminants, much of the digesta volume is in the rumen where the probability of survival of seeds is likely, and the uncertainty is medium due to differences between species.In ruminants, much of the digesta volume is in early stages of digestion in rumen where probability of survival of seeds is likely. Rumen contents constitute a significant part of the waste from slaughterhouses. Undigested rumen content removed at slaughtering is likely to contain viable weed seed with low uncertainty.

Fungi, protozoa and oomycetes: *Plasmodiophora brassicae, Synchytrium endobioticum, Spongospora subterranea, V. dahlia, V. albo-atrum, Sclerotinia spp. and T. caries* are likely to survive passage through the digestive tracts of animals. The uncertainty of this assessment is low. Other organisms with long living survival structures, e.g. *Claviceps purpurea* are likely to survive but the uncertainty of this assessment is high. Other fungal and oomycete plant pathogens are moderately likely to survive, but the uncertainty of this assessment is high.

Bacteria and viruses: It is unlikely that pathogenic bacteria and viruses survive in the digestive tract. The uncertainty of this assessment is medium.

Nematodes: PCN (*G. rostochiensis, G. pallida*) and cereal and grass cyst nematodes are moderate likely to survive and remain infective after passage through the alimentary canals of cows and sheeps. This probability assessment has medium uncertainty. PCN (*G. rostochiensis, G. pallida*) and cereal and grass cyst nematodes are unlikely to survive and remain infective after passage through the alimentary canals of pigs, with a low uncertainty.

Insects and mites: It is unlikely that phytophagous insects and mites will survive the processes of chewing and digestion if ingested by a grazing animal. The pests listed in Section 2.2.6 are rather soft bodied with thin exoskeletons that will be easily destroyed in these processes (mechanical digestion, low pH, lack of oxygen), and the organism will die. The uncertainty of this assessment is high.

3.3 Survival of pests during manure storage

3.3.1 Conditions during storage of manure

In their terms of reference, the Norwegian Food Safety Authority provided the following description of current practices regarding the management and handling of manure and digestive tract content by slaughterhouses:

The floors of transport vehicle are covered with bedding, often sawdust and shavings (kutterflis). On arrival at the slaughterhouse, the vehicle is cleaned. The bedding, and the manure produced during transport are collected in the manure cellar of the slaughterhouse, together with the manure produced by the animals at the slaughterhouse. At many slaughterhouses, the contents of the digestive tracts of the slaughterhouse animals are collected in the same manure cellar.

According to the Norwegian Food Safety Authority, the common practice is that the contents of the slaughterhouse manure cellar are transported to, and stored in, the manure cellar of a nearby farm. The manure is then applied onto agricultural fields in the same way as manure obtained directly from the farm. The slaughterhouse manure may be applied immediately or after some months of storage at the farm. A contract on the use of slaughterhouse manure between the slaughterhouse and the receiving farm is required. In addition, the animal by-product regulation requires a minimum of 21 days between manure application and harvesting of feed crops, and a minimum of six weeks between manure application and grazing on the pasture.

It is common practice for manure to be applied during spring tillage and in autumn. According to the regulation on organic fertilizers (LMD et al., 2003), manure may not be applied onto frozen ground and not during the period between 1. November to 15. February. In areas at risk of environmental pollution, the County Governor may, in addition, prohibit manure application during the period between 1. September to 1. November. Thus, farms may be required to store manure for periods of up to about half a year. The regulation requires that the capacity of the manure storage site is sufficient to store the manure until application is permitted. The capacity should be sufficient to contain a minimum of eight months of manure production. Manure is increasingly transported from farms with animals to neighbour farms without livestock. Organic farmers need animal manure to fertilize their crops. Current regulations prohibit transport of manure across county (fylke) borders.

According to the Norwegian Food Safety Authority, slaughterhouses have commented that treatment of manure is costly. Different ways of treatment have been discussed and tested. Plants for biogas production have experienced difficulties when using slaughterhouse manure, due to the content of bedding material. Some slaughterhouse manure is composted. There have been uncertainties concerning further operation of the compost plants due to restrictions in the regulation on animal by-products (NFD and LMD, 2016). However, several composting plants have been approved during 2015 for further operations, applying process parameters validated by the Norwegian Waste Management and Recycling Association or by the treatment facility itself.

A report from SSB shows that the most common type of manure storage in agriculture in Norway is a cellar suitable for holding slurry. In 2013, 77 % of the manure was stored in cellars or outdoor slurry pits. These numbers are based on a survey among a random sample of farms with different types of farming systems for both plant and/or animal production (Gundersen and Heldal, 2015).

3.3.2 Probabilities of pest survival during manure storage

3.3.2.1 Weed

Very few studies on seed viability in manure were identified in the literature search, apart from those on the effects of windrow composting and on anaerobic digestion in connection with biogas plants.

A North American study reported an 80% reduction in viability of seeds with soft coats, such as wild oats, after passage through the digestive tract of cattle. When three months of storage in manure was included following the digestion, very few seeds survived except for species with hard seed coats, such as *Chenopodium album* (Katovich and Becker, 2004).

There are several reports on the survival of different weed species when digested in bioreactors for biogas production. The anaerobic conditions in these reactors mean that they are somewhat comparable with manure cellars. In mesophilic reactors the temperature ranges from 20°C to 45°C, and in thermophilic reactors between 45°C and 55°C (Westerman et al., 2012). In a study using a mesophilic reactor 58 % of hard seeds survived for 30 days, but less than 1 % of seeds without a water impermeable layer survived. In thermophilic reactors exposure to 55°C for 24 hours, completely destroyed all exposed weed seeds, except *Fallopia convolvulus* (Eckford et al., 2012).

Aerobic windrow composting is generally an effective method of reducing viability of weed seeds. Windrow composting is the production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows (windrows). These rows are turned to improve porosity and oxygen content, to mix in or remove moisture, and to redistribute cooler and hotter portions of the pile.

A trial with weeds common in Nebraska in USA showed 100 % loss of viability after 4-5 months in the windrow, except for *Abutilon theophrasti,* although the temperature did not reach 60°C (Eghball and Lesoing, 2000). In a two year Canadian windrow study viability was lost in both *Avena fatua* and *F. convolvulus* seeds at a base temperature of 40°C, both years after 70 days. Seeds of *Thlaspi arvense* only lost viability in the second year of the trial (Larney and Blackshaw, 2003).

Composted swine manure did not increase the abundance of weed seeds in the soil seed bank in a trial in Montana (Menalled et al., 2005). A study from Alberta, Canada using manure from 12 weed species, including *T. arvense*, *F. convolvulus*, *A. fatua* and *C. album,* showed loss of viability in all species when the manure was composted for 4 weeks. The windrow was managed such that the core temperature was maintained between 55°C and 65°C for as long as possible (Tompkins et al., 1998). After 2 months in a windrow with a maximum temperature of 63°C, *Rumex obtusifolius* seeds did not germinate (Zaller, 2007). These results indicate that windrow composting could be a safe way for ensuring that weed seeds are not spread with slaughterhouse manure waste.

In conclusion, it seems probable that the temperature in manure storage is crucial for the efficiency of killing weed seeds. It is likely that temperature varies both between and within manure storage. It is therefore moderately likely that weed seeds will lose their viability in manure storage. The uncertainty in this assesemnt is high. In manure storage in which temperature reaches 55°C, seed viability could be effectively destroyed. High quality windrow composting is likely to destroy seed viability. The uncertainty is low.

