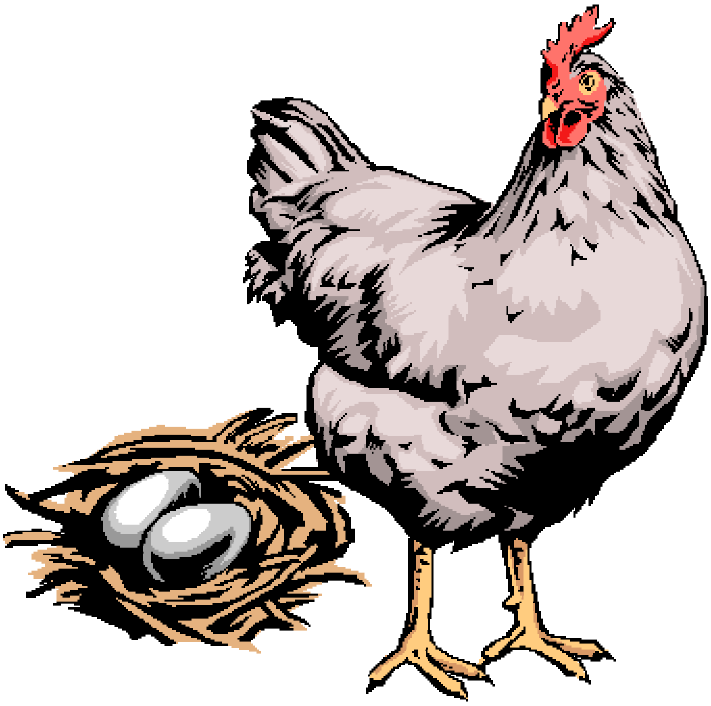
A risk analysis for broiler chains in the Netherlands.

An assesment of food safety hazards and liability risks.

Daphne Verreth
Januari 2009



Author:	Daphne M.I Verreth
Registration Number:	841111881090
Date:	May 2008 – December 2008
University:	Wageningen University Department Business Economics
Company:	Interpolis Verzekeringen N.V. Division Production management
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
	Drs. E.B.M.M Olde-Scheper Product management MKB Schade Bedrijven, Interpolis
Course number:	BEC-80436
ECTS:	36

Interpolis

WAGENINGEN UNIVERSITEIT
WAGENINGEN UR

I. PREFACE

In order to finish my master Management, Economics and Consumer Studies, specialisation Business Economics, I conducted a research for the product management department of NV Interpolis. The graduation course is carried out during 6 months. The aim of the study was to estimate the expected annual losses due to food safety hazards in the broiler production chain of the Netherlands, which eventually could be used to estimate (product) liability claims.

My graduation assignment has been facilitated to a large extent by Interpolis and my supervisor of the university, to whom I am very grateful. First, I want to thank Interpolis for giving me the opportunity to perform this research and special thanks to Mr. Ernest Olde-Scheper for his supervision. Besides, I had great support from all colleagues of Product Management through their geniality and sociability.

I would not have finished my graduation course without my university supervisor. I would like to thank Miranda Meuwissen for being a valuable, supportive supervisor. Her encouragements helped me throughout the realisation of this report. Finally, I would like to thank all other people, especially my parents and my boyfriend Bas, who have helped me performing this research through their comments and knowledge.

In the end, I hope this thesis will be a useful contribution to shed light and more control on the food chain and its possible risks.

Utrecht, Wageningen and Tilburg, December 2008

Daphne Verreth

II. SUMMARY

Since the food crises of recent years, e.g. BSE (2002) and dioxin (2003, 2006), food safety is top priority in the food industry, and their risks are increasingly be subject of liability claim discussions. In the farm-to-fork chain it is hard to estimate (product) liability claim costs because of the systematic nature of the risks.

This study takes the broiler supply chain as a case for the farm-to-fork analysis of food safety hazards and their associated risk factors and losses in the food chain. Three main food safety hazards in the broiler supply chain were selected: the microbiological contaminations *Salmonella* and *Campylobacter* and the chemical contamination dioxin. The objectives were: a) to review existing risks analyses in farm-to-fork chains, with a focus on food safety and including all stages of the broiler chain; and b) to design a quantitative risk analysis model for broiler chains in the Netherlands, which eventually could be used to estimate product liability claims.

Results

To review risks in complete farm-to-fork chains, data were hardly available. Documented cases from the broiler chain always considered only one or two stages of the chain, but never the chain as a whole. For instance, Bouwknegt et al. (2004) analysed risk factors of *Campylobacter* only in the stage of broiler farms and Van der Zee et al. (2004) studied prevalence percentages of *Campylobacter* and *Salmonella* only in the stage of retail and consumers. For *Campylobacter,* risk data were only available for the broiler farm, slaughterhouse, and the retail/consumer stage*.* The prevalence percentages per stage of the chain vary widely, which indicates these are rather unpredictable. For *Salmonella,* prevalence percentages in the different chain stages were almost all above 1%, which is above threshold levels allowed by EU regulations. Chain wide risk estimations of dioxin are not yet available.

The design of a quantitative risk analysis model was developed with a stochastic model using a Monte Carlo simulation. A Monte Carlo simulation is used to obtain insight into the distribution of the losses of a contamination crisis. Data found in literature for *Campylobacter, Salmonella* and dioxin were used as inputs into the model, and parameters were also discussed with broiler chain experts. Model results showed annual losses per stage and per contamination. In the retail/consumer stage, losses are based on consumer illness costs (COI). In all other stages, losses reflect property damage and business losses.

In this study, annual losses are shown for the 5% and 95% percentiles and for the mean, which could be interpreted as the best case, worst case and most likely scenario respectively. Our study indicates that the highest losses are to be expected from *Salmonella* contaminations. Only in a worst case scenario, a dioxin crisis may cause heavier losses. Annual chain losses are not equally distributed among the broiler chain actors. From the various stages considered, parent animal farms and broiler farms will usually face the highest losses.

For *Campylobacter*, changes in the prevalence percentages have impact on annual chain losses. If prevalence increases, annual losses become higher. Annual losses are further influenced by the degree of growth disruption and changes in financial variables, such as value of animals or turnover of a flock or a company. For *Salmonella,* the most important factors are financial variables, prevalence percentages and the degree of growth disruption. For dioxin, the annual losses are mostly affected by the probability of a crisis, the number of affected companies, and the duration of the contamination.

Alternative model scenarios

Some of the parameters in the model were changed, to describe three alternative scenarios: 1) not every stage in the chain is affected (dioxin); 2) the prevalence per stage (*Campylobacter and Salmonella*) was decreased to expected 2012 levels, and; 3) the financial values (*Campylobacter, Salmonella* and dioxin) were changed. These alternative model scenarios showed that the size of the losses is largely determined by the probability (prevalence) that a food crisis occurs. Expected annual chain losses decrease with respectively 51%, 33% and 66% for *Campylobacter, Salmonella* and dioxin. Only for *Campylobacter,* decreases in prices have significant impact on the size of annual chain losses.

(Product) liability claims

Annual losses per stage in the chain were used as input to estimate the size of product liability claims. The probability of submitting a successful claim is highest for a dioxin crisis. For almost all stages, indemnifications could be successful due to the fact that the origin of a dioxin contamination is easier to track and trace than in the case of *Campylobacter* and *Salmonella* contaminations*.* For *Campylobacter,* liability claims are expected not to be successful for any of the stages. For *Salmonella*, all annual chain losses can in principle be claimed, but chances of success are higher in the first stages of the chain (i.e. breeding farms, parent animal farms and hatcheries) than in the later stages of the chain (i.e. broiler farms, slaughterhouses and consumers). In the most likely scenario, 81% of the amount of possible overall chain claims is likely to be accounted to animal feed companies.

Recommendations

The main recommendation is to invest in prevention measures which can reduce the probability (prevalence) of a food crisis. Our study showed that the room for investment varies between €6.7 million in the case of *Campylobacter* and *Salmonella* and €1.2 million in the case of dioxin crises. This room for investment can be used in order to stimulate prevention in the different stages of the chain. Liability insurers should focus their attention on *Salmonella* and dioxin, as no claims are to be expected in the field of *Campylobacter.* Moreover, they should specify and differentiate the premiums according to the different stages in the chain and their associated risks and possible claims.

Table II.1 Overview of expected annual losses (mean per stage, mean per farm, 95% per stage) [1] and probability of successful liability claim

Stage	*Campylobacter*				*Salmonella*				Dioxin			
	Mean per stage (mln €)	**Mean per farm**[2] (€)	**95% per stage** (mln €)	**Success liability claim**[3]	**Mean per stage** (mln €)	**Mean per farm**[2] (€)	**95% per stage** (mln €)	**Success liability claim**[3]	**Mean per stage** (mln €)	**Mean per farm**[2] (€)	**95% per stage** (mln €)	**Success liability claim**[3]
Animal feed	n.p.[4]	n.p.	n.p.	n.a.	n.p.	n.a.	n.p.	n.a.	0.27	1,588	1.53	+/- (a.f.)
Breeding farm	n.p.	n.p.	n.p.	n.a.	0.046	9,200	0.049	+ (a.f.)	0.0035	700	0.018	+ (a.f.)
Parent animals	n.p.	n.p.	n.p.	n.a.	9.73	35,772	10.20	+/- (a.f., br)	0.094	346	0.54	+ (a.f., br)
Hatcheries	n.p.	n.p.	n.p.	n.a.	1.02	53,684	1.02	+ (a.f., br)	0.11	5,789	0.64	+ (a.f., br)
Broiler farm	3.24	4,616	5.76	-	1.76	2,511	3.11	+/- (a.f., ha)	0.79	1,127	4.31	+ (a.f., ha)
Slaughterhouses	n.l.	n.a.	n.l.	n.a.	1.12	56,000	1.12	-	0.63	31,500	3.40	+
Retail/consumer	0.96	262,50	1.40	-	0.095	2,660	0.13	-	n.l.	n.l.	n.l.	n.a.
Total	**4.20**	**-**	**7.16**	**0**	**13.77**	**-**	**15.63**	**9.81**	**1.90**	**-**	**10.45**	**1.63**
Top 3 important risk factors	1. Prevalence *Campylobacter* 2. Financial variables 3. Growth disruption				1. Financial variables 2. Prevalence *Salmonella* 3. Growth disruption				1. Probability dioxin crisis 2. Number of affected companies 3. Contamination duration			

[1] 5000 @Risk iterations.

[2] Expected annual losses per farm, company or consumer in the Netherlands.

[3] The success of a claim; - = relatively low probability of successful claim; +/- = probability of successful claim is unknown; + = relatively high probability of successful claim. Sum across chain stages is based on mean losses and includes + and +/- evaluations. () = to whom stage can claim: animal feed stage (a.f.); breeding stage (br); parent animal stage (p.a.); hatcheries stage (ha); broiler farm stage (b.f.).

[4] n.p. = not present, i.e. a *Campylobacter* respectively a *Salmonella* contamination does not occur in this stage; n.l.: (could be) present, but contamination does *not* lead to losses; n.a.: not applicable.

III. SAMENVATTING

Afgelopen jaren zijn er meerdere voedselcrisissen geweest, waaronder BSE (2002) en dioxine (2003, 2006). Hierdoor is de aandacht voor voedselveiligheidsrisico's verhoogd en onderwerp geworden van aansprakelijkheidsdiscussies. In de voedselketen is het moeilijk om (product) aansprakelijkheidclaims te voorspellen door de systematische aard van de risico's.

In dit onderzoek staat de kipfilet bedrijfsketen, (het vleeskuiken), model voor de 'farm-to-fork' risico analyse van voedselveiligheidsrisico's en de bijbehorende productschades die worden veroorzaakt. Drie belangrijke voedselveiligheidsrisico's zijn bestudeerd: de microbiologische besmettingen *Campylobacter* en *Salmonella* en een chemische besmetting; dioxine. De doelstellingen van dit onderzoek waren; a) bestaande 'farm-to-fork' risicoanalyses van de vleeskuiken keten bestuderen en b) een kwantitatief risico analyse model van de vleeskuiken keten te construeren. Dit model moet later kunnen worden gebruikt om de hoogte van (product) aansprakelijkheidsclaims in te schatten.

Resultaten

Volledige 'farm-to-fork' analyses waren nauwelijks beschikbaar. In de analyses uit de literatuur, werden slechts één of twee schakels van de keten in beschouwing genomen in plaats van de gehele keten. Bijvoorbeeld, Bouwknegt e.a. (2004) analyseerde *Campylobacter* risicofactoren in de schakel van vleeskuikenboerderijen en Van der Zee e.a. (2004) bestuurde prevalentie percentages van *Campylobacter* en *Salmonella* in de schakel van retail en consumenten.

Het ontwerpen van een kwantitatief risico analyse model is voltooid met een stochastisch model dat een Monte Carlo simulatie gebruikt. Een Monte Carlo simulatiemodel is gebruikt om inzicht te krijgen in de verdeling van schades door een voedselcrisis. De gegevens die in literatuur voor *Campylobacter*, *Salmonella* en dioxine werden gevonden, zijn gebruikt als input voor het model en besproken met experts uit de vleeskuikensector. De jaarlijkse schades zijn geschat voor alle schakels in de keten en per besmetting. In de consumenten schakel zijn de schades gebaseerd op ziektekosten van de consument. In alle andere schakels van de keten, zijn schades beschouwd als bedrijfsschade en bezitschade.

In dit onderzoek worden de jaarlijkse schades getoond voor het 5%-, de 95% percentiel en voor het gemiddelde. Deze kunnen worden geïnterpreteerd als respectievelijk 'het beste scenario', 'het slechtste scenario' en 'het meest voorkomende scenario'. Dit onderzoek heeft aangetoond dat de hoogste schades vallen indien een *Salmonella* crisis voorkomt. Alleen in het slechtste scenario veroorzaakt dioxine hogere schades. De jaarlijkse keten schades zijn niet evenredig verdeeld tussen alle schakels. De schakels van moederdier boerderijen en vleeskuikenboerderijen, zullen de meeste schade ondervinden indien een voedselcrisis voorkomt.

Voor *Campylobacter* hebben veranderingen in prevalentie percentages invloed op jaarlijkse schades. Als de prevalentie stijgt, stijgt de omvang van jaarlijkse schade. Jaarlijkse schades zijn daarnaast beïnvloedbaar door de mate van groeiverstoring bij vleeskuikens en financiële variabelen (zoals waarden van dieren en omzet). Voor *Salmonella* zijn de belangrijkste factoren financiële variabelen, de prevalentie percentages en de mate van groeiverstoring. Voor dioxine, zijn de jaarlijkse schades te beïnvloeden door de factoren: kans op een dioxine crisis, het aantal getroffen bedrijven en de besmettingsduur.

Alternatieve model scenario's

Enkele parameters in het model zijn veranderd om drie alternatieve scenario's te beschrijven: 1) niet elke schakel van de keten is getroffen door dioxine; 2) de prevalentie is per schakel in de keten gedaald tot verwachte percentages in 2012 en 3) financiële waarden zijn veranderd (*Campylobacter*, *Salmonella* en dioxine). Deze alternatieve scenario's laten zien dat de omvang van de schade met name bepaald wordt door de kans (of prevalentie) van een voedselcrisis. De verwachte schades dalen met respectievelijk 51%, 33% en 66% voor *Campylobacter, Salmonella* en dioxine. Alleen voor *Campylobacter* verandert significant de jaarlijkse schade door daling in financiële waarden.

(Product) Aansprakelijkheidclaims

De verwachtte jaarlijkse schades per schakel in de keten zijn gebruikt om de hoogte van (product) aansprakelijkheidsclaims te schatten. De kans op een succesvolle claim is het hoogst in het geval van een dioxine crisis. Voor alle schakels in de keten kan een claim succesvol zijn, door het feit dat de oorsprong van de contaminatie makkelijker is te volgen en vinden dan in het geval van *Campylobacter* en *Salmonella.* Schades door een *Campylobacter* crisis komen niet in aanmerking voor aansprakelijkheidclaims. In het geval van een *Salmonella* crisis, kunnen alle schades geclaimd worden, maar de kans op een succesvolle claim is hoger in de eerste schakels in de keten (de fokboerderijen, moederdier boerderijen en broederijen) dan in de latere schakels (vleeskuikenboerderijen, slachterijen en consumenten). In het meest voorkomende scenario, zal 81% van het totale bedrag aan mogelijke claims bij de schakel van diervoer bedrijven gelegd worden.

Aanbevelingen

De belangrijkste aanbeveling is dat er wordt geïnvesteerd in preventiemaatregelen die de kans (prevalentie) van een voedselcrisis verminderd. Dit onderzoek heeft aangetoond dat de investeringsruimte hiervoor varieert van €6,7 miljoen in het geval van *Campylobacter* en *Salmonella* en €1,2 miljoen in het geval van een dioxine crisis. Verzekeraars moeten zich met name richten op *Salmonella* en dioxine, aangezien er geen claims voor schade veroorzaakt door *Campylobacter* worden ontvangen. Daarnaast zouden zij de premies moeten specificeren en onderscheiden volgens de verschillende schakels in de keten en de daarbij horende risico factoren en mogelijke claims.

Tabel III.1 Overzicht verwachte jaarlijkse schades (gemiddelde per schakel, gemiddelde per bedrijf, 95% per schakel)[1] en kans op een succesvolle aansprakelijkheidsclaim.

Schakel	***Campylobacter***				***Salmonella***				**Dioxin**			
	Gemid. per schakel (mln €)	**Gemid. per bedrijf**[2] (€)	**95% per schakel** (mln €)	**Succes aanspr. claim**[3]	**Gemid. per schakel** (mln €)	**Gemid. per bedrijf**[2] (€)	**95% per schakel** (mln €)	**Succes aanspr. claim**[3]	**Gemid. per schakel** (mln €)	**Gemid. per bedrijf**[2] (€)	**95% per schakel** (mln €)	**Succes aanspr. claim**[3]
Diervoer	n.p.[4]	n.p.	n.p.	n.a.	n.p.	n.a.	n.p.	n.a.	0.27	1,588	1.53	+/- (a.f.)
(op) Fok	n.p.	n.p.	n.p.	n.a.	0.046	9,200	0.049	+ (a.f.)	0.0035	700	0.018	+ (a.f.)
Moederdieren	n.p.	n.p.	n.p.	n.a.	9.73	35,772	10.20	+/- (a.f., br)	0.094	346	0.54	+ (a.f., br)
Broederijen	n.p.	n.p.	n.p.	n.a.	1.02	53,684	1.02	+ (a.f., br)	0.11	5,789	0.64	+ (a.f., br)
Vleeskuiken	3.24	4,616	5.76	-	1.76	2,511	3.11	+/- (a.f., ha)	0.79	1,127	4.31	+ (a.f., ha)
Slachterijen	n.l.	n.a.	n.l.	n.a.	1.12	56,000	1.12	-	0.63	31,500	3.40	+
Consument	0.96	262,50	1.40	-	0.095	2,660	0.13	-	n.l.	n.l.	n.l.	n.a.
Totaal	**4.20**	**-**	**7.16**	**0**	**13.77**	**-**	**15.63**	**9.81**	**1.90**	**-**	**10.45**	**1.63**
Top 3 belangrijke risico	1. Prevalentie *Campylobacter* 2. Financiële variabelen 3. Groeivertraging				1. Financiële variabelen 2. Prevalentie *Salmonella* 3. Groeivertraging				1. Kans op dioxine crisis 2. Aantal besmette bedrijven 3. Besmettingsduur			

[1] 5000 @Risk iteraties

[2] Verwachte jaarlijkse schade per bedrijf, per boerderij, per consument in Nederland

[3] Het succes van een claim; - = lage kans op een succesvolle claim; +/- = kans op een succesvolle claim is onbekend; + = hoge kans op een succesvolle claim. De som van de totale keten is gebaseerd op het gemiddelde en houdt de + en +/- evaluaties in. () = naar wie de schakel kan claimen. Diervoer (a.f.); (op) fok (br); moederdier (p.a.); broederij (ha); vleeskuikenboerderij (b.f.).

