Liability Risks in Agri-food Supply Chains: the Case of Wet Feed

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Abstract— **Recent animal feed crises caused substantial damage throughout food supply chains and, consequently, initiated debates on the liability insurance cover of animal feed companies. In this framework, a quantitative risk analysis for wet feed producers in the Netherlands is presented. The simulation model developed is parameterised by among others data from three Dutch wet feed companies reflecting about 45% of the wet feed market in the Netherlands. The model addresses direct damage up to farm level. Default outcomes per crisis show that the number of contaminated farms is expected to be 117, with a variation from 19 farms in the 5% percentile to 331 farms in the 95% percentile. Projected direct damage per crisis is on average Euro 0.9 million, ranging from Euro 0.09 million (5%) to Euro 2.8 million (95%). The expected number of 117 farms consists of 15 sow farms, 31 hog farms, 49 dairy farms and 22 beef farms. Sensitivity analyses illustrate that the size of farms supplied with wet feed and the number of days in which contaminated wet feed is delivered are key variables in determining the eventual size of damage. Outcomes show the expected situation for the entire wet feed sector in the Netherlands—under the assumption that all wet feed companies have about the same risk profile as the sample companies whose data have been used to parameterise variables such as mixing rates and number of farms supplied each day. As the sample companies cover 45% of the total volume of wet feed in the Netherlands, their "share" in total damage is expected to be about the same, i.e. 45%. Similar conclusions hold for other wet feed companies whose risk profile is comparable to that of the sample companies. Outcomes are used in supply chain and insurance discussions on reviewing liability insurance covers of animal feed producers.**

Keywords— **Contamination risk, Simulation model, Direct damage**

1. INTRODUCTION

Due to a number of crises in the animal feed sector, which caused substantial damage in livestock supply chains, the issue aroused of increasing the liability insurance coverage for animal feed producers. In this framework, the objective of this project is to carry out a quantitative risk analysis for wet feed producers in the Netherlands, which could subsequently be used as a basis for (re)designing liability insurance schemes. More specifically, the objectives of this project are to (1) estimate the expected number of farms affected by a contamination in wet feed; (2) determine the expected geographical spread of these farms; and (3) calculate related farm-level damage. To adequately address these objectives, further specifications have been made, i.e. (i) the project focuses on wet feed suppliers in the Netherlands; (ii) farm types involved include pig and cattle farms; (iii) geographical spread has been specified to the level of provinces; (iv) primary producers affected include solely those who received contaminated wet feed; and (v) farm level damage includes damage related to the culling of animals, growth disruption and downgraded quality, and damage related to milk not being collected.

The three sample companies cover about 45% of the total amount of wet feed supplied in the Netherlands. The companies cover all provinces (12) and all categories of wet feed (6) plus roughage. Detailed data from these companies are used as input for the risk analysis model, such as with respect to sales per province and number of farms supplied per day. (Wet feed has been categorised by the OPNV, i.e. the Consultative body of wet feed producers, into six categories, i.e. products from (1) grain processing industries, such as wheat starch, maize glutenfeed, brewers' grains and brewer's yeast; (2) potato processing industries, such as potato pulp, potato peelings, potato cuttings and potato starch; (3) sugar industries, such as sugar beet pulp; (4) dairy processing industries, such as whey; (5) fermentation and alcohol industries, such as fermented wheat, mycelium feed and distillers solubles; and (6) other wet feed products, such as soy bean products and products from the processing of vegetables and fruit.

In estimating input parameters for the risk model, three further data sources are used, i.e. (1) data from the 2006 risk analysis on compound feed [1]; (2) past experience data from the period 1997/2006 regarding wet feed contaminations in the Netherlands; and (3) OPNV data on the average use of wet feed by various livestock sectors [2]. The size of input parameters varies according to the data set used. Scenario analyses will be carried out to show the related impact on results.

2. WET FEED IN THE NETHERLANDS

Livestock farms in the Netherlands mostly use compound feed, i.e. in total about 12 million tons, for which ingredients are mostly imported (75%), partly (50%) from outside the EU. Besides, livestock farmers feed so-called wet feed: in total 5 million tons. This wet feed originates mainly from the Netherlands (90%); 10% is imported from Belgium, Germany and France. Industries involved are mostly grain (39%), potato (29%), dairy (15%) and sugar processing industries (10%) [3]. About 60% of the wet feed is delivered to pig farms. This includes wheat starch, potato peelings and whey products. The other 40% is delivered to cattle farms. This includes beet pulp, brewers' grains and potato pulp. Table 1 shows the average percentages per sector for the various categories of wet feed. Table 1 also summarizes the data of the companies involved ("sample"): their joint volume includes 2.3 million tons, which is 45% of the total volume of wet feed supplied in the Netherlands. Furthermore, their assortment also includes some roughage such as maize and lucerne. With respect to the provinces supplied, sample data show highest volumes for Noord-Brabant (681,158 ton), Gelderland (418,830 ton) and Overijssel (268,019 ton).