3.3.2.2 Plant pathogenic fungi and protozoa

Only a few studies on the potential of plant pathogenic fungi and protozoa to survive in manure were found in the literature search. Studies on survival of plant pathogenic fungi during composting of organic material for gas production are included below. Several plant pathogenic fungi and protozoa have been found in manure. In some cases they have been shown to retain their pathogenicity during manure storage.

Raw manure can be a source of inoculum of the club root protozoa (*Plasmodiophora brassicae*) (Li, 2013 [in Chinese cited by (Chai et al., 2014)]). In the prairie provinces of Canada, the disease is spreading, and one of the pathways is application of raw manure from animals that have been fed with club root-infected fodder (Howard et al., 2010). In China, the pathways for dispersal of *P. brassicae* spores are movement of infested soil, soil erosion by wind and water, and livestock manure (Chai et al., 2014). Incubation in moist compost at 50°C for seven days or for one day at 60 °C, eradicated club rot (*P. brassicae*) resting spores from Chinese cabbage roots (Fayolle et al., 2006). Resting spores of *P. brassicae* survived in liquid manure during 24 hours of anaerobic fermentation in a test programme intended for developing the German Biowaste Ordinance (Philipp et al., 2005).

Wale (1987) stated that one pathway for spread of the powdery scab protozoa, *Spongospora subterranea,* to new fields was application of manure or slurry from animals fed on infected tubers. The resting spores of the potato wart-causing fungus, *Synchytrium endobioticum,* may also be spread by manure (EPPO, 1990; Franc, 2007).

Verticillium dahliae and *V. albo-atrum* have been found to survive as microsclerotia during storage of manure for at least 6 weeks (Huang et al., 1986) and 2 years (Lopez-Escudero and Blanco-Lopez, 1999), respectively. Pratt (2006) studied the effect of swine manure on hyphomycetes fungi in the genera *Bipolaris*, *Curvularia* and *Exserophilum*. The fungi differed significantly in the abilities of their conidia to survive in swine manure, but the cereal pathogen *B. sorokiniana* had 56 % survival of conidia at the end of a 4 week period. In Russia, the manure of animals that had been fed on infected potatoes is reported to be source of inoculum for the fungus that causes potato skin spot, *Polyscytalum pustulans* (Khar´kova, 1961).

Some useful information is available from research on survival of plant pathogenic fungi during anaerobic digestion or composting of animal and crop wastes. In anaerobic digestion experiments with infected plant materials, the survival of four plant-pathogenic fungi was determined (Bandte et al., 2013). Under anaerobic mesophilic conditions (35-42°C), the viability of *Sclerotinia sclerotiorum* and *Rhizoctonia solani* was lost within 6 hours. Sorghum infected with *Fusarium proliferatum* and *F. verticillioides* required a maximum of 138 hours for complete loss of viability under anaerobic conditions (Bandte et al., 2013).

Wang et al. (2008) placed barley grains infected with *F. graminearum* in the duodenum of cows and subsequently tested the viability of the fungus in the feces. Viability was lost after 4 days.

In conclusion, these published results indicate that some plant pathogenic fungi and protozoa with resting spores or sclerotia are likely to survive in manure storage. Manure can act as a source of inoculum for these pathogens. For most plant pathogenic fungi and Oomycete the likelihood of survival is considered moderately likely.

3.3.2.3 Plant pathogenic bacteria and viruses

Only in a single publication on this subject was identified during the literature search. According toElorrieta et al. (2003), high temperatures, unfavourable pH, competition and antagonistic actions from other microorganisms present in manure, as well as the length of exposure to such conditions could make the survival plant pathogenic bacteria and viruses unlikely.

Storage and use of manure is common in Norway, but there is no information on for how long time manure is stored before it is spread in the field. Most likely it will be stored for some months, thus making it unlikely that plant-pathogenic bacteria and viruses may survive.

A study of plant health risks associated with processing of plant-based wastes demonstrated that many plant-pathogenic bacteria and viruses were eradicated by a constant temperature of 60° C for 1 hour, although some species needed 82° C for 5 minutes or 90° C for 15 minutes, but the effects from lower temperatures and/or different durations were not examined (Noble et al., 2009). The duration of storage of manure would probably be several months, and in addition, there would be a temperature rise. The time and temperature factors indicate that survival of plant pathogenic bacteria and viruses would be unlikely with high uncertainty.

3.3.2.4 Plant parasitic nematodes

Studies on the effect of storing nematodes in manure were found in only a few reports in the literature search.

The potato cyst nematodes (*G. rostochiensis*) stored in cow-manure in buckets continued to be infective after 3 months of storage, but the temperatures were mostly below 30°C (Ländell, 1988). Cysts of nematodes stored in manure-stacks outdoors remained infective for 6 weeks (Evans, 1991; Ländell, 1988). Wet cysts of *G. rostochiensis* were killed within 30 minutes at temperatures of 58-59°C (Evans, 1991). Kemper (1958) reported that *G. rostochiensis* stored in stable dung did not survive temperature peaks of 72°C and 32°C. Therefore, survival of *G. rostochiensis* in stable dung depends on the temperature reached in the material, and hence varies with the conditions of the storage.

3.3.2.5 Phytophagous insects and mites

Studies on the fate of phytophagous insects and mites in manure storage were not found in the literature search. It should be noted that as the conclusion in Section 3.2.2.5 was that phytophagous insects and mites would be unlikely to survive the process of chewing and digestion should they be ingested by a grazing animal. Consequently they will not provide any risk via manure. The uncertainty of this assessment is high.

3.3.3 Conclusions on pest survival during manure storage

Weeds: The temperature in manure storage is crucial for the efficiency of killing weed seeds. It is likely that temperature varies both between and within manure storage. It is therefore moderately likely that weed seeds will lose their viability in manure storage. The uncertainty in this assesemnt is high. In manure storage in which temperature reaches 55 °C, seed viability could be effectively destroyed.

Fungi and protozoa: *Plasmodiophora brassicae, Spongospora subterranea*, *Synchytrium endobioticum, Verticillium dahlia and V. albo-atrum* are likely to survive in manure until it is applied on fields. The uncertainty of these assessments is medium. *Bipolaris sorokiniana* is moderately likely to survive during manure storage. The uncertainty of this assessment is medium. The survival of other fungal pathogens during manure storage is moderately likely, but the uncertainty of these assessments is high.

Bacteria and viruses: It is unlikely that plant-pathogenic bacteria and viruses survive during manure storage. However, some viruses may survive in vectors, such as the protozoan *Spongospora subterranea* and soil-dwelling nematodes. The uncertainty of these assessments is high.

Nematodes: The PCN (*G. rostochiensis*) is moderately likely to survive and remain infective after storage in cattle manure, with a medium uncertainty. This is also expected to be true for sheep manure, but with a high uncertainty due to the storage period in the experiment by Gillard in 1887 not being reported (Goffart, 1933). The PCN, and the cereal and grass cyst nematodes are unlikely to survive and remain infective after storage in pig manure, with high uncertainty.