[4] n.p.= niet aanwezig, een *Campylobacter* of *Salmonella* besmetting komt in deze schakel niet voor; n.l.: (kan) aanwezig zijn, maar er vallen *geen* schades door een besmetting; n.a.: niet van toepassing.

CONTENTS

H1 Introduction

1.1 Background

As a result of a number of crises during the last years, such as BSE (2002) and dioxin (2003, 2006), the attention for food safety has increased. As a reaction extra food safety rules at National and European level were established (Kroon et al., 2002). The General Food Law (GFL) is one of these rules which also includes tracking and tracing obligations within the food chain. These obligations are also supported by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV). Since the introduction of the GFL (1995), the food industry must register the whole chain starting from the origin of raw materials till the moment that consumers prepare the ingredient for a meal or eat the product at a catering service: the track and trace possibility from 'farm-to-fork'.

Food production is a complex process. Multiple risks are present within the farm-to-fork chain, such as food safety risks and food quality risks. The food safety risks can be categorized into (micro) biological (e.g. *Salmonella*), chemical (e.g. Dioxin), physical (e.g. glass) and other (allergenic free) risks (Meuwissen and Huirne, 2006). Risks due to crises that affect all firms in the food chain cannot be neglected. These risks are called systematic risks (Harrington and Niehaus, 1999).

These systematic risks and food safety rules have consequences for liability and for the liability insurance: the causes of losses are easier to trace and food companies in the (primary production) chain have more chance to be confronted with a claim (Hopstaken, 2004). According to Insurance Interpolis (Netherlands) the frequency and size of claims is increasing. An extended insurance cover enables industries to get a larger share of their losses compensated. However, product liability insurance schemes do not cover all losses and the most difficult issue in this part is the question who is liable for the losses (Interpolis, 2008). The MPA crisis (2002) had financial losses of more than €100 million, but until now there is just €3 million compensated by insurers due to these issues (LTO Nederland, 2007).

1.2 Objectives

In the 'farm-to-fork' chain it is hard to estimate (product) liability claim costs because of the systematic nature of the risks and problems of asymmetric information. Therefore, for insurers it is complicated to estimate adequate levels of premiums compared to the expected claim costs. This study focuses on the 'farm-to-fork' chain and associated product losses caused by food safety hazards.

Total 'farm-to-fork' risk analyses are hardly available, because of the complexity of the food chain.
Risk assessment for the farm-to-fork food chain can show the public health impact of foodborne illness, economic importance of the agricultural sector and food industry, establishment of causes of the risks and to measure how these losses caused by these hazards can be controlled (Havelaar et al., 2007). This study will take the broiler supply chain as a model for the analysis of food safety hazards and their risk

factors in the food chain.

More specifically, the objectives are to:

a) Review existing risk analyses in 'farm-to-fork' chains. The focus will be on food safety risks in all stages of the broiler chain.
b) Design a quantitative risk analysis model for broiler chains in the Netherlands, which eventually could be used to estimate product liability claims.

The risk analysis model will show an overview of annual losses and associated risk factors due to food safety hazards. This overview may constitute a step forwards in controlling the food chain. In order to achieve these objectives, research questions are formulated.

1. Which factors increase the chance of a food safety hazard?
2. Where are these risk factors situated in the chain?
3. What are the expected annual losses?
4. How do these losses affect the claims at the level of insurers?
5. What are the most important risk factors which influence the size of the claims?

Broiler supply chains

Worldwide, the consumption of broiler meat increases faster than other types of meat. Most likely this is because there are no religious objections for broiler meat and broiler meat is sold usually for a relatively low price (Wageningen UR project team, 2004). In the Netherlands there are 2686 poultry companies, from which 701 broiler farms, and in total 92,760,859 broilers and hens (CBS, 2007). This research will design a risk model for the broiler chain. The chain includes the animal feed companies, the primary production, the broiler farms, slaughterhouses, retail and consumers (see Figure 1).

Campylobacter, Salmonella and dioxin

In the current research, three main food safety hazards in the chicken meat supply chain are selected to study the food safety risk factors. These 3 hazards are microbiological contaminations with *Salmonella* and *Campylobacter* and a chemical, dioxin, contamination.

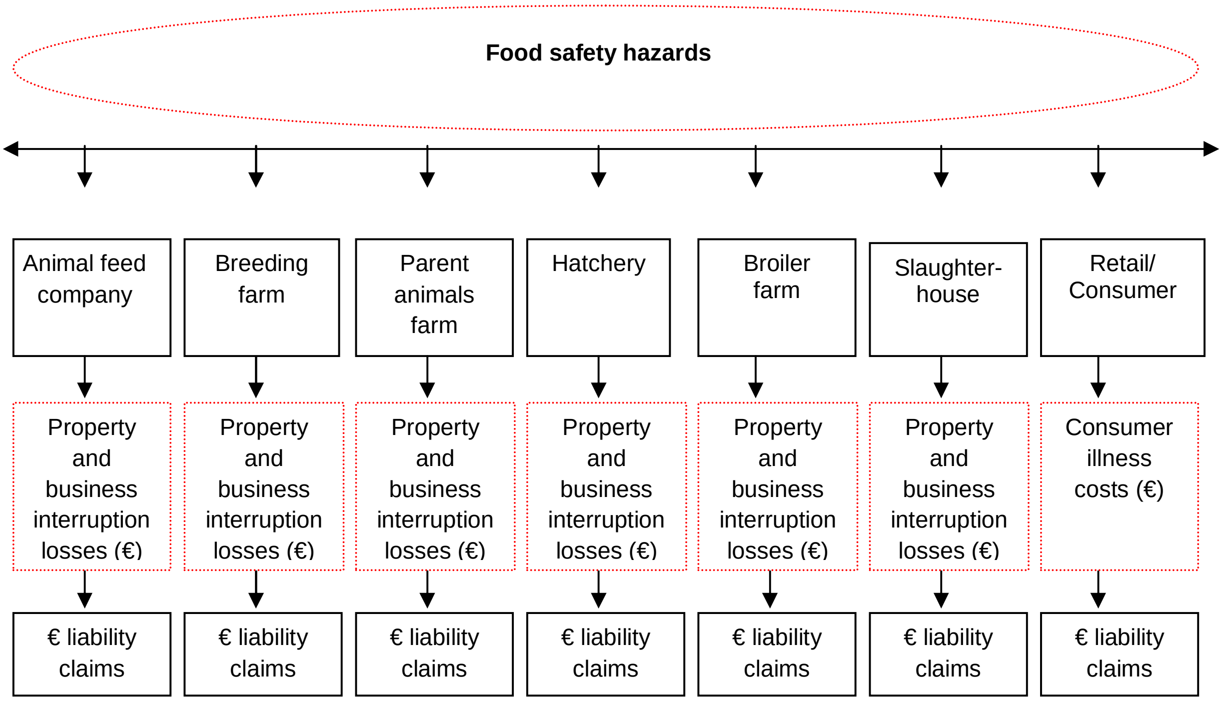


Figure 1. Overview research design

Annual losses are estimated for all stages of the broiler chain due to a food safety hazard. These annual losses are company losses. In the last stage, the retail/consumer stage, the annual losses regards consumer illness costs.

1.3 Outline thesis

Chapter 2 of this report gives an overview of the chain configuration and the risk prevention of the broiler chain. Chapter 3 focuses on risk factors of food safety hazards within the broiler chain and their characteristics. In chapter 4 are the methods and materials used in this research described. The next chapter, chapter 5, elaborates on the results retrieved from the research whereas chapter 6 gives an introduction on juridical issues and (product) liability. Chapter 7, as last, shows the conclusions, recommendations, discussion and suggestions for further research.

H2 Broiler production chain

2.1 Chain configuration

The broiler farm-to-fork chain is complex. It is a chain of farms and companies which influence the end-product (chicken meat). This chapter gives an overview of the chain configuration, the risk prevention and risk mitigation of the broiler chain.

The first stage, animal feed companies, deliver feed to all upstream stages till the stage of broiler farms. The feed production stage of the chain is one of the most important steps. Animal feed companies have a direct influence on the quality and safety of the end product (van Asseldonk et al., 2006). The primary production starts at the stage of breeding companies. The stocks are selected and improved. These are the grand-parent animals. From cross combinations of these grand-parent animals, hens and cocks are bred which have a different genetic composition: the parent animals. These hens give eggs which are transported to hatcheries. Broiler companies get hatched chicks supplied by the hatcheries (Nederlandse Vereniging tot Bescherming van Dieren, 2003). Within this the primary production is finished. Broilers grow, on average, 50 gram a day. These broilers are full-grown in circa 6 weeks (precisely 43.78 days). The broilers weigh around 2.2 kilos after these 6/7 weeks. Broilers below this 2.2 kilo are sold as entire animal, whereas more weighty broilers are slaughtered in parts (Nederlandse Vereniging tot Bescherming van Dieren, 2003). From the slaughterhouses the meat is transported to processors and wholesalers, and afterwards to consumers and catering services.

The batch size at each step in the broiler chain is defined as an ‘all-in all-out’ system: 100% of the broilers are transported to the next stage in the chain. That means that if, e.g., the broilers go to the slaughterhouse, the broiler farm gets only new hatchery chickens till the moment the whole farm is empty and cleaned. A short overview of this chain is given in figure 2.

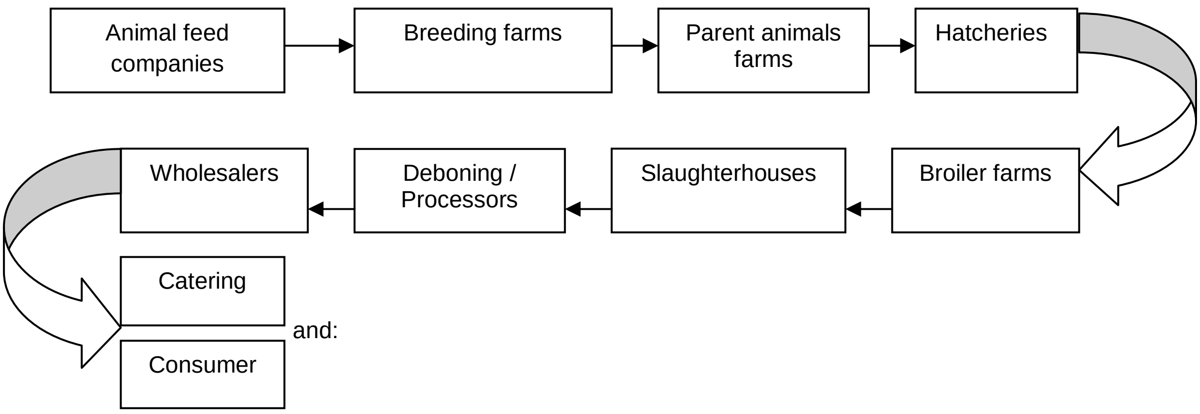


Figure 2.1 Broiler production chain

In the different stages of the broiler chain there is an import and export possibility. Table 2.1 gives an overview of all relevant statistic data, including the import and export numbers, of the broiler chain within the Netherlands. Most of these data is achieved from the Dutch Product Boards of Livestock, Meat and Eggs (In Dutch: PVE).

Table 2.1 Data of the broiler production chain the Netherlands

Chain stage	# Comp.	Organic comp. (%)	Animals (Million/ year)	Production end material (year basis)	Organic animal/ egg (%)	Import (year)	Export (year)
Feed	170[1]			1,483 ton [1]			
Breeding[2]	5						
Parent animals	272[2]	0,07[3]	4.7[2]	863 mln eggs[2]	0,32[3]	469 mln 1-d ch.[4]	394 mln 1-d ch.[4]
Hatcheries[2]	19			607 mln 1-day chickens		415 mln 1-d ch. [4]	130 mln 1-d ch. [4]
Broilers	701[2]	0,13[3]	42.2	912,000 ton[2]	1,56[3]	108,000 ton[2]	103,000 ton[2]
Slaughterhouses	20[2]	11,1[3]		674,900 ton[2]		79,900 ton[2]	7,600 ton[2]
Deboning[2]	297						
Consumption[2]				297,900 ton = 18.2 kg per consumer			

[1] Product Board Animal Feed (2004)

[2] Statistic annual report PVE 2007 (2008)

[3] Statline CBS, data from 2004 (2008)

[4] Statistic annual report PVE 2007 (2008): number includes hatched chicken and breed eggs

In 2007, 701 broiler farms were reported with an average number of 60,214 broilers per farm in the Netherlands (Statistic report PVE 2007, 2008). The value of the 912,000 kg ton production per year in 2007 is estimated at € 701 million per year, whereas 77% is linked at farm level and 23% to the level of slaughterhouses (Meuwissen et al., 2008a). In the following table important data are shown.

Table 2.2 Data regarding broilers revenues and costs[1]

Description	Value	Description	Value
Revenue (€/broiler)	1.76	Delivering weight (kg/broiler)	2.18
Costs (€/broiler)	1.45	Used feed (kg feed/kg del. broiler)	1.77
Gross margin (€/broiler)	0.31	Cost destruction and cleaning (€/broiler)	2.61[2]
Cost of feed (€/100 kg)	27.7	Labour income (€/average farm/year)	10,500[3]

[1] Data retrieved from: De Bont and van der Knijff (2007); [2] Van Asseldonk et al. (2006); [3] Mangen et al. (2005)

The percentage of broiler farms on the total of poultry farms in 2006 is 31.52% (LEI and CBS, 2007). Broiler meat can be delivered to wholesalers either as a fresh or as frozen product, respectively 60% and 40% (Tacken and van Horne, 2006). Fresh broiler meat goes mostly to supermarkets, whereas frozen meat is mostly used in further processing and in the foodservice (hotel and catering industry, institutions etc.). Chicken meat can be sold packed or unpacked, respectively 85% and 15% (Wageningen UR project team, 2004). Of all meat sold in the Netherlands, including beef, pork and chicken, 21.24% is chicken meat. From the total sold chicken meat 5.62% is sold as whole chicken, 47.9% as breast meat, 20.5% as leg meat, and 26% as other parts of the chicken (PVE, 2006). Consumers can eat chicken at home or out of home; in a restaurant, at work, fuel stations, school (GFK, 2005). Of all chicken meat is prepared 89% at home, while 11% is eaten out of home (GFK, 2005).

2.2 Risk prevention

In the broiler meat sector several quality systems are applied; IKB Chicken, Actionplan 2000+, ISO 9002 (now named ISO 9001:2000), HACCP, GMP+, and EurepGAP (now named GlobalGap) (Van der Roest et al., 2004). Moreover, industry initiatives for the animal feed industry exist; TrusQ and Safe Feed. Besides these quality systems for the broiler industry, purchase and delivery conditions are applied within the chain to prevent risks. Within this paragraph, these quality systems will shortly be described.

IKB Chicken

A large part of the companies (approximately 90%) in the production chain are participant of the 'IKB'-system of Product Board for Livestock, Meat and Eggs (PVE), division Product Board for Poultry and Egg in particular. This system entails an integrated chain control and has been developed to guarantee quality and to improve the position of the Netherlands as a poultry meat-exporting country. All participants are audited for compliance with the requirements by an independent certifying body once a year. This voluntary participation to this IKB-system, requires companies to follow rules, e.g.; all preceding links in the production chain must be IKB accredited; information about the flocks (origin, vaccination, medication, *Salmonella* status) is recorded; information is passed on and/or fed back through the links of the chain; the feed supplier must be GMP+ accredited; compliance with the *Salmonella* and *Campylobacter* Actionplan and some more (PVE, n.d.a).

Salmonella and Campylobacter Actionplan 2000+

The approach plan of *Salmonella* and *Campylobacter* started in the poultry sector in May 1997. The ending date of this plan was November 1999. The goals, a prevalence of >10% of *Salmonella* and a prevalence of >15% of *Campylobacter,* were not reached. Therefore, the Actionplan 2000+ is implemented. Companies in the poultry sector are obliged to take part in the *Salmonella* and *Campylobacter* Actionplan. The aim is to decrease the contamination levels of *Salmonella* in the poultry sector and to reach a contamination percentage of 0% at the start of the stage of slaughterhouses. This Actionplan states that each stage in the chain must monitor the ingoing and outgoing flow of animals on

Salmonella. The results of the approach plan stated that high contamination levels appear of *Campylobacter*. Some monitoring actions for *Campylobacter* are described in the Actionplan however, this plan is more focused on *Salmonella* (Actionplan, 2002). The ministry subsidise a project (CARMA) where the risk factors of *Campylobacter* are more investigated. The Actionplan has already resulted in a considerable decrease in the number of *Salmonella* infections (PVE, n.d.b).

In 2007 the European Commission ratified a regulation where targets for the reduction of the prevalence *Salmonella* (EC 646/2007) are settled. The target for the reduction of *Salmonella* is a reduction of the maximum percentage of flocks of broilers remaining positive of *Salmonella* to 1% or less in the breeding and parent animal stage by 31 December 2011 (EC 646/2007).

ISO 9002 (now named ISO 9001:2000)

ISO (International Organisation for Standardization) 9002 is a quality assurance model made up of quality system requirements. ISO-9002 is a standard which is applied to organisations that produce, install and service products. The companies have to show that quality is secured in their work. An organisation which is certified ISO-9002 must structurally offer quality. ISO 9002 is replaced by the ISO 9001:2000 which combines the three standards 9001, 9002, and 9003 into one (Website Wikipedia, n.d.a).

HACCP

HACCP (Hazard Analysis Critical Control Points) is a systematically analysis to identify, evaluate and to control at food safety hazards. HACCP requires that the complete production process is followed on possible food safety risks. HACCP is based on 7 principles (VWA, 2008a).

GMP+

Good Manufacturing Practice (GMP) is a quality system focused on the food-, pharmaceutical- and healthcare product industry. GMP+ is a system for the animal feed industry. Qualified auditors from independent, accredited certification bodies assess all the GMP^+ participants. These auditors establish or carry out analyses to see if the feed products and/or services from the companies comply with the norms. There are analyses of whether feed products comply with the product norms and an assessment of whether the feed safety system and the process control system comply with the requirements of the GMP^+: 2006 standards (PDV, n.d.).

EUREPGAP (now named GLOBALGAP)

EurepGAP (Eurep= Euro-retailer produce working group, GAP= Good Agricultural Practice) entails voluntary certification standards and procedures. The EurepGAP standard is designed to maintain consumer confidence in food quality and food safety. An important aspect is traceability. Other important goals are to minimize detrimental environmental impacts of farming operations, optimize the use of inputs and to ensure a responsible approach to worker health and safety (EurepGap, n.d.).

