Supply chain losses due to animal feed contamination:

scenario analyses for dairy and meat processing industries

MSc thesis
Business Economics Group
Wageningen University, the Netherlands

(L.A.) Alex van Andel

Registration number
850505 014 060

Examinator
Prof. Dr. Ir. A.G.J.M. Oude Lansink
Business Economics Group, Wageningen University

Supervisors
Dr. M.P.M Meuwissen
Business Economics Group, Wageningen University

Prof. dr. H.A.P. Urlings
Animal Nutrition Group, Wageningen University

Ir. C.L.H. Engel
Risk & Insurance Management, ABN AMRO

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Contents

Samenvatting

Contaminatiecrisissen in recente jaren hebben de discussie met betrekking tot de aansprakelijkheid in de voedselketen doen oplaaien. Verwerkende bedrijven eisen van leveranciers dat ze adequaat verzekerd zijn. Het is echter onduidelijk wat de schades in de voedselketen bij een contaminatiecrisis daadwerkelijk zijn. Doel van dit onderzoek is om voor zuivelbedrijven, varkensslachterijen en pluimveeslachterijen de directe en indirecte schades in kaart te brengen.

Directe schades voor verwerkende bedrijven zijn in dit onderzoek de waarde van de gecontamineerde producten en destructiekosten. Indirecte schades zijn schades door niet gecontamineerde producten die retour komen, schades door grenssluitingen of klantstakingen en schades doordat teruggevochten moet worden in (export)markten.

Een rekenmodel is gemaakt om de schades voor de verschillende scenario's in kaart te brengen. Parameters van scenario's verschillen in het aantal gecontamineerde primaire bedrijven en de duur van de contaminatiecrisis. Het meest waarschijnlijk scenario (most likely) heeft 220 gecontamineerde bedrijven per sector waarbij gecontamineerde producten voor 7 dagen worden verwerkt. Best case- en worst case scenario's zijn berekend met respectievelijk 12 en 737 gecontamineerde bedrijven en 1 dag en 30 dagen durende crises (Tabel 0.1).

Literatuuronderzoek toont aan dat schades bij contaminatiecrisissen in het verleden lagen tussen 0 en 132 miljoen euro. Veel schades zijn echter niet bekend of niet gekwantificeerd. Ook kunnen veel schades niet worden toegewezen aan ketenschakels, sectoren en type schade.

Het most likely scenario van dit onderzoek resulteert in een directe schade van 20 miljoen euro (contained) en 29 miljoen euro (widespread) per crisis. Deze directe schades zijn berekend met inschattingen van verwerkende bedrijven over het aantal betrokken verwerkingslocaties per scenario en publieke gegevens over productiewaardes van verwerkingslocaties. Uit de resultaten blijkt dat het aantal gecontamineerde primaire bedrijven de grootste invloed op het aantal betrokken verwerkende locaties heeft. De duur van de contaminatiecrises heeft echter de grootste invloed op de totale schade per crisis. Schades van de voedselketen inclusief voerleveranciers, primaire- en verwerkende schakel zijn berekend tussen 25 en 34 miljoen euro in het most likely scenario (Tabel 0.1)

Met bedrijfsspecifieke gegevens zijn directe in indirecte schade berekend van de bij dit onderzoek betrokken bedrijven. Directe schades in het best case scenario zijn 3%(best case) en 259% (worst case) van het most likely scenario. Indirecte bedrijfspecifieke schades zijn 34% (most likely) en 105 (worst case) van de bedrijfsspecifieke directe schades (Tabel 0.1)

Tabel 0.1: Overzicht berekende scenario's en resultaten

	Most likely	Best case	Worst case
Scenario description			
Number of contaminated farms	**659**	**37**	**2210**
• Dairy farms	199	11	688
• Hog farms	150	8	503
• Broiler farms	72	4	241
Duration[A]	**7**	**1**	**30**
Processing sites affected[B]			
• Contained	4	1	4
• Widespread	6	2	11
Direct supply chain losses (million euro)			
Feed and farm level[C]	5	0.2	18
Processing companies:			
• Contained	20	1	84
• Widespread	29	1	230
Total per crisis	**25-34**	**1**	**102-248**
Direct and indirect losses of processing companies (index)[D]			
Direct losses	**100%**	**3%**	**259%**
Indirect losses[E]	**34%**	**-**	**105%**

A: Number of days contaminated feed is produced and number of days contaminated products are processed
B: Processing sites affected include dairy processing, pig slaughterhouses and broiler slaughterhouses (n=3)
C: At feed level: salvage costs – At farm level: destruction of livestock, business interruption and growth disruption
D: Indexes are based on company-specific data (weighted average, n=3)
E: Expressed in % of direct losses

1 – Introduction

1.1 Background

Recent animal feed contamination crises in the Netherlands caused substantial losses in livestock supply chains. Therefore food safety assurance and related losses in case of a contamination of animal feed are increasingly important issues. In the Netherlands there is an increasing concern about feed and food safety after feed contaminations in 1999 (dioxin), 2002 (MPA), 2003 (dioxin), 2004 (dioxin and bone fragments) and 2006 (dioxin). These crises caused substantial losses in the supply chain and raised the issue of increasing the liability insurance cover for animal feed producers. Higher covers in principle enable farmers and processing industries to get a larger share of their losses compensated.

Most feed producers have been unified in recent years in either TrusQ (2003), set up by 6 larger feed producers, or SafeFeed (2005), founded by approximately 68 feed producers. TrusQ and SafeFeed are both founded to improve feed safety through a feed safety programme. All feed producers of TrusQ and SafeFeed are insured individually against liability. In addition, TrusQ members collectively concluded a surplus insurance to insure against liability in the event of e.g. a contamination crisis (Boerderij, 2007-a, TrusQ, 2007). This surplus insurance is effective since January 1, 2006. (TrusQ, 2005). Safe Feed expects to conclude a surplus insurance for its members in the first half of 2008 (Boerderij, 2008).

Processing industries require feed producers and other supply chain partners to be adequately insured. However, uncertainty exists about which chain partners can be hold liable and the extent of the liability insurance cover. If supply chain partners are not adequately insured, they will not be allowed to deliver their products to processing companies in the future. The extent to which chain partners need to be insured seems to be mostly related to losses at the processing industry level. But yet, reality for many stakeholders in the supply chain is that the size and the composition of these losses are not transparent.

In this framework, there is a strong need for quantitative insight into the amount of supply chain losses caused by animal feed contaminations, which is the motivation for this MSc research. This study focuses on the extent of the liability insurance cover related to the losses of processing industries. Previous estimations of supply chain losses due to animal feed contaminations indicate that contaminated compound feed leads to aggregated losses at farm level of on average 5.3 million euro per crisis. This amount ranges from 0.2 million euro to 18 million euro in 5% and 95% percentiles respectively (Van Asseldonk et al., 2006).

Contaminations in animal feed occur irregularly in time and place. Therefore it is difficult to derive general properties and predictive values about the probability of occurrence. The sophisticated quality assurance and tracking and tracing systems, which span the entire production chain, reduce the risk of a feed contamination substantially. However, the risk of contamination of compound and wet feed has not been reduced to zero (Van Asseldonk et al., 2006). This MSc thesis research does not focus on the probability of occurrence, but on the size of the losses that might occur in case of a contamination. In this chapter the insurability of these losses is also discussed.

Meuwissen and Huirne (2006) stated that there is a lot of uncertainty about the (im)possibility to finance losses by means of liability within the supply chain. Furthermore there is no level playing field with regard to restricted liability. Developments with regard to liability seem to increase the chances on both claims and an increased size of these claims. Recent developments are an increased claim culture, increasing accountable losses and increased traceability systems due to improved tracking and tracing programmes (Meuwissen and Huirne, 2006).

1.2 Objectives and research framework

Although the chain liability issue from feed contaminations relates to the whole supply chain, this research focuses on the losses of processing companies only. Losses on the processing industry level will be calculated for dairy, pig and poultry processing companies. More specifically, the objectives are:

(1) To estimate *direct* losses for dairy, pig and poultry processing companies due to a contamination in animal feed;

(2) To estimate *indirect* losses for dairy, pig and poultry processing companies due to a contamination in animal feed.

Losses will be quantified for different scenarios. Parameters of each scenario include the number of contaminated farms and the duration of an animal feed contamination crisis.

This research focuses on the processing or post-harvest part of the supply chain. Objective is to quantify losses of processing companies due to animal feed contaminations in the Netherlands.

As a final step outcomes are integrated with results of other studies to estimate losses for the supply chain from feed level up until the processing level.

Related research questions with regard to the scenarios are:

- How are the internal logistics of processing companies organised? What are the different product streams and how are contaminated products spread within the processing companies?
- What is the value of the contaminated products and the contaminated mixed products?

- How do scenarios affect market shares of processing companies on the various markets in which they operate?

Research framework

This research focuses on scenarios in which a contamination has occurred. It does not say anything about the probability of occurrence of a contamination in animal feed.

Participating companies in this research are dairy processing companies, pig slaughtering companies and poultry slaughtering companies. Involved companies cover at least 25% and up until 80% of the market share in its industry in the Netherlands.

Calculated losses reflect losses for the total markets (dairy, pigs and poultry) in the Netherlands. Assumption is that all contaminated products will be processed by involved companies. No correction for market shares is made, all contaminated farms deliver to involved companies.

1.3 Outline thesis

In chapter 2 the food supply chain is introduced. Paragraph 2.1 covers the complex networks in which numerous intermediate products move from one processing site to another in order to become a final product. Paragraph 2.2 introduces involved industries (dairy, hog and broiler processing industries). In chapter 3 definitions of direct and indirect losses are discussed and distinguished for this research. Chapter 4 covers a literature review on recent contamination crises, including a technical overview (paragraph 4.1) and an overview of the different supply chain losses (paragraph 4.2). Chapter 5 discusses the material and methods used in this research. Construction of scenarios (5.1), data gathering (5.2), the spreadsheet model (5.3) and assumptions (5.4) are reviewed. In chapter 6 the results of the spreadsheet model for direct losses (6.1) and indirect losses (6.2) are presented. In paragraph 6.3 an aggregation to chain losses is made to get insight in the total losses of the supply chain from feed level to processing level in case of a contamination crisis. In chapter 7, conclusions, discussion and recommendations for further research are presented.

2 – Food supply chain

An overview of the food supply chain is presented in this chapter to give insight in the specific food supply chain this research investigates. Focus of this research is put on the dairy, hog and broiler processing industry in the Netherlands.

2.1 Introduction to the food supply chain

The food supply chain is the supply chain in which the food industry operates. The food industry is the complex and global collective of diverse businesses and other stakeholders that together supply the food that is consumed by the world population. To put it simple, the food supply chain is the supply chain in which food flows from field to fork. This however, excludes suppliers who deliver to farmers. Therefore, the food supply chain is usually used in a broad way to cover all stakeholders in the production of food.

A simplified version of a food supply chain this research focuses on is viewed in Figure 2.1. A physical product stream (left arrow) goes from supplier, through all supply chain members, to the final consumer. A money stream (right arrow) flows the other way around from consumer to supplier. In the case of the dairy, pig and poultry supply chain, suppliers deliver raw materials to animal feed companies who deliver their feed to farmers. Farmers feed their cows, hogs or broilers with this feed. Milk, hogs or broilers are delivered from the farmer to the processor, which are selling their products to a retailer. The retailer delivers the products to the final member of the supply chain: the consumer.

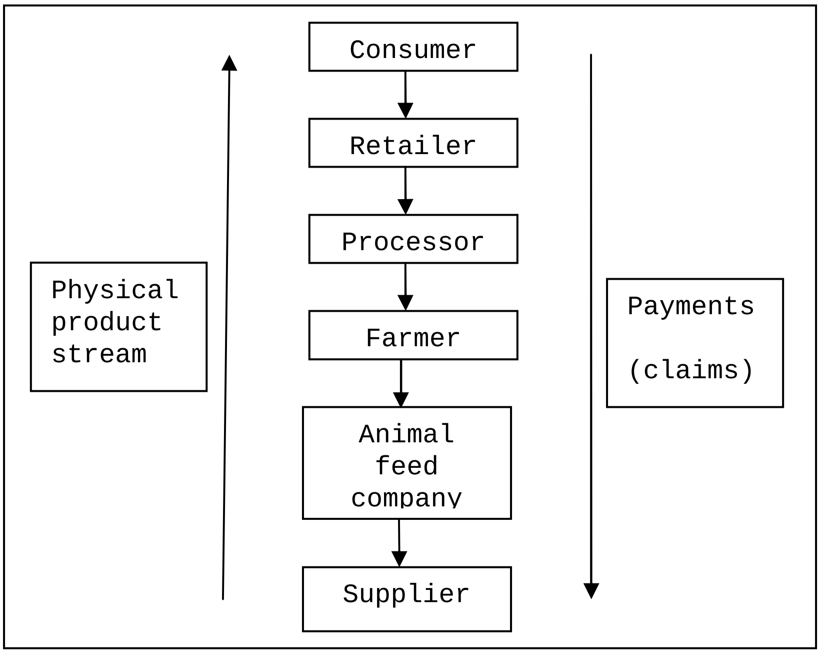

Figure 2.1: Simplified food supply chain.