Insects and mites: As phytophagous insects and mites would be unlikely to survive the process of chewing and digestion should they be ingested by a grazing animal, it is unlikely they will survive in stored manure, with high uncertainty.

3.4 Summary of conclusions on survival of pests in each step of the pathway

Tables 13 A-D summarise the conclusions on plant pest survival given in Section 3.1.2 (feed and bedding material), Section 3.2.3 (digestive tracts of domestic animals), and Section

3.3.3 (manure storage). For simplicity some of the conclusions from these sections are not tabulated individually, but are summarised collectively for a group of pests, or for a group of feed or bedding.

Table 13A. The probability (Prob) and uncertainty (Uncert) of weeds surviving in: a) storage and processing of food or bedding material, b) digestion by domestic animals, and c) storage in manure.

Scientific name of weed	Surviving storage and processing of feed and bedding material		Surviving digestion		Surviving storage in manure	
	Prob	Uncert	Prob	Uncert	Prob	Uncert
Avena fatua	Moderately likely	Medium	Moderately Likely	High	Moderately likely	Medium
Chenopodium album	Likely	Medium	Likely	Medium	Likely	Medium
Echinochloa crus-galli	Moderately likely	Medium	Moderately likely	Medium	Moderately likely	Medium
Fallopia convolvulus	Likely	Low	Likely	Low	Likely	Low
Rumex obtusifolius	Moderately likely	Medium	Likely	Medium	Moderately likely	Medium
Thlaspi arvense	Moderately likely	Low	Moderately likely	High	Moderately likely	High

Table 13B. The probability (Prob) and uncertainty (Uncert) of plant pathogenic protozoa, oomycetes and fungi surviving in: a) storage and processing of food or bedding material, b) digestion by domestic animals, and c) storage in manure.

Scientific name of protozoa, Oomycetes and fungi	Surviving storage and processing of feed and bedding material		Surviving digestion		Surviving storage in manure	
	Prob	Uncert	Prob	Uncert	Prob	Uncert
Plasmodiophora brassicae	Likely	Low	Likely	Low	Likely	Medium
Spongospora subterranea	Likely	Low	Likely	Low	Likely	Medium
Syncytrium endobioticum	Likely	Low	Likely	Low	Likely	Medium
Phytophthora infestans	Moderately likely	High	Moderately likely	High	Moderately likely	High
Bipolaris sorokiniana	Moderately likely	High	Moderately likely	High	Moderately likely	Medium
Claviceps purpurea	Likely	Medium	Moderately likely	High	Moderately likely	High
***Fusarium* spp.**	Moderately likely	High	Moderately likely	High	Moderately likely	High
***Mastigosporium* spp.**	Moderately likely	High	Moderately likely	High	Moderately likely	High
Microdochium nivale	Moderately likely	High	Moderately likely	High	Moderately likely	High
***Rhyncosporium* spp.**	Moderately likely	High	Moderately likely	High	Moderately likely	High

Scientific name of protozoa, Oomycetes and fungi	Surviving storage and processing of feed and bedding material		Surviving digestion		Surviving storage in manure	
	Prob	**Uncert**	**Prob**	**Uncert**	**Prob**	**Uncert**
***Sclerotinia* spp.**	Likely	Low	Likely	Low	Moderately likely	High
Tilletia caries	Likely	Low	Likely	Low	Moderately likely	High
***Ustilago* spp.**	Likely	Low	Moderately likely	High	Moderately likely	High
***Verticillium* spp.**	Likely	Low	Likely	Low	Likely	Medium

Table 13C. The probability (Prob) and uncertainty (Uncert) of plant pathogenic bacteria and viruses surviving in: a) storage and processing of food or bedding material, b) digestion by domestic animals, and c) storage in manure.

Scientific name	Surviving storage and processing of feed and bedding material		Surviving digestion		Surviving storage in manure	
	Prob	**Uncert**	**Prob**	**Uncert**	**Prob**	**Uncert**
Bacteria	Likely	High	Unlikely	Medium	Unlikely	High
Viruses	Likely	High	Unlikely	Medium	Unlikely	High

Table 13D. The probability (Prob) and uncertainty (Uncert) of plant parasitic nematodes surviving in: a) storage and processing of food or bedding material, b) digestion by domestic animals, and c) storage in manure.

Scientific name of nematode	Surviving storage and processing of feed and bedding material		Surviving digestion		Surviving storage in manure	
	Prob	Uncert	Prob	Uncert	Prob	Uncert
***Anguina* spp.**	Moderately likely	High	Unlikely	High	Unlikely	High
Ditylenchus dipsaci	Moderately likely	High	Unlikely	High	Unlikely	High
D. destructor	Moderately likely	High	Unlikely	High	Unlikely	High
***Pratylenchus* spp.**	Moderately likely	High	Unlikely	High	Unlikely	High

Scientific name of nematode	**Surviving storage and processing of feed and bedding material**		**Surviving digestion**		**Surviving storage in manure**	
	Prob	Uncert	Prob	Uncert	Prob	Uncert
Subanguina radicicola	Moderately likely	High	Unlikely	High	Unlikely	High
Punctodera punctata	Moderately likely	High	Unlikely	High	Unlikely	High
Heterodera avenae	Moderatly likely	Medium	Moderatly likely	High	Unlikely	High
H. filipjevi	Moderatly likely	Medium	Moderatly likely	High	Unlikely	High
H. trifolii	Moderatly likely	Medium	Moderatly likely	High	Unlikely	High
Globodera rostochiensis	Moderatly likely	Medium	Moderatly likely	Medium	Moderatly likely	Medium
G. pallida	Moderatly likely	Medium	Moderatly likely	Medium	Moderatly likely	Medium
Meloidogyne hapla	Moderatly likely	High	Moderatly likely	High	Unlikely	High

Table 13E. The probability (Prob) and uncertainty (Uncert) of insects and mites surviving in: a) storage and processing of food or bedding material, b) digestion by domestic animals, and c) storage in manure.

Scientific name	Surviving storage and processing of feed and bedding		Surviving digestion		Surviving storage in manure	
	Prob	Uncert	Prob	Uncert	Prob	Uncert
Insects	Unlikely	High	Unlikely	High	Unlikely	High
Mites	Unlikely	High	Unlikely	High	Unlikely	High

4 Probability of spread of plant pests

The probability of spread of plant pests with slaughterhouse manure and the contents of the intestinal tracts from domestic animals depends on: 1) the probability of association with the pathway at origin (Chapter 2): 2) the probability of the pest surviving the different steps of the pathway (Chapter 3): and 3) the probability of the pest being deposited upon and establishing on the receiving agricultural area.

The probability of spread also depends on the volume of slaughterhouse manure applied on fields untreated, on the geographic distances between the farms at the origin of the pathway and the farms at the end of the pathway, and on the probability of the pest to establish on the receiving agricultural area. These three factors are considered in this chapter.

4.1 Volume of manure from slaughterhouses applied onto fields

According to the Norwegian Food Safety Authority, the amount of manure produced from slaughterhouses varies with type and number of animals slaughtered. For large slaughterhouses, the volume is considerable, presumably 1000 m^3 or more per year.