TrusQ

The aim of TrusQ is to secure food safety to significantly reduce the risk of animal feed being mixed with unwanted constituents. In the field of monitoring, quality control, tracking and tracing and crisis management are made concrete agreements concerning the choice of raw materials and suppliers. TrusQ is setting requirements for logistic and production processes of raw materials. These agreements are based on the combined knowledge of six compound feed producing companies, which together have more than 50% of the Dutch compound feed market (TrusQ, n.d.). TrusQ members collectively insured themselves for an amount of €75 million per incident with a maximum of € 150 million per year.

Safe Feed

Safe Feed aims to enhance and deepen GMP+. It can be compared with TrusQ. Safe Feed includes more than 70 producers, which represent approximately 50% of the Dutch compound feed market. Because GMP+ system is deepened within Safe Feed, the quality safety increases and the insight in the quality of raw materials is improved. Safe Feed promotes the transparency of (and for) suppliers (Safe Feed, n.d.).

2.3 Risk mitigation

Several risks can occur within the broiler chain. According to Garlick (2007), risk is the chance of something happening that will have an impact on objectives. A risk is often specified in terms of an event or circumstance and the consequences which may occur from it. Moreover, risk is measured as a combination of the consequences of an event and their likelihood. Likelihood is used as a general description of probability or frequency (Garlick, 2007). In this study, risk is defined as described above and shows the economic impact of food safety hazards in the broiler chain.

Risk mitigation involves the adoption of a safety culture and a number of organisational strategies which can affect and limit risk (Davies and Walters, 1998). These risks can be seen as the likelihood of an occurrence, the severity of an actual occurrence, of a threat or a loss, economic risk, regulatory changes, casualties, natural disasters, fraud or etc. (EAG, n.d.) Davies and Walters (1998) give examples of (organisational) strategies which mitigate risk and can be linked to mitigate food safety risks: e.g. 'set comprehensive and institutionalized norms and rules for handling safety problems' and 'provide appropriate checks and balances within systems'. The first one includes guidelines for action, whereas the second example can be linked at a monitoring system within an organisation. These guidelines and/or monitor system are also applied in the food chain. The following subsections give a description of risk mitigation strategies in the broiler production chain.

Product recall

Product recall is an action where a certain product, product range or products of the market are obtained, because these do not apply with the standards and specifications. The Food and Consumer Product

Safety Authority (Dutch: VWA) must directly be informed if a producer believes that his/her products are disabled. Product recall can have large financial consequences: the image of the producer/company, the destruction costs, and advertisements for consumers, for example. Product recalls are estimated as a direct damage for feed producers, processors and the distribution channel and are generally not covered (Meuwissen et al., 2008a). There exists a possibility that the damage in the product is discovered when the product already lies in the shops or already is in the possession of the consumer. In that case the damaged product must be called back from trade. If a product is called back when the product is already in the possession of the consumer, it is named a pure product-recall and is categorized as a salvage cost. Liability insurance schemes generally consider ‘collection and destruction of contaminated products’ as risk mitigation. Chapter 6 elaborates on the insurability of product recall and salvage costs.

Tracking and Tracing

Traceability can be defined as the ability to trace the history of a product’s origin including the identity of the farms and the marketing firms along a supply chain (Pouliot and Sumner, 2006). According to Pouliot and Sumner (2006) traceability back to the farm of origin include: a) protecting the general reputation of a product, a firm, an industry, or a country; b) differentiating products by suppliers who provide traceability; c) improving supply management by firms; d) monitoring and assuring production or processing methods; f) isolate losses from a food safety or product quality problem what indirectly improves food safety.

According to van Asseldonk et al. (2006) a tracking and tracing system which spans the entire production chain have reduced the risk of feed/food contamination. A tracking and tracing system is applied for feed producers, farmers, processors and the distribution channel (Meuwissen et al., 2008a). For example, a feed supplier with a tracking- and tracing system is obliged to show relevant information (contact, delivery and supplier data) within 4 hours during an urgent matter (GFL, 2002).

H3 Risk review: state of the art

3.1 Food safety risks in the broiler production chain

The microbiological zoonöses *Salmonella* and *Campylobacter* are the most important and most frequent food safety hazards in the broiler chain (Nauta et al., 2005a). Microbiological risk refers to all risk caused by bacteria. These are living microorganisms which can cause food spoilage and possibly food poisoning for the consumer (Yeung and Morris, 2001). Zoonöses are diseases which can be transferred from animal to human. Mostly this happens by consumption of food (ter Horst, 2006). In 2006, the VWA received 560 reports of food infection cases by consumers. The most important food hazards were *Salmonella* and *Campylobacter*. Instead of the 560 reported cases of VWA, food infections incidents are estimated at 300,000 till 750,000 cases per year. This huge difference can be explained with the fact that not every patient with gastrointestinal complaints consults a doctor (Doorduyn et al., 2007). The poultry sector is considered as a source for these human infections, and mostly for the bacteria *Salmonella* (ca. for 75%) and the bacteria *Campylobacter* (20-40%).

Chemical risks include residues in food due to antibiotics fed to chickens as well as the remnants of agricultural chemicals in animal feed eaten (Yeung and Morris, 2001). Dioxins, a chemical contamination, originate from combustion of chemical and household waste (AgriHolland, n.d.). It is the most attentive chemical contamination by the poultry and broiler sector.

This chapter will elaborate on these 3 possible food safety hazards in the broiler chain, respectively *Campylobacter* and *Salmonella*, and dioxin. Each paragraph gives a description of the hazard, the associated prevalence and associated important systematic risk factors. Prevalence is a statistical concept referring to the number of cases, or percentage, of a disease that are present in a particular population at a given time.

3.2 Microbial contamination: *Campylobacter*

Campylobacter is a bacterium which can lead, very fast, to a food infection. The incidence of *Campylobacteriosis* is estimated to be 80,000 cases per year in the Netherlands (Havelaar et al., 2005; VWA, 2008b). *Campylobacter* is frequently found in broiler chickens and broiler meat. It is estimated that 40%, as upper limit, and 20% as lower limit, of the positive *Campylobacter* cases can be linked to poultry (Mangen et al., 2007). People can be exposed to *Campylobacter* by the consumption of improperly heated broiler meat, other foods that are cross-contaminated with *Campylobacter* during food preparation, direct contact with animals, contaminated surface water and foreign travel (Nauta et al., 2007; Mangen et al., 2007). Symptoms are diarrhoea, dehydration and possibility of fever. Elderly and young children are less resistant and have more chance to get a *Campylobacter* infection. In general, *Campylobacter* does not grow above a temperature of 45℃ or below a temperature of 30℃ (Havelaar, 2001). Consumer illness costs due to *Campylobacter* are estimated at €21 million per year (Mangen et al., 2007).

3.2.1 Prevalence

Different prevalence of *Campylobacter* exists at each stage of the chain in the broiler production chain: e.g. 36.7% of all broilers are contaminated with *Campylobacter* before they enter the slaughterhouse (Heuer et al., 2001). Hatcheries are free of *Campylobacter*, so breeding eggs and one-day-chickens test negative for *Campylobacter* infection. The prevalence percentages are given in table 3.1.

Table 3.1 Prevalence *Campylobacter*

Stage	Unit	Source	Factor	Prevalence
Broiler farm	%	Katsma et al., 2005	Entrance flock prevalence	44.4%
	%/flock	Hartnett et al., 2002	Prevalence end of stage	71.0%
	%/flock	Havelaar, 2001		82.0%
	%/flock	Jacobs-Reitsma et al., 2000		60.8%
	%/flock	Kauna et al., 2007		81.8%
Slaughterhouses	% broilers	Heuer et al., 2001	Cont. before slaughtering	36.7%
	% farms	Van der Zee et al., 2004	Contamination	35.35%
	%carcass	Christensen et al., 2001		45.0%
Detail shop/ Retail	%/year	Van der Zee et al., 2004	Contamination	32.5%
	%	VWA, 2007	organic broiler meat	29.8%
Supermarket	%/ year	Van der Zee et al., 2004	Contamination	30.4%
Butcher	%/ year	Van der Zee et al., 2004	Contamination	21.7%
Poulterer	%/ year	Van der Zee et al., 2004	Contamination	29.5%
Marketpoulterer	%/ year	Van der Zee et al., 2004	Contamination	36.7%
Chicken meat	%/ year	VWA, 2007	Whole chicken	9.5%
	%/ year	VWA, 2007	Leg meat	19%
	%/ year	VWA, 2007	Breast meat	11.4%
Chicken meat	%/ year	VWA, 2007	Other parts	16.0%
Consumer	%/ year	Havelaar et al., 2005; VWA, 2008b	COI cases	80,000

3.2.2 Risk factors

Lot of authors did already research on risk assessment of *Campylobacter*. These researches are mostly very technical related. Some risk factors are named in table 3.2.

Table 3.2 Risk factors *Campylobacter*

Stage	Unit	Source	Factor	Value
Broiler farm	hour	Mangen et al., 2007	Infection time	1
	%	Rodenburg et al., 2004	Organic farms	35
	Yes/no	Bouwknegt et al., 2004	Other animals on farm	Y:29.3% N:22%
	Yes/no	Bouwknegt et al., 2004	Animals on nearby farm (i.e. within 1 km)	Y:27.3% N:10.3%
	Days	Bouwknegt et al., 2004	Age of broilers	>36 days 42.9%
	Number	Bouwknegt et al., 2004	Number of broiler houses on the farm	>/5 33.3%
	Number	Bouwknegt et al., 2004	Flock size 1.1-9999 2.10000-19999 3.20000-29999 4.>/30000	 1: 41.7% 2: 32.1% 3: 25.4% 4: 12.5%
Storage	time/Celsius	Mangen et al., 2007	Freezing meat	2weeks/-20℃
Retail	%	Kramer, 2003	Organic/not organic meat	49/43
All chain	summer %	Bouwknegt et al., 2004	Season contamination effect	32.6
	winter %			12.9

3.3 Microbial contamination: *Salmonella*

Salmonella is a gut bacterium which is mostly found at poultry- and pig meat and eggs. Almost 1600 forms of *Salmonella* exist, however, just 5 types are not allowed in broiler meat. *Salmonella* has the same symptoms as *Campylobacter* and, also, elderly and young children are more sensitive to it. Contamination with *Salmonella* can occur at different ways. Horizontal contamination takes place by direct contact between chickens, via the air, the manure, feed or the environment. Vertical contamination takes place via the mother animal. Antibiotic medicines are a way to prevent *Salmonella*. Moreover, the monitoring actions help to discover *Salmonella* contaminations. Even low infection levels of *Salmonella* in the meat can be dangerous for consumers because the bacteria multiply themselves in the chicken meat.

Hens can be contaminated with *Salmonella* starting from the breeding stage. When *Salmonella* is discovered in that stage, the flock has to be destructed. When hens are contaminated with *Salmonella* in farms of the parent animals farm stage, the flock has also to be destructed and (breeding) eggs are not allowed to be further used. In the hatcheries stage is monitoring done at the start of the stage. The results define how the breeding eggs are distributed (logistic breeding). When *Salmonella* is discovered in broiler farms, nothing happen, however, the stalls have to be (professional) cleaned before a new flock enters and the broilers are logistic slaughtered. Slaughterhouses slaughter contaminated meat logistically. That means that contaminated meat is mostly slaughtered at the end of the day (VWA, 2008c). Monitoring costs are subsided by the Dutch Ministry LNV.

3.3.1 Prevalence

As mentioned before, prevalence is a statistical concept referring to the number of cases, or percentage, of a disease that are present in a particular population at a given time. For *Salmonella* also different prevalence exist within the broiler production chain: 35% of all broilers in the broiler farm are contaminated with *Salmonella* after entering the slaughterhouse (Actionplan, 2002). The Actionplan 2000+, described in chapter 2, has already resulted in a considerable decrease in the number of *Salmonella* contaminations (PVE, n.d.b). The monitoring of *Salmonella* prevents contaminations further in the supply chain. Therefore, prevalence numbers, which were estimated before 2000 are not taken into account. The percentages are given in table 3.3.

Table 3.3 Prevalence *Salmonella*

Stage	Unit	Source	Factor	Value
Animal feed companies	year	PDV, 2006	Contamination	0.1%
Breeding farms	% flocks	Actionplan, 2002	Contamination	1.0%
Parent animal farms	% flocks	Actionplan, 2002	Contamination	6.0%
Hatcheries		Actionplan, 2002	Contamination	9.0%
Broiler farms	% flocks	Actionplan, 2002	Contamination	25.0%
Slaughterhouses	% flocks	Actionplan, 2002	Contamination	35.0%
Supermarket	%	Van der Zee et al., 2004	Contamination	7.0%
Butcher	%	Van der Zee et al., 2004	Contamination	10.6%
Poulterer	%	Van der Zee et al., 2004	Contamination	6.8%
Market poulterer	%	Van der Zee et al., 2004	Contamination	6.6%
Retail	%/ whole chicken	VWA, 2007	Contamination	5.9%
	% leg meat	VWA, 2007	Contamination	5.1%
	% breast meat	VWA, 2007	Contamination	11.9%
	% other parts	VWA, 2007	Contamination	8.5%
	% organic	VWA, 2007	Contamination	4.0%
Consumer	number	Mangen et al., 2007	COI cases (a year)	75,000

3.3.2 Risk factors

Salmonella can be found in ingredients of animal feed. The following ingredients have more risk regarding *Salmonella*: sunflower seed scrap, sunflower seed products, soy scrap, soy bread beans, corn gluten fodder, animal flours, vegetable oil, soybean poll, reap seed oil and palm oil (de Graaf, 2008). Broiler feed exists for, approximately, 35% wheat, 30% soy scrap and 15% from corn. The remaining 20% are filled in with by-products (Cotteleer et al., 2004). The particular risks for *Salmonella* are summarized in table 3.4.

Table 3.4 Risk Factors *Salmonella*

Stage	**Unit**	**Source**	**Risk Factor**	**Value**
Broiler farm	%	Nauta, 1998	Cross contamination	100% if grandparent is contaminated
				100% if eggs are contaminated
	days	Mangen et al., 2007	Infection time	3 till 6
	%	Rodenburg et al., 2004	Organic meat contamination	13
Transport	%	Nauta, 1998	Cross contamination	Within flock:75
Retail	%	Kramer, 2003	Organic/non organic meat	4 resp. 8

3.4 Chemical contamination: dioxin

Dioxins originate from combustion of chemical and household waste (AgriHolland, n.d.). Dioxins and chemically-related compounds occur as widespread, low-level contaminants in animal feed and the human food supply. It is the most attentive chemical contamination by the poultry and broiler sector. Via gas emissions, water or fixed rests, dioxins can enter the environment. Consumption of dioxins leads to substances in the body fat. Dioxin can cause birth deviations, progress cancer and influence the hormone metabolism. A small part of the dioxin comes from other sources, e.g. via smoking or traffic (AgriHolland, n.d.). If animal feed is contaminated with a (too) high level of dioxin, feed companies are ordered to stop immediately their activities. They cannot produce feed again before an allowed level of dioxins is obtained (LNV, n.d.).

3.4.1 Prevalence

Literature does not describe the prevalence of dioxin in the broiler production chain. One prevalence percentage is known about the egg production chain. De Vries (2001) reported in 2001 that 9% of organic consumption eggs are contaminated with a too high level of dioxin, compared with conventional consumption eggs.

3.4.2 Risk factors

Risk factors of dioxin in the broiler production chain are almost never mentioned. Previous dioxin crises give some information.

In January 1999 a dioxin crisis occurred in Belgium. The dioxin entered animal feed and quickly spread across national borders and had trade impacts (Buzby and Chandran, 2003). The crisis occurred when 60-80 tons of fat was contaminated and used in animal feed in Belgium. In total 500 ton of contaminated animal feed was distributed to 10 compound feed companies. In Belgium alone, 445 poultry farms were infected and besides farms in Germany, France and the Netherlands. The dioxin crisis caused an estimated decrease in total food industry production of 10% in June 1999 (Buzby and Chandran, 2003).

Sales of poultry meat products were sold 53.5% lower in 1999 than in 1998. The Belgian government estimated that the dioxin crisis cost €465 million. Moreover, 12,500 ton of poultry meat was destroyed (van Andel, 2008). The Dutch agricultural cooperation Cebeco, owner of poultry processor Plukon, reported a lower profit of 5 million because of the dioxin crisis (Website Trouw, 2000). The dioxin crisis illustrated that a food safety crisis can impose high financial and political costs on industries and countries (Buzby and Chandran, 2003).

In 2003, the Netherlands witnessed a dioxin crisis. Approximately 3124 tons of contaminated compound feed were distributed to poultry farms. Other dioxin crises took place in 2004 and 2006. There was a contamination of poultry only in 2006, which involved the compound feed producers. The crisis affected 275 primary producers, including producers in the cattle and pig sector. It means that a dioxin crisis in the Netherlands occurred 4 times in the last 10 years, where 3 times the poultry sector was affected. Till now, it never happened that consumers were contaminated with dioxin due to consumption of chicken meat.

3.5 Supply chain losses

The systematic nature of the risks in the 'farm-to-fork' chain and problems of asymmetric information makes it hard to estimate liability claim costs. Each stage of the chain can have losses due to a food safety hazard and their associated risks. Risk decreasing developments have been determined based on legislation, quality programmes, and a number of company-specific developments (Meuwissen and Huirne, 2006).

3.5.1 Losses in the broiler production chain

Annual losses from a food safety hazard can become very high. Supermarkets sell chicken meat as *Salmonella* free and/or *Campylobacter* free. This is according to the VWA not yet successfully reached and is according to scientists, not possible. That means that consumers have always chance to buy chicken meat that is contaminated with *Salmonella* and/or *Campylobacter*. Large food crises related to these zoonöses have not yet happened in the Netherlands.

Circa 14,000 people asked for medical help for *Campylobacter* in one year (VWA, 2008b) and 16 per 100,000 people for *Salmonella* (Van Pelt et al., 2006). During the last ten years 7 *Campylobacter* epidemics occurred in the world, 2 crises were related with contaminated chicken products (both in catering/restaurant). Nine large *Salmonella* crises occurred in the last 15 years, and also 2 crises were linked to chicken meat. The largest crisis of these 2 occurred in Spain 2005 (VWA, 2008b). With regard to the chemical contamination, dioxin, there were 4 large feed crises in the past 10 years. The poultry sector was involved 3 times. The supply chain losses were very high and were spread by different countries and in different stages of the chain.

Van Andel (2008) studied the amount of supply chain losses due to animal feed crises. He took into account 6 large animal feed crises; dioxin crises of 1999, 2003, 2004 and 2006, MPA crisis (2002) and crisis of bone fragments in 2004. Besides the poultry sector, the hog and cattle sector were also considered. After his review on these feed crises it became clear that the amount of supply chain losses is unknown for many crises. Van Andel (2008) showed that, in the most likely scenario, 72 broiler farms would be contaminated for 7 days. Supply chain losses for poultry slaughtering were, in the most likely scenario, €3 till €5 million.

Contaminated products, such as contaminated feed, or contaminated chicken meat, generally results into losses. This can be direct losses, such as the value decrease of the product, or indirect losses, such as temporary price decreases as a result of reduced consumer faith (Huirne and Meuwissen, 2006).