While the physical product stream goes up in Figure 2.1, payments go down. Payments are made because of the delivery of the physical product. Every next channel in the supply chain assumes delivered products are safe. In case there is something wrong with a product, caused by for example a contamination in animal feed, members in the supply chain might claim their losses (inner arrow Figure 2.1) at the previous supply chain member, the supplier of the contaminated product. With respect to this and the framework of this research, it is of crucial importance to determine the type and size of losses that occur if contaminated products are delivered from farmer to processor. In this research a focus is put on the processing industry in the supply chain. Losses on retail and consumer level are not covered.

Figure 2.1 might imply differently, but food supply chains are complex networks in which numerous intermediate products move from one processing site to another in order to become a final product. The numerous interrelationships between processing sites (and companies) are illustrated for part of the meat and milk supply chains in Figure 2.2. The multiple interrelationships imply that, potentially, contaminated products can easily be mixed with non-contaminated products. Non-contaminated products become contaminated too in this way. In addition, due to the many interrelationships that exist within food supply chains, other parties such as supermarkets and foreign customers might be confused about which specific batches and products are contaminated and which are not. As a consequence they could induce large product recalls.

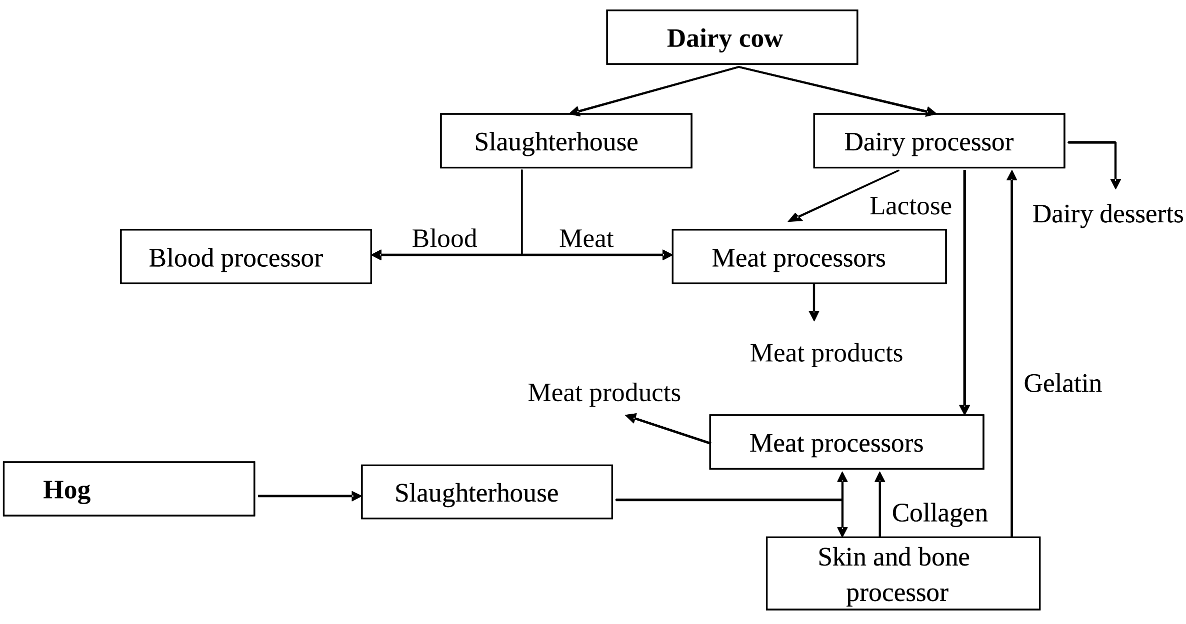

Figure 2.2: Illustration of interrelationships in dairy and meat supply chains (Meuwissen et al., 2008)

Figure 2.2 illustrates that contaminated, mixed-contaminated and perceived to be contaminated are closely related. However, liability insurance schemes only compensate *direct losses*, i.e. costs related to *contaminated* products. It is therefore crucial to strictly define what we mean by contaminated and to define and distinguish direct and indirect losses in this research. Chapter 3 will cover this.

The pork supply chain can illustrate the complexity of dairy and meat supply chains. First of all, the pork supply chain in the Netherlands is self-sufficient. In 2003 the Netherlands was self-sufficient for 227% (Hoste et al., 2004). This indicates that at least 117% of the Dutch pork production is exported if no pork products are imported. This means that at least 50% of an average hog is exported.

There are also big differences in the use of hogs. Percentage of meat used and suitability for human consumption varies between 48% and 68% per hog. There are hogs of 70 kg, but also of 110 kg, and there are all sorts of combinations to classify hogs (e.g. weight, percentage of fat and type). For processors this implicates a gamut of sales markets. There are also important differences in the values of different pork products on the world market. What is of low value on the Dutch market can be of high value in e.g. South Korea and vice versa (Hoste et al., 2004).

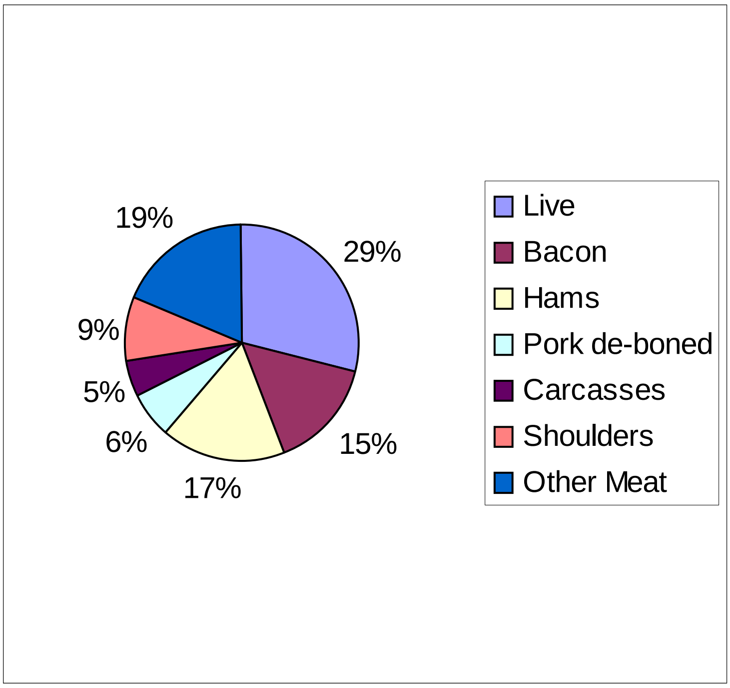

Figure 2.3: The consumer euro – added value in the pork supply chain (data and calculations of Hoste et al., 2004)

Sales value of pork products is not one-on-one linked to production costs in the supply chain. However, Figure 2.3 gives an indication of the costs made in the pork supply chain. Total costs are composed of the price the consumer pays in the supermarket in the Netherlands. It shows the division of costs in the pork supply chain of an average hog of which 25 kg. is sold to a Dutch supermarket. Other revenues (by-products and export) as well as all costs are also taken into account (Hoste et al., 2004). Costs off-farm includes 36%. Slaughterhouses and boning have a 12% share and main part of the consumer euro (Figure 2.3) is in costs of suppliers (e.g. animal feed, breeding) (29%), retail (24%) and prepackers (20%).

2.2 Dairy, hog and broiler processing in the Netherlands

The total Dutch agricultural and food supply chain added value of 21,9 billion euro in 2004. Total size of the Dutch agricultural and food sector was 40,4 billion euro in 2004, 9,4% of the total Dutch economy. The Netherlands is ranked third as the world's largest exporter of agricultural products (Ministry of Agriculture, 2007).

Mainstream livestock supply chains in the Netherlands are characterised by intensive livestock farming, increasing scale of production, large and consolidated processing companies and sizeable exports. From the three supply chains considered in this research: dairy, pork and poultry meat, the number of farms is highest in dairy supply chains, i.e. 22,301 farms (Table 2.1). The number of processing sites is also highest in dairy chains (50). Processing companies jointly process 11,600 million kg milk, 1,283 million kg pork and 884 million kg poultry meat. Average product values at processing level are euro 0.44/kg, euro 1.39/kg and euro 0.79/kg for dairy products, pork and poultry meat products respectively.

Combining production values and number of processing sites, daily production values per site are on average 279.452 euro for dairy processing, 305.395 euro for pig slaughtering and 112.973 euro for poultry slaughtering.

Table 2.1: Farm and processing industry characteristics of dairy, hog and broiler supply chains[1].

	Dairy	Hogs	Broilers
Farm level			
Number of farms	22.301	7.963	674
Animals per farm	61	688	58.394
Annual production	7.417 kg milk/ dairy cow	91 kg[2]/hog 3.05 hogs/place	2.1 kg[2]/broiler 7 broilers/place
Processing industry level[3]			
Production (1000 ton/year)	11.625	1.283	884
Production value (million euro/year)	5.100	1.784	701
Average value per kg (euro)	0.44	1.39	0.79
Number of companies	15	9	15
Number of sites	50	16	17
Average production value per site (euro/day)	279.452	305.395	112.973

[1]Sources: Bunte et al. (2003), Dairy Product Board (2007), LEI and CBS (2007), Animal Sciences Group (2007).

[2]Slaughter weight.

[3]For dairy referring to dairy processing companies and sites. For hogs and broilers referring to slaughtering companies and sites.

Dairy processing in the Netherlands

If we classify the dairy production sites by production output the 50 sites are used for:

- Cheese production (19)
- Consumption milk (11)
- Milk powder (10)
- Butter (5)
- Evaporated milk (3)

Two factories are not classified for production output (Dairy Product Board, 2007).

The distribution of milk production in percentages at the processing industries (Figure 2.4) shows that most milk is processed into cheese (51%). Over 1 billion euro value was added by dairy processors in 2004 (Van Leeuwen, 2006).

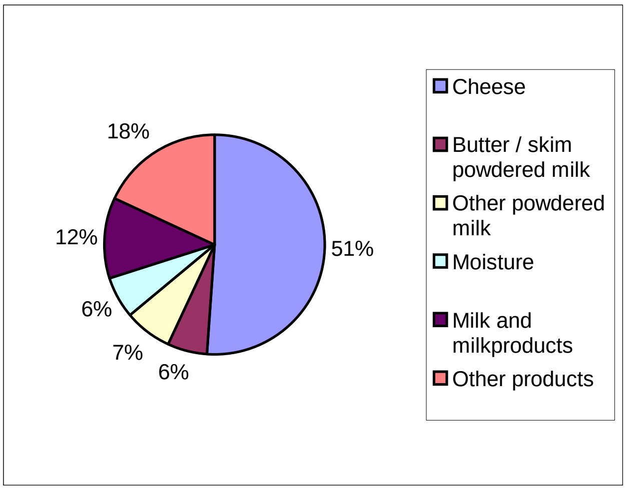

Figure 2.4: Distribution of milk at processing industries in the Netherlands (source: Dairy Product Board, 2007).

Hog processing in the Netherlands

The value of a hog is determined by the value of the carcass. This value depends on the amount of marketable meat, the distribution of this meat into different product streams and the intrinsic quality of the meat. According to Hoste et al. (2004) about 70 kg of the living weight of a hog of 114 kg is used for human consumption. Other parts of a hog consist of, among others, bones (18 kg), intestines (8 kg), organs, hair (1 kg) and blood (4,5 kg). Two kg also dries out after slaughtering of the hog. Furthermore, the carcass of a hog consists of fat, bacon and rind, which can be delivered only partially together with fresh pork meat. Parts of a hog are also not suitable for fresh meat consumption, but are sold for a lower price through other channels than the fresh meat channel (Hoste et al., 2004; Vlaamse overheid, 2006).

In Figure 2.2 the interrelationships within the milk and meat processing industries were shown. In Figure 2.5 is shown how within the hog processing industry several product streams come into existence at time of slaughter. In Figure 2.5 a simplified overview is presented of these different product streams. Even though the figure is simplified, it is clear that all sorts of products originate from a hog (Hoste et al., 2004).