According to a recent report from SSB (Gundersen and Heldal, 2015), 41 % of the agricultural area of Norway was fertilized with animal manure at least once in 2013. In total, 49 % of the applied phosphorus, 54 % of the applied potassium, and 32 % of the applied nitrogen came from animal manure. About half of the agricultural area included in the survey was grassland. Of this grassland area 55 % was fertilized with animal manure. Animal manure is used to a certain extent on cereals and oilseed crops. About 10 % of the vegetable crop area included in the survey was fertilized with animal manure.

Traditional machinery, like wide spreaders for liquid manure (breispreder), is most commonly used. About 50 % of the manure was applied using manure spreaders, 20 % was applied using direct jet injection of liquid manure into the soil (jetvogn), and 9 % was applied as wide spread solid manure (gjødselvogn). Manure from slaughterhouses amounts to only a small fraction of the total manure application.

4.2 Location of slaughterhouses and farms in Norway

Several companies in Norway are involved in slaughtering and butchery. The farmers' cooperative company, Nortura, is the biggest by far with a turnover of 18 234 mill NOK in 2013. The largest private companies are Nordfjordkjøtt, with a turnover of 2 242 mill NOK in 2013, and Grilstad, with a turnover of 1 503 mill NOK the same year. The smaller companies have an annual turnover of <100 mill NOK.

Most slaughterhouses are located in agricultural areas, based on a regional supply of slaughter animals, and farmers are likely to appreciate receiving extra manure from slaughterhouses in their neighbourhood.

However, the industry is not static, and in 2014 Nortura acquired Fatland, the third in size of the private slaughter companies and Prima Jæren, one of the smaller slaughter companies. In the recent decades, the industry has rationalized and consolidated its activities by reducing the number of slaughterhouses and by building larger and more mechanized plants. This increases the average transport distance from the farms to slaughterhouses, and may thereby elevate the risk of domestic spread of plant pests and weeds that would otherwise be limited to specific regions in Norway.

4.3 Probability of establishment

The probability of a plant pest establishing on the receiving agricultural area depends on the availability of host plants, the suitability of the environment, and cultural practices in the area. For the purposes of this assessment, it is assumed that the crops grown in the receiving areas are similar to those grown in the area at the origin of the pathway (the area where plants for feed or bedding were grown). It is also assumed that the cultural practices and control measures are similar. The availability of host plants and the conditions in place that are dependent on the crops and cultural practices in the receiving agricultural areas are therefore not considered to act as a barrier to the probability of plant pests establishing, provided that they are viable in the slaughterhouse manure that is applied.

There may be differences in climatic conditions between the receiving agricultural area and the area at the origin of the pathway. As the number of slaughterhouses has been reduced during recent decades as a component of rationalization and consolidation, animals are transported over longer distances from farm to slaughterhouse, often from one county to another. However, in most cases it can be assumed that any differences in climate have an insignificant influence on the probability of plant pests establishing in the receiving agricultural area. Climatic conditions are therefore not considered in this assessment.

In conclusion, provided that viable plant pests or weed seeds are present in the slaughterhouse manure when applied to agricultural fields, it is likely that the plant pest will establish, assuming that host plants or suitable crops are present. The uncertainty of this assessment is medium.

4.4 Conclusions on probability of spread

In Table 14, conclusions are provided for the different types of plant pests, regarding their probability of spread to receiving agricultural areas with slaughterhouse manure and contents of the intestinale tracts from domestic animals.

Table 14. Conclusions on probability of spread given survival

Scientific name	Pest occurrence	Probability of spread by manure
Avena fatua	Weed under phytosanitary regulation	Moderatly likely
Chenopodium album	Common	Likely
Echinochloa crus-galli	Expanding weed	Unlikely/Moderately likely
Fallopia convolvulus	Common	Likely
Rumex obtusifolius	Common in coastal areas	Moderatly likely
Thlaspi arvense	Common	Likely
Plasmodiophora brassicae	Common	Likely
Spongospora subterranea	Common	Likely
***Verticillium* spp.**	Common	Likely
Foliar fungi of crops	Common	Moderately likely
Root and tuber fungi of crops	Common	Moderately likely
Plant pathogenic bacteria	Common	Unlikely
Plant pathogenic viruses	Common	Unlikely
***Anguina* spp.**	Common	Unlikely
***Ditylenchus* spp.**	Common	Unlikely
***Pratylenchus* spp.**	Very common	Unlikely
Subanguina radicicola	Common	Unlikely
Punctodera punctata	Common	Unlikely
***Heterodera* spp.**	Common	Unlikely
Globodera rostochiensis	Nematode under phytosanitary regulation	Moderately likely
Globodera pallida	Nematode under phytosanitary regulation	Moderately likely
Meloidogyne hapla	Common	Unlikely
Insect pests	Common	Unlikely
Mite pests	Common	Unlikely

5 Pests with the potential for resulting in highly negative consequences

This chapter identifies plant pests that can pose highly negative consequences if spread to a new agricultural area. These are pests that both a) were identified in 2.2 to possibly be associated with the pathway at origin, and b) are known from the literature to pose serious damage to the crop or to cause other serious problems to the farm, and c) have a restricted occurrence in Norway. The identified pests are listed in table 15. Characterizations of the possible consequences of their spread are also given in the table. Such consequences could be reduced crop yield or quality, restricted future use of the land, extra costs due to control measures, restricted use of machinery or cooperation with other farms, etc.

With a few exceptions, there is no reason to assume that the prevalences of pests on the farms receiving manure from the slaughterhouses are any different from the pest prevalence at the origin of the pathway. It is only in those cases where a pest is not present in the receiving agricultural area, or present at low prevalence, that the consequences of spread of these serious pests would be highly negative. This is why only pests with restricted occurrence in Norway are included in table 15. Restricted occurrence could be due to strict regulation of the pest, typically quarantine pests, or that the pest is newly introduced to Norway.

It is important to keep in mind that all plant pests are injurious to plants or plant products, and that spread of all plant pests are unwanted, also those not considered to be the most serious ones. Spread could cause increased prevalence of the pest, which is unfortunate in itself. Spread could also contribute to the genetic variation among the pest population.

Table 15. Plant pests that may cause highly negative consequences if spread to new agricultural areas. Only pests with restricted occurrence in Norway are included, and they have all been identified in section 2.2 to possibly be associated with the pathway at origin.

Plant pest	Negative consequences if spread to a new agricultural area
Avena fatua	According to the Phytosanitary regulation, farmers are obliged to control infestations and monitor their land each year, and several restrictions are imposed on the property. This means additional labour and economic costs for a farmer. This is particularly negative for those with contracts for growing seeds for planting. If infestation with wild oats is found, the farmer will lose the contract and obtain a considerable lower price for the harvest.
Echinocloa crus-galli	*Echinocloa crus-galli* is a fast spreading, alien species, which is very competitive, even in cereals, and the weed can destroy vegetable fields. Effective herbicides are available if the timing of the application is right. However, timing is problematic because the seeds germinate over a long period, and even very late germinating seedlings are able to establish in a cereal field. The cost of control is high, due to the requirements for a specific and expensive herbicide, and an extra spray operation is required. If this weed appears on fields with seeds for planting, the weed will be effectively spread over large distances. *E. crus-galli* is unlikely to survive during ensilage, however survival during digestion and manure storage is moderately likely.
Synchytrium endobioticum	The potato wart fungus, *S. endobioticum,* is under Phytosanitary regulation. The potato wart fungus is a serious pathogen that reduces the yield and quality of the potato harvest.
Globodera rostochiensis, G. pallida	The potato cyst nematodes (PCNs) are under Phytosanitary regulation. The PCNs represent a serious problem, as they can survive for up to 32 years in soil following an infestation. PCN infestation reduces potato yield and quality.