Yeung and Yee (2002) studied different loss components for consumers in case of contaminated chicken meat. They recommended a list of potential loss components, namely health, financial, time, lifestyle, performance, social and psychological losses. Health loss includes loss in income and days off because of ill health; financial loss means that when chicken meat is contaminated, consumers often dispose it; time loss indicates time spent for claiming refund from the shop if the chicken is contaminated, seeking medical help and being housebound for a few days or hospitalised for a period of time (if contaminated chicken meat causes illness); lifestyle loss includes restricted diet, loss of freedom and valuable activities with respect to food safety risks; taste loss is considered as the loss of taste in chicken due to overcooking which is done to ensure all bacteria are killed (Yeung and Morris, 2001); psychological loss is linked to purchasing a specific brand to enhance self-image and/or self-esteem. At last, social loss, i.e. consumers may feel embarrassed if their guests become ill after a meal which contained contaminated chicken meat, exists (Yeung and Yee, 2002).

This study focuses on the direct losses. In this study annual losses are considered as property damage and business losses. Consumer illness costs (COI) are considered as annual losses in the last stage, the retail/consumer stage. COI include: 1) medical expenses (doctor consults, hospital) 2) time lost from work by employees (Buzby et al., 2001).

H4 Materials and methods

4.1 Introduction

Many factors influence the occurrence of food safety hazards, as described in chapter 3. However, not all described factors influence the size of possible losses. The subsections explain the selection and parameterization of the variables for the design of the risk analysis. An overview of how losses are estimated is presented per contamination. Paragraph 4.4 makes clear how the estimated losses are related to estimate (product) liability claims. Paragraph 4.5 clarifies which assumptions are made in the model.

4.2 Monte Carlo simulation

The impacts of risks can be assessed by a qualitative and/or quantitative method, a so-called "risk-analysis". A quantitative method, for example, is a stochastic model using a Monte Carlo simulation. A Monte Carlo simulation obtains insight into the distribution of the losses of a contamination crisis (van Asseldonk et al., 2006) and it incorporates the effects of uncertainty and variability in the analysis (Garlick, 2007). In this study the effects of uncertainty are important to take into account due to the wide variation of variables (see table 3.1-3.4). The software for a Monte Carlo simulation is @RISK, an add-in via Excel.

Stochastic variables are the basis of a Monte Carlo simulation. If the range of a variable's uncertainty is unknown, then the nature of variables is deterministic. Deterministic variables are variables with a fixed value. A stochastic variable is a variable that is defined on a collection with a chance definition, an uncertainty effect (Garlick, 2007). The variable must be measurable and must take into account the probability of certain values (distribution of probability) and the relation between variables (correlations). The Monte Carlo simulation distinguishes the stochastic variables in different functional probability distributions. In this study, we use the Poisson distribution, the discrete distribution and the triangular distribution respectively. A discrete distribution arises when each figure is equally likely, i.e. different prevalence percentages of different authors. In risk analysis the Poisson distribution is important because it represents events, i.e. a food crisis, that may happen several times, rather than just once. Triangular distributions have a triangular shape and reflect the minimum, most likely and maximum values. The most likely value is the peak of the triangle (Garlick, 2007).

4.3 Model variables

Variables are selected for each stage of the broiler production chain. The technical and economic variables (deterministic) which are used for all three contaminations are mentioned in table 4.1. The stochastic and specific deterministic variables are described for the three contaminations separately.

Table 4.1. Technical and economic variables (deterministic) in broiler chain simulation model.

Stage	Nr.	Source	Variable description	Value
Animal feed comp.	1.	PDV, 2004	Production compound broiler feed in NL	1,483
	2.	Bont and van der Knijff, 2007	Cost of feed per 100 kg	27.7
Breeding farms	3.	KWIN, 2008	Revenue per hen (18 weeks old)	8.75
	4.	KWIN, 2008	Vacancy	28
	5.	KWIN, 2008	Number of animals per round	12,500
	6.	PVE, 2008	Number of breeding companies	5
Parent animal farms	7.	KWIN, 2008	Revenue per consumption egg	0.005
	8.	KWIN, 2008	Number of consumption egg/hen	10
	9.	PVE, 2008	Number of animals	4,700,000
	10.	PVE, 2008	Production material	848,000
	11.	PVE, 2008	Number of (grand)parent companies	272
Hatcheries	12.	KWIN, 2008	Capacity number chickens per week	790,000
	13.	KWIN, 2008	Value one-day chicken	0.275
	14.	PVE, 2008	Number of hatcheries	19
	15.	Nauta et al., 1998	Stay of chicken	20
Broiler farms	16.	PVE, 2008	Number of conventional broiler farms	701
	17.	CBS, 2008	Number of organic broiler farms	88
	18.	PVE, 2008	Average number of broilers per farm	60,214
	19.	PVE, 2008	Costs	1.45
	20.	PVE, 2008	Gross margin	0.31
	21.	PVE, 2008	Value per broiler	1.76
	22.	Van Asseldonk et al., 2006	Costs destruction and cleaning	2.61
	23.		Production costs organic broilers	200
Retail/ consumer	24.	CBS, 2008	Habitants NL	16,445,636
	25.	PVE, 2008	Consumption chicken meat consumer	18.2
	26.	PVE, 2008	Kg chicken meat to sell	298.4
	27.	PVE, 2008	Production whole chicken	13
	28.	PVE, 2008	Production part chicken	87

4.3.1 Campylobacter

Campylobacter does not occur in the production chain, upstream of the broiler farms. Deterministic variables (table 4.3) from broiler farms to the retail stage are therefore only taken into account. The only damage that can occur due to *Campylobacter* within broiler farms is growth disruption of the broilers (Personal communication, 2008b). Slaughterhouses do not have losses due to a *Campylobacter* contamination. Contaminated slaughtered meat goes, as usual, to the deboning companies and wholesalers (Personal communication, 2008e).

Table 4.2 shows only the specific variables which can be used to calculate annual losses due to *Campylobacter.* The slaughterhouse stage is therefore not mentioned in this table.

Table 4.2 Variables *Campylobacter* (stochastic and deterministic) in broiler chain simulation model.

Stage	**Nr.**	**Unit**	**Source**	**Variable**	**Prob. Distr.**	**Parameterisation** *Overall*	*min.*	*m.l.*	*max.*
Broiler farm	1.	days	KWIN, 2008	Production period	Triang.	42.5	36	42.5	48
	2.	days	KWIN, 2008	Vacancy	Triang.	9.5	6	9.5	16
	3.	%	Nauta et al., 2007	Contamination conventional farm	Determ.	44.4			
	4.	%	Hartnett et al., 2002	Cont. chance within flock	Discrete (each 0.25 chance)	71			
	5.	%	Havelaar, 2001			82			
	6.	%	Jacobs-Reitsma et al.,2000			60.8			
	7.	%	Kauna et al., 2007			81.8			
	8.	%	Havelaar, 2001	Cont. chance between flock	Discrete (each 0.33 chance)	35			
	9.	%	Havelaar et al., 2005			29			
	10.	%	Katsma et al., 2004			27			
	11	%	Rodenburg et al., 2004	Cont. chance organic farm	Determ.	35			
	12.	%	Van Asseldonk et al., 2006	Growth disruption	Triang.	20	1	20	50
Retail	13.	numb	Havelaar et al., 2001	*Campylobacter* COI cases	Determ.	80,000			
	14.	€/y	VWA, 2008a	Consumer illness cost by campy.	Determ.	2E+07			
	15.	%	Mangen et al., 2007	*Campylobacter* because of poultry	Triang.		20	30	40
	16.	%	VWA, 2007	Contamination whole chicken	Determ.	9.5			
	17.			Contamination part chicken	Discrete (chance 0.33; 0.33; 0.29; 0.05)	11.4		(breast)	
						19		(leg)	
						29.8		(organic)	
						16		(other)	

The rate of circulation within the broiler farm stage is calculated via 365 (days within a year) divided by the production period plus vacancy (table 4.2, nr. 1+2). In the consumer/retail stage the consumer illness costs (COI) due to *Campylobacter* are calculated per consumer: €21 million divided by 80,000 COI cases (table 4.2, nr. 13+14) is a COI of €262.50. Moreover, to know how many people go to a hospital for *Campylobacter* due to consumption of chicken meat, a factor is calculated: 80,000 COI cases times the probability of 0.2-0.4 (table 4.2, nr. 15) divided by the total habitants of the Netherlands (table 4.1, nr. 24). The discrete probability function of the variable 'contamination part chicken' (table 4.2, nr. 17) is not equal. The amount of people who buy conventional chicken meat is larger than the amount of people who buy organic chicken meat. The chances are retrieved from the statistic report of PVE 2007.

The way of calculating annual losses from *Campylobacter* per stage is listed in table 4.3. For instance, circa 289 kg ton chicken meat is available for sales in the Netherlands (table 4.1, nr. 26). From these 289 kg ton is 13% sold as a whole chicken and 87% as different parts of chicken meat (table 4.1, nr. 27+28). Multiplying these amounts with prevalence (table 4.2, nr. 16+17), the amount of contaminated (kg) meat is known. The average Dutch consumer eats 18.2 kg chicken meat per year (table 4.1, nr. 25) and therefore, the model estimates how many consumers have purchased contaminated chicken meat. This number of people multiplied by the percentage of people who have illness times the COI of €262.50 (see above), per consumer, results in expected annual losses for the retail/consumer stage.

Table 4.3 Calculations annual losses *Campylobacter*

Stage	Calculations annual losses *Campylobacter*[1]
Animal feed	n.p.
Breeding	n.p.
Parent animals	n.p.
Hatcheries	n.p.
Broiler farm	**[**613 (number of conventional farms) * 0.444 (flock prevalence) * Average flocks per farms (nr) * contamination chance between flock (%) * contamination chance within flock (%) * 60,214 (number of broilers per flock) * growth disruption (%) * 0.31 (gross margin**]** + **[**88 (number of organic farms) * 0.35 (contamination chance organic farms) * 60,214 (animals per flock) * growth disruption (%) * €0.31 (gross margin per broiler)**]**
Slaughterhouse	n.l.
Retail/Consumer	**[[**298,400,000 (kg chicken meat to sell) * 0.13 (% whole chicken) * 0.095 (contamination chance whole chicken)**]** + **[**298,400,000 (kg chicken meat to sell) * 0.87 (% parts chicken) * average contamination chance part chicken) (%)**]]** / **[**18.2**]** (kg per consumer) * **[***Campylobacter* cases per year by poultry/ 16,445,636 (habitants NL) * € 262.50 (consumer illness cost per consumer)**]**

[1] n.p. = not present, i.e. a *Campylobacter* contamination does not occur in this stage; n.l.: (could be) present, but contamination does *not* lead to losses.

4.3.2 Salmonella

As mentioned in paragraph 3.4, a *Salmonella* contamination can happen in the breeding stage till the moment where consumers prepare chicken meat. In table 4.4 the specific variables for *Salmonella* are mentioned.

Table 4.4 Variables *Salmonella* (stochastic and deterministic) in broiler chain simulation model.

Stage	Nr.	Unit	Source	Variable	Prob. Distr.	Overall	Parameterisation min.	m.l.	max.
Breeding farms	1.	days	KWIN, 2008	Production period	Triang.	133	126	133	140
	2.	days	KWIN, 2008	Vacancy	Determ.	28			
	3.	%	Actionplan, 2002	Contamination	Determ.	1			
Parent animal farms	4.	days	KWIN, 2008	Production period	Triang.	343	315	343	365
	5.	%	Actionplan, 2002	Contamination	Determ.	6			
	6.	numb	KWIN, 2008	Breeding eggs per hen	Triang.	153	140	153	160
	7.		KWIN, 2008	Revenue per breeding egg		0.16	0.15	0.16	0.17
Hatcheries	8.	%	Actionplan, 2002	Contamination	Determ.	9			
Broiler farms	9.	days	KWIN, 2008	Production period	Triang.	42.5	36	42.5	48
	10.	days	KWIN, 2008	Vacancy	Triang.	9.5	6	9.5	16
	11.	%	EFSA, 2007	Cont. per flock	Triang.	7.5	6.6	7.5	8.3
	12.	%	Rodenburg et al., 2004	Cont. Organic farms	Determ.	13			
	13.	%	Van Asseldonk et al., 2006	Growth disruption	Triang.	20	1	20	50
Slaughter-house	14.	%	Personal communication, 2008e	Cont. per flock	Determ.	10			
	15.	€	Personal communication, 2008e	Costs per contaminated flock	Determ.	500			
	16.	numb	Personal communication, 2008e	Animals per flock	Determ.	20,000			
Retail/ consumer	17.	%	Van Pelt et al., 2006	*Salmonella* because of chicken meat	Determ.	17			
	18.	%	VWA, 2007	Cont. *Salmonella* whole chicken	Determ.	5.9			
	19.	%	VWA, 2007	Contamination part chicken	Discrete (resp. chance of 0.33, 0.33, 0.29, 0.05)	11.9 5.1 4.0 8.5		(breast) (leg) (organic) (other)	
	20.	€/y	Van Pelt et al., 2006	Consumer illness cost by	Determ.	7E+06			
	21.	numb	Van Pelt et al., 2006	*Salmonella* COI cases	Determ.	2631			

Within the parent animals stage the rate of circulation is calculated via 365 divided by the production period (see table 4.4, nr. 4). The average turnover per flock in this stage can change due to stochastic variables and is calculated with:

[‘Revenue per breeding egg’] * [‘number of breeding eggs per broiler’ + ‘revenue per consumption egg’] * [‘number of consumption eggs per hen’] * [‘number of hens per flock’] (see table 4.1, nr 7-9, table 4.4, nr. 6+7).

The average turnover per round in the hatcheries stage is €4,345,000. The rate of circulation is calculated via 52 (weeks) divided by 20 (weeks) (see table 4.1, nr. 14); and is therefore 2.6. The rate of circulation is also calculated in the stage of broiler farms. The annual losses in the broiler farms are related with growth disruption (table 4.4, nr. 13) due to a *Salmonella* contamination

In slaughterhouses, contaminated broilers are logistic slaughtered. The extra costs for logistic slaughtering are €500 per flock (table 4.4, nr. 15). Costs like reputation costs and complementary restrictions are not considered in the model. The COI per consumer caused by *Salmonella* was estimated to be €2,660.28 (€7 million of costs divided by 2631 cases: table 4.4, nr. 20+21). *Salmonella* infection due to consumption of chicken meat has a factor of 0.17 (table 4.4, nr. 17).

Table 4.5 gives an overview of how annual losses are calculated via @ Risk. For instance, 6% of all flocks are contaminated in the parent animal stage (table 4.4, nr. 5). The contaminated flocks per year, of all parent animal farms, multiplied by the turnover per flock (see above) estimate annual chain losses per year in the parent animal stage.

Table 4.5 Calculations annual losses *Salmonella*

Stage	**Calculations annual losses *Salmonella*[1]**
Animal Feed	n.p.
Breeding	**[**number of days per round (days) * 0.01 (contamination chance per round) * 33,000 (broilers per round) * 5 (number companies) * **[**(value hen) + €2.61 (costs destruction and cleaning)**]]**
Parent animals	**[[**0.06 (contamination chance per flock) * number of flocks per company * 272 (number companies) * turnover per flock (€)**]** + **[**0.06 (contamination chance per flock) * number of flocks per company * animals per flock * €2.61 (costs destruction and cleaning)**]]**
Hatcheries	**[**2.6 (number of rounds per year) * 0.09 (contamination chance per round) * €688,090 (turnover per round for all flocks)**]**
Broiler farm	**[**Average flocks per farms per year (nr) * 0.25 (contamination chance per flock) * 613 (conventional farms) * 60,214 (animals per flock) * growth disruption (%) *€0,31 (gross margin)**]** + **[**88 (number of organic farms) * average flocks per farms per year (nr) * 0.04 (contamination chance organic farms) * 60,214 (animals per flock) * growth disruption (%) * €0.31 (gross margin per broiler)**]**
Slaughterhouse	**[[**675,000,000 (production slaughtered-weight / 0.7 (rest slaughtered weight)] / 2.18 (average weight broilers) / 15 (number of slaughterhouses) / 20,000 (average number of broilers per flock in slaughterhouses)**]** ***[**0.1 (contamination chance per flock) * €500 (costs per flock)**]**
Retail/Consumer	**[[[**298,400,000 (kg chicken meat to sell) * 0.13 (% whole chicken) * 0.095 (contamination chance whole chicken)**]** + **[**298,400,000 (kg chicken meat to sell) * 0.87 (% parts chicken) * average contamination chance part chicken) (%)**]]** / 18.2 (kg per consumer)**]** * **[**447 (cases *Salmonella* by broilers) / 16,445,636 (habitants NL)**]** * € 2,660 (consumer illness cost per consumer)

[1] n.p. = not present, i.e. a *Salmonella* contamination does not occur in this stage.

4.3.3 Dioxin

As mentioned before; much information is available on the contamination chance of the microbial contaminations, contamination chances of dioxin however, are hardly available. Risk analyses and associated losses in case of a (chemical) food hazard in the broiler production chain, are conducted by Van Asseldonk et al. (2006) and Meuwissen et al. (2008a).

Van Asseldonk et al. (2006) conducted an analysis of contamination risks in the production of compound feed. Meuwissen et al. (2008a) used this research as input for a risk analysis in the broiler farm and processing industries (slaughterhouses). These analyses are based on previous feed crises, like dioxin. The production values by sector were based on NEVEDI (Dutch Association of Animal Feed Industry) statistics in the research of Van Asseldonk et al. (2006). Employees of NEVEDI were asked to fill in a questionnaire about stochastic assumptions in the model. Via this way some variables were parameterised and which also are used as input for this study.

Table 4.6 Variables dioxin (stochastic variables) in broiler production chain

Stage	Nr.	Unit	Source	Variable	Prob. Distr.	Parameterisation Overall	*min.*	*m.l.*	*max*
Animal feed companies	1.	numb.	Van Asseldonk et al., 2006	Affected compound feed producers	Triang.	15	1	15	70
	2.	days	KWIN, 2008	Duration contamination	Triang.	3	1	3	10
	3.	%	Van Asseldonk et al., 2006	Growth disruption	Triang.	20	1	20	50
Broiler chain	4.	numb	Van Asseldonk et al., 2006	Contaminated farms	Triang.	220	12	220	737

It is assumed that the duration of contamination, which is in the most likely scenario 3 days for the poultry sector, applies to each stage of the broiler production chain. Van Asseldonk et al. (2006) calculated that in the most likely scenario 659 farms were contaminated. The contaminated farms were equally divided over 3 branches (cattle, pigs and poultry). Therefore, the number of contaminated farms per sector was approximately 220 (table 4.6, nr. 4). In this study farm types are further specified to the stages of the broiler production chain on the relative frequencies, in percentage, per sector. Meuwissen et al. (2008a) also used above figures to calculate the losses in the broiler farm and in slaughterhouses, but did not specify the affected farms in all stages. They made the assumption that the probability of becoming affected is equal for all farms within a sector (like broiler farms, breeding farms, hatcheries). This is also the assumption within this study.

According to van Andel (2008) in the most likely scenario 4 slaughterhouses (include dairy processing, pig slaughterhouses and broiler slaughterhouses) are affected. The contaminated slaughterhouses are equally divided over these branches. It would mean that in the most likely scenario 2 slaughterhouses would be affected, in the best case scenario 1 and in the worst case scenario 3 affected broiler slaughterhouses. The probability of a dioxin crisis is based on statistics. As mentioned in paragraph 3.4, in the last 10 years a dioxin crisis affecting the poultry sector occurred 3 times (i.e. the annual probability is 0.3).