Table 1 Amount of wet feed supplied in the Netherlands[1], % per livestock sector, and sample data

	Total	Grain	Potato	Sugar	Dairy	Ferm.	Other	Rough.
***Netherlands*[2]**								
Total (ton kg)	*5 150 000*	*2 000 000*	*1 468 000*	*507 000*	*785 000*	*250 000*	*140 000*	-
% Pig		0.69	0.55	0.05	1.00	0.75	0.64	0.00
% Cattle		0.31	0.45	0.95	0.00	0.25	0.36	1.00
***Sample*[3]**								
Total (ton)	*2 343 054*	*832 942*	*838 482*	*506 096*	*7 280*	*12 609*	*110 386*	*35 260*
Groningen	97 061	24 590	34 946	29 073	2 979	1 103	319	4 051
Friesland	207 199	73 391	58 371	69 561	0	25	1 448	4 403
Drenthe	64 093	13 449	24 041	25 551	0	0	445	608
Overijssel	268 019	78 965	90 954	83 417	1 532	1 868	6 734	4 549
Flevoland	39 125	7 647	4 901	25 289	0	21	144	1 123
Gelderland	418 830	157 000	145 000	87 631	0	1 954	20 392	6 853
Utrecht	95 476	27 925	30 499	31 257	106	599	2 120	2 968
Noord-Holland	48 807	13 617	11 786	17 376	0	0	4 296	1 733
Zuid-Holland	215 666	109 000	49 809	41 596	62	2 779	8 314	4 105
Zeeland	21 194	7 149	8 073	4 625	0	371	923	53
Noord-Brabant	681 158	254 000	283 000	80 212	1 542	2 791	55 904	3 710
Limburg	186 426	66 209	97 103	10 507	1 058	1 098	9 346	1 104

[1]Wet feed is categorised into products from: (1) grain processing industries ("grain"), such as wheat starch, maize glutenfeed and brewer's yeast; (2) potato processing industries ("potato"), such as potato pulp and potato starch; (3) sugar industries ("sugar"), such as sugar beet pulp; (4) dairy processing industries ("dairy"), such as whey; (5) fermentation and alcohol industries ("ferm."), such as fermented wheat, mycelium feed and distillers solubles; (6) other wet feed suppliers ("other"), such as soy bean products and products from the processing of vegetables and fruit; and (7) roughage suppliers ("rough."), including straw and lucerne.

[2]Data OPNV (Consultative body of wet feed producers, www.opnv.nl). Data are for 2006 and do not include roughage. Roughage data are derived from sample data.

[3]Sample data are for three companies: 2 x January 2006/December 2006, 1x July 2006/June 2007.

Table 2 Examples of developments enhancing risk prevention of animal feed (1997/2006)

	97/01	02	03	04	05	06
Legislation						
Regulation 178/2002/EC: General Food Law[1]		X				
Directive 2002/32/EC: Undesirable substances in animal feed		X				
▪ Extended requirements for lead, fluorine and cadmium					X	
▪ Idem, for dioxins and dioxin-like PCBs						X
Comm. Decision 2004/217: Prohibited materials for animal nutrition				X		
Directive 183/2005/EC: Requirements for feed hygiene					X	
Sector initiatives						
Good Manufacturing practices (GMP)	< 97					
GMP plus HACCP (GMP+)		X				X[2]
Only accredited products based on risk assessment			X			
Procedures for recall, early warning and tracking and tracing			X			
Industry initiatives						
TrusQ[3]			X			
SafeFeed[4]					X[4]	

[1]178/2002/EC laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.
[2]New version of GMP+, among others to fully include requirements set by directive 183/2005/EC and to better respond to foreign companies' needs.
[3]The aim of TrusQ is to use systematic screening of suppliers and raw materials to significantly reduce the risk of animal feeds being mixed with unwanted constituents. TrusQ is setting stringent requirements for logistic and production processes of raw materials. These are based on the combined knowledge and experience of quality control in six compound feed producing companies, which between them hold more than 60% of the Dutch compound feed market. TrusQ might be seen as a further deepening of GMP+.
[4]Safe Feed aims to enhance and deepen GMP+. It includes more than 60 producers and from 2007 onwards also wet feed companies can become a member.

3. RISK PREVENTION

Among others due to the various crises in animal feed during recent years, there has been an increased attention for food and feed safety. During the last five years this has led to a number of new directives at EU level and, in addition, to a number of sector and private initiatives. Table 2 gives a number of examples showing the increased attention for food and feed safety.

The table shows that from 2002 onwards there have been continuously new initiatives, updates and more stringent requirements for animal feed suppliers to fulfil. Monitoring of "sector progress", for instance with respect to tracking and tracing and the set-up of integrated risk analyses, was done by among others Netherlands Institute of Food Safety [4] and Netherlands Court of Audit [5].

4. RISK ANALYSIS

A. Previous contamination crises in wet feed

Three crises are reviewed on the basis of their main variables (Table 3), i.e. (1) number of suppliers affected; (2) number of days in which contaminated wet feed is delivered; (3) livestock sectors involved; (4) number of farms involved; (5) duration of the standstill; and (6) number of farms from which livestock is destructed. Besides the crises described, no other crises for wet feed could be identified[1].

MPA 2002 [6]. A severe crisis in the Dutch compound and wet feed sector was the MPA (Medroxy Progesteron Acetate) contamination in June 2002. The contamination started at the Wyeth company in Ireland. Glucose-syrup from this pharmaceutical firm ended up at the firm

[1] Dioxin crises of 2003 (bread meal) and 2006 (fat) related to *compound* feed.

Bioland in Belgium. This firm made deliveries of MPA-contaminated syrup to primary producers (pig farms), which delivered in their turn to compound feed companies and, indirectly, to wet feed companies. As a consequence, numerous companies producing different feed products (wet feed, compound feed, molasses, vinasses) were involved. The duration in which contaminated feed was produced is not transparent since the contamination was quite diffuse. The contamination was detected by pig farmers facing fertility problems of their sows.