The current distribution of *A. fatua* and *E. crus-galli* is limitied in Norway. *Avena fatua* is regulated, while *E. crus galli* is spreading. The viability of both *A. fatua* and *E. crus-galli* seeds is reduced during feed processing, during digestion and in manure storage.The temperature in manure storage is crucial for inactivation, because the species can enter undigested with bedding material. If spread to new farms *A. fatua* as well as *E. crus-galli* are likely to pose practical and economic consequences.

Synchytrium endobioticum was last detected in Norway more than 20 years ago, but the Norwegain Food Safety Authority has not yet been declared the country free from this pathogen. With increased potato import the pathogen may be reintroduced. Potato cultivars currently grown in Norway are resistant to race 1 of the pathogen, which is the only race that has been detected in Norway. In continental Europe there are races with virulence on commonly grown potato varieties in Norway.

The distribution of the potato cyst nematodes *Globodera rostochiensis* and *G. pallida* (PCNs) is limited in Norway. Most potato farms are free from these pests, but PCN has been detected on more than 6000 properties in Norway. Black nightshade (*Solanum nigrum*) is a weed host for PCN. Their cysts may be transmitted by farm machinery from infested farms to non-contaminated land.

6 Risk reduction options

The risk reduction options can be grouped into five categories: 1) storage conditions of manure and digestive tract content; 2) Separation of manure and digestive tract content; 3) Avoidance of specific types of feed for a defined period before transport to the slaughterhause; 4) Choice of crop after manure application and 5) Composting of manure and digestive tract contents. Starvation of animals, e.g. like what is common for fish in aquaculture, before transport and slaughter in order to empty the digestive tract, is not an option due to animal welfare reasons as well as human safety issues that will emerge when handling starved animals.

Overall, given the information in Table 15 (where it is concluded that only two weed species, one fungal species and two nematode species are assessed to cause highly negative consequences) the risk reduction option No.3 i.e. avoidance of specific types of feed for a defined period before transport to the slaughterhouse emerges to have the highest efficiency and the lowest asoociated uncertainty. With regard to feasibility the latter risk reduction option is also be feasible. A systems approach where two or more of the RROs are combined could also result in a higher efficiency.

Table 16. Risk reduction options. Scale: Low, medium, high.

Options	Efficiency	Uncertainty	Feasibility
Storage conditions of manure and digestive tract content	High for weeds and nematodes, low for potato wart	Medium	Difficult to achive lethal temperature
Separation of manure and digestive tract content	Low	Medium	Good
Avoidance of specific types of feed for a defined period before transport to the slaughterhause	High	Low	Good
Choice of crop after manure application	Medium	Low	Medium
Composting of manure and digestive tract contents	High for weeds and nematodes, low for potato wart	Medium	Medium

6.1 Storage of manure and digestive tract content

If the temperature in the storage facility is 55°C or more, the viability of the *Avena fatua* seeds will be reduced, decreasing their potential for spread.

Manure storage is unlikely to reduce the probability of spread of *Synchytrium endobioticum.* The information available is insufficient to suggest by how much the risk will be reduced by a certain period of storage.

Manure storage is likely to reduce the risk of spread of PCNs. The cyst nematodes are moderately likely to survive and remain infective after storage of cattle and sheep manure. The PCNs and other cyst nematodes are unlikely to survive in pig manure.

6.2 Separation of manure and digestive tract content

If the manure from slaughterhouses is to be used fresh on agricultural land, the risk of spreading *A. fatua* seed will be reduced, if the Australian practice of disposing the rumen content in a landfill is followed.

Source-separation of manure and digestive tract content are of no importance regarding survival of *S. endobioticum* and PCNs.

6.3 Avoidance of specific types of feed for a defined period before transport to the slaughterhouse

The plant health risk from spread of untreated slaughterhouse manure on the receiving farm could be reduced by avoiding use of animal feed potentially containing plant pests or weed seed during the period prior to slaughter.

Grazing of animals on pasture or feeding animals with uncooked vegetable waste and whole oats in the seven days prior to transport to the slaughterhouse should be avoided to minimize the potential risk for spread of *A. fatua*, *S. endobioticum* and PCNs in the manure at the time of application.

6.4 Choice of crop after manure application

Regarding possible content of *A. fatua* seeds in the slaughterhouse manure applied, the plant health risk will not vary with the type of crop grown the following years after application. In order to limit spread of plant pests, there are strict requirements for the plant health status of seed crops (ref Såvareforskriften).

Avoidance of potato and vegetable crops the year of application of slaughterhouse manure will reduce the risk for spread of *A. fatua*, *S. endobioticum* and PCNs that may survive in the digestive tract and in manure.

6.5 Composting of manure and digestive tract contents

In their terms of reference, the Norwegian Food Safety Authority did not request an assessment on composting of manure and digestive tract contents as a potential risk-reduction option. However, several studies show that composting of manure affects the likelihood of survival of plant pests. Therefore, this option is discussed here.

Weeds: Aerobic windrow composting is an effective method of reducing the viability of weed seeds. Windrow composting is the production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows (windrows). These rows are turned to improve porosity and oxygen content, to mix in or remove moisture, and to redistribute cooler and hotter portions of the pile. A trial with common Nebraska weeds showed 100 % loss of viability after 4-5 months in the windrow, except for *Abutilon theophrasti,* although the temperature in the windrow did not reach 60°C (Eghball and Lesoing, 2000). In a Canadian study both *Avena fatua* and *Polygonum convolulus* seed lost viability after 70 days at a base temperature of 40°C despite of placement in the windrow (Larney and Blackshaw, 2003). Seeds of *Thlaspi arvense* only lost viability in the second year of the trial. Composted swine manure did not increase the abundance of weed seeds in the soil seed bank in a trial in Montana (Menalled et al., 2005). A study from Alberta, Canada showed that, when manure, containing seeds from 12 weed species, including *T. arvense*, *P. convolvulus*, *A. fatua*, and *Chenopodium album* was composted for 4 weeks, all weed seeds lost viability. The windrow maintained a core temperature between 55°C and 65°C for as long as possible (Tompkins et al., 1998). *Rumex obtusifolius* seeds were unable to germinate after 2 months in a windrow with a maximum temperature of 63°C (Zaller, 2007). These results indicate that windrow composting is a reliable method to prevent weed seed in slaughterhouse manure being spread to agricultural land.

PCNs failed to reproduce after eight days of composting, where all material had reached a temperature of minimum 50 °C during the period (Bøen et al., 2006). Hencwe, this can be regarded as a satisfactory method for sanitation of PCN. Data on any effect of composting of manure and digestive tract content on other nematodes, plant pathogens and insects have not been found in the literature search.