Table 4.7 gives the stochastic figures of affected companies specified to each stage of the broiler production chain. For instance, the relative frequency of breeding companies is 0.23%. The number of affected breeding companies will therefore be 1 (220*0.0023 = 0.506) in the most likely scenario.

Table 4.7 Affected companies specified in broiler production chain

Stage	**% poultry farms**	**Affected companies in most likely scenario**	**Affected companies in best case scenario**	**Affected companies in worst case scenario**
Total # affected farms[1]	-	220	12	737
Breeding	0.23	1	0	2
Parent animal	12.28	28	2	94
Hatcheries	0.86	2	0	6
Broiler farms	31.65	69	4	232
Total # affected slaughterhouses[2]	-	4	1	8
Slaughterhouses	-	2	1	3

[1] Data retrieved from van Asseldonk et al. (2006)

[2] Data retrieved from van Andel (2008).

Some stochastic variables which are used by the risks *Salmonella* and *Campylobacter* are also used by the model for dioxin. These variables are the production periods and vacancies (table 4.4, nr. 1, 2, 4, 9, 10) and the calculations of rate of circulations of all stages, and the average turnover per week of the parent animal stage (see explanation *Salmonella*).

The average turnover per day is €31,035.71 in the hatcheries stage. The impacts per conventional broiler, respectively an organic broiler, of €4.37 and €5.32 (table 4.1, nr.18, 20-22), are used in the broiler farm stage. At last the average production value per day per slaughterhouse is € 96,027.4. In case of a dioxin contamination it is assumed that the whole turnover is lost for the number of days of contamination. Till now consumers never became dioxin infected due to consumption of chicken meat. No losses occur, therefore, in the retail/consumer stage.

Table 4.8 Calculations annual losses dioxin

Stage	Calculations annual losses Dioxin[1]
Animal Feed	**[**Probability crisis (times/year) * number affected companies (nr) * daily production per farm(kg ton/farm) * number of days in which contaminated compound feed is produced (nr) * cost of feed (€/kg ton)**]**
Breeding	**[**Probability crisis (times/year) * number affected companies (nr) * **[**€ 8,75 (value hen per period) / production period (days)**]** * contamination duration (days)**]**
Parent animals	**[**Probability crisis (times/year)* number affected companies (nr) * daily turnover (€) * contamination duration (days)**]**
Hatcheries	**[**Probability crisis (times/year) * number affected companies (nr) * contamination duration (days) * average turnover a day (€/day)**]**
Broiler farm	**[[**Probability crisis (times/year) * 60,214 (average animals per farm) * contamination duration (days) * number affected companies (nr) * **[**€1.76 (value per broiler) + €1,45 (costs per broiler) +€2.61 (costs destruction and cleaning)**]]** + **[**growth disruption (%) * €0.31 (gross margin per broiler) * contamination duration (days) * 60,214 (average animals per farms) * non-affected companies (nr)**]]**
Slaughterhouse	**[**Probability crisis (times/year) * €106,697 (average production value per day per slaughterhouse)* number affected companies (nr) * contamination duration (days)**]**
Retail/Consumer	n.p.

[1] n.p. = not present, i.e. a dioxin contamination does not occur in this stage.

4.4 Estimate (product) liability claims

Above paragraphs explained how annual losses are estimated in this study. If the annual losses are expected to known, the (product) liability claims per year can also be estimated. Together with personal communication (2008d) the possibility of a successful liability claim are related to the components (aspects like business interruption, turnover, etc.) of expected annual losses. A positive, unknown or negative success will be given to the claimable amount. A positive success means that there is a positive chance that the claim gets assigned to the disadvantaged farms in the stage. An unknown success means that the chance that that the claim gets assigned to the disadvantaged farms in the stage is unknown. A negative success means that the disadvantaged farms in the stage have no, or a little, chance to receive indemnities for claims filed.

Besides these estimated claimable amounts per stage and the probability of a successful claim, the expected claim per stage is provided: an actor in the broiler production chain can receive a claim due to a contamination in the product of the actors who he/she supplied to.

4.5 Assumptions research

In this study assumptions are made for the risk analysis model. First, generic assumptions are listed and are meant for all three food safety hazards; *Campylobacter*, *Salmonella* and dioxin. Second, specific assumptions for each hazard are listed separately.

Generic assumptions

1. Only the broiler production of the Netherlands is taken into account. Financial consequences of import and export of broilers and/or eggs have not been considered in the model.
2. Pharmaceutical suppliers (medicines for broilers) are not taken into account.
3. It is assumed that cross-contamination does not occur through employees and/or visitors of the farms/companies.
4. It is assumed that cross-contamination or a decrease or increase of prevalence does not occur during transport.
5. It is assumed that cross-contamination does not occur during preparation of chicken meat by consumers.
6. In the retail/consumer stage of the broiler production chain annual losses are limited as COI (consumer illness costs), instead of property damage and business interruption losses at this stage.
7. Stages of retail industry, wholesalers and catering are excluded in the model, because data is lacking and specific information is missing regarding sales data.

Specific assumptions for Campylobacter

C1. (Prevention) Compensations from Ministry or other agents are not taken into account.

C2. Costs of swamps/monsters, to investigate if there is a contamination, are not taken into account.

C3. It is assumed that between different types of *Campylobacter* no difference of prevalence and contamination chances exists.

Specific assumptions for Salmonella

S1. (Prevention) Compensations from Ministry or other agents are not taken into account.

S2. Costs of swamps/monsters to investigate if there is a contamination, is not taken into account.

S3. It is assumed that between different types of *Salmonella* no difference of prevalence and contamination chances exists.

Specific assumptions for dioxin

D1. No products are allowed to be consumed or produced further in the chain in case of a dioxin contamination. Assumed is that all products (hens, broilers and/or eggs) have to be taken out of the food supply chain.

D2. It is assumed that the number of duration of a dioxin contamination applies to each stage of the broiler chain. During the period of contamination, the farm/company won't be able to make any turnover.

D3. It is assumed that the probability of becoming affected (i.e. on average 0.3 per year) is equal for all farms and companies in all stages of the broiler chain.

H5 Results

5.1 Annual losses

This chapter presents the results of the analysis from the stochastic model. In this study, the annual losses are shown for the 5%, 95% percentile and for the mean. The 5% percentile, 95% percentile and the mean are interpreted as the best case, worst case and most likely scenario for annual losses respectively. These annual losses are specified per food safety hazard and per stage in the chain.

5.1.1 Annual losses per food safety hazard

Campylobacter

As mentioned before in paragraph 4.3.1, losses due to *Campylobacter* occur in the broiler farm stage and in the retail/consumer stage. *Campylobacter* does not cause losses in the slaughterhouse stage.

Table 5.1 Annual losses of Campylobacter (5%, mean, 95%)[1]

Stage	5% (mln €)	Mean (mln €)	95% (mln €)
Broiler farm	1.06	3.24	5.76
Retail/consumer	0.60	0.96	1.40
Total	**1.66**	**4.2**	**7.16**

[1] 5000 @Risk iterations

Results show that annual losses are expected to be €3.24 million in the broiler farm stage, with a variation from €1.06 million (5%) to €5.76 million (95%). This variation is mainly caused by the increased percentage of growth disruption and downgraded quality of the broilers.

Annual losses are expected to vary between €0.6 million (5%) and €1.40 million (95%) in the retail/consumer stage. In this stage the maximum of annual losses is €2.22 million (not in table). As mentioned in paragraph 3.2, annual health losses due to *Campylobacter* were estimated at €21 million (VWA, 2008c). From this €21 million, however, €4.2 million to €8.4 million were caused by direct consumption of infected chicken meat. These VWA results significantly differ from the expected losses. A possible explanation for the difference might be related to the fact that:

- As mentioned in paragraph 3.2., per year circa 80,000 people visit a doctor due to a *Campylobacter* infection. From literature it is estimated that 20% to 40% of those visits are related to the consumption of chicken meat (table 4.2, nr. 15), which means that approximately 16,000 to 32,000 people become ill. The VWA survey assumes that from the €21 million annual health losses caused by *Campylobacter* (table 4.2, nr. 14), also 20% to 40% is related to consumption of chicken meat, which results in range from €4.2 million to €8.4 million losses.
- In this study is assumed that 0.09% to 0.19% of all habitants in the Netherlands become ill due to consumption of *Campylobacter* infected chicken meat. These percentages are calculated by

16,000 to 32,000 people divided by 16,455,386 (habitants Netherlands). These percentages are multiplied with the number of people who purchased contaminated chicken meat times the COI of €262.50 per consumer. This approach results into fewer losses.

This approach is preferred above the approach of VWA, because it provides more detailed information in expected annual losses.

Salmonella

As mentioned in paragraph 3.3, *Salmonella* can contaminate feed, broilers, eggs and chicken meat starting from the breeding stage to the stage of retail/consumer. As variables in the hatcheries and slaughterhouse stage are modelled deterministically, values in the 5%, 95% and mean do not vary.

Table 5.2 Annual losses of *Salmonella* (5%, mean, 95%)[1]

Stage	5% (mln €)	Mean (mln €)	95% (mln €)
Breeding	0.043	0.046	0.049
Parent animals	9.27	9.73	10.20
Hatcheries	1.02	1.02	1.02
Broiler farm	0.57	1.76	3.11
Slaughterhouses	1.12	1.12	1.12
Retail/consumer	0.05	0.09	0.13
Total	**12.07**	**13.77**	**15.63**

[1] 5000 @Risk iterations

Results show that the annual losses in the breeding stage are expected to between €43,000 (5%), and €49,000 (95%). These annual losses are relatively low compared with the other stages. This is mostly caused by the small number of breeding companies in the Netherlands and the low prevalence in this stage (see table 2.1; table 4.2). Many breeding companies which supply hens and cocks in the Netherlands are situated in foreign countries. These companies are excluded from this study.

The next stage, the parent animal stage, expects relatively high annual losses varying between €9.27 million (5%) and €10.20 million (95%). This amount of loss is dependent on the number of breeding eggs per hen; the revenue per breeding egg; and the purchase price of the hens. In case of a *Salmonella* contamination, the value of the hen is subsidised by Ministry LNV. If the prices of the hens are not taken into account, expected annual losses are between €6.55 million (5%) and €7.42 million (95%).

For the retail/consumer stage, expected annual losses vary between €0.05 million (5%) and €0.13 million (95%). However, van Pelt et al. (2006) estimated that these losses were circa €1.0 million. The difference between expected results of our model and the results of van Pelt et al. (2006) might be related to the fact that:

- From literature it is estimated that 17% of the *Salmonella* consumer illness cases are related to consumption of chicken meat (table 4.4, nr. 16). Van Pelt et al. (2006), have assumed that from the €7 million annual health losses caused by *Salmonella* (table 4.4, nr. 19), also 17% is related to consumption of chicken meat, which results in higher losses.
- In this study is assumed that 0.003% off all habitants in the Netherlands become ill due to consumption of *Salmonella* infected chicken meat. This percentage is calculated by number of *Salmonella* cases (table 4.4, nr. 20) multiplied with 17%. This approach results into fewer losses.

The last approach is chosen, because it provides more detailed information in expected annual losses.

Dioxin

Dioxin contaminates animals via animal feed. Previous dioxin crises have shown that cross-contamination does not occur. Moreover, till now consumers were never infected with a dioxin contamination due to consumption of chicken meat.

Annual losses in the best case scenario (5%) are expected to be €0 in all stages of the chain. This is caused by the Poisson distribution of the Monte Carlo model. This distribution represents crisis that may happen several times, rather than just once. A probability of 0.3 means that a crisis can happen 0 times in a year, once in a year, 2 times in a year, 3 times in a year and 4 times in a year (in the worst case scenario). In the best case scenario, the probability is zero (0 times in a year), which results in no losses.

Table 5.3 Annual losses of dioxin (5%, mean, 95%) [1]

Stage	**5% (mln €)**	**Mean (mln €)**	**95% (mln €)**
Animal feed	0	0.27	1.53
Breeding	0	0.0035	0.018
Parent animals	0	0.094	0.54
Hatcheries	0	0.11	0.64
Broiler farm	0	0.79	4.31
Slaughterhouses	0	0.63	3.40
Total	**0**	**1.90**	**10.45**

[1] 5000 @Risk iterations

According to these results, annual losses are expected to be the highest in the stages of broiler farms and slaughterhouses. Expected annual losses of broiler farms significantly increase to a worst case scenario to €4.31 million. This large step between the mean and 95% percentile is mainly caused by 1) the increased number of contaminated farms, 101 to 231 in the mean and 95% percentile respectively; and 2) the increased number of days in which contaminated feed is delivered: 4.6 days and 9.3 days respectively (see table 4.5 and table 4.6).

Meuwissen et al. (2008a) already estimated the losses of poultry slaughtering. They estimated losses between €3 million to €5 million in the most likely scenario, and in the worst case scenario losses of €14 and €37 million euro. In this research, the expected losses of broiler slaughterhouses are much lower. The difference between the expected model results and Meuwissen et al. (2008a) is probably due to the facts that in this study 1) less slaughterhouses are affected by the crisis, 2 in this study and 4 slaughterhouses in the research of Meuwissen et al.; and 2) less days of contamination duration, 3 and 7 days respectively (see table 4.5 and table 4.6). These differences in variables are chosen, because in this study it is applied to the poultry sector in particular, while the variables of Meuwissen et al., apply to more live stock sectors.

Another interesting observation is that annual chain losses are expected to increase 5 or more times in the worst case scenario compared with the most likely scenario in all affected stages of the chain. This is mainly caused by the facts that in the worst case scenario more companies are affected; and the number of days in which contaminated feed is delivered increases.

5.1.2 Annual losses per chain stage

Annual chain losses of the food safety hazards are expected not to be equally distributed among the broiler chain actors. From the various stages considered in the most likely scenario, parent animal farms and broiler farms are expected to face highest losses.

5.2 Important factors affecting annual losses

Various risk factors influence the size of losses due to food safety hazards (see chapter 3 and 4). This paragraph shows the most important risk factors which influence the size of expected annual losses per food safety hazard. These factors are estimated by correlation analyses of the Monte Carlo model. The analyses calculate a correlation between -1 and 1 of the variables. These correlations show the level of impact on the size of annual losses. A correlation near +1 means that if the variable increase, the annual losses increase also. A negative number near -1 means that if the variable increase, the annual losses decrease. The variable has no or a little impact on the size of annual losses if the correlation is near 0.

5.2.1 Risk factors annual losses Campylobacter

For *Campylobacter*, in broiler farms the expected size of annual losses is mostly influenced by the stochastic variable of growth disruption and downgraded quality of the broilers (+0.97). The variables ‘contamination *Campylobacter* in chicken parts’ (+0.88) and the ‘percentage *Campylobacter* responsible of chicken meat’ (+0.48) have increasing impact on the size of the annual losses.

In each stage the prevalence of *Campylobacter* is an important risk factor. If prevalence increases, the size of the annual losses becomes higher. Moreover, financial variables such as values of animals and/or turnovers of a flock or company, impact the size of annual losses.

5.2.2 Risk factors annual losses Salmonella

For *Salmonella*, different risk factors impact the size of annual losses per stage:

- In the breeding stage the value of a hen has impact on the size of expected annual losses (+0.88). Moreover, the production period has a decreasing impact (-0.48) on these annual losses.
- In the parent animals stage, the 'revenue per breeding egg' and the 'number of breeding eggs per hen' have influence on the size of expected annual losses, with +0.67 and +0.61 respectively. Both stochastic variables determine the deterministic variable turnover per flock', which again influences the size of annual losses.
- The size of annual losses in the stage of broiler farms is also mostly influenced by the stochastic variable: growth disruption and downgraded quality of the broilers (+0.98).
- As last, in the consumer/retail stage the variable 'contamination *Salmonella* in chicken parts' has a high decreasing impact (+1) on the size of annual losses in this stage.

Summarized, different risk factors impact the size of expected annual losses due to *Salmonella*. The most important factors are 1) 'financial variables' (like values and turnovers); 2) 'prevalence *Salmonella*'; and 3) 'growth disruption'.

5.2.3 Risk factors annual losses dioxin

For dioxin, in all stages of the chain, the same variables impact the size of annual losses. These stochastic variables are: 1) 'probability of a dioxin crises'; 2) 'number of affected companies'; and 3) 'contamination duration'. The last two variables have a much smaller impact on the losses than the first variable, +0.77, +0.23 and +0.18 respectively.

5.3 Alternative model scenarios

The parameters in the model were changed, with a particular focus on the most important factors as mentioned above, to describe and compare three alternative model scenarios which deal with developments that are likely to occur in the future.

1. *Not every stage in the chain is affected (dioxin)*

In the default calculations it was assumed that all stages in the broiler chain are affected in case of a dioxin crisis (see paragraph 4.5, assumption D4). According to Van Andel (2008), the animal feed companies of the broiler production chain, broiler farms and poultry processing industries (slaughterhouses) were affected 3 times in these 10 years. Until now, stages like breeding companies, parent animal companies and hatcheries were never confronted by a contamination (Personal communication, 2008a). In that case, the annual losses for the whole chain would be lower. Moreover, an assumption could be made that risk mitigation will prevent a possible next dioxin crisis (Meuwissen et al., 2008b). The probability of a dioxin crisis is changed in this alternative model exercise which results in different losses compared with the default scenario.

a) Only animal feed stage, broiler farm stage and slaughterhouse stage are affected: a probability of 0.3 is applied to the animal feed stage, broiler farm stage and slaughterhouse stage. A probability of 0.0 is applied to the stages of breeding companies, parent animal companies and hatcheries.
b) A lower probability in the animal feed stage, broiler farm stage and slaughterhouse stage: a probability of 0.2 is applied to the animal feed stage, a probability of 0.1 in the broiler farm and slaughterhouse stage and a probability of 0.0 is applied to the stages of breeding companies, parent animal companies and hatcheries. The probability of animal feed companies is higher because a dioxin contamination starts in animal feed and this stage is affected 4 times in these 10 years.
c) Lower probability in all stages: a probability of 0.2 is applied to the animal feed stage, a probability of 0.1 is applied to the stages of breeding companies, parent animal companies, hatcheries, broiler farms and slaughterhouses.

Table 5.4 shows the differences in € million between the expected values of the described situations and expected default model results. In case of a lower probability in the animal feed, broiler farm and slaughterhouse stage, the annual losses decrease with €1.25 million compared with the default model results. It means that almost 66% of expected annual losses decrease if the probability decrease in the affected stages and the breeding, parent animal and hatcheries stages are not affected. If all stages of the chain are affected however, and with a lower probability, annual losses decrease with 62%.