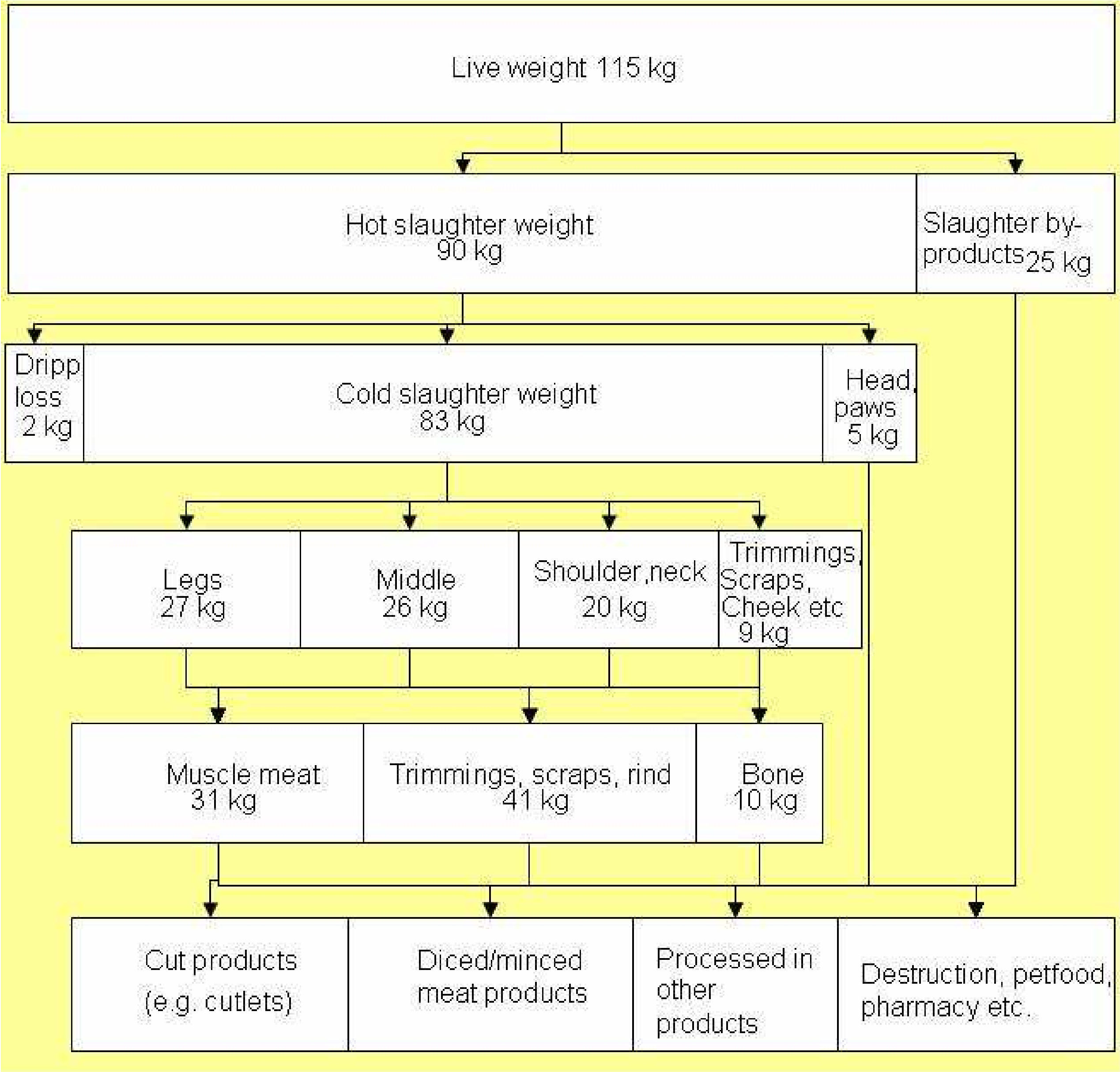

Figure 2.5: Overview of product streams arising at time of slaughter of a hog (Hoste et al., 2004).

In 2005 there were 21 hog slaughterhouses in the Netherlands with more than 25.000 slaughterings a year. In 2004 there were still 24 of these slaughterhouses. Hog slaughterhouses added 690 million euro of value to the Dutch economy in 2004. According to the Product Board for Livestock, Meat and Eggs, in 2006, there were 15 hog slaughterhouses in the Netherlands with more than 100.000 slaughterings a year. Almost half of these (six slaughterhouses) slaughtered more than 1.000.000 hogs a year. The average number of slaughterings increased in 2006 in comparison with both 2004 and 2005 (Product Board for Livestock, Meat and Eggs, 2006; Product Board for Livestock, Meat and Eggs, 2007; Van Leeuwen, 2006).

The slaughter pigs supply chain includes suppliers (including feed producers) up until the slaughterhouses. The slaughterhouses added value of 690 million euro in 2004. (Van Leeuwen, 2006).

Figure 2.6 gives insight in the products streams hog processing companies are exporting. Main export products include live, bacon and ham. These products total 61% of the total export of hog products.

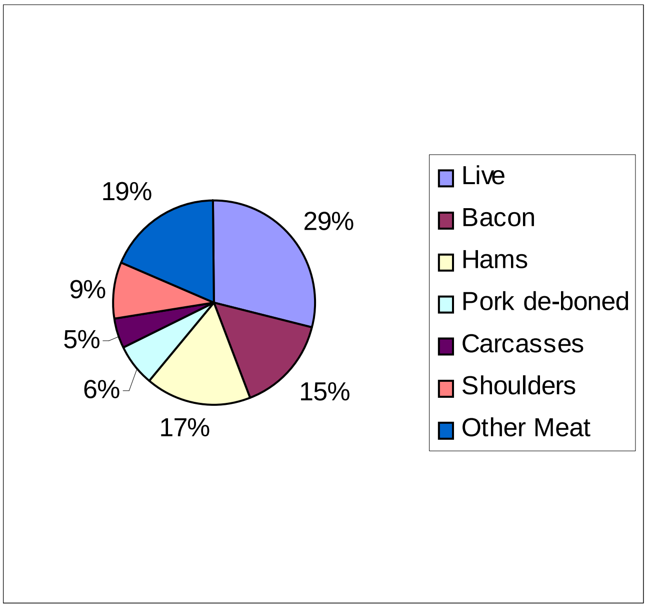

Figure 2.6 Export of product streams of hogs Dutch processing industry (source: Product Board for Livestock Meat and Eggs, 2006).

Broiler processing in the Netherlands

The poultry supply chain include e.g. feed producters, distributors, breeders, broiler farms, farms with laying hens and processors. In 2004, poultry processing companies added value of 230 million euro (Van Leeuwen, 2006).

In 2006 there were 15 broiler slaughterhouses with a supply of over 10.000 ton a year. Five of these slaughterhouses had a supply of over 40.000 ton a year. Average supply went up between 2005 and 2006, but did not compensate for the fact that there were two slaughterhouses (with at least 10.000 slaughterings per year) less in 2006. Therefore, production decreased by 1% in 2006 (Product Board for Livestock, Meat and Eggs, 2007).

3 – Definitions of direct and indirect losses

Due to the occurrence of several animal feed contamination crises in recent year in the Netherlands (see chapter 4) attention is drawn to the risks of such crises. By means of risk-financing instruments associated liability losses can be transferred from feed producers to other parties (insurance industry). Both the insurability of contaminations in animal feed for feed producers as well as the definitions of direct and indirect losses will be discussed in this chapter.

3.1. Literature review on liability

In practice, the originator of a contamination does not always compensate losses. Reasons for this are common law (restricted liability, accountability of losses), the supply chain itself (bankruptcy of firms) and the content of the liability insurance (coverage, maximum amount) (Meuwissen and Huirne, 2006).

Liability risks are, in most cases, insurable risks. With respect to the insurability in the food and agribusiness main characteristics about the current situation are:

- All stakeholders in the chain are in principle insured.
- Participation is not obligatory but directs to 100%.
- Covered liability is both legal and contractual.
- Insurable losses are salvage costs, business losses and human losses. Non-insurable losses are other capital losses and product recall costs.
- Insurable amount is varying from under 5 million euro until above 10 million euro. TrusQ members collectively insured themselves for an amount of 75 million euro per incident
- Maximum coverage is standard twice the insured amount per year (Meuwissen and Huirne, 2006).

With regard to the insurability of product recall in food supply chains, Skees et al. (2001) state that processing firms are not given the right incentives by the market to implement costly, but safer, food production systems. Demand for higher-priced, safer food is not substantial enough to change the behaviour of the majority of the food processing industry. Recall insurance products may be the best method for giving incentives to processing firms to achieve greater food safety standards. Recall insurance products still must cope, however, with problems due to asymmetric information. This is potentially a serious problem in an environment where inspections are lacking in quality and quantity (Skees et al., 2001).

Skees et al. (2001) focus on the situation in the United States of America describe recall insurance products in two categories:

(1) A supplement or endorsement to the general liability policies available to commercial policyholders.

(2) Exclusive product recall policies.

In the United States there are only few insurance products from category two. One of them (from MRM MacDougall Risk Management) categorise losses into four areas:

(1) Recall expenses

(2) Lost gross profit

(3) Rehabilitation expenses

(4) Crisis response

The second category covers loss for “12 months following discovery” or lost profit during a smaller period where “the sales revenue remain less than the level that could have been reasonably projected had the product tampering not occurred” (Skees et al., 2001). Developments show that capital losses that are not related to business losses and human losses are insurable under conditions in the United States. In the current situation in the Netherlands this is not the case.

Van Asseldonk et al. (2005) defined direct and indirect losses on farm level. Direct losses are the value of animals destroyed under depopulation and welfare control measures and the costs of organisation aspects such as the monitoring of farms in restriction zones. Consequential or indirect losses that arise at farm level include business interruption, losses related to established restricted zones, additional repopulation costs, losses from emergency vaccination and price effects (Van Asseldonk et al., 2005).

Business interruption losses are losses due to farm buildings becoming (partly) empty due to stamping out, welfare slaughters or breeding prohibition. Losses related to established restriction zones are losses occurred because farms in restriction zones face periods in which animals and manure can not be transported from the farm. Animal welfare problems, extra feeding costs and emergency measures for housing of pigs and storage of manure are all losses related to established restriction zones. Additional repopulation costs are losses that include extra costs of animal health problems. Losses from emergency vaccination are losses that might arise from above categories in a situation in which vaccinated animals are destroyed. For reasons of social acceptability, the rendering of vaccinated animals is under debate. In future epidemics, meat and milk from vaccinated animals may be destined to the local market, which likely leads to extra costs and/or lower prices. Something similar may apply to animals under welfare slaughter programs. Price effects and corresponding losses relate to aspects as the size of an epidemic, reactions of other countries and whether vaccination is applied (Van Asseldonk et al, 2005).

As discussed in Chapter 2, in case of a contamination in animal feed, contaminated, mixed-contaminated and non-contaminated ("perceived to be contaminated") are closely related. Liability insurance schemes however, only compensate direct losses, i.e. losses related to (mixed-)contaminated products. Therefore, it is of crucial importance to strictly define both direct losses and indirect losses. Contaminated and mixed-contaminated products relate to direct losses, while "perceived to be contaminated" or non-contaminated products and corresponding losses relate to indirect losses (Table 3.1).

Table 3.1: Direct and indirect losses related to contaminated products (processing stage).

Product	Location of products in chain	Direct losses	Indirect losses
Contaminated and mixed products	First processing companies	Destruction, business interruption	-
	Post processing companies, distribution channel, consumer level	Tracking, tracing, notification, destruction, business interruption	-
Non-contaminated products	Distribution channel, consumer level	-	Product recall, returned products, decreased demand, regaining (export) markets

If contaminated products are still in first processing companies, direct losses mainly include costs of product destruction and some business interruption. As soon as contaminated products have been delivered to post processing companies, distribution channels and consumers, direct losses also include risk mitigation costs such as tracking and tracing and costs of notification. Losses related to non-contaminated products, i.e. indirect losses, occur due to for instance product recalls, the returning of products and a (temporarily) decreasing demand. These losses do not include destruction of products but deal with, among others, relocating recalled and returned products and investments needed to regain (export) markets.

3.2. Current study

With respect to the scenarios or this MSc research direct losses are defined as:

- Losses related to the physically contaminated products including mixed-contaminated products.

Direct losses of this research relate to the contaminated products itself and other products that are contaminated because of mixture with the contaminated products. Direct losses mainly contain the value of contaminated products, some company-specific direct losses also include some destruction costs. Direct losses for first processing companies are included (destruction and business interruption), direct losses for post processing companies are not included (Table 3.1)

Contaminated milk that is mixed with uncontaminated milk in a storage tank at a dairy processing site is considered as totally contaminated milk and as direct loss in this research. The direct losses as defined here are in practice considered to be insurable losses.

Indirect losses for this research are defined as:

- Losses not directly related to the stream of physically contaminated products.

Indirect losses of this research include returned products, decreased demand and regaining export markets. Product recalls are not included (Table 3.1).

Examples of indirect losses as defined for this research are non-contaminated products that are returned by customers of processing companies, losses that due to border closures and losses due to processing companies that need to regain parts of their export markets after a contamination crisis. The indirect losses are of course also caused by a contamination in animal feed and are a consequence of this. However, these losses are indirect because the losses are not directly related to the physically contaminated product stream. Indirect losses as defined here are in practice considered as non-insurable losses.

4 – Literature review on previous contamination crises

A literature review is carried out in order to map the type and size of losses for the different stakeholders in the supply chain that occurred in recent crises. The whole food supply chain, including the processing industries, is reviewed.

Two types of crises are studied: contamination crises and livestock epidemic crises. Contamination crises are discussed in this chapter since scenarios in this research relate to such crises. Although the size of losses of livestock epidemics are not comparable with losses of contamination crises, the type of losses in such crises might be similar. After the literature review on livestock epidemics, it appeared that contamination crises and livestock epidemic crises differ too much. Therefore, the review on livestock epidemics is put in Appendix 1.

In this chapter a technical description of previous contamination crises is presented in paragraph 4.1. The type and size of losses of recent contamination crises are investigated. In paragraph 4.2, losses are subdivided into losses on the feed level, on the farm level and on the processing level. In addition, losses are subdivided into direct and indirect losses. A distinction between losses per sector (dairy, pigs and poultry) is also made.

4.1 - Previous contamination crises

Several feed crises have occurred in The Netherlands ranging from the dioxin crisis in 1999 to another dioxin crisis in 2006. Technical descriptions of these crises are presented in this paragraph. Focus is put on the number of primary producers affected and the duration of the crises. A distinction between the feed sectors affected (compound and/or wet feed) is also made.

4.1.1 Technical description

Dioxin 1999

In January 1999, at the Flemish fat-melting company Verkest, 40-50 kg of mineral oil containing polychlorinated biphenyls (PCBs) was admixed to fat delivered to ten animal feed producers. Between January 15 and 31, animal feed containing fat contaminated with PCB and dioxins was distributed to poultry farms and to a lesser extent also to rabbit, calf, cow and pig breeding and raising farms. Most farms were located in Belgium, but distribution took also place to farms in The Netherlands, France and Germany. The contamination was detected because of a decrease in egg production and hatching together with an epidemic of chicken edema disease (Van Larebeke et al., 2001). The crisis related to compound feed (no wet feed) and pig, cattle and poultry sectors were all confronted with the contamination. (Van Asseldonk et al., 2006).