7 Uncertainties in the assessment

A major challenge in conducting this assessment and preparing the report has been the scarcity of published research on the survival of weed seeds, plant pathogens and plant pests in the processing of feed and bedding material, in the digestive tract of domestic animals, and in manure. Based on the very limited literature on these subjects, the panel has assessed the probability of pests being associated with the pathway at origin, surviving the various steps of the pathway, and being spread on farms receiving manure from slaughterhouses. The shortage of literature on these subjects has resulted in high uncertainty in most of the assessments made.

In the following text of this chapter, the uncertainties in the different steps of the current Opinion are presented for each chapter. The uncertainties in most of these assessments are high because the scarcity of published research on the subjects.

<u>Identification of pest sources in the animal diet and bedding (Chapter 2.1)</u>

The use of concentrated feed ingredients produced directly on the farm has traditionally been limited in Norway. In recent years, the number of farms using robotic milking systems has increased, and on many of these farms, feeding a total mixed ration (TMR) or a partly mixed ration (PMR) have increased. In TMR or PMR systems, concentrate ingredients can be fed to animals without previous grinding or heat treatment. Home-grown grain of cereals, legumes and rape are used, but the extent of this is unknown. The quality of food wastes and various by-products used in TMR or PMR may vary, but they originate from material of food quality.

The quality of silage and other forages varies considerably among farms. The majority of silage and forage is used at the farm, but trade of baled silage and forage between farms is increasing.

Reliable data on feed and bedding material used in slaughterhouses and in transport vehicles is lacking. However, sawdust or wood shavings are probably used as bedding material, and a concentrate mixture and dry forage (hay or straw) are probably used if feeding is needed at the slaughterhouse prior to slaughtering.

In Norway no systematic survey of pests in animal diet and beeding has been made.

<u>Pest identity and probability of association with the pathway at origin (Chapter 2.2-2.3)</u>

The distribution of regulated plant pathogens, pests and weeds within Norway is well mapped within the country.

To enforce the domestic Regulations on wild oats The Norwegian Food Safety Authority keeps a register of farms with wild oats.

Since the first detection of *Synchytrium endobioticum* in Norway in 1914 all new infection sites have been registred by the Plant Protection Authorities. The eradication of the pathogen during the post-war period has been successful.

The distribution of PCNs has been systematically surveyed during the periods 1955-1999 and 2009-2015. In these surveys, more than 100 000 samples were analysed.

The geographical distributions of non-regulated plant pests within Norway are not well characterized, because few systematic surveys have been made. Furthermore, limited data are available the importance of different plant pests. Therefore, the assumption has been made, that most plant pests considered are present in all areas of Norway where the climate is suitable for the pests and their hosts.

To our knowledge, the species, genera, families and orders mentioned in Section 2.2.6 are the most relevant phytophagous insects and mites found in grasslands in Norway and that are considered as plant pests. However, various other species, including phytophagous ones, belonging to the same or other orders as those already mentioned, will also occur as part of the site- specific biodiversity at each location. It is a possibile that newly introduced species are present in Norway without our knowledge.

If a weed species is well controlled at the origin of the pathway, then very few weed seeds will reach the slaughterhouse with livestock.

As shown in Section 2.1.1, some feed and feed ingredients are imported to Norway (see Appendix II). Import of potatoes and other vegetables for the food industry, hay, cereal straw, bedding materials and whole oats are potential pathways for introduction of plant pests. The current volume of this import is limited. The probability of manure and digestive tract content from slaughterhouses being pathways for introduction of weeds and plant pests due to import from other countries is not within the scope of this opinion, and therefore import commodities are not considered in the current report.

The quarantine pests *Ralstonia solanacearum* on potatoes and *Xanthomonas translucens* pv. *translucens* in cereals and grasses are examples of pests that might potentially be introduced by such import. To date neither pest have been detected in Norway, but they would be of considerable concern if introduced and spread.

<u>Survival in feed and bedding material (Chapter 3.1)</u>

It is well documented that weed species with hard seed coat may survive the ensiling process, but data from systematic comparisons between seeds with different level of seed hardiness are lacking.

Grass bales wrapped in polyethylene are the most common way to make silage. Information about the effect of this method of ensiling on weed seed survival is lacking.

The main dock species in Norway is *Rumex longifolius*, although closely related to *R. obtusifolius*, it is unknown whether *R. longifolius* seeds are destroyed by ensiling.

There is limited information available on survival of specific plant pathogens during the preparation and storage of feed and bedding. Studies on survival of plant pathogens in hay were not identified in the literature search.

Studies on the survival in of plant pathogenic bacteria and viruses, and of phytophagous insects and mites in the storage or processing of feed and bedding material were not identified in the literature search.

Information on the survival of cyst nematodes in ensilage and haylage is lacking.

<u>Survival in the digestive tract of domestic animals (Chapter 3.2)</u>

Significant year-by- treatment interactions can be expected, indicating that factors that vary between years, e.g. weather conditions might affect weed seed survival.

In ruminants, much of the digesta volume is in the rumen where the survival of weed seeds is likely. Rumen content will constitute a significant part of the waste from slaughterhouses.

There is limited information available on the survival of plant pathogens in the digestive tract of animals. There is not enough information available to make conclusions for specific animal species.

The literature search did not identify specific studies on the fate of plant-pathogenic bacteria and viruses in the digestive systems of animals.

There is limited information available on the survival of plant-parasitic nematodes in the digestive tracts of animals.

The literature search was negative for specific studies on the fate of insects or mites in the digestive system of animals.

<u>Survival during manure storage (Chapter 3.3)</u>

The content and treatment of manure (such as storage conditions and storage period) might influence the conditions in the manure, and thus the survival of the different plant pests. The various factors and conditions vary both between and within manure storage. Statistics on the content and handling of slaughterhouse manure by the slaughterhouses and the receiving farms are lacking.

The literature search identified very few publications on weed seed viability in manure apart from some of the effects of windrow composting and anaerobic digestion in connection with biogas plants.

The temperature achieved in manure storage is probably a crucial factor regarding how effectively seeds of different weed species are killed. The temperature probably varies both between and within manure storage systems. The uncertainty remains high regarding weed seed survival, if a sufficient temperature cannot be guaranteed and reproduced every year. Only hard seeds e.g. from *Fallopia convolvulus* are able to survive storage and processing of forage, passage through the digestive tract, and high temperature in manure storage. *Polygonum convolvulus* is used as a model species and therefore included in several studies. More detailed data on survival of other species that are able to survive are missing.

Information on the survival of most plant-pathogenic fungi, viruses or bacteria in manure is lacking. Furthermore, little information is available regarding the effect of storage time at different temperatures on survival of these pests.

The effect of manure storage on the survival of nematodes has been described in only a few reports, and in one of these studies the duration of manure storage was not reported.

<u>Probability of spread of pests (Chapter 4)</u>

No studies of the spread of plant-pathogenic bacteria and viruses by animal manure were identified in the literature search.

The probability of spread of plant pests with slaughterhouse manure and content of the intestine tract from domestic animals depends on the probability of association with the pathway at origin (Chapter 2), and the probability of surviving the different steps of the pathway (Chapter 3). Thus, all the uncertainties previously listed in this chapter are also relevant here.

The probability of spread also depends on the probability of the pest establishing on the receiving agricultural area. Some assumptions are made that affect the uncertainty of this part of the assessment:

1. It is assumed that the crops grown in the receiving areas are similar to those grown at the area at the origin of the pathway (the area where plants for feed or bedding were grown).