Table 5.4 Mean annual losses for default scenario and scenario type 'not every stage in the chain is affected'[1]

Stage	Default (mln €)	Δ a.f., b.f and sl. affected [2] (mln €)	Δ Lower probability in a.f., b.f., and sl. (mln €)	Δ Lower probability in all stages (mln €)
Animal feed	0.27	0	-0.10	-0.10
Breeding	0.0035	- 0.0035	- 0.0035	- 0.0023
Parent animals	0.094	- 0.094	- 0.094	- 0.063
Hatcheries	0.11	- 0.11	- 0.11	- 0.073
Broiler farm	0.79	0	-0.53	-0.53
Slaughterhouses	0.63	0	-0.41	-0.41
Total (rounded)	**1.90**	**-0.21**	**-1.25**	**-1.18**

[1] 5000 @Risk iterations

[2] a.f.= animal feed stage; b.f.= broiler farm stage; sl.=slaughterhouse stage

2. A decrease of prevalence per stage (Campylobacter and Salmonella) to expected 2012 levels

Poultry products obtained from retail stores were scrutinised on the percentages of *Salmonella* and *Campylobacter* bacteria from 1996 till 2004 (van der Zee et al., 2005) and to 2006 (VWA, 2007). In 2006 *Salmonella* was present on average in 8.4% of the samples. Next, 14.2% of the samples contained *Campylobacter*. Compared to previous years this was a decrease for *Salmonella* as well as *Campylobacter* (see figure 5). The figure shows the prevalence of 2 types of *Salmonella* and *Campylobacter spp.* In this study it is assumed that no difference exists between the types of *Salmonella* and *Campylobacter* (see paragraph 4.5, assumptions C4 and S4). According to the years 1996-2006 an average annual decrease of prevalence of 10.9% is showed for *Salmonella*. *Campylobacter* shows a prevalence of 6.78% as an average annual decrease.

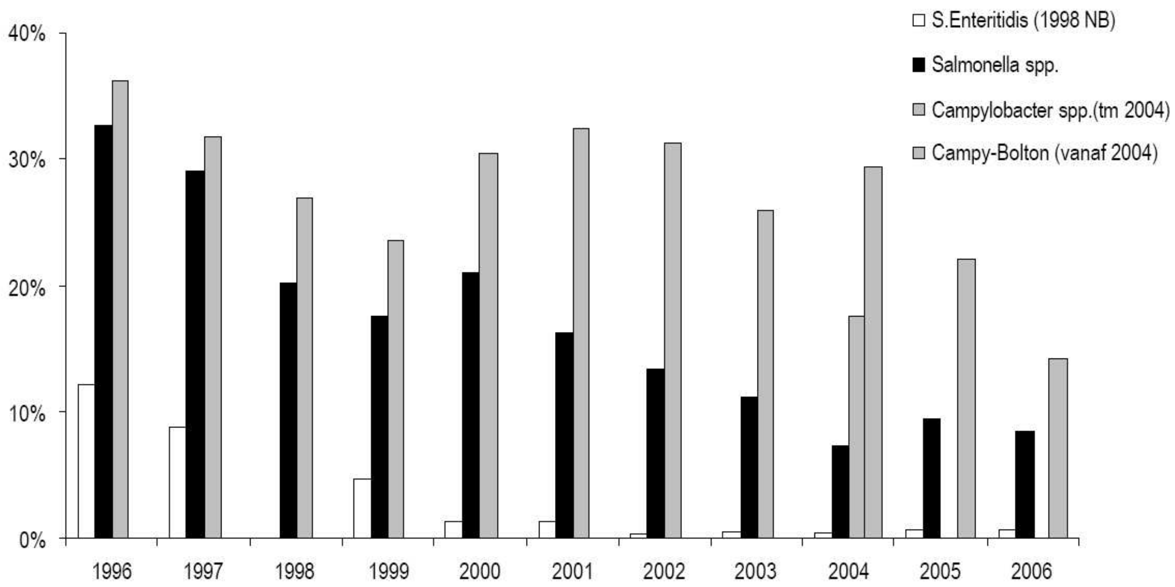


Figure 5. Contamination percentages of *Salmonella* and *Campylobacter* in poultry products from retail stores. Picture retrieved from VWA, 2007.

Since the start of the approach plan in 1997 and the Actionplan 2000+ (2002) of *Salmonella* and *Campylobacter* (described in paragraph 2.2), a decrease of prevalence of *Campylobacter* and *Salmonella* was also notified in the other stages of the broiler chain. Table 5.5 shows the *Salmonella* prevalence estimated by the approach plan in 1997, the Actionplan 2000+ (2002) and personal communication (2008b; 2008e).

Table 5.5 Prevalence *Salmonella* in broiler production chain

Stage	1997[1]	2000[1]	2006[2]	Difference
Breeding	5%	1%	n.a.[3]	-80%[4]
Parent animal	20%	6%	n.a.[3]	-70%[4]
Hatcheries	45%	9%	n.a.[3]	-80%[4]
Broiler farm	50%	25%	7.5%	-70%[5]
Slaughterhouse	75%	35%	10%	-71%[5]

[1] Source Actionplan 2000+ (2002).

[2] Source personal communication (2008b; 2008e).

[3] n.a.: no prevalence information available.

[4] Difference of prevalence between 1997 and 2000.

[5] Difference of prevalence between 2000 and 2006.

In 2007 the European Commission issued a regulation regarding targets for the reduction of the prevalence of *Salmonella* (EC 646/2007). As mentioned in paragraph 2.2, the target for the prevalence of *Salmonella* in the breeding, parent animal stage is set to 1% or less by 31 December 2011 (EC 646/2007). According to differences shown in table 5.5, personal communication and EFSA (2007), prevalence of *Salmonella* decreased and will reach the estimated targets. The alternative scenario is based on the assumption that the targets are achieved in the year 2012. In this study it is assumed that the trend wise decrease of prevalence, calculated in table 5.5, will continue for the next years.

For instance, in the breeding stage the prevalence is 1% in 2000. The prevalence has decreased by 80% in 3 years, or in other words; 20% of the first prevalence remained. In the year 2012, 12 years further, the prevalence of 2000 will be a multiplied by $0.2^{\wedge 4}$. This results in [1%* 0.2 * 0.2 *0.2 * 0.2] = 0.0016% in the breeding stage in 2012.

The contamination percentages in the stage of retail/consumer are calculated via the average annual decrease of 10.9%. This annual decrease is estimated to the year 2006. In the year 2012, 6 years further, this annual decrease is 6 times multiplied, so $10.9\%^{\wedge 6}$. Table 5.5 shows the default model prevalence and the estimated prevalence in year 2012 for *Salmonella.*

Table 5.6 Expected prevalence *Salmonella* in 2012

Stage		**Default**	**2012**
Breeding		1%	0.0016%
Parent animals		6%	0.0486%
Hatcheries		6%	0.0144%
Broiler farm		7.5%	2.25%
Slaughterhouses		10%	2.9%
Retail/consumer	Whole chicken	5.9%	3%
	Chicken parts	4%; 5.1%; 8.5%;12%	2%; 2.6%; 4.3%; 6%

For *Campylobacter* it is assumed that the prevalence will not decrease as much as for *Salmonella*. It is assumed that prevalence of *Campylobacter* decrease with the half of the estimated differences described in table 5.5. For instance, *Salmonella* showed a decrease of 70% for 6 years in the stage of broiler farms For *Campylobacter* it is assumed that the prevalence percentage decrease with 35% per 6 years, instead of 70%. In our default model, the prevalence percentage is estimated for the year 2006. For the year 2012, 6 years further, the literature prevalence (see table 4.2, nr. 3-10) is multiplied with 65%, e.g. 44.44% multiplied with 0.65 results in a prevalence of 28.87%

The contamination percentages in the stage of retail/consumer are calculated via the average annual decrease of 6.78%. This annual decrease is estimated to the year 2006. In the year 2012, 6 years further, this annual decrease is 6 times multiplied, so 6.78%$^{\wedge 6}$. The default model prevalence and the estimated prevalence of 2012 are shown in table 5.6 for *Campylobacter.* The stage of slaughterhouses is excluded, because of no losses due to *Campylobacter.* Table 5.7 shows multiple percentages per stage in the chain. These prevalence percentages are given by different authors (see paragraph 4.2) and are all used in this alternative model scenario.

Table 5.7 Expected prevalence *Campylobacter* in 2012

Stage		**Default**	**2012**
Broiler farm		44.44%	28.87%
	Within flock	71%; 82%; 60.8%; 82%	46%; 53.3%; 39.5%; 53%
	Between flock	35%; 29%; 27%	22.7%; 18.8%; 17.6%
Retail/consumer	Whole chicken	9.5%	6.23%
	Chicken parts	19%; 11.4%; 29.8%; 16%	12.47%; 7.48%; 19.56%; 10.5%

A comparison from the expected results of this alternative scenario and default model results is found in table 5.8. As can be seen from table 5.8, reduced prevalence causes annual losses to decrease both for *Salmonella* as for *Campylobacter*. For instance, the *Salmonella* default model estimated current annual losses of €13.77 million, and circa €9.19 million in 2012, a decrease of 33%. The highest decreases of annual losses are in the breeding stage and hatcheries in case of a *Salmonella* crisis in 2012. This is mostly because of the strong decrease (-80% per 3 years). The decreases of annual losses in both affected stages are also relatively high in case of a *Campylobacter* crisis in 2012, with 56.8% and 31.3% in the broiler farm and retail/consumer stage respectively.

Table 5.8 Mean annual losses for default scenario and scenario type 'decrease of prevalence per stage to expected 2012 levels'[1]

Stage	***Salmonella***		***Campylobacter***	
	Default (mln€)	Δ **2012**(mln€)	**Default** (mln€)	Δ **2012** (mln€)
Animal feed	n.p.[2]	n.p.	n.p.	n.p.
Breeding	0.046	- 0.039	n.p.	n.p.
Parent animals	9.73	- 1.84	n.p.	n.p.
Hatcheries	1.02	- 0.86	n.p.	n.p.
Broiler farm	1.76	- 0.99	3.24	- 1.84
Slaughterhouses	1.12	- 0.80	n.l.	n.l.
Retail/consumer	0.095	- 0.048	0.96	- 0.3
Total	**13.77**	**- 4.58**	**4.2**	**- 2.14**

[1] 5000 @Risk iterations.

[2] n.p. = not present, i.e. a *Campylobacter* respectively a *Salmonella* contamination does not occur in this stage; n.l.: (could be) present, but contamination does *not* lead to losses.

3. *Change in financial variables (Campylobacter, Salmonella and dioxin)*

In our model are financial values retrieved from a Dutch livestock database (KWIN, 2008). Financial values can change due to constant or temporary factors.

Constant factors: e.g. price changes of raw materials or price changes of animals, influence size of losses. Feed costs are responsible for 50% of the total costs of the poultry sector. The composition of broiler feed can change, depending on the prices of the different raw materials. Besides the large share of feed in the total costs, the prices of one-day-chickens are important (Cotteleer et al., 2004). According to Bolhuis and Wisman (2008) the gross margin of broiler farms decline in 2008, in spite of higher revenues (+8%). The high price of broiler feed (+27%) and the increasing price of one-day-chickens (+9%) have further raised the production costs.

Besides constant factors, which have a continuous impact on values, also temporary factors can influence values (Cotteleer et al., 2004). Temporary values have impact on the short time, for example in case of food crises. An example of international influence on the prices of chicken meat was the strong rising import of Brazilian salted chicken meat in the European Union. Because of the lower price of this Brazilian chicken meat, the price of Dutch chicken meat sank under market value. On the other hand, in 2001 the BSE-crisis had increased the consumption of chicken meat due to a decreased consumption of beef. Therefore the prices of chicken meat increased in that period.

In 1999 a *Salmonella* contamination occurred, which also had a negative impact on the market value of chicken meat (Cotteleer et al., 2004). Due to this *Salmonella* crisis the producer price of chicken meat decreased from an average value of €0.69 at the end of 1998, till a minimum value of €0.32 in July 1999 (Cotteleer et al., 2004). According to personal communication (2008b), the value (per kg) of broilers decreased by 10% in the stage of broiler farms due to Avian Influenza. In 2007, the average value per kilo was €0.84.

An alternative scenario is carried out to see what the impact is of change in financial values on annual losses. Two situations are described which shows variation in financial values of last years.

a) <u>Constant factors:</u> In the model parameters, the price of feed and the price of one-day chickens are increased with 27% and 9% respectively (Bolhuis and Wisman, 2008). Moreover, in the model parameters, the revenue per broiler is increased with 8% and production costs per broiler are raised with 19% (it is assumed that 10% of the increase of price of feed is related to the production cost per broiler plus de extra increasing costs of one-day-chickens).
b) <u>Temporary factors</u>: In the model parameters, the revenue per broiler (broiler farm stage) is decreased with 30% (an average is taken from Cotteleer et al. (2004) and personal communication (2008b)). Due to a temporary factor, it is assumed that the price of one-day chickens is decreased by 9%. Therefore the production costs are 9% lower and the gross margin per broiler decreases significantly. These changes are adapted in the model parameters.

Table 5.9 shows the differences in € million between the expected values of the described situations and the expected default model results specified by contamination and per stage in the chain. According to these results, temporary factors cause a decrease for all three contaminations in the expected annual losses.

For *Campylobacter,* temporary factors and constant factors cause a decrease with 71% and 34% respectively. This is mostly caused because of the low gross margin. The margin is important for the costs of growth disruption and therefore causes high losses. Constant and temporary factors do not impact the size of annual losses in the retail/consumer stage.

For *Salmonella,* temporary factors cause also a decrease in the annual losses however, constant factors result into an increase of expected annual losses. This is because the increased price of one-day-chickens, which cause higher losses in the stage of hatcheries.

For dioxin, a decrease in expected annual losses is also influenced by temporary factors. Constant factors result into an increase of expected annual losses. This is mostly caused by the facts that the price of feed and one-day-chickens increases, which results in higher annual losses.

Table 5.9 Mean annual losses for default scenario and scenario type 'change in financial values'[1]

	Campylobacter			*Salmonella*			Dioxin		
Stage	**Def.**[2]	Δ Cons. (€mln)	Δ Temp	**Def.**	Δ Cons. (€mln)	Δ Temp	**Def.**	Δ Cons. (€mln)	Δ Temp
Animal feed	n.p.[3]	n.p.	n.p.	n.p.	n.p.	n.p.	0.27	+0.07	0
Breeding	n.p.	n.p.	n.p.	0.046	0	0	0.0035	0	0
Parent an.	n.p.	n.p.	n.p.	9.73	0	0	0.094	0	0
Hatcheries	n.p.	n.p.	n.p.	1.02	+ 0.9	-0.09	0.113	+0.02	-.0007
Broiler farms	3.24	-1.41	-3.00	1.76	-0.77	-1.63	0.79	-0.03	- 0.13
Slaughterh.	n.l.	n.l.	n.l.	1.12	0	0	0.63	0	0
Retail/cons.	0.96	0	0	0.095	0	0	n.l.	n.l.	n.l.
Total	**4.2**	**-1.41**	**-3.00**	**13.77**	**+0.13**	**-1.72**	**1.90**	**+0.06**	**-0.13**

[1] 5000 @Risk iterations for the default scenario, constant factors and temporary factors scenario

[2] Expected results for the default scenario, and the alternative scenario with constant and temporary factors.

[3] n.p. = not present, i.e. a *Campylobacter* respectively a *Salmonella* contamination does not occur in this stage; n.l.: (could be) present, but contamination does *not* lead to losses.

Summary alternative scenarios

To summarize, from expected default results compared with the retrieved results from all alternative scenarios, it seems that:

Food safety hazard perspective

- For *Campylobacter,* lower financial values due to temporary factors leads to highest differences, a decrease expected annual chain losses of 71%. A lower prevalence causes a decrease of expected annual chain losses of 51%.
- For *Salmonella,* expected 2012 prevalence percentages leads to a decrease of expected annual chain losses of 33%.
- For dioxin, a lower probability of occurrence in the animal feed, broiler farm and slaughterhouse stage and a zero probability for the other stages, is expected to decrease annual chain losses by 66%.

Individual stages perspective

- The stages of animal feed companies, breeding farms and parent animals are most sensitive for changes in parameters which refer to reduce probability of a food crisis.
- For the stage of hatcheries, a lower probability and a lower prevalence have impact on decrease of expected annual losses.
- For the stage of broiler farms and slaughterhouses, all three alternative model scenarios have significant impact on the size of annual losses. E.g., in the broiler farm stage, on average, annual losses decrease with 67%, 54% and 45% for alternative model scenario 1, 2 and 3 respectively.
- For the stage of retail/consumers, a lower prevalence has impact on decrease of expected annual losses.

H6. Juridical issues: liability insurance

6.1 Insight into juridical issues

To estimate possible (product) liability claims from the retrieved results of chapter 5, this chapter will first elaborate on liability issues.

Liability is defined as: ‘one is responsible if he/she inflict losses to a person or material which belongs to a third’ (Interpolis, 2005). A principle of the law on liability is that everyone carries his/her own loss. To compensate the suffered losses, the person responsible for the loss has to be identified. Liability law is divided in legal liability and contractual liability.

- The agreement (contractual liability): Two or more parties make a certain agreement with each other. The rights and duties of the parties are registered in the agreement. Each party involved must comply with the obligations of the agreement. The disadvantaged party can address the other party to compensate for their losses. A shortcoming or damage is accountable if these are to blame to the debtor (Interpolis, 2005).
- The law (legal liability): In law, legal liability is a situation in which a person is liable, such as situations concerning damage to a property or reputation (Willems, 2007).

6.1.1 Product liability

The term product liability can be defined as follows: ‘the producer can be held liable for damage which arises as a result of an inferior product’. Risk liability applies for the producer of the (inferior) product. It means that the producer can be held liable for damage, without prove of unlawful or accountable behaviour (NIBESVV, 2000). In other words, the question whether the producer was already familiar with the imperfection of the product or not, is irrelevant (Willems, 2007). A product is inferior or poor, if it does not offer the expected security, condition or quality (Heeres, 2005). In the present study only products with microbial and chemical food safety hazards are considered. The product liability regulation only deals with damage, suffered by consumers (NIBESVV, 2000).

To claim damage through product liability, four requirements have to be satisfied (Heeres, 2005).

- One or more responsible persons and producers.
- The injured person must have suffered from damage.
- A causal connection between the poor product and suffered damage.
- The injured person must prove the suffered damage.

In the literature the following losses that have to do with product liability, are distinguished (Heeres, 2005):

- *Property damage* are losses as a result of damage or destruction or loss of property.
- *Product recall and salvage costs* are losses related to the costs of destruction and recall of products.
- *Pure ability damage* are ability losses which are not property damage and/or personal damage, e.g. business interruption losses.
- *Personal damage* are injuries, immaterial damage (including death losses).

6.2 (Product) liability and insurability in the food production chain

A large number of persons and producers in the food production chain are considered, within the framework of product liability, as a producer (Heeres, 2005). The scope of the liability can be limited and moderated. In many agreements restrictions are incorporated. These restrictions result into other liability rules. Many parties consider the agricultural entrepreneur as the most vulnerable stage in the food production chain. For animal feed producers, the insurable amount ranges from €5 million to €10 million. Insurable losses are property losses (business losses), personal losses, and salvage costs. Non-insurable losses are other capital losses and product recall costs (van Andel, 2008).

According to Buzby and Frenzen (1999) most people who suffer from a foodborne illness never seek legal compensation. Claims may not be filed due to legal costs, time, or other limitations. The wide variety of food consumed by individuals makes it complicate to link a foodborne illness to a specific food product and form. Moreover, most foods cannot be made risk-free. For example, *Campylobacter* is a bacteria naturally found in poultry that may contaminate poultry products despite intensive efforts to prevent, reduce, or eliminate contamination. Therefore, the defendant may not be held liable for the contamination (Buzby et al., 2001).