In Belgium around 200 farms were put in quarantine and products of primary producers were destroyed. Also, 93.148 ton of meat was destroyed, of which 45.000 ton of pig meat and 12.500 ton of poultry meat (Houins, 2007).

MPA 2002

On June 27, 2002, the Dutch government declared that on three sow farms MPA (Medroxy Progesterone Acetate) was discovered in raw materials of wet mixes and slaughtered sows. Because of fertility problems on 3 sow farms since May 2002 research was done to see if something was wrong with the animal feed. This appeared to be a contamination with MPA. Source of the contamination was the Irish glucose syrup producer Wyeth Medica Ireland, which exported a dangerous waste stream as a not dangerous stream. The Belgian company Bioland imported the waste stream and delivered the MPA-contaminated syrup to both compound feed producers as well as to primary producers (pig farms). From these companies the contaminated products were further distributed through the supply chain (Product Board Animal Feed, 2002-b). In consultation with the Dutch Ministry of Agriculture, the Dutch Association Animal Feed Industry and supply chain partners, the European Commission ordered a recall of all compound feed contaminated with MPA through melasse (Product Board Animal Feed, 2002-a).

Several companies at the beginning of the supply chain bought raw materials from companies that did not apply to GMP+ quality standards (Product Board Animal Feed, 2002-b).

The period in which contaminated feed was produced is not clear since the contamination was quite diffuse. Numerous companies, producing both compound feed as well as melasse, were involved. The duration in which contaminated compound feed was produced was up to six weeks. For wet feed the period that contaminated feed was produced is not clear. Both compound feed and wet feed producers were involved. Agricultural sectors involved were the pig and cattle sector (Product Board, 2002-b)

Due to instructions of the Ministry of Agriculture a total of 73.000 pigs were destroyed during the MPA crisis (Eindhovens Dagblad, 2004).

Dioxin 2003

On February 12, 2003 the Dutch food supply chain faced a dioxin contamination in bread meal. The German company Trockenwerk Thüringen GmbH exported contaminated bread meal since December 2002 to Velthof Veevoeders BV and it was spread to four compound feed producers and one farmer. On February 12, two tracks of the contaminated bread meal were known. As a result of this, 237 cattle farms were blocked on February 14, 2003. Farms with pigs, minks, ducks and cows (no dairy farms) were involved. Based on results of test slaughters a cluster of companies was unblocked from February 24 till March 6. At the end of March 2003 the final eight blocked farms (with sows and piglets) were unblocked (Product Board Animal Feed, 2003).

In the 2003 dioxin crisis one animal feed producer bought raw material from a not GMP certified company. The four involved compound feed companies did buy their raw material from a (at that moment) GMP certified company (Product Board Animal Feed, 2003).

The period in which contaminated feed was produced was from the end of December until the end of January. The feed sector involved in the 2003 dioxin crisis was the compound feed sector. Agricultural sectors affected were the pig-, cattle- and poultry sectors.

Dioxin 2004

In October and November 2004 the Dutch feed sector was confronted with a contamination of dioxin in potato by-products coming from the potato processing industry. On October 22 the Food and Consumer Product Safety Authority reported an increased level of dioxin in a sample of milk. Cause was the potato processing industry using potato-sorting soil, originating from Germany, which proved to be 'naturally' contaminated with dioxin (Product Board Animal Feed, 2005-a).

On October 25, transport of all animals and products derived from animals of two dairy farms, including the one from the contaminated sample, were blocked. These two primary producers bought the same potato by-products from the same supplier from the same location; McCain in Lelystad. Between October 22 and November 19 a total of 196 farms were blocked. These are all cattle farms that bought potato by-product from one of the three production locations of the potato processor in question; McCain (Product Board Animal Feed, 2005-a).

Because of precautionary measures, milk of about 50 involved dairy farms was stored separately during the blockade period, awaiting further test results (Agrarisch Dagblad, 2004-a; Product Board Animal Feed, 2005-a). Animal feed producers involved in the 2004 dioxin crisis were wet feed producers. Agricultural sectors affected were both the pig and the cattle sector (Product Board Animal Feed, 2005-a; Van Asseldonk et al., 2006).

Bone fragments 2004

In November and December 2004 the Dutch animal feed sector faced a number of positive analysis results of bone fragments in German beet pulp. An early warning signal (EWS) was issued in order to alert all stakeholders involved regarding this issue in the beginning of November 2004. Earlier, on October 20, 2004, the Irish government reported about bone fragments in German beet pulp. Because the Food and Consumer Product Safety Authority (VWA) did not pass this announcement to the Product Board Animal Feed, this message reached the Product Board Animal Feed only at November 5. At the same time, the Product Board Animal Feed received a report of similar nature from the raw materials trade sector. As a consequence companies involved responded by intensifying the inspection on the delivery of German beet pulp. Result of this was a number of positive results on bone fragments in the course of November 2004 (Product Board Animal Feed, 2005-b).

The incident with bone fragments was discovered at the very beginning of the food chain. This allowed the companies involved to take adequate measures at an early stage. Because of this there were no losses for subsequent links. As a result no positive batches were sold en no compound feed producers were affected (Product Board Animal Feed, 2005-b). Wet feed sector and the compound feed producers were both involved but no primary producers were affected.

Dioxin 2006

On January 24, 2006 the Dutch feed production chain faced a dioxin contamination in pig fat from Belgium. The contamination was identified through an increased level of dioxin in a sample taken at December 15, 2005 from a storage tank of compound feed company Bouman B.V. in Andel. As a results of this 275 farms were blocked. All blocked farms purchased feed of Bouman B.V. in which an increased level of dioxin was determined. The Food and Consumer Product Safety Authority (VWA) carried out test slaughters to determine if the dioxin level in the meat was exceeded. It appeared that in some cases the dioxin level was exceeded. By one individual farm the potentially contaminated hogs were taken out of the food supply chain. On February 7, Vion and 12 involved pig farmers decided to take all hogs of more than 50 kg (7.700 hogs on total) out of the supply chain. These 12 farms possessed pigs that contained such a dioxin level that they could not be sold to the consumer market (Product Board Animal Feed, 2006). The pigs of less than 50 kg were not taken out of the market, because the level of dioxin at the time of slaughter would be below the EU-limiting value (RIVM and RIKILT, 2006). Last farms were released on February 10, 2006.

Duration of the dioxin 2006 crises from discovery of the contamination until the date last farms were released was 17 days (Food and Consumer Product Safety Authority, 2006; Product Board Animal Feed, 2006). Compound feed producers were the only producers involved. Sectors affected were the pig, cattle and poultry sector.

4.1.2 Key characteristics

In Table 4.1 the key characteristics of discussed contamination crises can be found. The number of primary producers affected, duration of the crisis in days and the type of animal feed producers involved distinguish the different crises. Duration of the crisis in Table 4.1 relates to the period contaminated feed was produced. This is the period contaminated feed was spread throughout the supply chain. In other words the time between discovery of a contamination and the moment last blocked farms were released. The duration of the crises is further specified in Table 4.1.

Table 4.1: Key characteristics of recent contamination crises.

	Number of primary producers affected	Duration of crisis (days)	Sectors involved	
			Compound feed	Wet feed
Dioxin 1999	1821	15[A]	X	-
MPA 2002	685	≤42[B]	X	X
Dioxin 2003	237	≤49[B]	X	-
Dioxin 2004	196	29[C]	-	X
Bone fragments 2004	0	0 [A]	-	X
Dioxin 2006	275	17[C]	X	-

A: Days contaminated products were spread throughout the chain.
B: Days contaminated feed was produced.
C: Days between discovery of contamination and release (unblocking) of last farms.

4.2 Supply chain losses

In this paragraph supply chain losses of contamination crises, that were described in paragraph 4.1 are reviewed. Paragraph 4.1 and Table 4.1 showed that technical information on contamination crises, such as the number of farms affected, is easily accessible. However, details on losses occurred are hardly available (Table 4.2). In addition, if losses are found it is hard to quantify them or to classify them in direct vs. indirect losses or to different sectors (Table 4.3). All information found on supply chain losses is presented in this paragraph.

Dioxin 1999

Production value of the Belgian agriculture in 1999 decreased with 500 million euro in comparison with the five previous years. Total financial damage of the dioxin crisis in 1999 in Belgium was estimated at 437 million euro. Products of primary producers were destroyed for an amount of 250 million euro. The image of all Belgian food was damaged. The consequences of the crisis were large with regard to trade relations of Belgium with several countries. Bans on Belgian products were imposed (Houins, 2007).

For Dutch processing industries the 1999 dioxin crisis also had financial consequences. Dairy processor Campina Melkunie suffered a loss of 13,6 million euro in 1999 because of the dioxin crises. The result of dairy processor Friesland Coberco decreased with 18,1 million euro in 1999 (Kingmans, 2000). Dutch agricultural cooperation Cebeco, owner of poultry processor Plukon, reported a lower profit of 6.8 million euro because of the dioxin crisis (Cebeco, 2000; De Telegraaf, 2000).

In The Netherlands a huge decrease in sales and consumption of poultry meat occurred. Production in 1999 also decreased with 0,5%, partly because of the dioxin crisis. The crises also had huge influences on exports. Borders were closed for poultry meat from The Netherlands and extra guarantees for poultry meat were demanded from the Dutch government and involved companies. Up until late 2000 a number of borders stayed closed for Dutch poultry meat (Bondt et al., 2003; Nepluvi, 2001).

MPA 2002

A recall of all compound feed contaminated with MPA through melasse was ordered by the European Commission (Product Board Animal Feed, 2002-a) and a total of 73.000 pigs were destroyed because of the MPA crisis. The 2002 MPA crisis caused an extra decrease in sales revenue in pig meat in The Netherlands. Export volume of pig meat also decreased by almost 12% because of temporarily border closures as a reaction on the MPA crisis (Product Board for Livestock, Meat and Eggs, 2003-a).

Losses of the MPA-crisis for the feed industry are estimated at approximately 33 million euro. These expenses were mainly caused by feed destruction and recalls. Losses on farm level are estimated at 35 million euro. Losses consisted of destruction costs of animals and losses in income due to lower prices. Prices of hogs went down with 13%. Losses on processing level are estimated at 25-50 million euro, consisting of export limitations and a temporarily lower production. Losses for the Dutch government are estimated at 6 million euro due to organisation and monitoring costs. The Ministry of Agriculture estimated total losses of the MPA-crisis at 107-132 million euro. This total however does not include losses caused by regaining export markets (Ede Stad, 2003; LEI, 2003; LNV, 2002).

Feed producers and farmers claimed 7,1 million euro. Furthermore, sector organisations and feed producers claimed for an unknown amount at the company that caused the MPA-crisis. Animal feed producers and primary producers arranged a 3 million euro settlement, but no other compensation was paid. The public prosecutor in The Netherlands also charged two pig farmers and an advisor for delivering contaminating products in the supply chain. Fines of 200 thousand euro were demanded (Eindhovens Dagblad, 2004). The Irish company Wyeth Medica Ireland that caused the contamination was also summoned in 2006 by the Irish attorney general. The fact that a dangerous waste stream was sold as a not dangerous steam was charged. Furthermore, the Belgium company Bioland that purchased the contaminated feed was declared bankrupt in 2002 (Agrarisch Dagblad, 2006-c). Animal feed companies that purchased and delivered contaminated products (Zeeland Voeders, Porker Foods and Genuva BV) were demanded a total of 82 thousand euro in appeal by the public prosecutor because of negligence (Agrarisch Dagblad, 2006-b).

Dioxin 2003

No information regarding supply chain losses is found.

Dioxin 2004

During the crisis there were temporarily lower turnovers in Greece, South Korea and Singapore (NLTO, 2004). As a result of the dioxin crisis in 2004 South Korea closed its borders for meat and dairy products from The Netherlands for 12 days. Especially the Dutch cheese sector suffered from the closure; in 2003 two million kg of cheese was exported to South Korea, but now borders were closed for 12 days which led to lower turnovers for cheese exporting companies (Agrarisch Dagblad, 2004-b; Agrarisch Dagblad 2004-c).

Farmers who suffered losses from the 2004 dioxin crisis have all been compensated (Nieuwe Oogst, 2005). The amount of this compensation is not specified.

In December 2004, 71 primary producers claimed losses for a total amount of 150 thousand euro. 59 claims were directed to feed suppliers and 12 claims were directed to the government. These farmers had the opinion that the blocking of their farms was unjustified. The farmers of the two dairy farms that were blocked first agreed upon a claim settlement with McCain (NLTO, 2004). The amount of this settlement was not published.

Dairy processor Friesland Foods tried to claim losses because of a lower turnover, because of lower prices in Greece during the 2004 dioxin crises (Dagblad van het Noorden, 2005).

Losses could have been higher according to the Dutch Federation of Agriculture and Horticulture. Looking at the level of dioxin found in meat and milk a bigger crises was just avoided (ANP 2004; NLTO, 2004).

Bone fragments 2004

As a result of surveillance positive batches beet pulp contaminated with bone fragments were not sold and no primary producers were affected (Product Board Animal Feed, 2005-b).