Dioxin 2004 [7]. In October/November 2004, the Dutch animal feed sector was confronted with dioxin contamination of potato by-products within the potato processing industry. This was caused by detection of raised levels in milk in the context of the dairy industry monitoring program.

The contamination was caused by a number of potato processing companies using potato sorting clay, originating from Germany. This sorting clay proved to be "naturally" contaminated with dioxin.

Bone fragments 2004 [8]. In November-December 2004, the Dutch animal feed sector was confronted with a number of positive analysis results for bone fragments in German beet pulp. Initially, an early warning signal (EWS) was deemed sufficient in the beginning of November 2004. By mid November 2004 precautionary measures were taken after strong indications that this was not an incidental event, but could rather be a structural problem due to the use of bone meal or bone phosphate as a fertilizer in beet crops. Due to early discovery companies involved could take measures at an early stage, which implied that the impact on subsequent stages of the chain was non-existent.

Table 3 Key characteristics of recent contamination crises in wet feed [6, 7, 8]

	MPA Syrup 2002 Netherlands	Dioxin Potato by-products 2004 Netherlands	Bone fragments Beet pulp 2004 Netherlands
Feed companies affected	Compound feed Wet feed	Wet feed	Wet feed
Wet feed			
Number of suppliers	3 traces (a, b, c)	3 (5 sites)	2 (Germany)
Duration (days)	59[1] / 12[2] (a) < 7 (c)	11[3]	16[4]
Sectors involved	Pigs (a, c) Cattle (silage, b)	Pigs Cattle	-[5]
Number of farms involved	55 (pigs, a) 32 (cattle, b) >1000 (pigs, c)	196 (pigs and cattle)	0[5]
Duration of standstill (weeks)	< 6 (pigs, a)	< 2[6]	0
Number of farms from which livestock is destructed	27 (> 50,000 pigs, a)	0	0

[1]From first notification of fertility problems until identification of all farms supplied with contaminated wet feed.
[2]From identification of MPA until identification of all farms supplied.
[3]From first notification of exceeded dioxin limits in milk to identification of the causing factor, i.e. sorting clay.
[4]From first RASFF-notification until enforcement of strict monitoring program.
[5]As a result of surveillance, positive batches were not sold.
[6]For most dairy farms, milk was collected and stored separately until test results were known.

Table 4 Economic variables of livestock farms[1]

	Pig		Cattle	
	Sows	Hogs	Dairy	Beef
Compensation (Euro/animal)	600	62	1 293	741
Destruction and cleaning (Euro/animal)	400	150	1 000	1 000
Gross margin (Euro/animal/year)	380	67	2 368	202
Milk revenues (Euro/cow/day)			21 litre x Euro 0.31/litre	

[1]Epidemic disease analyses, 2000-2006 and [9].

B. Damage components and farm structure

In the risk model, damage is calculated for *one part of the chain*, i.e. the farmers, and only for those farmers who *received contaminated wet feed*. For this group of farmers, the following direct damage components are considered: (1) *growth disruption and downgraded quality* of livestock as a result of intake of contaminated wet feed and damage associated with the standstill period; (2) *destruction and compensation* in case livestock is culled (assumed to be only applicable to meat farms, i.e. farms with hogs and beef cattle); and (3) *lost revenues for dairy farmers* associated with milk not being collected. Related economic parameters for the various types of livestock farms are listed in Table 4. Farm size and frequency per province are taken from [10].

C. Risk modelling assumptions

Variables. The risk model includes a number of distinct variables, as listed in the first column of Table 5, together with their unit of measurement (second column). The variables reflect the probability of a contamination in a batch of wet feed (variable 1), the number of wet feed suppliers' sites involved (variable 2), the type of wet feed involved (variable 3) and the number of days in which contaminated wet feed is being delivered (variable 4).

Next, the variables reflect the livestock sector affected, i.e. pigs and, or, cattle (variable 5), the number of farms supplied per suppliers' site per day (variable 6) and the cumulation of affected farms due to the mixing of wet feed (variable 7). Variable 8 mimics the dispersion of wet feed across the Netherlands.

Variables 9, 10 and 11 simulate the consequences at farm level, i.e. whether or not animals are culled, whether there are problems of growth disruption and downgraded quality including its length, and whether or not milk from dairy farms is collected, including the related number of days.

Stochastic and deterministic variables. Most variables are defined as *stochastic* variables; specified functional forms (Poisson, Discrete, Cumulative, Triangular) are listed in the third column of Table 5. Variables for which no relevant probability distributions could be identified are modelled in a *deterministic* way, such as the livestock sector(s) affected (variable 5) and the degree of cumulation by mixing wet feed ingredients (variable 7).