Van Asseldonk et al. (2006) defined direct and indirect losses at farm level. Direct losses are the value of animals destroyed, welfare control measures and the costs of organisation aspects such as the monitoring of farms in restriction zones. Indirect losses which arise at farm level include business interruption (vacancy), losses related to established restricted zones and additional costs like losses from emergency vaccination and price effects (Van Asseldonk, 2005).

Existing liability insurances in food chain

Different insurers offer specific liability insurance to agricultural companies. The ‘AVAB’ (Dutch: aansprakelijkheidsverzekering agrarische bedrijven) insurance knows three important exclusions: 1) Damage to the products caused by the agricultural entrepreneur himself, which is entrepreneurship risk; and 2) product-recall (Willems, 2007).

Product recall is excluded because an insurer cannot estimate the damage scope of product recall. This systematic risk impedes an insurer to make agreements in advance. The difference between product recall, which is not insurable, and salvage costs, is hardly detectable, i.e. product recall happens when damages didn't occur yet, however, costs are made to prevent any damage (e.g. place a warrant advertisement in papers). Salvage costs are costs for actions taken to prevent immediately threatened danger (e.g. people are already sick, and actions are taken to prevent other damages (Personal communication, 2008d).

6.3 Product liability and insurability within this research

Every participant in each stage of the chain assumes that products supplied by actors of the previous stage are safe. In case of a contamination in the supplied product, the incurred losses could be claimed from the supplier, e.g., at the previous stage in the chain (Van Andel, 2008). The delivered product of inferior quality may be recalled and the costs involved are charged to the actor of the previous stage.

Within broiler production chain, farms/companies work on basis of contracts. Contracts may have restrictions; aspects such as price, requirements of the product (e.g. weight, quality) and time of deliverance are settled in the contract. The size of the claims may also depend on restrictions in the contract.

Consumers can use the regulation of product liability and legal liability. The product (chicken meat) should be safe and without a contamination. If the consumer can prove that he/she suffered a disease from the purchased chicken meat, it is very likely that all estimated COI must be covered by the producer. Via a tracking and tracing system it is possible to trace the origin of the contamination. The responsible actor can be identified. However, as already mentioned, it is hard to prove for consumers that they became ill because of a microbial contamination in the chicken meat.

The annual losses in the production chain are related to property damage and business losses. If the disadvantaged person or farm can prove the causal relation that the supplier is responsible for the delivered inferior products (the eggs, broilers or chickens), the losses can be claimed, including even the costs of destruction and interruption of business processes. If business interruption is a matter of concern and not due to the inferior product, e.g. due to a delivery delay, then these costs are not insured (Personal communication, 2008c).

6.3.1 Claim options for Campylobacter

For *Campylobacter,* expected annual losses fall in the stage of broiler farms and in the consumer/retail stage. *Campylobacter* occurs on-farm in broiler farms and therefore the farms of this stage cannot claim their losses and the success of an indemnification will be negative.

Only the consumer can try to claim his/her illness costs (product liability). As mentioned before, this is often a difficult case because chicken meat cannot be sold *Campylobacter* free and it is hard to prove the causal relation. The success of an indemnification is negative due to several reasons: the consumer has to prove that the *Campylobacter* contamination is due to consumption of chicken meat. Most likely the consumer submits his/her claim weeks after the meat has been consumed, e.g., after occurrence of the contamination. As a consequence, it is often difficult to prove unambiguously that he/she has eaten the contaminated meat (for example through evidence such as a packaging or bill of the meat). Most likely many consumers will not take all this effort to cover their COI.

Because the success of a claim is negative, the broiler farm stage will not receive possible claims from next stages.

Table 6.1 Indemnification options and expected claim per stage *Campylobacter*

Stage	Default (mln €)	Indemnification options per stage[1] (mln €)			Claim per stage (mln €)	
		Claimable[2]	**Success**	**Specification**	**Possible claims**	**From whom**
Broiler farm (bf)	3.24	0	n.a.	▪ contaminated in own farm: own costs	0	n.a.
Retail/ consumer (rc)	0.96	0.96	-	▪ track/trace contaminated chicken meat difficult ▪ difficult to prove causal relation	n.a.	n.a.
Total	**4.2**	**0.96**	**0**			

[1] Somewhere in chain, based on contractual, legal and product liability.

[2] n.a.= not applicable.

6.3.2 Claim options for Salmonella

For *Salmonella*, all property damage and business interruption losses and COI can in principle be claimed, but chances of success are higher in the first stages of the chain (i.e. breeding farms, parent animal farms and hatcheries) than in the later stages of the chain (i.e. broiler farms, slaughterhouses and consumers) due to the fact that in later stages it is hard to prove the causal relation.

For instance, the annual losses are expected to be €1.76 million in the broiler farm stage. These losses relate to growth disruption and downgraded quality of the broilers. This growth disruption is caused by e.g. bowel diseases due to *Salmonella*. For a farmer it is hard to prove that these bowel problems are caused by *Salmonella* (and not by, e.g. antibiotics). If the farmer has proved the cause of bowel problems, it is still hard to prove that this *Salmonella* contamination is due to inferior products of the previous stage or feed producer and not due to contamination on-farm. Therefore, the chance on a successful claim is unknown. In the stage of retail/consumer, the success of a claim is negative due to the same reasons as explained by *Campylobacter.* The success of a claim of the stage of parent animals is unknown because a part of the estimated annual losses are subsidized by Ministry LNV.

Table 6.2 Expected claimable amount and claims of the expected annual losses *Salmonella*

Stage	**Default** (mln €)	**Indemnification options per stage**[1] (mln €)			**Claim per stage** (mln €)	
		Claimable	**Success**	**Specification**	**Possible claims**	**From whom**[3]
Animal feed (a.f.)	n.p.[2]	n.a.	n.a.	n.a.	9.81	br, b.f., p.a., ha
Breeding (br)	0.046	0.046	+	▪ causal relation inferior feed	9.76	b.f., p.a., ha
Parent animals (p.a.)	9.73	6.98[4]	+/-	▪ causal relation inferior feed or hens	2.78	ha, br
Hatcheries (ha)	1.02	1.02	+	▪ causal relation inferior eggs	1.76	br
Broiler farm (b.f.)	1.76	1.76	+/-	▪ difficult to find causal relation growth disruption	0	n.a.
Slaughterhouse (sl)	1.12	0	-	▪ contamination approved ▪ costs logistic slaughtering not insured	0	n.a.
Retail/consumer (rc)	0.095	0.095	-	▪ track/trace contaminated chicken meat difficult ▪ difficult to prove causal relation	n.a.	n.a.
Total	**13.77**	**9.90**	**9.81**			

[1] Somewhere in chain, based on contractual, legal liability and product liability.

[2] n.a.= not applicable; n.p.= not present, a *Salmonella* contamination does not occur in this stage.

[3] Stage can receive a claim from breeding stage (br); parent animal stage (p.a.); hatcheries stage (ha); broiler farm stage (b.f.).

[4] Part of losses is subsidized by Ministry and therefore lower claimable amount.

The stage of animal feed companies won't suffer directly from a *Salmonella* crisis. However, they can expect to receive claims up to €9.81 million. This amount is based on the losses from the later stages, i.e. the breeding farm, parent animal, hatcheries and broiler farm. An animal feed producer supplies feed to all stages and feed can be contaminated with *Salmonella.* Via contractual liability, stages can claim their loss to the previous stage. Through legal liability, stages of the chain can claim directly at the origin of the contamination (i.e. at animal feed companies).

The slaughterhouse stage and broiler farm stage will receive no possible claim due to the facts that their next stages, i.e. the slaughterhouse stage and retail/consumer stage, will not have a successful claim and therefore will not claim to other stages.

6.3.3 Claim options for dioxin

For dioxin, the probability of submitting a successful claim is positive for almost all stages. Claims could be successful due to the fact that the origin of a dioxin contamination is easier to track and trace than in the case of *Campylobacter* and *Salmonella* infections*.* Via contractual liability stages can claim their loss to the previous stage due to inferior product(s). Not all affected stages do have a contract with the supplier where the contamination originates. In that case legal liability might be applied.

Because a dioxin contamination starts always in the stage of animal feed companies and potentially affects all stages, animal feed companies risks to receive the accumulated claims of the whole chain. If the contamination can be traced to a single producer, this company receives claims from actors within different stages of the chain and probably goes bankrupt (same as the case of MPA). As a result, many affected companies will still not receive their money.

Table 6.3 Expected claimable amount and claims of expected annual losses dioxin

Stage	Default (mln €)	Indemnification options per stage[1] (mln €)			Claim per stage (mln €)	
		Claimable	Success	Specification	Possible claims	From whom[3]
Animal feed (a.f.)	0.27	0.27	+/-	▪ causal relation inferior feed ▪ or self originator	1.63	br, b.f., p.a., ha, sl
Breeding (br)	0.0035	0.0035	+	▪ causal relation inferior feed ▪ legal liability to originator contamination	0.094	pa
Parent animals (p.a.)	0.094	0.094	+	▪ causal relation inferior feed and hens ▪ legal liability to originator contamination	0.11	ha
Hatcheries (ha)	0.11	0.11	+	▪ causal relation inferior feed ▪ legal liability to originator contamination	0.79	br
Broiler farm (b.f.)	0.79	0.79	+	▪ causal relation inferior feed and 1-day-chickens (contractual) ▪ legal liability to originator contamination	0.63	sl
Slaughterhouse (sl)	0.63	0.63	+	▪ causal relation inferior feed and broilers (contractual) ▪ legal liability to originator contamination	n.a.[2]	n.a.
Total	**1.90**	**1.90**	**1.90**			

[1] Somewhere in chain, based on contractual, legal liability and product liability.

[2] n.a.= not applicable due to no losses in the next stage.

[3] Stage can receive a claim from breeding stage (br); parent animal stage (p.a.); hatcheries stage (ha); broiler farm stage (b.f.) and slaughterhouse stage (sl).

H7 Conclusions and discussion

7.1 Main Conclusions

This study estimated the expected annual losses due to food safety hazards in the broiler chain. This chapter provides the main conclusions of the study. Subsequently, we will also discuss limitations of this study. Finally, several suggestions for further research will be given.

Objective a) *Review existing risk analyses in 'farm-to-fork' chains. The focus will be on food safety risks in all stages of the broiler chain.*

For the literature review, examples of complete farm-to-fork analyses were hardly available. The risk analyses of the broiler production chain which were found in literature always considered only one or two stages of the chain, but never the chain as a whole.

Campylobacter

- For *Campylobacter,* risk data were only available for the broiler farm, slaughterhouse, and the retail/consumer stage. The prevalence percentages per stage of the chain vary widely (see table 3.1). This variation shows that prevalence percentages for *Campylobacter* infections are rather unpredictable.
- In our default scenario, circa 44% of all broiler farms are infected with *Campylobacter.* From these infected farms, on average 60% of their flocks are contaminated. This is a relatively high percentage. However, from a loss perspective this high prevalence may be regarded as less important. The broilers suffer only slightly, and are allowed to be slaughtered for consumption.

Salmonella

- For *Salmonella,* prevalence percentages in the different chain stages were almost all above 1%, which is above threshold levels allowed by the EU regulation. Prevalence percentages of broiler farms and slaughterhouses are relatively high compared with other stages. Probably, in these stages *Salmonella* multiply themselves very fast.
- In the first stages of the broiler production chain (breeding, parent animal, and the hatcheries stage), hens have to be destructed when a *Salmonella* contamination occurs. Therefore, contamination percentages have a high impact. In the broiler farm and slaughterhouse stage, the broilers do not have to be destructed and therefore, from a loss perspective the prevalence numbers are less important.

Dioxin

- Chain wide risk estimations of dioxin are not yet available. From literature, circa 69 broiler farms are affected, which is 10% of the total number of broiler farms. This is relatively high, because a dioxin contamination is often noticed before the amount of farms is affected due to the track and trace system and quality rules.

<u>Objective b)</u> *Design a quantitative risk analysis model for broiler chains in the Netherlands, which eventually could be used to estimate product liability claims.*

A quantitative risk analysis model was developed with a stochastic model using a Monte Carlo simulation. The model is based on economic and technical variables of the broiler chain which are published every year by Dutch databases of the livestock sector. The prevalence data for *Campylobacter, Salmonella* and dioxin as found in literature were used as inputs into the model.

The model can probably be used for other food production chains, provided that the variables are adapted to the particular chain. The required economic and technical variables are available for all kinds of livestock chains. In the literature, an example of a similar model was never found. To our knowledge, this is the first time that such a model has been developed. Our model gives insight in the relation between stages and how the risks develop themselves in the chain. The model estimates annual chain losses for each stage in the broiler chain caused by the three tested food safety hazards. Because of the increased attention for food safety risks in the food consumption chain and the systematic nature of these risks, this may be of high value for actors in the broiler chain and insurers. Moreover, this model can be used for insurers as input for a risk assessment. To date, the model is only applicable for food safety hazards.

Expected annual losses

Our study indicates that the highest losses are to be expected from *Salmonella* infections. Only in a worst case scenario, a dioxin crisis may cause heavier losses. The annual chain losses are not equally distributed among the broiler chain actors. From the various stages considered, parent animal farms and broiler farms will usually face the highest losses.

Important factors affecting the losses

- For *Campylobacter*, the annual losses are very sensitive for changes in the prevalence percentages. If prevalence increases, the annual losses become higher. The annual losses are further influenced by the degree of growth disruption and changes in financial variables, such as value of animals or turnover of a flock or a company.
- For *Salmonella,* the most important risk factors are financial variables, the prevalence of *Salmonella* and the percentage of growth disruption.
- For dioxin, the annual losses are most strongly affected by the probability of a dioxin crisis, the number of affected companies, and the duration of the contamination.

Alternative model scenarios

The parameters in the model were changed, with a particular focus on the most important factors as mentioned above, to describe and compare three alternative scenarios: 1) not every stage in the chain is affected (dioxin); 2) the prevalence per stage (*Campylobacter and Salmonella*) decreases to expected 2012 levels, and; 3) the financial values (*Campylobacter, Salmonella* and dioxin) are changed.

- The first scenario showed lower annual losses compared to expected default results. If the probabilities of a dioxin crisis decrease in all stages, overall chain losses decrease with €1.18 million per year. If the probability of occurrence for a dioxin crisis decrease for the stages of animal feed companies, broiler farms and slaughterhouses and at the same time, the probability for a crisis in the other stages is set to zero, annual chain losses decrease with €1.25 million, i.e. 66% of the total losses in the default scenario. Apparently, for dioxin losses, the 'other stages' (i.e. breeding farms, parent animal farms and hatcheries) are not important.
- The second scenario estimated annual losses for *Campylobacter* and *Salmonella* in 2012 using prevalence predictions from literature. Both contaminations cause lower annual chain losses, which decrease respectively with -€2.14 million, i.e. 51%, and with -€4.58 million, i.e. 33%, compared to the default results.
- The third scenario worked with a change in financial values for 2 possible situations. A first situation considered a generic increase of price due to, for example, an increase in constant factors such as the price of raw materials or chickens. The second situation considered a sudden drop in prices due to changes in temporary factors, for example food crises like BSE, causing a drop in sales. For *Campylobacter* both situations result in lower annual chain losses compared to the default scenario. From the two tested situations, the one using a change in temporary factors resulted in the biggest reduction (71%) of the losses.

  The tested changes in financial values have similar effects on the estimated losses for *Salmonella* and a dioxin crisis. When constant factors are changed, the losses increase with 1% and 3% respectively. Changes in the temporary factors lead to a decrease of annual chain losses due to respectively 12.5% and 6.8%.

In conclusion, these alternative model scenarios showed that the size of the losses due to a food crisis is largely determined by the probability that such a hazard occurs (prevalence). Prevention measures which could reduce the prevalence risks may significantly reduce the size of the losses. Only for *Campylobacter,* decreases in prices have impact on the size of the annual chain losses.

(Product) liability claims

From the three tested food safety hazards, the probability of submitting a successful claim is highest for a dioxin crisis. For almost all stages indemnifications could be successful due to the fact that the origin of a dioxin contamination is easier to track and trace than in the case of *Campylobacter* and *Salmonella* infections. Via contractual liability stages can claim their loss to the previous stage. Through legal liability stages of the chain can claim directly to the origin of the contamination. Because a dioxin contamination starts always in the stage of animal feed companies and potentially affects all stages, animal feed companies risks to receive the accumulated claims of the whole chain.

For *Campylobacter,* liability claims are expected not to be successful for any of the stages. Farms in the broiler farm stage cannot claim their losses, because contamination occurs on-farm. Claims of consumers are also not expected to be successful due to the fact that it is often difficult to prove: 1) the causal relation; and 2) that the consumer has eaten the contaminated meat (i.e. through evidence such as a packaging or a bill of the meat). Therefore, the risks for claims due to Campylobacter losses are not high, at any of the stages in the broiler chain.

For *Salmonella*, all property damage and business interruption losses and COI can in principle be claimed, but chances of success are higher in the first stages of the chain (i.e. breeding farms, parent animal farms and hatcheries) than in the later stages of the chain (i.e. broiler farms, slaughterhouses and consumers). The main reason for this difference is related to the fact that slaughterhouses and retailers/consumers have not many chances to submit a successful claim and as a result, their claims won't have any impact on other chain stages. The stage of animal feed companies won't suffer directly from a *Salmonella* crisis. However, they can expect to receive claims up to € 9.81 million. This amount is based on the losses from the later stages: the breeding farm, parent animal, hatcheries and broiler farm. An animal feed producer supplies feed to all stages and feed can be contaminated with *Salmonella.* Via contractual liability, stages can claim their loss to the previous stage. Through legal liability, stages of the chain can claim directly at the origin of the contamination (i.e. at animal feed companies).

In the most likely scenario, possible claims can raise to € 14.46 million due to food safety hazards. From this amount, 81% (€11.44 million) is likely to be accounted to animal feed companies.

Table 7.1 gives an overview of the expected results in the most likely scenario per stage and per farm, the expected results of the worst case scenario (95%) and shows the probability of successful claims.

Table 7.1 Overview of expected annual losses (mean per stage, mean per farm, 95% per stage)[1] and probability of successful liability claim

Stage	*Campylobacter*				*Salmonella*				Dioxin			
	Mean per stage (mln €)	Mean per farm[2] (€)	95% per stage (mln €)	Success liability claim[3]	Mean per stage (mln €)	Mean per farm[2] (€)	95% per stage (mln €)	Success liability claim[3]	Mean per stage (mln €)	Mean per farm[2] (€)	95% per stage (mln €)	Success liability claim[3]
Animal feed	n.p.[4]	n.p.	n.p.	n.a.	n.p.	n.a.	n.p.	n.a.	0.27	1,588	1.53	+/- (a.f.)
Breeding	n.p.	n.p.	n.p.	n.a.	0.046	9,200	0.049	+ (a.f.)	0.0035	700	0.018	+ (a.f.)
Parent animals	n.p.	n.p.	n.p.	n.a.	9.73	35,772	10.20	+/- (a.f., br)	0.094	346	0.54	+ (a.f., br)
Hatcheries	n.p.	n.p.	n.p.	n.a.	1.02	53,684	1.02	+ (a.f., br)	0.11	5,789	0.64	+ (a.f., br)
Broiler farm	3.24	4,616	5.76	-	1.76	2,511	3.11	+/- (a.f., ha)	0.79	1,127	4.31	+ (a.f., ha)
Slaughterhouses	n.l.	n.a.	n.l.	n.a.	1.12	56,000	1.12	-	0.63	31,500	3.40	+
Retail/consumer	0.96	262,50	1.40	-	0.095	2,660	0.13	-	n.l.	n.l.	n.l.	n.a.
Total	**4.20**	**-**	**7.16**	**0**	**13.77**	**-**	**15.63**	**9.81**	**1.90**	**-**	**10.45**	**1.63**
Top 3 important risk factors	1. Prevalence *Campylobacter* 2. Financial variables 3. Growth disruption				1. Financial variables 2. Prevalence *Salmonella* 3. Growth disruption				1. Probability dioxin crisis 2. Number of affected companies 3. Contamination duration			

[1] 5000 @Risk iterations.