Dioxin 2006

China, Hong Kong, Japan, Taiwan and Southern Korea closed the borders for Dutch pig meat. Japan also closed her frontiers for poultry products for a week. (Agrarisch Dagblad, 2006) The incident led to losses for cattle farmers and for the meat industry. There was a substantial fall in prices for hogs in The Netherlands compared to the increasing prices on the German and Belgian markets (Product Board Animal Feed, 2006).

The Dutch Federation of Agriculture and Horticulture (LTO Nederland) went to the Dutch court to claim market losses. The claim was not about losses of individual primary producers supplied with contaminated animal feed, but about losses that include the whole supply chain, losses due to lower prices for hogs (LTO, 2006). Pig slaughter Vion claimed 900 thousand euro at feed companies Bouwman and Profat (Belgium). Vion also took 7.700 pigs out of the market because of the risk of an increased level of dioxin (Nieuwe Oogst, 2006).

Overview of supply chain losses in recent crises

As discussed, the crises described caused losses in the supply chain. These losses can be divided into losses on feed and farm level and losses of processing industries. Other losses are also specified, e.g. expenses by the government or not quantified losses. If losses are not mentioned this implicates no information was found. Losses are in million euros.

Table 4.2: Losses allocated to feed- farm- and processing food supply chain stage in previous feed contamination crises.

	Feed	Farm	Processing industries	Other	Total
Contamination crises					
Dioxin 1999	n.a.	n.a.	38,5[A]	border closures[B]	38,5[C]
MPA 2002	33	35	25-50	6[D] regaining export markets[E]	107-132[F]
Dioxin 2003	n.a.	n.a.	n.a.	n.a.	
Dioxin 2004	n.a.	0,15G	n.a.[H]	n.a.	0,15[C]
Bone fragments 2004	n.a.	0	0	0	0
Dioxin 2006	n.a.	n.a.	0,9[I]	Border closures Fall in prices[K]	0,9[C]

n.a. = not available
A: Lower profits of processing companies.
B: Border closures remained up until late 2000.
C: Own estimation based on found literature.
D: Government expenses.
E: Regaining export markets not included in total reported losses.
F: Reported total losses.
G: Claim by primary producers.
H: Claim of Friesland Foods because of lower turnover in Greece (unknown amount).
I: Claim by Vion.
J: Border closures for a week to several export markets.
K: Substantial fall in prices of hogs.

If losses could be allocated to different sectors and/or direct and indirect losses this distinction is made in Table 4.3. Only quantified losses are put in the table. Losses are in million euro.

Table 4.3: Losses allocated to type (direct/indirect) and sector (dairy/pig/poultry) if applicable.

	Direct losses			Indirect losses		
	Dairy	Pig	Poultry	Dairy	Pig	Poultry
Contamination crises						
Dioxin 1999				31,7[A]		
MPA 2002						
Dioxin 2003						
Dioxin 2004						
Bone fragments 2004						
Dioxin 2006		0,9[B]				

A: Lower profits of dairy processors Campina Melkunie and Friesland Coberco.
B: Claim by pig processor Vion.

As can be obtained from Table 4.3., losses of recent contamination crises are hard to classify. Losses as presented in Table 4.2 are either not classified or classified losses cannot be quantified. Therefore most losses could not be classified to sectors or direct vs. indirect losses.

5 - Material and methods

The objective of this research is realised by analysing the losses of dairy and meat processing companies in different scenarios in case of a contamination in animal feed. As a starting point the report *The production of compound feed in The Netherlands: an analysis of contamination risks* by Van Asseldonk, Meuwissen and Huirne (2006) is used. Van Asseldonk et al. studied the number of contaminated feed companies, the losses per contamination and the annual loss. Losses in the report of Van Asseldonk et al. include the feed- and farm stage, but not the processing stage of the supply chain.

Van Asseldonk et al. (2006) consulted experts employed by Nevedi (Dutch Association of Animal Feed Industry) members by means of a questionnaire. Van Asseldonk et a. presented aggregated statistics on the outcomes of these questionnaires. The most likely scenario developed by Van Asseldonk et al. is used as the most likely scenario for this MSc research and parameters are further developed to get insight in the losses for dairy and meat processing companies. More information about the research of Van Asseldonk et al. (2006) can be found in paragraph 5.1. The different losses processing companies face with respect to a contamination in animal feed are categorized and quantified based on literature research and in depth interviews with experts of processing companies.

Seven what-if scenarios are defined in this research. Results are calculated in a Microsoft Excel spreadsheet model. Parameters have been put into this model. The amount of contaminated products is derived from the number of contaminated farms, duration of a crisis, average number of animals per farm and the average circulation rate of animals on a farm. Paragraph 5.2 gives more insight into the spreadsheet model.

Experts of dairy and meat processing companies determined the effect of the number of contaminated farms and the period of the crises on the processors losses. Important parameters are the size and number of both production locations and batches affected. Both give an indication of the multiplier with regard to the losses on the processors level. Purchase costs, production costs and market value of products indicate the value of these contaminated products in the different production stages.

Distribution of products within the processing industries and a corresponding time line give insight in the production process of processors. It clarifies at which stage of the supply chain from processor to consumer contaminated products are at a certain time. This is how value can be assigned to contaminated products at different times at the processing stage of the supply chain to get insight in the losses of processing companies at different times.

5.1 Scenario description

Different scenarios are developed to gain insight into the different losses processing industries face in case of a contamination in animal feed. Scenarios are set up based on the research and scenarios of Van Asseldonk et al. (2006) and are further developed for dairy and meat processing industries.

Scenarios of Van Asseldonk et al. (2006) are set up based on experts of companies connected to Nevedi, the Dutch Association of Animal Feed Industry. Ten experts were consulted by means of a questionnaire about stochastic assumptions in the model of Van Asseldonk et al. Three-point estimates (minimum, most likely and maximum) were elected to parameterise the probability distributions (Van Asseldonk et al., 2006). The questionnaire included questions in relation to a contamination crisis about:

- The probability of occurrence.
- Number of compound feed companies involved in a recall.
- Size of compound feed company involved.
- Sectors (cattle, pigs, poultry) involved.
- Duration of production of contaminated compound feed.

Scenarios and results of Van Asseldonk et al. show both the average value as well as the standard deviation of the number of contaminated farms and the annual losses induced by contaminated compound feed.

Table 5.1: Results of most likely scenario of Van Asseldonk et al. (2006).

	Mean	Standard deviation
Number of contaminated farms	659	760
Loss per contamination (euro)	5.266.231	6.514.340
Annual loss (euro)	1.050.840	3.570.290

Stochastic elements by means of expert judgements in the research of Van Asseldonk et al. (2006) also included a most likely occurrence of a contamination crisis of once in five years and a most likely duration of seven days.

With regard to this research the number of contaminated farms and the period (number of days) contaminated products are processed are the main parameters. The spread of the contamination throughout the Netherlands is also an important parameter, however this parameter will be not be discussed here since, in practice, this parameter is closely related to the two other parameters.

In Table 5.2 an overview is presented of scenarios developed for this research. In Table 5.1 mean and standard deviation were presented. In Table 5.2 mean (most likely scenario) and 5% and 95% percentiles (what-if, best case and worst case scenarios) are presented. In the most likely scenario the number of contaminated farms is 659. This most likely scenario is derived from the most likely scenario of Van Asseldonk et al. (2006). The contaminated farms are equally divided over three branches: cattle, pigs and poultry. Therefore the number of contaminated farms per sector is approximately 220. In the scenarios, farm types are further specified to dairy, hog and broiler farms based on the relative frequencies per sector. The assumption is made here that for individual farms the probability of becoming affected is equal for all farms within a sector (e.g. sow and hog farms, beef cattle and dairy farms and farms with laying hens and broiler farms). No literature has been found that contradicts this distribution, that there is a difference in the risk of occurrence of a contamination in animal feed in each of the sectors and farms.

The number of days contaminated compound feed is produced by a compound feed company is, according to the report of Van Asseldonk et al., most likely 7 days. The duration of a crisis in the different scenarios indicate the period in which contaminated products are processed. In scenarios it is assumed that the number of days as estimated by Van Asseldonk et al. (2006) can be interpreted as the number of days in which contaminated dairy and meat products are processed. This mimics a situation in which animal feed contaminations are not detected at feed-, farm- or at the industries level.

Table 5.2: Most likely and alternative scenarios.

	Most likely scenario - overall	Most likely scenario per sector	Alternative scenarios - 5% percentile overall	Alternative scenarios - 5% percentile per sector	Alternative scenarios - 95% percentile overall	Alternative scenarios - 95% percentile per sector
Number of contaminated farms	659	220	37	12	2210	737
Number of days contaminated products processed	7	7	1	1	30	30

In alternative scenarios the main parameters; the number of contaminated farms and the number of days contaminated products are processed, are varied and best case and worst case scenarios are evaluated. The sensitivity of parameters is also measured. Parameters are changed to clarify how a variation in one or more parameters influences the losses and to clarify if and where there is a bending in the losses with respect to the parameters.

The number of farms contaminated in the alternative scenarios (Table 5.2) is derived from the 5% and 95% percentile of the most likely scenario of Van Asseldonk et al. (2006). The one day and 30 days duration is based on the minimum and maximum duration of the production of compound feed from this report. The alternative scenarios are developed and calculated to evaluate contamination crises in best and worst case scenarios and to measure sensibility of the two main parameters. The 5% percentile has a number of 37 and the 95% percentile has a number of 2210 contaminated farms. In alternative scenarios contaminated farms are also equally divided over the three investigated branches and are approximately 12 (5% percentile) and 737 (95% percentile).

In Table 5.3 all scenarios of all sectors are summarised. As stated before, the number of contaminated farms is equally divided over the three investigated branches. In Table 5.3 all scenarios are shown per sector (cows, pigs or poultry); these are the calculated scenarios. Composition for each scenario and sector are discussed below Table 5.3. The number of days contaminated products processed is not explained since this parameter is equal for every sector. Alternative scenarios are calculated in the same way as the most likely scenario for all industries (dairy, pigs and poultry).

Table 5.3: Calculated scenarios.

	Most likely	More farms	Less farms	More days	Less days	Best case	Worst case
Number of farms contaminated	659	2210	37	659	659	37	2210
Dairy farms	199	688	11	199	199	11	688
Hog farms	150	503	8	150	150	8	503
Broiler farms	72	241	4	72	72	4	241
Number of days contaminated product processed	7	7	7	30	1	1	30
Dairy	7	7	7	30	1	1	30
Hogs	7	7	7	30	1	1	30
Broilers	7	7	7	30	1	1	30

Number of contaminated farms and amount of contaminated milk dairy processing industry

90,64% of cattle farms in the Netherlands are dairy farms. Therefore the number of contaminated dairy farms is 199 (90,64% of 220 contaminated cattle farms) in the most likely scenario. The average size of a dairy farm in the Netherlands is 61 cows. These cows give 20,32 kg of milk per day on average (LEI and CBS, 2006). The contaminated amount of milk in the most likely scenario is hence 1.726.651 kg.

Number of contaminated farms and amount of contaminated meat hog processing industry

The 150 contaminated hog farms in the most likely scenario is derived from the total of 220 contaminated pig farms including sow farms. 68,33% of pig farms are hog farms (LEI and CBS, 2006) and hence the most likely scenario gives a number of 150 contaminated hog farms. The number of contaminated hog farms of other scenarios are also based on the 68,33% of hog farms. The average number of hogs on a farm is 688. The average circulation rate of hogs is 3,05, calculated with a waste rate of 2,7%. Together with the average slaughter weight of a hog of 91 kg, the size of the contaminated hogs can be determined in kg. In the most likely scenario this is 549.321 kg (Animal Science Group, 2006).

Number of contaminated farms and amount of contaminated meat broiler processing industry

The number of contaminated farms per sector in the most likely scenario is 220 (Table 3.2). The percentage of broiler farms on the total of poultry farms is 32,7% (LEI and CBS, 2006). The number of broiler farms contaminated will therefore be 72 in the most likely scenario for the poultry processing industry.

The number of contaminated broilers in the most likely scenario will be 564.422 based upon the average number of 58.394 broilers in a broiler farm (LEI and CBS, 2006) and the rate of circulation of 7,00 (Animal Sciences Group, 2007). The rate of circulation is based upon a production period of 42,5 days and a period of on average 9,5 days before a new production period. Together with the average weight of a broiler of 2,150 kg the size of contaminated broilers in kilograms is obtained (Animal Sciences Group, 2007).

Input parameters

An overview of the different input parameters, used to construct the scenarios of this reserach can be found in Table 5.4. Information on farm and processing industry characteristics was presented in Table 2.1. An overview of parameters used to calculate the losses for processing industries are presented and discussed in paragraph 5.3.

Table 5.4: Input parameters.

	Cattle	Pig	Poultry
Percentage of farms per branche involved[A]	90,64	68,33	32,7
Average number of animals per farm	61	688	58,394

A: Specified for dairy farms, hog farms and broiler farms.

5.2 Data collection

In addition to the literature review as presented in chapter 4, data is gathered by interviews with experts of processing companies. Experts from four processing companies including a dairy processor, a poultry slaughterhouse and a pig slaughterhouse have been interviewed. One to four experts per company were interviewed. Four to nine interviews per company were conducted, including the meeting of the Ernst & Young research (see below), to gather all necessary information to get insight into the direct and indirect losses processing companies face.