Data. In order to parameterise the variables, four sources of data can be used (fourth column of Table 5): (1) *Sample data of wet feed companies*. Detailed data including daily information per type of wet feed, supplier and client have been analysed. Data are from three companies and cover the period January 2006/December 2006 (2 companies) and July 2006/June 2007 (1 company). The companies supply about 45% of all wet feed supplied in the Netherlands, and they cover all provinces and types of wet feed. Sample data can be used to parameterise variables such as variable 3 (wet feed sector affected), variable 6 (number of farms supplied per suppliers' site) and variable 8 (dispersion across the Netherlands). (2) *Data from 2006 risk analysis on compound feed* [1]. Data originate from a quantitative risk analysis for the compound feed sector in the Netherlands. Data were mainly derived from expert elicitation. Although the wet feed and compound feed sector show a number of apparent differences, general risk parameters such as the probability of contamination are expected to be largely congruent (Appendix B). Expert 2006 estimations can for instance be used to quantify variables such as the probability of a contamination occurring (variable 1) and the number of days in which contaminated wet feed is delivered (variable 4). (3) *Past experience data on wet feed crises (1997/2006)*. Data from the past ten years as reflected in Table 3 do not fully consider the risk prevention enhancing developments as listed in Table 2. Still, for some variables, no other estimations are available. Also, these data can be seen as worst case estimations. Past experience data can for instance be used to quantify variable 1 (probability of a contamination occurring), variable 2 (number of wet feed suppliers' sites involved), variable 4 (number of days in which contaminated wet feed is delivered) and variables 11a and 11b (percentage of dairy farms at which milk is not collected and the related time period). (4) *Data OPNV on wet feed in the Netherlands*. National figures on the total volumes of wet feed per category and the usage per livestock sector can be used to parameterise variable 3 (wet feed sector affected) and variable 5 (livestock sector(s) affected).

Parameterisation. The columns of Table 5 referring to the quantification of variables, i.e. column 6 and beyond, distinguish (1) overall parameters; and (2) specifications per wet feed category. The "overall parameters", i.e. variable 1 (probability of contamination), variable 2 (number of wet feed suppliers' sites involved), variable 4 (number of days in which contaminated wet feed is delivered), variable 7 (cumulation) and the farm-level consequence variables (9, 10 and 11) are not specified per type of wet feed, while the other variables are made wet feed category specific. With regard to the *deterministic* variables, values mentioned are directly used in the risk model. For instance, in case of a contamination there is—using sample data—always a 0.36 chance that the contamination occurs in products from the grain industry. With respect to *stochastic* variables, values indicated are clarified per functional form. *Poisson*. The listed parameter (e.g. 7 days for variable 4 in case of using the expert 2006 data) reflects the *average* number of days in which contaminated feed is delivered. However, when running the risk model the number of days will vary for each iteration, from 0 (minimum) to 19 (maximum). *Discrete* (only for variable 2: number of wet feed sites involved). Parameters specify the probability of each situation occurring. Using past experience data the probability of having 2, 3 or 5 sites involved is equal to 1/3 for each situation. *Cumulative*. This type of distribution has been used for variable 6 (number of farms supplied per site per day). Parameters exactly reflect the sample data analysed. For instance, for products from the grain industry, the number of farms delivered can be 0 (minimum), 1 (10%, 20% and 30% percentiles), 2 (40% and 50% percentiles), etc., up to a maximum of 21. *Triangular*. Triangular distributions are used for the farm-level consequence variables (9, 10a and 11a). Parameters reflect the minimum, most likely and maximum values. For instance, for variable 11a (percentage of farms which face no collection of milk) values will be between 0% (minimum), 2% (most likely) and 5% (maximum).

D. Scenario description

Three future scenarios have been identified. *Scenario "expert 2006"* uses a combination of the data sources described but with a focus (as far as relevant) on the expert 2006 data originating from the risk analysis for compound feed. This scenario can be described as a situation in which recent developments in the field of risk prevention are incorporated. Basic assumptions on the probability of a contamination and the number of days in which contaminated feed is produced are taken from the 2006 expert elicitation for compound feed. *Scenario "past experience"* also uses a combination of the data sources described but uses more of the past experience data from the period 97/06. This scenario is close to a situation of "repeating the past, as if no lessons are learned from previous crises". *Scenario "more culling and no collection of milk"* again uses all data sources described but with some additional assumptions about the percentage of farms culled and the percentage of farms facing no collection of milk. This scenario is a "what-if scenario" in case future responses from processing companies become stricter. Data sources and assumptions per scenario are explained in Appendix A.

Table 5 Stochastic and deterministic variables in the Monte Carlo simulation model and parameterisation (overall, and per type of wet feed[1])

Variable	Unit	(Risk) function	Source(s)	Description	Parameterisation							
					Overall	Grain	Potato	Sugar	Dairy	Ferm.	Other	Rough
1. Contamination in day batch (%, year)	%/year	Poisson	Expert 2006	Mean = 1/5 y.	0.20							
			Data 97/06	Mean = 3/10 y.	0.30							
2. Wet feed suppliers (sites) involved	Number	Discrete	Data 97/06	2, 3, 5 sites	0.33; 0.33; 0.33							
3. Wet feed sector affected	Sector	Determ.	Sample[2]	Volumes sample		0.36	0.36	0.22	0.003	0.01	0.05	0.02
			Data 97/06	3 sectors involved		0.33	0.33	0.33	0	0	0	0
			Data OPNV[3]	Volumes NL		0.39	0.29	0.10	0.15	0.05	0.03	-
4. Duration (days)	Number	Poisson	Expert 2006	Mean = 7 d.	7							
			Data 97/06	Mean = 25 d.	25							
5. Livestock sector(s) affected	Sector	Determ.	Data OPNV[4]	*Pig*		0.69	0.55	0.05	1.00	0.75	0.64	0.00
				Cattle		0.31	0.45	0.95	0.00	0.25	0.36	1.00
6. Number of farms supplied per supplier (site) per day	Number	Cumul.	Sample	*Mean*		3.64	3.72	8.18	1.23	1.66	2.03	2.19
				Minimum		0	0	0	0	0	0	0
				10% percentile		1	1	1	1	1	1	1
				20% percentile		1	1	1	1	1	1	1
				30% percentile		1	1	2	1	1	1	1
				40% percentile		2	2	3	1	1	1	1
				50% percentile		2	2	4	1	1	1	2
				60% percentile		3	3	5	1	2	2	2
				70% percentile		4	5	7	1	2	2	2
				80% percentile		5	6	10	1	2	3	3
				90% percentile		9	9	27	2	3	4	4
				Maximum		21	18	61	2	4	10	10