2. It is assumed that the agricultural practices and control measures are similar at the receiving area and at the origin of the pathway. Thus, the availability of host plants and conditions in the receiving agricultural areas are therefore not considered to restrict the probability of establishment of plant pests if they are viable in the slaughterhouse manure applied to the receiving land.

3. Although there might be some differences in climatic conditions between the receiving agricultural area and the area at the origin of the pathwayin most cases it is assumed that differences in climate will have an insignificant influence on the probability of establishment of plant pests in the receiving agricultural area. Climatic conditions are therefore not considered in our assessment.

Pests resulting in negative consequences (Chapter 5)

As previously stated, the geographical distribution of most plant pests within Norway is not well characterized, due to the lack of systematic surveys.In addition, few data are available on thei importance of the various potential plant pathogens, with the exception of potato ring rot, which is a quarantine disease under official control. It is assumed that the pathogens considered here occur in all areas of Norway where the climate is suitable for the pathogen and its hosts. It is in those cases where a pest is not present, or is present at only low prevalence, typically quarantine pests, that the negative consequences of spread could be significant.

8 Answers to the terms of reference

The Norwegian Food Safety Authority requested VKM to provide an opinion on the probability of plant pathogens, pests and weeds being spread to new agricultural areas if digestive tract content and manure originating from slaughterhouses were applied untreated onto agricultural fields.

VKM was also asked to specify which plant pests and weeds would pose practical and/or economic consequences if spread.

Specified questions:

1. Sources of plant pests and weeds

   To what extent are feedstuffs, bedding materials, pasture etc. possible sources to plant pests and weeds in slaughterhouse manure?

In production of concentrate ingredients, except for whole oat for horses, the combination of hammer milling, high temperature and mechanical workload created during the heat-treatment processes (steam pelleting or expander pelleting) is likely to kill microorganisms, insects, mites and nematodes and destroy the germination abilities of seeds. Whole oats are used untreated in horse feed, and plant pests might survive in this concentrate.

Weeds: In forages, harvesting of grass at early stages of maturity reduces the probability for viable weed seeds in the forage. The probability of survival of seeds increases when harvesting is at a later stage of maturity. The ensiling process reduces viability of many weed seeds, although not all. Survival of weed seeds in bedding material is only expected when straw is used. When whole oat is used as horse feed, the survival is likely. Survival in other feed is moderately likely. Species with hard seed coat might survive, but systematic comparable data between seeds with different level of seed hardiness are lacking.

Plant pathogenic fungi, oomycetes and protozoa: Plant pathogenic fungi are likely to survive in non-treated concentrates, such as whole oat and home-grown cereals, grain legumes, and rapeseed. Plant pathogenic fungi, oomycetes and protozoa are likely to survive in stored potatoes and root vegetables, food waste and in straw and hay. Plant pathogenic fungi are moderately likely to survive in silage and haylage.

Bacteria and viruses: Plant pathogenic bacteria and plant pathogenic viruses are unlikely to survive ensiling and haylage. Plant pathogenic bacteria and plant pathogenic viruses are likely to survive in hay and straw used as feed or bedding material.

Nematodes: PCNs (*G. rostochiensis, G. pallida*) are moderately likely to survive ensiling for silage and haylage. All cyst nematodes are likely to survive storage of bedding material like haulm. *Anguina* spp, *Ditylenchus dipsaci*, *Punctodera punctata*, *Heterodera avenae, H.*

filipjevi, *G. rostochiensis* and *G. pallida* are all likely to survive storage in hay. Potato rot nematode (*D. destructor*), root lesion nematode (*Pratylenchus* spp) and root knot nematode *Meloidogyne hapla* are likely to survive storage of tubers. PCNs are likely to survive in contaminated soil.

Insects and mites: Hay is too dry for insects and mites, and they will either escape from the harvested material or die as the material dries. Untreated root vegetable waste or potatoes may contain living insect larvae when fed to animals.

2. Spread

- To what extent can digestive tract content and manure from slaughterhouses contribute to the spread of plant pests and weeds to new agricultural areas? Will the risk depend on the species (cattle, sheep/goat, horses, and pigs)?

Weeds: Seeds from broad-leaved *Rumex* species, *Chenopodium album and Fallopia convolvulus* are likely to survive passage through the digestive tract of animals. Seeds of *Avena fatua* and *Thlaspi arvense* are moderately likely to survive in the digestive tract. The probability of survival of weed seeds in faeces is highest in horses, followed by large ruminants, small ruminants, and then pigs. The temperature in manure storage is crucial for the efficiency of killing weed seeds. It is moderately likely that weed seeds will lose their viability in manure storage. In manure storage in which temperature reaches 55°C, seed viability is destroyed.

Fungi and protozoa: *Plasmodiophora brassicae, Spongospora subterranea*, *Synchytrium endobioticum, Verticillium dahlia and V. albo-atrum* are likely to survive passage through the digestive tracts and during manure storage.

Bacteria and viruses: It is unlikely that plant pathogenic bacteria and viruses survive in the digestive tract and during manure storage.

Nematodes: PCNs and the cereal and grass cyst nematodes are moderate likely to survive and remain infective after passage through the alimentary canals of cows and sheep and remain infective after storage in manure. The PCNs, and the cereal and grass cyst nematodes are unlikely to survive and remain infective after storage in pig manure.

Insects and mites: Phytophagous insects and mites are unlikely to survive the process of chewing and digestion should they be ingested by a grazing animal, and it is unlikely they will survive in stored manure.

3. Effect of risk reduction options

- To what extent will storage of digestive tracts content and manure from slaughterhouses reduce the risk of spread of plant pests and weeds?

If the temperature in the storage facility is 55°C or more, the viability of the *Avena fatua* seeds will be reduced, decreasing their potential for spread.

Storage of manure and digestive tract content is unlikely to reduce the spread of *Synchytrium endobioticum.*

Storage of manure and digestive tract content is likely to reduce the spread of PCNs. The cyst nematodes are moderately likely to survive and remain infective after storage of cattle and sheep manure. The PCNs and other cyst nematodes are unlikely to survive in pig manure.

- To what extent will source-separation of manure and digestive tract content reduce the risk of spread of plant pests and weeds if only the manure fraction is applied untreated on agricultural land?

When manure from slaughterhouses is to be used fresh on agricultural land, the risk of spreading *A. fatua* seed will be reduced, if the Australian practice of disposing the rumen content in a landfill is followed.

Source-separation of manure and digestive tract content will not affect survival of *S. endobioticum* and PCNs.

- Can the risk of spread be reduced if vegetable waste potentially containing plant pests or weeds is avoided as feed during the last period before slaughter (specify for different animal species and period before planned transport to slaughtering)?

The plant health risk from spread of untreated slaughterhouse manure on the receiving farm can be reduced by avoiding use of animal feed potentially containing plant pests or weed seed during the period prior to slaughter.

Grazing of animals on pasture or feeding animals with uncooked vegetable waste and whole oats in the seven days prior to transport to the slaughterhouse should be avoided, to minimize the potential risk for spread of *A. fatua*, *S. endobioticum* and PCNs in the manure.

- Does the risk of spread vary with the type of crop grown the following years after application?