In the period September 11, 2007 to November 13, 2007 co-operation took place between this MSc research and a research carried out by Ernst & Young. The objective of the Ernst & Young research was to quantify the insurable, direct losses for dairy and meat processing companies in order to show animal feed suppliers (Safe Feed and TrusQ) the size of the losses for different scenarios. In addition to the processors, the LTO (Dutch Federation of Agriculture and Horticulture) and the ZLTO (Southern Dutch Federation of Agriculture and Horticulture) participated in this research too. The questionnaire and scenarios developed for this MSc research, to map the direct losses, was used as the initial concept of the questionnaire and scenarios of the Ernst & Young research. The questionnaire and scenarios have been further developed in several project group meetings. Information gathering for the research of Ernst & Young and this MSc research was done concurrently. Presence during joint project group meetings, in which the group of experts was involved, gave insight for this research that could not have been gained without the Ernst & Young research.

Data gathering of this MSc research focused on the expected number of processing sites affected in each scenario and the expected size of the losses per site. In order to map the size of direct losses, logistics of processing sites were mapped in order to:

- Quantify the size of the (mixed-)contaminated milk- or meat stream
- Assign contaminated milk or meat to different product streams
- Assign a corresponding value to the different product streams
- Correct for products already consumed with help of a time line for each product

Company-specific direct losses were calculated with this information.

Aggregated averages direct losses of the processing level of the food supply chain are calculated with the public figures on average daily production values per site are used (Table 2.1). In this way, direct losses reflect the lost value of products of first processing companies.

In order to map company-specific indirect losses, information gathering included:

- Return of non-contaminated products because of a contamination crisis
- Non-deliverable products due to border closures or customer rejection of non-contaminated products
- Regaining of (export) markets, lost due to a contamination crisis

5.3 Spreadsheet model

Direct losses

Aggregated average direct losses are calculated with expert information on the number of processing sites involved and public figures on average daily production values per production site (Figure 5.1). 20% percentile (contained) and 80% percentiles are calculated and presented for aggregated average direct losses.

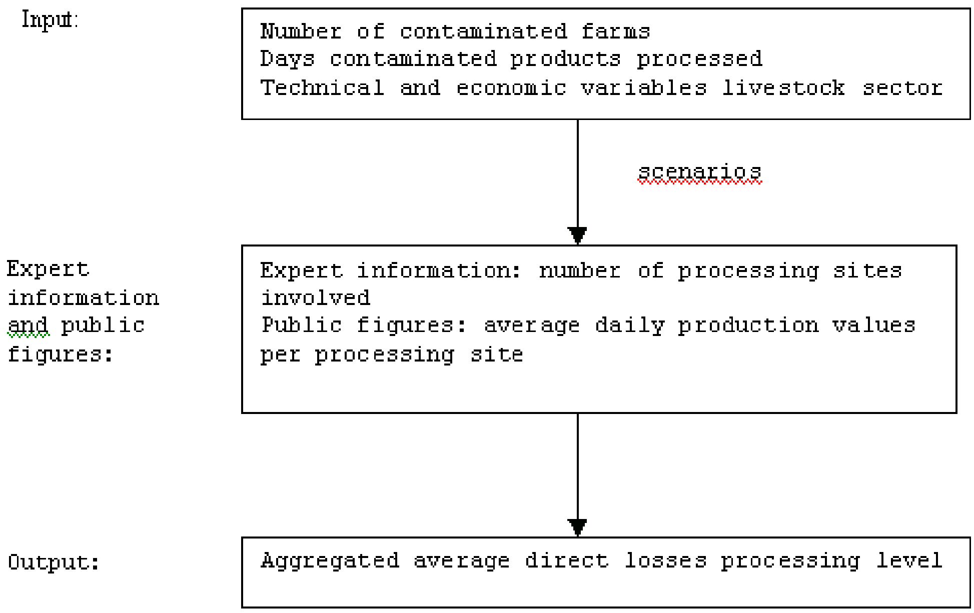

Figure 5.1: Overview of spreadsheet model to estimate aggregated average direct losses at processing level.

In Figure 5.2 an overview of the different inputs as used in the spreadsheet model is presented for the company-specific direct losses. Public figures have been replaced by company-specific expert information.

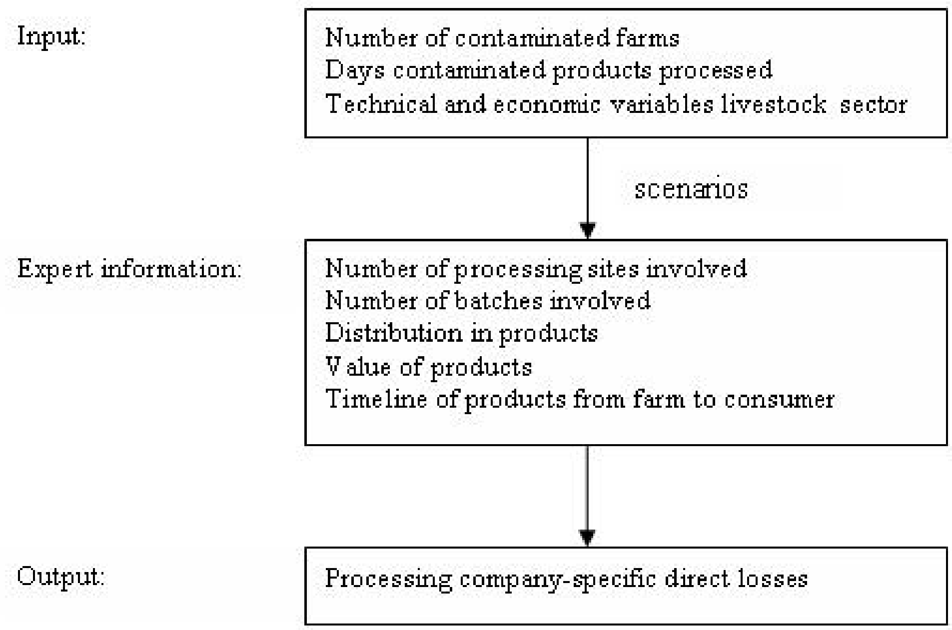

Figure 5.2: Overview of spreadsheet model to estimate processing company-specific direct losses.

Other company-specific information (next to the number of processing sites involved) is gathered through in-depth interviews with experts of processing companies. Gathered information is used to calculate the company-specific direct losses. Size and value of different products streams are mapped and a timetable for the production of every product is developed and a corresponding value is linked to this.

Paragraph 5.1 explained the determination of the number of contaminated farms and days contaminated products are processed. The number of contaminated farms as well as the duration of a contamination crisis reflects the number of process locations where contaminated products will be processed.

The logistics of processing companies are mapped to gain insight in the spread of contaminated products within the processing companies. The size of contaminated milk or meat in kg and the value of contaminated products in euro reflect the size and value of the contaminated product stream. Batch sizes as well as tracking and tracing systems lead to the spread of contaminated products within the processing companies. Size and value of contaminated product mixed through blending reflect the size and value of the mixed-contaminated product stream. Not only contaminated products are included. Both non-contaminated dairy products that were stored together with contaminated products in a truck or silo and meat that cannot be traced back to either contaminated or non-contaminated hogs or broilers in slaughterhouses are included.

The value of contaminated products including pipeline show that for certain scenario with a duration of 7 or 30 days some products are already consumed and are hence not part of the supply chain any more. Therefore the value of these products is no longer a loss and a correction is made in the spreadsheet model for the products already consumed. Especially in scenarios with a 30-day duration this is an important correction for the company-specific direct losses.

In chapter 6, a distinction is made between aggregated average direct losses of processing companies and company-specific direct losses. Aggregated average direct losses are calculated with processing industry characteristics of dairy, hog and broiler supply chains (Table 2.1). The number of processing sites involved, estimated by participating processing companies, is linked to the publicly available information on processing sites, in order to present quantified direct losses.

Company-specific direct losses include additional expert information next to the number of processing sites involved (Figure 5.2). Number of contaminated batches, distribution in products, value of different products as well as the timeline of products from farm to consumer is included.

Basically, the spreadsheet model is the same for every industry. However, some industry specific adjustments are made. In the dairy supply chain milk is transported from a farm to a processing site by trucks. Milk is stored in silos. Both in the truck as well as in the silos, contaminated products are mixed with non-contaminated products. The (mixed-)contaminated products can be allocated to different product streams (consumption milk, butter, cheese, casein, lactose, whey, powdered milk, evaporated milk etc.). Broilers are allocated to product streams such as breasts, drumsticks and wings. Hogs are allocated to products such as legs, middle, shoulder, neck etc. (Figure 2.5). For all industries the size of every product stream is linked to a corresponding value. Also, with regard to the time line of products from farm to consumer, a correction is made in results of scenarios for products already consumed.

Because of confidentiality of participating companies, company-specific results of each scenario are presented on an index scale. Results of direct losses consist of:

- Contaminated products
- Contaminated and mixed-contaminated products
- Contaminated and mixed-contaminated products, corrected for products already consumed

Indirect losses

Indirect losses are calculated with company-specific variables. Estimations for indirect losses are made by participating companies. These are company-specific losses. The most likely and the worst case scenario are evaluated.

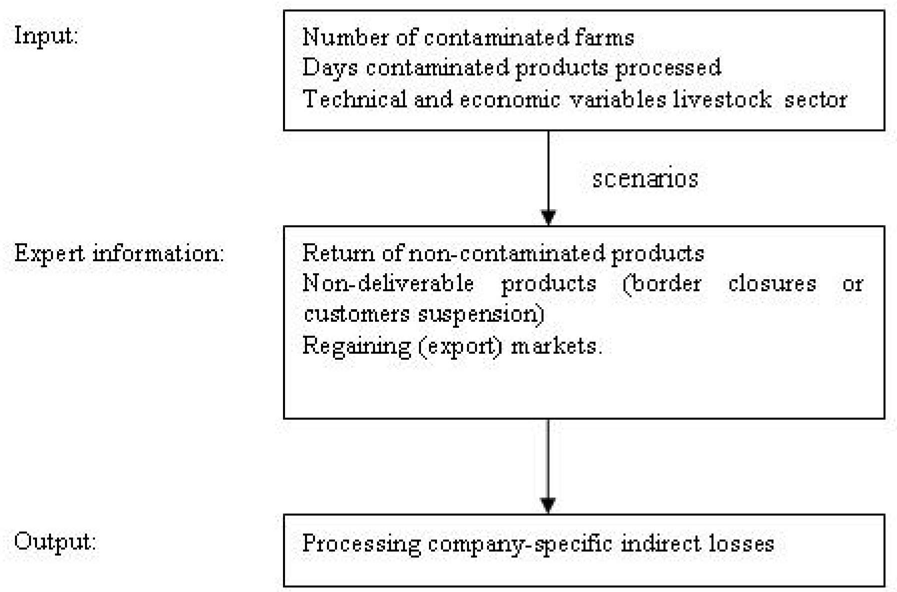

Figure 5.3: Overview of spreadsheet model to estimate processing company-specific indirect losses.

The indirect losses consist of:

- Non-contaminated products returned at time of a contamination crisis.
- Products that can not be delivered because of border closures or customers suspension of purchases because of a contamination crisis.
- Regaining (export) markets.

Since indirect losses are also company-specific losses, these are reported on an index scale, which supports the main objective to map the indirect losses: to put them in perspective with direct losses.

5.4 Assumptions within this research

An important assumption made in this research is that the duration of the crises as presented by Van Asseldonk et al. (2006) is used as the number of days contaminated products are processed by the processing companies. This mimics a situation in which a contamination is not discovered on feed-, farm- or processing stage. It assumes a contamination is detected at the end of the duration of a scenario (either 1, 7 or 30 days).

In addition, equal probabilities for both sectors are assumed with regard to a contamination. Equal distribution to sectors (cattle, pig and poultry) is assumed. Within sectors (sow and hog farms, beef cattle and dairy farms, farms with laying hens and broiler farms) distribution is based on the relative frequencies per sector.

The scenarios of this research assume a contamination in which all contaminated products and mixed-contaminated products have to be taken out of the food supply chain. The nature of the contamination is that serious that no products are allowed to be consumed because certain safety levels are exceeded. On the other hand, the contamination is not that serious that consumer will become ill or even die from the contaminated products. This indicates that for certain scenarios with a long duration some products will be consumed before detection and therefore a correction for products already consumed is made for calculated direct losses.

6 - Results

6.1 Direct losses

As defined in chapter 4 the direct losses in this research are losses of processing industries directly related to the physical contaminated product stream.

6.1.1 Aggregated average direct losses

In Table 6.1 the number of processing sites affected and estimated direct losses are presented. Results indicate that experts of involved companies have rather different opinions about the expected number of processing sites affected in each scenario. Estimated numbers range from company 1: 2 sites (best case) to 15 sites (worst case) sites affected, whereas numbers from company 2 range from 1 processing site (best case) to 3 processing sites contaminated (most likely, more farms, more days, less days and worst case).

Results reflect the (publicly available) information on the production value per processing site (Table 2.1) combined with estimations of experts of processing companies. Losses reflect the total production value of a site. This implicates that if contaminated products are present at a processing site, all day production of this site will be contaminated, i.e. is perceived to be mixed-contaminated. Experts of processing companies approved this. Causes are both tracking and tracing systems, that cannot trace back only contaminated products after they are processed, as well as large batch sizes on processing sites.

Table 6.1: Number of processing sites affected and estimated aggregated average direct losses (million euro).