[1]Wet feed has been categorised into 7 categories: (1) grain processing industries, “grain”; (2) potato processing industries, “potato”; (3) sugar industries, “sugar”; (4) dairy processing industries, “dairy”; (5) fermentation and alcohol industries, “ferm.”; (6) other wet feed deliverers, “other”; and (7) roughage deliverers, “rough.”.
[2]The amount of wet feed in the sample covers 45% of the total amount of wet feed supplied in the Netherlands.
[3]OPNV stands for Consultative body of wet feed producers. Data do not include roughage.
[4]Probabilities for roughage are derived from sample data.

Table 5 (continued) Stochastic and deterministic elements in the Monte Carlo simulation model and parameterisation (overall, and per type of wet feed)

Variable	Unit	(Risk) function	Source(s)	Description	Parameterisation							
					Overall	Grain	Potato	Sugar	Dairy	Ferm.	Other	Rough.
7. Cumulation	Number	Determ.	Sample	2.6% mixed[5]	1.05							
8. Percentage dispersion across the Netherlands	% per province	Determ.	Sample	Volumes sample								
				Groningen (%)		3	4	6	41	9	0	11
				Friesland (%)		9	7	14	0	0	1	12
				Drenthe (%)		2	3	5	0	0	0	2
				Overijssel (%)		9	11	16	21	15	6	13
				Flevoland (%)		1	1	5	0	0	0	3
				Gelderland (%)		19	17	17	0	15	18	19
				Utrecht (%)		3	4	6	1	5	2	8
				Noord-Holland (%)		2	1	3	0	0	4	5
				Zuid-Holland (%)		13	6	8	1	22	8	12
				Zeeland (%)		1	1	1	0	3	1	0
				Noord-Brabant (%)		30	34	16	21	22	51	11
				Limburg (%)		8	12	2	15	9	8	3
9. Culling of animals on meat farms[6]	% farms	Triang.	Expert 2006	Hogs, beef[7]	0; 15; 40							
10a. Growth disr. & downgraded quality	%	Triang.	Expert 2006	Pigs[8]	0; 5; 40							
				Cattle[8]	0; 5; 45							
10b. Duration (days)	Number	Poisson	Expert 2006	Pigs: mean = 10 d.	10							
				Cattle: mean = 5 d.	5							
11a. No collection of milk[9]	% farms	Triang.	Data 97/06	Dairy[10]	0; 2; 5							
11b. Duration (days)	Number	Poisson	Data 97/06	Mean = 7 d.	7							

[5]Mixing percentage (2.6%) is weighted average from industries in sample. The assumed mixing ratio is 1:3. For instance, for wet feed *i* with volume of 100,000 ton: 0.974*100,000 + (0.026*3*100,000) = 105,200, which is 1.05 times the original 100,000. It is assumed that mixing batches in storage capacity (i.e. 2% of total volume in sample) is not causing additional risk, as this is not a continuous process; storage capacity is filled during several months and subsequently emptied during a limited number of weeks.
[6]Expert 2006 estimations for *all* farms were 0% (minimum), 5% (most likely) and 15% (maximum). Recalculation to meat farms only: 0% (minimum), 15% (most likely) and 40% (maximum).
[7]Values indicate minimum, most likely and maximum % of meat farms culled.
[8]Values indicate minimum, most likely and maximum % of growth disruption and downgraded quality.
[9]Calculated *in addition to* damage under 10a/b.
[10]Values indicate minimum, most likely and maximum % of dairy farms facing no collection of milk.

5. RESULTS

A. Scenario results

Results (Table 6) show that in the expert 2006 scenario the expected number of pig and cattle farms receiving contaminated wet feed is 117, with a variation from 19 (5%) to 331 farms (95%). Related damage per contamination is expected to be Euro 0.9 million, Euro 0.09 million and Euro 2.8 million respectively. Annual projected damage is on average Euro 0.2 million.

In the past experience scenario, the projected number of contaminated farms significantly increases to on average 484. This sharp increase is mainly caused by the increased number of days in which contaminated wet feed is delivered: on average 25 instead of 7 days.

Furthermore, the clustering of contamination in the three sectors of grain, potato and sugar leads to an increased number of contaminated farms caused by the possibly large number of farms supplied per day for these categories of wet feed (see Table 5). The higher amount of expected annual damage, i.e. Euro 1 million, is also influenced by the higher chance of a contamination occurring: 3 per 10 year instead of 1 per 5 year.

In the more culling and no collection of milk scenario the projected number of contaminated farms is equal to the expert 2006 scenario. However, due to the more severe farm-level consequences, projected damage per contamination is expected to increase to about Euro 2.7 million, with 5% and 95% percentiles of Euro 0.4 million and Euro 6.7 million respectively.