Regarding possible content of *A. fatua* seeds in the slaughterhouse manure, the plant health risk will not vary with the type of crop grown the following years after application.

Avoidance of potato and vegetable crops the year of application of slaughterhouse manure will reduce the risk for spread of *A. fatua*, *S. endobioticum* and PCNs that may survive in the digestive tract and in manure.

9 Data gaps

In this chapter, areas of lack of knowledge and/or data related to the risk assessment are described. All data gaps described in table 16 were identified during the risk assessment.

Table 16. Data gaps identified during the risk assessment.

Data gaps	Consequences associated with lack of data (For VKM, the Norwegian Food Safety Authority and society in general)
Little is known about temperature and other conditions important for the survival of plant pathogens and seeds of the most important weed species in haylage stored in plastic wrapped bales, processing of animal feed, passage through the digestive tract, and during manure storage and handling.	Better knowledge in this field will reduce the risk in slaughterhouses and manure of viable plant pathogens and seeds, and make the use of manure from slaughterhouses in agriculture more safe.
Information is scarce on the geographical distribution and economic importance of many of the plant pathogens assessed in the current opinion. Systematic surveys are badly needed.	Knowledge of distribution and importance of plant pathogens and seeds will improve safety measures in handling animals in the slaughterhouse, and the risk of distributing manure to agricultural land.
Statistics are lacking on the amount of homegrown concentrates, by-products and waste from the food industry and groceries (bread, fruits, vegetables etc.) that are used as animal feed in Norway.	Statistics would make it possible to evaluate more precisely to what extent animal feeds contribute to the spread of plant pests and seeds through slaughterhouse manure and animal manure in general.

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Appendix I

Ratings and descriptors

Ratings and descriptors are modified from Appendix E in: EFSA PLH Panel (EFSA Panel on Plant Health), 2015. Scientific Opinion on the risks to plant health posed by *Xylella fastidiosa* in the EU territory, with the identification and evaluation of risk reduction options. EFSA Journal 2015; 13(1):3989, 262 pp. doi:10.2903/j.efsa.2015.3989

Table AI-1. Rating of probability of association with the pathway at origin

Rating	Descriptors
Unlikely	The likelihood of association would be low because the pest: • prevalence is zero or low; • does not feed on or attack the respective host plant(s) by the time of harvesting and/or grazing; • does not carry mature seeds by the time of harvesting and/or grazing; • escapes the harvester and/or grazing animal by active migration (winged insects);
Moderately likely	The likelihood of association is considered moderate because the pest: • prevalence is moderate; • feeds on or attack the respective host plant(s) by the time of harvesting and/or grazing, but the pest population size is currently moderate; • carries moderate amounts of mature seeds by the time of harvesting and/or grazing; • partly escapes the harvester and/or grazing animals by active migration (winged insects);
Likely	The likelihood of association would be high because the pest: • prevalence is high; • feeds on or attack the respective host plant(s) by the time of harvesting and/or grazing, and the pest population is at its peak; • carries large amounts of mature seeds by the time of harvesting and/or grazing; • does not escape the harvester and/or grazing animal by active migration (less mobile species of insects and mites or immobile and less mobile life stages of insects and mites);

Table AI-2. Rating of the probability of survival

Rating	Descriptors
Unlikely	The likelihood of survival is considered low because: • the pest is particularly sensitive to the exposing conditions; • the conditions are highly unfavourable compared to the tolerance of the pest; • the exposure time is very long compared to the tolerance of the pest;
Moderately likely	The likelihood of survival would be moderate because: • the pest is moderately sensitive to the exposing conditions; • the conditions are moderately unfavourable compared to the tolerance of the pest; • the exposure time is moderately long compared to the tolerance of the pest;
Likely	The likelihood of survival would be high because: • the pest is insensitive to the exposing conditions; • the conditions are not unfavourable compared to the tolerance of the pest; • the exposure time is short compared to the tolerance of the pest;

Table AI-3. Rating of the probability of establishment

Rating	Descriptors
Unlikely	The likelihood of establishment would be low because: • of the limited availability of host plants; • the unsuitable environmental conditions over the majority of the risk assessment area; • the occurrence of other obstacles preventing establishment;
Moderately likely	The likelihood of establishment would be moderate because: • hosts plants are abundant in some areas of the risk assessment area; • environmental conditions are suitable in some areas of the risk assessment area; • only few other obstacles to establishment occur;

Rating	Descriptors
Likely	The likelihood of establishment would be high because: • hosts plants are widely distributed in the risk assessment area; • environmental conditions are suitable in the risk assessment area; • no obstacles to establishment occur;

Table AI-4. Rating of the probability of spread

Rating	Descriptors
Unlikely	The likelihood of spread would be low because: • association with the pathway at origin is unlikely; • survival through the whole pathway is unlikely; • establishment on the receiving agricultural area is unlikely;
Moderately likely	The likelihood of spread would be moderate because: • association with the pathway at origin is moderately likely; • survival through the whole pathway is moderately likely; • establishment on the receiving agricultural area is moderately likely;
Likely	The likelihood of spread would be high because: • association with the pathway at origin is likely; • survival through the whole pathway is likely; • establishment on the receiving agricultural area is likely;

Table AI-5. Ratings used for describing the level of uncertainty

Rating	Descriptors
Low	No or little information or no or few data are missing, incomplete, inconsistent or conflicting. No subjective judgement is introduced. No unpublished data are used.
Medium	Some information is missing or some data are missing, incomplete, inconsistent or conflicting. Subjective judgement is introduced with supporting evidence. Unpublished data are sometimes used.
High	Most information is missing or most data are missing, incomplete, inconsistent or conflicting. Subjective judgement may be introduced without supporting evidence. Unpublished data are frequently used.

Appendix II

Imported feed and bedding as source of pests into the pathway

Norway does not import animals for slaughter in domestic slaughterhouses. Under the Governments current policy, animal import is not a pathway for introduction of plant pests and weed seeds from foreign countries. Changes in that policy may open new pathways for introduction of alien plant pests and weed seeds.

Import of hay, cereal straw, bedding materials and whole oats are potential pathways for introduction of plant pests and weed seeds. The current volume of this import is very limited.

The hay import in 2014 represented only 0.8% of the domestic production, and the limited import of hay originated in neighbouring countries: Sweden (18 600 tonnes), Denmark (1 500 tonnes), Finland (400 tonnes), Lithuania (400 tonnes), while there was less import from the Netherlands and Germany (SSB). The import of cereal straw in 2014 was very limited and originated in neighbouring countries: Denmark (500 tonnes), Sweden (200 tonnes) and Finland (200 tonnes) (SSB).

Import of whole oats has a significant volume. In 2014 the oats import, excluding seed for planting, corresponded to 8.1% of the domestic production. The major exporting countries were Finland (8 400 tonnes), Sweden (8 300 tonnes), Estonia (5 100 tonnes) and Denmark (3 300 tonnes), while the oats import from Lithuania, the Netherlands and Germany was more limited (SSB).

Import of plant carbohydrates and plant proteins as raw materials for domestic production of concentrates have significant volumes. As the production process kills plant pests and weed seeds, this import is not a pathway for introduction of plant pests and weeds.

The risk of introduction of plant pests and weed seeds with the pathways import of hay, cereal straw, bedding materials and oats is not considered in this assessment.