	Most likely	More farms	Less farms	More days	Less days	Best case	Worst case
Processing sites affected							
- Company 1	6	10	3	10	6	2	15
- Company 2	3	3	2	3	3	1	3
- Company 3	6	6	2	6	3	1	6
- *Percentiles (contained, 20%); (widespread, 80%)*	*4; 6*	*4; 8*	*2; 3*	*4; 8*	*3; 5*	*1; 2*	*4; 11*
Industry losses (million euro), contained							
- Dairy processing	8	8	4	34	1	0	34
- Pig slaughtering	9	9	4	37	1	0	37
- Poultry slaughtering	3	3	2	14	0	0	14
- *Total per crisis*	*20*	*20*	*10*	*84*	*2*	*1*	*84*
Industry losses (million euro), widespread							
- Dairy processing	12	16	6	67	1	1	92
- Pig slaughtering	13	17	6	73	2	1	101
- Poultry slaughtering	5	6	2	27	1	0	37
- *Total per crisis*	*29*	*39*	*15*	*167*	*3*	*1*	*230*

A comparison between the best and worst case scenario shows that ranges of affected processing sites across observations are wider for the worst case scenario. This might be due to large companies having a high degree of specialisation across processing sites, implying that a similar amount of contaminated farms affects relatively more processing sites in case of a large company. Contained and widespread range from respectively 4 and 6 sites in the most likely scenario to 4 and 11 sites in the worst case scenario.

Results show that with regard to the number of processing sites affected the impact of moving from less farms to more farms is perceived to be larger than moving from less days (i.e. 1 day) to more days (30 days). This all indicates that the number of farms contaminated has more impact on the number of processing sites affected than the duration of a contamination crisis. However, duration of a contamination crisis has more impact on the industry losses if we compare the losses of both contained and 80% percentile for more farms and more days. This is caused by the cumulative effect on losses occurring when the numbers of days is increased.

Expected direct losses are highest for pig slaughtering companies, i.e. 9 million euro and 13 million euro in the most likely scenarios, for contained and widespread scenarios figures respectively. Aggregated direct losses per crisis, across branches, in the most likely scenarios, are expected to be 20 million euro (contained) and 29 million euro (widespread). Worst case scenarios outcomes are 84 million euro and 230 million euro respectively. Differences across scenarios show that from a loss perspective the number of days of processing contaminated products is a crucial factor.

6.1.2 Index of company-specific losses

In Table 6.2 the direct losses for involved companies are presented in terms of an index. Total losses are indexed at 100 and the percentage of losses for contaminated and contaminated-mixed product are compared to the total losses. Furthermore, the most likely scenario is indexed at 100 and alternative scenarios are compared to this most likely scenario for each industry. The company-specific losses are calculated with the same estimations of experts of processing companies for number of processing sites affected (Table 6.1), but are further specified with company-specific information (paragraph 5.3).

Table 6.2: Company-specific direct losses (index).

	Most likely	More farms	Less farms	More days	Less days	Best case	Worst case
Industry losses:							
- Dairy processor	100	167	50	286	18	4	358
- Pig slaughterhouse	100	100	33	202	8	3	202
- Poultry slaughterhouse	100	100	67	219	20	7	219
Losses all industries (total losses each scenario = 100):							
- Contaminated products	7	18	1	12	8	2	37
- Contaminated mixed products	119	121	123	274	102	102	291
- Total losses corrected for products already consumed	100	100	100	100	100	100	100
Index of total losses (most likely=100):							
- Total losses corrected for products already consumed	100	124	42	233	12	3	259

Largest losses occur in the worst case scenario for all industries. Both pig and poultry slaughterhouses have same losses in the more days and worst case scenarios (index of 202 and 219 respectively) as well as for the most likely and more farms scenarios (index of 100 for both sectors). This shows that for involved processors in the hog and broiler supply chain the number of farms affected does not affect size of losses for these scenarios. In Table 6.1, only the most likely and more farms scenario, as well as the less days and best case scenario, are in line with this, and only for contained scenarios. Explanation for pig and poultry slaughterhouses having relatively similar losses is that a relatively low number of contaminated farms already implicate contamination of a large number of processing sites. Even if more farms are contaminated this does not affect the losses at the processing industries because the same number of processing sites is affected. Reasons are the interrelationship within the processing sites and the specialization across different processing sites within a company.

Similar duration of a crisis with either most likely or highest number of farms affected has no influence on the total losses. Only less farms affected shows lower losses compared to the most likely scenario (which has same duration but more farms affected).

Company-specific direct losses also show that variation over scenarios is the largest for the dairy processing industry. Indexes vary from 4 (best case), to 358 (worst case) in this sector.

Losses of contaminated products contribute 1 tot 37% to the total losses. The influence of the spread of contaminated products within processing companies can be obtained from this percentage. In the most likely scenario value and losses are only 7% of the total losses and this is 37% in the worst case scenario. Remarkable is that in the worst case scenario, this percentage is the largest. This is caused by the large correction for products already consumed. The contaminated products only cover 13% of the losses if the correction for products already consumed is not made in this scenario. The mixture of contaminated products at processing sites account for the largest part of the losses at the processing industry level. Another example of this is the what-if scenario less farms. In this scenario, contaminated product are only 1% of the total losses of this scenario. Still, these losses increase to 42% of the most likely scenario in the processing stage of the supply chain.

Correction for products already consumed varies from 2% (less days and best case scenario) to 191% (worst case scenario). As can be obtained from Table 6.2, in scenarios with a duration of 30 days (more days and worst case), there is a large correction made for products already consumed. Total losses are corrected for consumption for 174% (more days) and 191% (worst case) respectively of the total losses for each scenario. This shows that a large share of products processed within these 30 days are already consumed and cannot be considered as a loss anymore. This correction is obviously much lower in scenarios with a 7 days (19% to 23%) and 1 day duration (2%).

6.1.3. Reflection on results direct losses

Table 6.3: Estimated aggregated direct losses compared to company-specific direct losses (index).

	Most likely	More farms	Less farms	More days	Less days	Best case	Worst case
Estimated direct losses *contained*	100	100	50	420	10	5	420
Estimated direct losses *widespread*	100	134	52	576	10	3	793
Company-specific direct losses	100	124	42	233	12	3	259

In Table 6.3 estimated losses of aggregated average direct losses for contained and widespread scenarios are compared to the company-specific losses. All losses are put in an index with the most likely scenario of each approach set at 100.

Most likely scenario has an index of 100 representing losses of 20 and 29 million euro for contained and widespread respectively. The worst case scenario of the company-specific losses has an index of 259, which is relatively low compared to estimated direct losses of both the contained (indicating a loss of 84 million euro) and widespread (indicating a loss of 230 million euro) aggregated average direct losses. This is based on the index of 420 and 793 in the worst case scenario compared to the most likely scenario. This large difference is caused by the company-specific information included in Table 6.2. Main explanation for this difference is the correction for products already consumed. With a duration of 30 days a significant amount of products processed at the beginning of the worst case scenario is already consumed. For the estimated losses this correction is not made. This is also true for the more days scenario. In company-specific direct losses a correction of 174% and 191% is made, which supports this explanation. If this correction was not made, the index of the company-specific worst case scenarios would have been 743 , which would have been more in line with the indexes of estimated direct losses of 420 (contained) and 793 (widespread) for the worst case scenario of aggregated average direct losses.

For scenarios besides more days and worst case scenarios the differences are smaller, which confirms that the differences in more days and worst case scenarios is mainly caused by correction for consumption.

Reasons for (other) differences are likely to be caused by company-specific reasons. Involved companies and sites can produce other products than an average company and production site in the Netherlands.

In Table 6.4 the main parameters; number of contaminated farms and duration contaminated products are processed, are indexed. A comparison can be made between the relative variation in outcomes of involved companies and the relative variation of parameters.. If one combines both Table 6.2 (total losses and Table 6.4 the influence of each parameter can be further studied. The index of company-specific direct losses is taken here (not the aggregated average direct losses). Company-specific results better reflect the practical situation at involved processing companies.

Table 6.4: Index of main parameters (most likely = 100).

	Most likely	More farms	Less farms	More days	Less days	Best case	Worst case
- Number of contaminated farms (all industries)	100	335	6	100	100	6	335
- Dairy processing	100	346	6	100	100	6	346
- Pig slaughtering	100	335	5	100	100	5	335
- Poultry slaughtering	100	335	6	100	100	6	335
- Number of days contaminated product processed (all industries)	100	100	100	429	14	14	429
- *Total losses corrected for products already consumed (from Table 6.2)*	*100*	*124*	*42*	*233*	*12*	*3*	*259*

The influence of e.g. an increase of at least 225% (index of 335) in the number of contaminated farms compared to the increase of losses, which increases only with (on average) 24% in the more farms scenario for involved companies. Furthermore there is a larger difference in the number of days contaminated products are processed than the difference in number of farms contaminated. Number of contaminated farms varies in a ratio of 6-100-335 respectively, and duration varies in a ratio of 14-100-429 respectively, in what-if scenarios. Total losses vary from 2 to 259 and show a lower variation than the underlying parameters.

Furthermore, scenarios indicate that the number of days contaminated products processed have a larger effect on losses than the number of contaminated farms. However, Table 6.4 shows that variation in number of days is larger than the variation in contaminated farms, which also should be taken into account.

6.2 Indirect losses

Table 6.5 Parameters indirect losses`

	Return[A]	Non-deliverable[B]	Regaining markets[C]	Percentage of indirect losses[D]
Most likely scenario:				
- Company 1	x	-	-	26%
- Company 2	x	x	x	291%
- Company 3	x	x	x	5%
Worst case scenario:				
- Company 1	x	-	-	46%
- Company 2	x	x	x	531%
- Company 3	x	x	x	99%

x: Loss included in indirect losses for processing company
-: Loss not included in indirect losses for processing company
A: Return of non-contaminated products
B: Products non-deliverable due to border closures and customer suspension of purchases
C: Regaining (export) markets
D: Percentage of company-specific indirect losses compared to company-specific direct losses

Table 6.5 shows experts have rather different opinions about the indirect losses that could occur. Company 1 only expects losses due to return of non-contaminated products at time of the contamination crises. The other two companies expect also losses due to border closures or customer suspension of purchases and regaining of export markets.

However, companies expect that for both scenarios, most likely and worst case scenario, the same losses would occur. These losses are of a different scale in both scenarios, but too company-specific to be specified here. Table 6.6 gives more insight in the company-specific result of indirect losses and these result and underlying parameters are explained below. The index of direct vs. indirect losses are weighted averages of company-specific results on both type of losses.

Table 6.6: Index of direct vs. indirect losses[A].

	Most likely	Worst case
Direct losses (=100)	100	100
Indirect losses[A]	34	105

A: Weighted average of direct and indirect company-specific losses

Indirect losses are approximately 34% of the direct losses in the most likely scenario. In the worst case scenario this percentage is increased to 105%. This indicates that in the worst case scenario indirect losses for processing companies tend to be higher than the direct losses.

Since direct losses in the worst case scenario are 259% of the most likely scenario (Table 6.2), the 105% of indirect losses in the worst case scenario, reflect tot even larger indirect losses than the 259% of direct losses. Hence, indirect losses in the worst case scenario are larger than the 259% of company-specific direct losses in the most likely scenario.

The main reason for the relative large differences in estimated indirect losses is caused by the duration of a contamination crisis. First of all, in the worst case scenario processing companies experience a larger duration of sales problems. Regaining export markets may also take longer. Another explanation for the difference might be retailers who plan consumer bargains way in advance. In case of an animal feed contamination and possible negative media exposure, retailers will not plan actions with, for example, poultry meat. This might have large influence on the sales volume of a poultry slaughterhouse. This influence will most probably become larger and larger when a contamination crisis has a larger duration.

Furthermore, processing industries cannot adjust properly to varying market situations. Processing companies face a constant stream of products (milk or meat) which is hard to adjust. Dairy farms have cows who give milk constantly. Also for hog and broiler farms it is hard to adjust supply in case of a contamination in animal feed with circulation rates of 3 and 7 per year respectively. Even broiler farms have a production period of approximately 52 days before they can adjust to changing market situations. Furthermore, these 52 days only reflect the broiler farm stage and not e.g. the breeding stage and other suppliers.

It also remains to be seen whether e.g. farmers can use their production capacities for other purposes than the normal purpose. It is clear, that for scenarios in which borders are closed or customers do not want products of certain processors, indirect losses are huge. Products that are produced and processed anyway need to be sold to other markets for lower prices or high-value products need to be transferred into lower-value products in order to get at least some money for it. Indirect losses tend to go up when duration of a crisis is longer, both absolute as in comparison with direct losses. Especially since direct losses do not increase linear due to the correction for products already consumed. This correction is larger for scenarios with a larger duration of a crisis. In contradiction, indirect losses do increase in scenarios with a larger duration.

6.3 Aggregation to chain losses

The processing direct and indirect losses are linked to already known losses up to the farm and feed level (Van Asseldonk et al., 2006) to get an overall picture of the losses of the supply chain. However, this overall picture only covers the feed, farm and processing stage of the supply chain. Other stages (e.g. retailers) are not covered. Furthermore, quantified losses only relate to direct losses.

Van Asseldonk et al. (2006) calculated losses of 5.3 million euro in the most likely scenario with a standard deviation of 6.5 million euro. This research estimated direct losses at 20 million euro (contained) and 29 million euro (widespread) in the most likely scenario.

In the most likely scenario, direct supply chain losses are estimated at 25-34 million euro (Table 6.7). Results of the best case scenario and worst case scenario show losses of one million euro and losses between 102 and 248 million euro respectively.