Table 6 Scenarios for the Netherlands as a whole (mean, 5% percentile, 95% percentile), 5000 @Risk iterations

	Total		
	Mean	5%	95%
Scenario "expert 2006"			
Number of contaminated farms	**117**	**19**	**331**
Damage per contamination (euro)	946 729	90 043	2 774 434
Annual damage (euro)	196 808	0	1 312228
Scenario "past experience"			
Number of contaminated farms	**484**	**133**	**1219**
Damage per contamination (euro)	3 368 605	601 601	8 789 519
Annual damage (euro)	1 007 856	0	5 872 699
Scenario "more culling and no collection of milk"			
Number of contaminated farms	**117**	**19**	**331**
Damage per contamination (euro)	2 677 688	384 337	6 742 602
Annual damage (euro)	566 124	0	3 770 705

Table 7 Scenarios for the Netherlands as a whole, total and specified per sector (mean), 5000 @Risk iterations

	Total (mean)	Pigs (mean)		Cattle (mean)	
		Sows	Hogs	Dairy	Beef
Scenario "expert 2006"					
Number of contaminated farms	**117**	**15**	**31**	**49**	**22**
Damage per contamination (euro)	946 729	6 215	765 582	19 326	155 606
Annual damage (euro)	196 808	1 325	160 158	3 984	31 340
Scenario "past experience"					
Number of contaminated farms	**484**	**50**	**102**	**230**	**102**
Damage per contamination (euro)	3 368 605	20 739	2 547 033	92 503	708 331
Annual damage (euro)	1 007 856	6 283	756 129	28 186	217 258
Scenario "more culling and no collection of milk"					
Number of contaminated farms	**117**	**15**	**31**	**49**	**22**
Damage per contamination (euro)	2 677 688	6 215	2 088 577	159 981	422 915
Annual damage (euro)	566 124	1 325	447 952	32 843	84 004

Numbers in Table 6 are aggregated across pig and cattle farms. Table 7 shows the subdivision of expected values to specific livestock sectors (sows, hogs, dairy, beef). For all scenarios total damage is highest for hog farms and lowest for sow farms. Comparing the expert 2006 scenario and the scenario of more culling and no collection of milk, it is shown that in the latter scenario damage for hog and beef farms increases by a factor of 3. Damage at dairy farms even becomes 8 times higher.

B. Sensitivity analyses

In scenario analyses, multiple parameters are changed at the same time. In order to see the impact of changing only *one* variable, Table 8 shows six sensitivity analyses with regard to the expert 2006 scenario.

(1) Increasing the length of the period in which contaminated feed is delivered causes the expected number of contaminated farms to significantly increase, from 117 to 338. Expected damage per contamination increases from Euro 0.9 million to Euro 2.7 million. 95% percentile damage increases from Euro 2.7 million to Euro 7.1 million.

(2) Increasing the average size of pig farms in all provinces to 350 sows and 2000 hogs causes expected damage per contamination to increase to Euro 2.6 million.

(3) If wet feed companies would increase their mixing of batches to 1.5 instead of 1.05, the expected number of farms affected in case of a contamination increases to 167. Related damage per contamination increases from Euro 0.9 million to Euro 1.4 million.

(4) Not collecting any milk during a period of one week increases the expected damage per contamination to Euro 1.1 million.

(5) Reducing the number of wet feed suppliers involved in a contamination crisis has a large impact on the expected number of contaminated farms. This number reduces to 35 with a 95% percentile below 100, i.e. 97.

(6) If the number of farms supplied per day would decrease (mimicked as a maximum closely to the 90% percentile) the expected number of contaminated farms reduces to 100. (Note that the 5% percentile stays the same, i.e. 19.)

Table 8 Sensitivity analyses for scenario "expert 2006" (mean, 5%, 95% percentile), 5000 @Risk iterations

	Total		
	Mean	5%	95%
Expert 2006			
Number of contaminated farms	**117**	**19**	**331**
Damage per contamination (euro)	946 729	90 043	2 774 434
Annual damage (euro)	196 808	0	1 312 228
Sensitivity analyses			
(1) Increased length of producing contaminated feed (20 days)			
Number of contaminated farms	**338**	**90**	**848**
Damage per contamination (euro)	2 743 556	431 364	7 115 198
Annual damage (euro)	562 821	0	3 646 986
(2) Increased size of pig farms[1]			
Number of contaminated farms	**117**	**19**	**331**
Damage per contamination (euro)	2 566 542	163 578	7 871 769
Annual damage (euro)	534 538	0	3 626 053

[1]Size of pig farms in all provinces is set to 350 (sows) and 2000 (hogs). Previous numbers were on average 280 and 640 respectively.

Table 8 (continued) Sensitivity analyses for scenario "expert 2006" (mean, 5%, 95%), 5000 @Risk iterations

	Total		
	Mean	5%	95%
(3) Increased cumulation (1.5)			
Number of contaminated farms	**167**	**27**	**473**
Damage per contamination (euro)	1 351 822	129 322	3 966 329
Annual damage (euro)	280 890	0	1 872 412
(4) At 100% of dairy farms milk is not collected (1 week)			
Number of contaminated farms	**117**	**19**	**331**
Damage per contamination (euro)	1 087 385	129 114	3 023 336
Annual damage (euro)	225 667	0	1 466 366
(5) Only one supplier (site) affected			
Number of contaminated farms	**35**	**7**	**97**
Damage per contamination (euro)	285 029	31 418	755 482
Annual damage (euro)	58 628	0	402 317
(6) Less farms supplied[2]			
Number of contaminated farms	**100**	**19**	**268**
Damage per contamination (euro)	824 490	87 992	2 366 746
Annual damage (euro)	172 948	0	1 157 014

[2]Specified as [maximum number of farms supplied = 90% + 1], see variable 6 in Table 4.4. For example: maximum number of farms supplied from grain processing industries = 9 + 1 instead of 21.

5. CONCLUSIONS

This project focused on wet feed in the Netherlands. Quantified damage relates to damage at *farm* level (pigs and cattle); is does not refer to possible damage further along the chain. Also, damage is only quantified for those farms who *received* contaminated feed. Damage components considered relate to the culling of animals, growth disruption and downgraded quality and to milk not being collected.

Main conclusions per scenario. Three future scenarios have been evaluated: (1) "expert 2006", (2) "past experience", and (3) "increased culling and no collection of milk". In the *expert 2006 scenario* the expected number of contaminated farms equals 117, with a variation from 19 farms (5% percentile, i.e. in 5% of the cases) to 331 farms (95% percentile, i.e. in 95% of the cases). Projected damage per contamination is on average Euro 0.9 million, ranging from Euro 0.09 million (5%) to Euro 2.8 million (95%). The expected number of 117 farms consists of 15 sow farms, 31 hog farms, 49 dairy farms and 22 beef farms. Expected damage is highest for hog farms, i.e. Euro 0.8 million. On individual farm-level, expected damage per contamination is about Euro 400 per sow farm, Euro 25,000 per hog farm, Euro 400 per dairy farm and Euro 7,000 per beef farm. In the hog sector, 70% of the aggregated damage occurs in three provinces: Noord-Brabant, Gelderland and Limburg. In the dairy sector, damage is expected to be more equally spread across provinces.

In the *past experience scenario*, the projected number of affected farms increases to 484 (average), varying from 133 (5%) to 1219 (95%). Projected damage per contamination is Euro 3.4 million, Euro 0.6 million and Euro 8.8 million respectively. The expected number of sow, hog, dairy and beef farms involved increases to 50, 102, 230 and 102 respectively. The sharp increase in these numbers is mainly caused by the increased number of days in which contaminated wet feed is delivered: on average 25 days instead of 7 days. Furthermore, the clustering of contamination in the three sectors of grain, potato and sugar leads to an increased number of contaminated farms caused by the possibly large number of farms supplied per day for these categories of wet feed.

In the *increased culling and no collection of milk scenario*, the expected number of contaminated farms is equal to the expert 2006 scenario. However, due to the more severe farm-level consequences, projected damage per contamination increases to Euro 2.7 million (average), with 5% and 95% percentiles of Euro 0.4 million and Euro 6.7 million respectively. Expected individual farm damage is Euro 400 for sow farms, Euro 70,000 for hog farms, Euro 3,200 for dairy farms and Euro 19,000 for beef farms.

Expert 2006 scenario is the basis scenario. From the various future scenarios presented, the expert 2006 scenario is considered as the *basis scenario*. First of all, input parameters of this scenario reflect up to date developments in the field of risk prevention, including both legislative changes and sector and industry initiatives. Secondly, probability, seriousness and overall risk scores, as derived from Product Board Animal Feed risk analyses, support the congruence of general risk parameters for wet feed and compound feed. Relative *probability* scores for wet feed and compound feed are found to be 0.56 and 0.44 respectively. Relative *seriousness* scores are 0.52 and 0.48 respectively. Relative *overall* risk scores are 0.47 and 0.53 respectively.

The past experience scenario can be interpreted as a *worst case scenario* "as if nothing has been learned from previous crises". The increased culling and no collection of milk scenario is a *what-if scenario* in case of possibly increasing farm-level consequences in the future.

Key parameters determining the size of damage

Sensitivity analyses for the expert 2006 scenario showed that expected damage is decisively determined by the *size of farms supplied* and the *number of days* in which contaminated wet feed is delivered. Increasing the average size of pig farms in all provinces to 350 sows and 2000 hogs caused the extreme damage (95% percentile) to increase from Euro 2.8 million to Euro 7.9 million. In case of increasing the number of days to 20, projected extreme damage increased to Euro 7.1 million. (Increasing the rate of mixing of wet feed (*cumulation*) to 1.5 and increasing the percentage of dairy farms at which *milk is not collected* to 100% had relatively less impact on the extreme damage; 95% percentile damage in these analyses was Euro 4.0 million and Euro 3.0 million respectively.) From the perspective of reducing the size of damage, the largest effect was found for the situation in which only *one wet feed supplying site* would be affected. In this case projected extreme damage reduced to Euro 0.8 million.

Damage for sample companies. Outcomes presented show the expected situation for the entire wet feed sector in the Netherlands—under the assumption that all wet feed companies have about the same risk profile as the three "sample companies" whose data has been used to parameterise variables such as number of farms supplied per day and mixing rate (cumulation). As the three sample companies cover 45% of the total volume of wet feed in the Netherlands, their "share" in total damage is expected to be about the same, i.e. 45%. In line with this, similar conclusions hold for other wet feed companies whose risk profile is to a large degree comparable.