Table 6.7: Overview of calculated scenarios and results.

	Most likely	Best case	Worst case
Scenario description			
Number of contaminated farms	**659**	**37**	**2210**
• Dairy farms	199	11	688
• Hog farms	150	8	503
• Broiler farms	72	4	241
Duration[A]	**7**	**1**	**30**
Processing sites affected[B]			
• Contained	4	1	4
• Widespread	6	2	11
Direct supply chain losses (million euro)			
Feed and farm level[C]	5	0.2	18
Processing companies:			
• Contained	20	1	84
• Widespread	29	1	230
Total per crisis	**25-34**	**1**	**102-248**
Direct and indirect losses of processing companies (index)[D]			
Direct losses	**100%**	**3%**	**259%**
Indirect losses[E]	**34%**	**-**	**105%**

A: Number of days contaminated feed is produced and number of days contaminated products are processed
B: Processing sites affected include dairy processing, pig slaughterhouses and broiler slaughterhouses (n=3)
C: At feed level: salvage costs – At farm level: destruction of livestock, business interruption and growth disruption
D: Indexes are based on company-specific data (weighted average, n=3)
E: Expressed in % of direct losses

Quantified aggregated supply chain losses include:

- Salvage costs (feed level)
- Losses arising from growth disruption, losses associated with a standstill period and destruction of livestock (farm level)
- Direct losses as defined for this research (processing level)

7 – Conclusions and discussion

7.1 Conclusions

Conclusions about the literature review on supply chain losses of recent contamination crises, average direct losses on the processing level[1], as well as company-specific direct[2] and indirect[3] losses are presented in this chapter. Direct and indirect losses reflect the calculations of the different scenarios developed in this research.

Literature

Recent feed contamination crises have shown aggregated supply chain losses between 0 and 132 million euro. However, many losses are either not known at all or not quantified. Furthermore, losses can often not be allocated to loss types, sectors or supply chain stages.

Direct losses

Scenarios of this research show average direct losses on the processing level of 20 million euro (contained) and 29 million euro (widespread) in the most likely scenario. Best case and worst case scenario show losses of 1 million euro (both contained and widespread) and 84 (contained) and 230 million euro (widespread) respectively.

Company-specific direct losses show best case, most likely and worst case scenario losses in a ratio of 3:100:259, showing that company-specific direct losses in the worst case scenario are 159% larger than in the most likely scenario.

The parameter number of farms contaminated has the biggest influence on the number of processing sites contaminated. However, the duration of a crisis influences the size of the losses for processing companies more.

Indirect losses

Indirect losses are large and increasing when duration of a crisis increases. In the most likely scenario the ratio of company-specific direct losses vs. indirect losses is 100:34. In the worst case scenario this ratio is 100:105. It shows that the company-specific indirect losses are larger than the company-specific direct losses in the worst case scenario.

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[1] Average direct losses on the processing level include value of contaminated products

[2] Company-specific direct losses include value of contaminated products and destruction costs…

[3] Company-specific indirect losses include returned products, decreased demand and regaining export markets.

Aggregation to supply chain losses (feed, farm and processing stage).

An estimation of supply chain losses, including the feed, the farm and the processing stage of the food supply chain, show losses between 25 and 34 million euro in the most likely scenario of this research. Best case and worst case scenario show losses of 1 million euro and losses between 102 and 248 million euro respectively. Losses include the feed level[4], the farm level[5], and the first processing level[6] of the food supply chain.

7.2 Discussion

Quantified losses cannot be equated with losses of involved processing companies.

This research' objective is to increase the transparency of processing industries losses with regard to a contamination in animal feed. However, company-specific losses are presented on an index scale. Publicly available information on processing sites, combined with expert information on the number of processing sites affected, lead to quantified losses on the processing industry level. Yet, quantified losses can not be equated with losses of involved processing companies.

Duration of a crisis in practice might be different from calculated scenarios.

Duration of a crisis is in this research is defined as the period in which contaminated products are processed. In practice, one could argue if a contamination crisis in which product are processed for either 1, 7 or 30 days could occur. Furthermore, the total duration of a contamination crisis exist of more than the days in which contaminated products are processed only. Therefore, duration of a contamination crisis, in practice, might even be longer than the 30 days of the worst case scenario of this research. However, in this research, it is assumed that, at the first processing stage of the food supply chain, contaminated products are processed in these 30 days for the worst case scenario.

Probability of occurrence of a contamination crisis.

This research has not investigated the probability of occurrence of each of the scenarios. The probability of occurrence of the most likely scenario of once in five years (most likely scenario of Van Asseldonk et al., 2006), is based on compound feed production in the Netherlands and has not been further investigated. Furthermore, from 1999 up until now, six animal feed crises (in both compound and wet feed sector) have occurred. Quantified aggregated supply chain losses of these crises varied from 0 to 132 million euro.

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4 Salvage costs

5 Losses arising from growth disruption, losses associated with a standstill period and destruction of livestock

6 Direct losses as defined for this research

Impact of type and size of feed companies on supply chain losses.

The impact of type and size of feed companies has not been researched in depth. Parameters on number of contaminated primary producers and processing sites are not linked to different types and size of feed producers has not been connected to different scenarios. Scenarios implicate that contaminations of even small animal feed companies may lead to large losses at the processing industry level. In scenarios with few contaminated farms, losses still approach half of the losses of the most likely scenario. Furthermore, it is not clear whether different types and size of feed companies lead to different scenarios and corresponding losses. In addition, it may depend on size of production location, origin of the contamination (raw material or contamination at site) as well as area a geographical concentration of feed producers whether size and type of feed companies lead to varying losses at the processing industry level.

7.3 Recommendations for further research

Liability for mixed-contaminated products.

Losses of first processing industries have been mapped in this research. Furthermore, the large influence of the spread of contaminated products and corresponding losses within processing companies is determined. Further research could focus on the question whether compound and wet feed producers are liable for the large spread of their products by processing companies further along the chain. The same question applies to primary producers. Up until now it is not clear whether feed producers are fully liable for contaminated products they deliver. At the processing stage contaminated products are mixed with non-contaminated products and corresponding losses are increased because of this. Remaining question is who is liable for this mixture; feed suppliers and farmers, who delivered the initial contaminated product stream or processing companies, who spread the contamination within their own company.

Risk profile for individual feed companies.

Risk profiles for individual feed companies might be another focus for additional research. It might be of interest to investigate what the influence of the type and size of feed companies is on the risk profile with regard to an animal feed contamination. In the discussion, this is already reviewed. Issues on type of feed company (e.g. compound feed vs. wet feed), size and area of delivery (geographical distribution) might be interesting topics of further research.

Specification of average supply chain losses to individual processing companies.

An estimation of average supply chain losses and especially losses on the processing stage of the supply chain is presented in this research. To gain further insight to losses of individual processing companies, quantified company-specific losses should be presented, instead of an index. Furthermore, since direct and indirect company-specific losses are rather different between companies. By presenting quantified company-specific direct and indirect losses, more transparency about supply chain losses will be obtained. This would give important information for both feed producers as farms on the amount they should insure their selves for specific supply chains.

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Appendix 1 – Literature review on recent livestock epidemic crises

Swine fever 1997

In February 1997 there was a classical swine fever outbreak in The Netherlands. Because of this epidemic the amount of pigs in The Netherlands decreased from about 14 million to 11.4 million (Agrarisch Dagblad, 1998-a). The production of hogs decreased with 25% to 1,4 million ton in 1997 (Volkskrant, 1998).

For almost half a year it was prohibited to breed pigs. This prohibition was later declared illegal and the Ministry of Agriculture later compensated losses for pig breeders for several dozens of millions. The total amount of this compensation is never specified, but the compensation consisted of an amount of approximately 170 euro per sow (Agrarisch Dagblad, 2003).

Foot and mouth disease 2001

On March 21, 2001 foot and mouth disease was discovered in The Netherlands at a farm in Olst. A standstill for transport from, in and to The Netherlands for amongst others cattle, pigs and poultry was declared on the same day. A number of 26 farms were affected with foot and mouth disease. On approximately 2600 farms a total of 260.000 animals were destroyed (Ministry of Agriculture, 2001-a; Ministry of Agriculture, 2001-b).

Avian influenza 2003

In February 2003 avian influenza was discovered in The Netherlands. At 255 locations avian influenza was determined. All animals of all locations were destroyed. In addition animals of 1094 locations were destroyed preventively. Therefore a total of 30,7 million animals were destroyed (Agriholland, 2007-a).

Blue tongue 2006

In August 2006 the livestock epidemic blue tongue was discovered in The Netherlands. After several days it appeared that the virus affected over 10 companies. A total of 456 farms were affected with blue tongue (Agriholland, 2007-b). In 2007 blue tongue was detected at over 6442 farms in The Netherlands. Sheep are present at 3241 of these farms; cows are present at 3146 of these affected farms (Agrarisch Dagblad, 2008; Boerderij, 2007-b).

Supply chain losses of recent livestock epidemics

Swine fever 1997

In the pig sector 8000 jobs were lost as a consequence of the swine fever, 13% of employment before swine fever. About 2500 jobs were lost at farm level as well as 600 jobs in the processing industry. Because of swine fever the production value of the Dutch meat industry was limited in 1997 and decreased by 908 million euro in comparison with 1996 (Volkskrant, 1998).

Losses of the swine fever in 1997 are estimated at 3 billion guilders, approximately 1,36 billion euro. More than 50% of this amount was spent to buy-up compensations to primary producers and about 190 million euro was spent on implementation (Agrarisch Dagblad, 1999).

The outbreak of swine fever in 1997 had radical consequences for meat processing companies. Nine slaughterhouses were closed and purchase prices for processing companies went up with 50%. Dutch consumers did not reacted heavily on the outbreak of swine fever; consumption decreased with 20% at first, but was back at the average level in 2 months. Swine fever also did not worsened the image of pig meat among Dutch consumers. Although the image of Dutch pig farming got worse, Dutch consumers did not link this to consumption of meat (Product Board for Livestock, Meat and Eggs, 1998; VTM, 1997).

Pig processor Dumeco made a profit of 13,6 million euro in 1997, a growth of 63% in comparison with 1996. However, turnover decreased with 17% because of swine fever. The lower turnover was mainly caused by the lower supply of hogs. This was caused during the time it was prohibited to breed pigs for almost half a year (Agrarisch Dagblad, 1998-b).

Foot and mouth disease 2001

The Dutch Bureau for Economic Policy Analysis estimated losses of the 2001 foot and mouth disease outbreak in The Netherlands at 2,8 billion guilders, approximately 1,27 billion euro. Losses consisted of 545 million euro for the agricultural sector and approximately 500 million euro for other supply chain partners (feed and processing sector). Other losses were not related to the supply chain, for example losses of the leisure industry (CPB, 2001).

According to the dairy product board, foot and mouth disease hardly influenced the international dairy market in 2001 (Dairy Product Board, 2002). Countries as Russia, China, Australia and New Zealand however, blocked the import of Dutch dairy products for over a week (Agrarisch Dagblad, 2001). Dairy processors Campina and Friesland Coberco Dairy Foods reported lower profits in 2001 because of the FMD-crisis of 7 million euro and 8 million euro respectively (Campina, 2002; FDCF, 2002).

The FMD-crisis also influenced the sales of slaughterhouses. A reduction of 20% in sales occurred in May 2001. Sales on foreign markets even decreased with 33% in that month (CBS, 2001).

Avian influenza 2003

Direct losses of affected farmers were estimated at 300 million euro. This amount did not include losses due to a standstill in production. Indirect losses as a result of lower prices are estimated at 500 million euro. Losses after the epidemic in order to recover markets are not specified, but are estimated at hundreds of millions euro (Saatkamp, 2006).

Blue tongue 2006

According to the Dutch Federation of Agriculture and Horticulture and according to the cattle export company Veepro-Holland an export ban on living animals could cause losses of 20 million euro if it lasts for 2 months. Yearly export of living animals is 70-100 million euro (Agriholland, 2007-b) Because of a ban on the export of living animals 10% less breeding animals were exported in 2006 (Reformatorisch Dagblad, 2006).

Losses of the 2006 blue tongue crisis are estimated at 53 million euro including losses due to the export ban. Losses of blue tongue in 2007 are estimated at 81 million euro (LTO, 2007).

Table A1.1: Supply chain losses recent livestock epidemics.

	Feed	Farm	Processing industries	Other	Total
Swine fever 1997		>27,2[A]		Lower turnover[B]	1360[C]
Foot and mouth disease 2001		540		500 supply chain[D]	1270[C]
Avian influenza 2003		800		Regaining export markets[E]	800[C]
Blue tongue 2006					53[F,G]

A: Buy-up compensations.
B: 17% lower turnover of Dumeco.
C: Reported total losses.
D: 500 million euro related to losses for the supply chain apart from the farm level.
E: Estimated at hundreds of millions euro.
F: Own estimation based on found literature.
G: Losses in 2007 due to blue tongue are estimated at 81 million euro.

Table A1.2: Direct and indirect losses of processing industries per sector in previous livestock epidemics.

	Direct losses			Indirect losses		
	Dairy	Pig	Poultry	Dairy	Pig	Poultry
Livestock epidemics crises						
Swine fever 1997		>27,2[A]				
Foot and mouth disease 2001				15[B]		
Avian influenza 2003			300			500

A: Buy-up compensations.
B: Lower profits of dairy processors Campina and Friesland Coberco Dairy Foods.