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APPENDIX A DATA AND ASSUMPTIONS PER SCENARIO

Table A Description of scenarios and data sources used per scenario (chances with respect to scenario "expert 2006" are in bold)

Variables	Scenario "expert 2006"	Scenario "past experience"	Scenario "more culling and no collection of milk"
1. Contamination in day batch (%, year)	On average 1 per 5 year [EXPERT 2006]	**On average 3 per 10 year** [DATA 97/06]	On average 1 per 5 year [EXPERT 2006]
2. Wet feed suppliers (sites) involved	Equal chance for 2, 3 or 5 sites [DATA 97/06]	Equal chance for 2, 3 or 5 sites [DATA 97/06]	Equal chance for 2, 3 or 5 sites [DATA 97/06]
3. Wet feed sector affected	Based on sample volumes [SAMPLE]	**Clustered in grain, potato and sugar** [DATA 97/06]	Based on sample volumes [SAMPLE]
4. Duration (days)	On average 7 days [EXPERT 2006]	**On average 25 days** [DATA 97/06]	On average 7 days [EXPERT 2006]
5. Livestock sector(s) affected	Based on national figures about wet feed fed to pigs and cattle [OPNV]	Based on national figures about wet feed fed to pigs and cattle [OPNV]	Based on national figures about wet feed fed to pigs and cattle [OPNV]
6. Number of farms supplied per supplier (site) per day	Based on sample data [SAMPLE]	Based on sample data [SAMPLE]	Based on sample data [SAMPLE]
7. Cumulation	Derived from mixing ratio in sample data [SAMPLE]	Derived from mixing ratio in sample data [SAMPLE]	Derived from mixing ratio in sample data [SAMPLE]
8. Dispersion across the Netherlands	Derived from sales per province [SAMPLE]	Derived from sales per province [SAMPLE]	Derived from sales per province [SAMPLE]
9. Culling of animals on meat farms	On average 15% [EXPERT 2006]	On average 15% [EXPERT 2006][1]	**50% of meat farms is culled** [ASSUMPTION]
10a. Growth disr. & downgraded quality	On average 5% for all farm types [EXPERT 2006]	On average 5% for all farm types [EXPERT 2006]	On average 5% for all farm types [EXPERT 2006]
10b. Duration (days)	On average 10 days (pigs) and 5 days (cattle) [EXPERT 2006]	On average 10 days (pigs) and 5 days (cattle) [EXPERT 2006]	On average 10 days (pigs) and 5 days (cattle) [EXPERT 2006]
11a. No collection of milk	On average at 2% of the farms [DATA 97/06]	On average at 2% of the farms [DATA 97/06]	**At 100% of dairy farms milk is not collected** [ASSUMPTION]
11b. Duration (days)	On average 7 days [DATA 97/06]	On average 7 days [DATA 97/06]	On average 7 days [DATA 97/06]

[1]Expert 2006 estimations are rather similar to past experience data from 97/06.

APPENDIX B RISK SCORES OF COMPOUND FEED AND WET FEED

The congruence between (ingredients for) wet feed and compound feed at industry level is elaborated on in the tables below, in which probability, seriousness and risk scores for a number of important wet feed and compound feed components are compared. Relative *probability* scores for wet feed and compound feed are 0.56 and 0.44 respectively. Relative *seriousness* scores are 0.52 and 0.48 respectively. Relative *overall* risk scores are 0.47 and 0.53 respectively. Scores are derived from the Product Board Animal Feed integrated risk analyses.

	Relative importance		**# hazards**[3]	**Scores**		
	Compound feed[1]	Wet feed[2]		Probability[4]	Seriousness[5]	Risk[6]
Barley	2	0	26	36	61	83
Beet molasses	1	0	25	10	79	106
Brewers' industry	0	13	38	51	85	114
Carrot processing	0	0	21	17	87	103
Citrus pulp	2	0	33	44	76	97
Dairy industry	0	14	24	32	44	53
Maize industry	10	5	28	39	73	91
Palm and palm kernels	10	0	44	35	97	141
Peas	4	0	26	30	61	77
Potato processing	0	27	42	48	76	79
Rape seed meal and expellers	10	0	39	39	86	187
Rye	3	0	26	33	63	84
Soya bean industry	11	0	54	57	228	255
Sugar beet cuttings	0	1	11	6	41	47
Sugar beet pulp	2	12	20	11	92	108
Sunflower seed	2	0	40	44	82	110
Triticale	14	0	24	22	28	83
Wheat	25	0	26	36	61	82
Wheat mill prodcuts	4	0	36	49	94	116
Wheat processing industry	1	28	50	73	137	166
	100	**100**				

	Relative risk scores		
	Probability	Seriousness	Risk
Compound feed	**0.44**	**0.48**	**0.53**
Wet feed	**0.56**	**0.52**	**0.47**

[1]Based on feed preparation formulas

[2]Based on data OPNV (Consultative body of wet feed producers)

[3]Chemical, microbiological, physical and "other" hazards

[4]Calculated as: [# hazards in probability class "small"x 1] + [# hazards in probability class "moderate"x 2] + [# hazards in probability class "large"x 3]

[5]Calculated as: [# hazards in seriousness class "small"x 1] + [# hazards in seriousness class "moderate"x 2] + [# hazards in seriousness class "large"x 3]

[6]Sum of risk scores (see matrix below) for all hazards identified

Risk score per hazard	Seriousness		
Probability	Small	Moderate	Large
Small	1	2	3
Moderate	2	3	4
Large	3	4	4

Source: hazard classifications (small, medium, large) for all scores were established by Product Board Animal Feed
Additional calculations were carried out for this project.