[2] Expected annual losses per farm, company or consumer in the Netherlands.

[3] The success of a claim; - = relatively low probability of successful claim; +/- = probability of successful claim is unknown; + = relatively high probability of successful claim. Sum across chain stages is based on mean losses and includes + and +/- evaluations. () = to whom stage can claim: animal feed stage (a.f.); breeding stage (br); parent animal stage (p.a.); hatcheries stage (ha); broiler farm stage (b.f.).

[4] n.p.= not present, i.e. a *Campylobacter* respectively a *Salmonella* contamination does not occur in this stage; n.l.: (could be) present, but contamination does *not* lead to losses; n.a.: not applicable.

7.2 Discussion

Like every academic study, this study is not without limitations. The present paragraph gives an overview of these limitations and discusses their effects on the outcome of the study.

1. A first limitation is the fact that hardly any quantitative data are available about risk factors in the whole broiler chain. For instance, risk factors such as cross contamination, or the amount of barns in the farm, could not be quantified and used. Also concrete and specific information on retail sales is missing. As a result, it was impossible to estimate property damage and losses due to business interruption for the retail/consumer stage. In the current study, losses in this stage were based on COI (consumer illness costs), and this is obviously a thin basis for the study.
2. The stages of the retail industry, catering and wholesalers are not taken into account in this study due to a lack of data. If the stages of retail industry, catering and wholesalers would be included in the model, overall annual chain losses would increase.
3. In this study only the broiler production of the Netherlands is taken into account. Financial consequences of import and export of broilers and/or eggs were not considered in the model. Broilers and/or eggs from foreign countries could be more or less expensive than Dutch products, thereby affecting the loss estimations.
4. In this study it is assumed that the duration of a dioxin contamination takes about 3 days for each stage of the broiler chain. However, the total duration of a contamination crisis could be longer than these 3 days. A decrease in price or lower sales of chicken meat can last several months. This limitation would have a negative impact on annual losses.
5. The data of COI due to *Campylobacter* used in this study are not supported by the perception of personal communication (2008e). Personal communication (2008e) claimed that the percentage consumers who are ill of *Campylobacter* due to consumption of chicken meat, is very low, ca 5%, instead of 20% to 40% as is written by scientists. This would mean that consumer illness costs of *Campylobacter* are almost zero. Furthermore, the results of the research done by personal communication, showed that consumers cannot become ill due to *Campylobacter*.

These limitations indicate that the expected default losses either are over or under estimated. Table 7.2 shows these estimations.

Table 7.2 Estimations limitations compared to default losses

Food safety hazard	Lim.	**Over** estimation of default losses	**Under** estimation of default losses
Campylobacter	(1) Less quantified data	X[1]	X
	(2) Retail industry, catering & wholesalers excluded	X	
	(3) Import and export excluded	X	X
	(5) COI prevalence % are much lower	X	
Salmonella	(1) Less quantified data	X	X
	(2) Retail industry, catering &	X	
	(3) Import and export excluded	X	X
Dioxin	(1) Less quantified data	X	X
	(2) Retail industry, catering & wholesalers excluded	X	
	(3) Import and export excluded	X	X
	(4) Duration of contamination longer		X

[1] X = this limitation has over/under estimated default losses

7.3 Suggestions for further research

A suggestion for further research is to collect more data. In this model only prevalence data are taken into account and not risk factors as, e.g. season effect or amount of barns, which influence prevalence percentages. More specific data, give more detailed information about expected annual losses and refine our model.

According to our results of the alternative model scenarios, it seems that our outcomes are very sensitive for a change in parameters in our model. This could mean that these parameters have direct impact on annual losses, not only in the model but also in general. Therefore, another suggestion for further research is to do a risk analysis in another food chain. If the same changed parameters have impact on the outcomes, it could be concluded that these parameters influence in general size of annual losses.

More specific for insurers, a suggestion for further research is to do a cost-efficiency analysis of the room for investment in relation to possible prevention measures.

H8 Recommendations

This study is done at the insurance company NV Interpolis. In this chapter some recommendations are formulated to enable NV Interpolis to use the results of the study.

Broiler chain perspective

The main recommendation to the broiler chain is to invest in prevention measures which can reduce the prevalence of a food crisis. Our study showed that the room for investment varies between €6.7 million in the case of *Campylobacter* and *Salmonella* and €1.2 million in the case of dioxin crises.

- For broiler chains, it is highly recommendable to reduce prevalence of *Salmonella* and *Campylobacter.* Each year 16,000 to 32,000 and 450 people get ill due to consumption of chicken meat from *Campylobacter* and *Salmonella* respectively. Based on our risk analysis the room for investment in, for example, prevention measures, is maximally €6.72 million. Prevention measures on the slaughterhouse and retail/consumers are advised.
- Similarly, further reduction of the probability of a dioxin contamination is also recommendable. To reduce the probability of a dioxin crisis from 3 per 10 year (i.e. 0.3) to a probability of 0.2 (for the animal feed companies) and 0.1 (for the broiler farms and slaughterhouses) and zero (for the other stages), the room for prevention investment is €1.25 million for the chain as a whole.

Liability insurance perspective

Recommendations to liability insurers are twofold. Firstly, they should focus their attention on *Salmonella* and dioxin, as no claims are to be expected in the field of *Campylobacter*. And secondly, they should specify and differentiate the premiums according to the risks incurred at the different stages in the chain and their associated risks and possible claims.

These recommendations can be further specified by the following considerations:

- If insurers base their indemnities on actual losses due to temporary factors, then premiums can be lower. However, most likely claims are based on values before a food crisis and therefore insurers should base their premiums on the expected default losses.
- From the various stages, parent animal farms and broiler farms are expected to face the highest losses. Previous stages could receive a claim. Risk-based underwriting assessment should therefore focus on probability of occurrence (animal feed companies) and probability (prevalence) of occurrence of contamination and financial values (farm level).
- One of the discussion points (see paragraph 7.3, point 4) states that a dioxin crisis has longer impact on turnovers than the applied 3 days. It is recommendable that insurers base their premium on the default losses, but also compensate extra losses of (on average) the next month.

References

Agriholland (n.d). *Dossier Dioxines.* Retrieved May 26, 2008, from http://www.agriholland.nl/dossiers/dioxines/home.html.

Andel, A., van. (2008). *Supply chain damage due to animal feed contamination: scenario analyses for processing industries*. Thesis Business Economics Wageningen, Wageningen University.

Asseldonk, M., van, Meuwissen, M., Huirne, R. (2006). *The production of compound feed in the Netherlands: an analysis of contamination risks.* Wageningen: Institute for Risk Management in Agriculture, Wageningen UR.

Bolhuis, J. and Wisman, A. (2008). *Tweede kwartaal vleeskuikens 2008: saldo fors lager door duur voer.* Den Haag: LEI, Agricultural Economics Research Institute. Retrieved 14 October 2008 from http://www.lei.dlo.nl/content/agri-monitor/pdf/Tweede%20kwartaal%20vleeskuikens %20saldo%20fors%20lager%20door%20duur%20voer.pdf.

Bont, C.J.A.M., de, Knijff, A., van der. (2007). *Actuele ontwikkeling van bedrijfsresultaten en inkomens in 2007*. Den Haag: LEI, report 1.07.04.

Bouwknegt, M., Giessen, A.W., van de, Dam-Deisz, W.D.C., Havelaar, A.H., Nagelkerke, N.J.D., Henken, A.M. (2004). Risk factors for the presence of *Campylobacter* spp. in Dutch broiler flocks. *Preventive Veterinary Medicine,* no. 62, 35–49.

Buzby, J.C., Frenzen, P.D., Rasco, B. (2001). *Product liability and microbial foodborne illness*. Washington: Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report no. 799.

Buzby, J.C., Chandran, R. (2003). The Belgian dioxin crisis and its effects on agricultural production and exports. In J.C. Buzby (eds.), *International Trade and Food Safety: Economic Theory and Case Studies*, *Agricultural Economic Report*, no. 828, 125-139.

Buzby, J.C., and Frenzen, P.D. (1999). Food safety and product liability. *Food Policy,* no. 24, 637-651.

CBS, Statistics Netherlands (2007). *Landbouwtelling-gewassen en dieren totaal*. Retrieved May 23, 2008, from http://statline.cbs.nl/StatWeb/publication/?VW=TandDM=SLNLandPA=71284NEDandD1=414-449,454-460,481-489,509-528,546-557andD2=aandHD=080401-1449andHDR=G1andSTB=T.

CBS, Statistics Netherlands (2008). *Biologische landbouw - Aantallen bedrijven, arealen gewas en veestapel*. Retrieved June 19, 2008, from http://statline.cbs.nl/StatWeb/publication/?DM=SLNLandPA=7332llbandD1=0,11,19,30-35,478-480andD2=aandD3=aandD4=4-9andHDR=TandSTB=G2,G3,G1andVW=T.

Christensen, B., Sommer, H., Rosenquist, H., Nielsen, N. (2001). *Risk assessment on Campylobacter jejuni in chicken products.* Copenhagen, Denmark: Danish Veterinary and Food Administration.

Cotteleer, G., Kornelis, M., Bolhuis, J. (2004). *Prijsprojecties voor de pluimveesector*. Den Haag: LEI, report 8.04.02. Retrieved from http://www.lei.dlo.nl/publicaties/PDF/2004/8_xxx/8_04_02.pdf.

Davies, H., Walters, M. (1998). Do all crises have to become disasters? Risk and risk mitigation. *Disaster Prevention and Management, 7,* no. 5, 396-400.

Doordeyn, Y., Broek, M.J.M., van den, Duynhoven, Y.H.T.P., van. (2007). *Registratie voedselinfecties en-vergiftigingen bij de Inspectie voor de Gezondheidszorg en Voedsel en Waren Autoriteit 2006.* Bilthoven: RIVM, report 300103001/2007.

EAG (n.d). *The following is a collection of unique terms we encounter in our consulting work with clients*. Retrieved July 22, 2008, from: http://www.eagconsultants.com/glossary.html.

EurepGap (n.d). *Standard Documents.* Retrieved July 2, 2008, from http://www.globalgap.org/cms/front_content.php?idart=3andidcat=9andlang=1.

European Community Regulation (EG) nr. 646/2007. *The European Parliament and the council as regards a Community target for the reduction of the prevalence of Salmonella enteritidis and Salmonella typhimurium in broilers and repealing Regulation (EC) No 1091/2005*. Retrieved October 24, 2008 from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:151:0021:0025:EN:PDF

Garlick, A. (2007). *Estimating Risk: a management approach.* Hampshire: Gower Publishing Limited.

General Food Law (2002). *Laws for traceability*. Verorderning EG 178/2002.

GfK, Panel Services Benelux (2005). *GfK C3 Foodservice Monitor*. Dongen: GfK.

Graaf, M., de. (2008). *Risk classification in the compound feed sector*. Thesis Wageningen Business Economics, Wageningen University.

Harrington, S.E., Niehaus, G.R. (1999). *Risk Management and Insurance.* New Delhi: McGraw-Hill.

Hartnett, E., Kelly, L.A., Gettinby, G., Wooldridge, M. (2002). A quantitative risk assessment for *Campylobacter*s in broilers: work in progress. *International Biodeterioration and Biodegredation, 50,* 161-165.

Havelaar, A.H. (2001). *Campylobacteriose in Nederland - Risico's en interventiemogelijkheden*. Bilthoven: RIVM, report 250911001.

Havelaar, A.H., Nauta, M.J., Mangen, J.J., Koeijers, A., de, Bogaardt, M-J., Evers, E.G., Jacobs-Reitsma, W.F., Pelt, W., van, Wagenaar, J.A., Wit, G.A., de, Zee., H., van der,. (2005). *Kosten en baten van Campylobacter bestrijding in Nederland.* Bilthoven: RIVM, report 250911008/2005.

Havelaar, A.H., Bräunig, J., Christiansen, K., Cornu, M., Hald, T., Mangen, M-J. J., Molbak, K., Pielaat, A., Snary, E., Pelt, W., van, Velthuis, A., Wahström, H. (2007). Towards an integrated approach in supporting microbiological food safety decisions. *Zoonöses and Public Health, 54*, no. 3-4*,* 103-117.

Heeres, H. (2005). *Productaansprakelijkheid voor levensmiddelen*. Den Haag: Koninklijke Vermande.

Heuer, O.E., Pedersen, K., Andersen, J.S., Madsen, M. (2001). Prevalence and antimicrobial susceptibility of thermophilic *Campylobacter* in organic and conventional broiler flocks. *Lett. Applied Microbiology*, *33*, 269-274.

Hopstaken, A. (2004). Voedselveiligheid en traceerbaarheid. *Voedingsmiddelentechnologie*, *37*, no. 12, 35.

Horst, M., ter. (2006). Dieren bron van talloze ziektes. *Boerderij weekblad voor de landbouw, 91,* no. 31, 6-8.

Interpolis (2005). *Basisopleiding aansprakelijkheid*. Implementatie en opleidingen. Retrieved in hardcopy from Interpolis N.V.

Interpolis (n.d). *Aansprakelijkheid verandert. Doet u mee?.* Retrieved May 26, 2008, from http://www.interpolis.nl/zakelijk/ondernemer/thema/agro/preventietips/Preventietips/aansprakelijkheid.aspx.

Jacobs-Reitsma, W.F., Becht, C., Verspaandonk, A., Putirulan, F.F., Plas, J., van der, Havekes, M. (2000). *Gecombineerde eindrapportage van de projecten: "Beheersing van Campylobacter in de vleeskuikenhouderij" en "Tracering van Campylobacter door middel van genotypering".* Lelystad: ID-Lelystad, report 294.47027.02.02.

Katsma, E., Koeijer, A., de, Jacobs-Reitsma, W., Wagenaar, J., Fisher, E., Jong, M., de. (2004).*Transmissie model voor risk assessment van Campylobacter prevalentie in vleeskuikens.* Lelystad: Animal Sciences Group, report ASG 04/0001856.

Katsma, W.E.A., Koeijer, A.A., de, Fischer, E.A.J., Jacobs Reitsma, W.F., Wagenaaar, J.A. (2005). *Campylobacter prevalence in broiler flocks in the Netherlands. Modelling transmission within and between flocks and efficacy of interventions.* Lelystad: Animal Sciences Group, report ASG05/I00113.

Kauna, S.L., Santos, L.R., Rodrigues, L.B., Borsoi, A., Moraes, H.L.S., Salle, C.T.P., Nascimento, V.P. (2007). Risk factors and likelihood of *Campylobacter* colonization in broiler flocks. *Brazilian Journal of Poultry Science, 9,* no. 3, 201- 204.

Kramer, G. (2003). *Integrale vergelijking van regulier en biologisch kippenvlees*. Den Haag: Dutch Consumers Association, report PS02007.

Kroon, S.M.A., van der, Gaasbeek, A.F., van, Laarhoven, W.H.M.M., van, Roest, J.W., van der, Schans, J.W., van der. (2002). *Risicobeheersing op bedrijfsniveau - een casus in de varkensvoerketen*. Den Haag: LEI, report 5.02.05.

KWIN, Quantitative Information Livestock 2007-2008 (2007). *Kwantitatieve informatie Veehouderij*. Lelystad: Animal Sciences Group, 333-395.

LEI, Agricultural Economics Research Institute and CBS, Statistics Netherlands (2007). *Land- en tuinbouwcijfers 2007*. Retrieved July 14, 2008, from http://www.lei.dlo.nl/publicaties/PDF/2007/PR_xxx/PR_07_03.pdf.

LNV, Dutch Ministry of Agriculture, Nature and Food Quality (n.d). *Dioxin.* Retrieved May 25, 2008, from: minlnvhttp://www.minlnv.nl/portal/page?_pageid=116,1640572and_dad=portaland_schema=PORTALand p_document_id=110046andp_node_id=946899andp_mode=BROWSE.

LTO Nederland (2007). *Gezond ondernemen - Programma voor voedselveiligheid and aansprakelijkheid*. Retrieved May 23, 2008, from http://www.lto.nl/nl5149395-Publicaties.hmtl --> Gezond ondernemen 'Programma voor voedselveiligheid and aansprakelijkheid'.

Mangen, M.J., Havelaar, A.H., Poppe, K.J. (2005). *Controlling Campylobacter in the chicken meat chain.* The Hague: LEI, Report 6.05.01.

Mangen, M.J., Wit, G.A., de, Havelaar, A.H. (2007). Economic analysis of *Campylobacter* control in the Dutch broiler meat chain. *Agribusiness, 23,* no.2, 173-192.

Meuwissen, M.P.M., and Huirne, R.B.M. (2006). *Aansprakelijkheid in voedselketens; risicoanalyse en risicofinanciering*, Wageningen: Institute for Risk Management in Agriculture, Wageningen UR.

Meuwissen, M.P.M, Andel, A.L.A., van, Asseldonk, M.A.P.M., van, Huirne, R.B.M. (2008a). *Supply chain damage due to animal feed contamination: scenario analyses for processing industries.* Wageningen: Institute for Risk Management in Agriculture, Wageningen UR.

Meuwissen, M.P.M., Asseldonk M.A.P.M., van, Huirne, R.B.M., (2008b). *Liability risks in agri-food supply chains: the case of wet feed.* Paper presented at the EAAE-meetings, Gent, Belgium, August 27-29, 2008.

Nauta, M.J. (1998). *Modellering van de transmissie van Salmonella via pluimveevlees, van bedrijf tot consument: de stand van zaken*. Bilthoven: RIVM, report 257851001.

Nauta, M., Fels-Klerx, I., van der, Havelaar, A. (2005). A poultry-processing model for quantitative microbiological risk assessment. *Risk Analysis, 25,* no.1*,* 85-98.

Nauta, M.J., Jacobs-Reitsma, W.F., Havelaar, A.H. (2007). A risk assessment model for *Campylobacter* in broiler meat. *Risk Analysis,* 27, no.4. 845-861.

Nederlandse Vereniging tot Bescherming van dieren (2003). *Pluimveehouderij in 2030 – Visie van de Dierenbescherming op de toekomst van de pluimveehouderij in Nederland*. Den Haag: Dierenbescherming.

NIBESVV, Nederlands instituut voor het Bank-, verzekering- en effecten bedrijven (2000). *Aansprakelijkheidsrecht.* Retrieved in hard copy from Interpolis NV.

PDV, Product Board Animal Feed (2004). *Resultaten Mengvoeder enquete.* Retrieved June 25, 2008 from http://www.pdv.nl/lmbinaries/mv-enq_2004.pdf.

PDV, Product Board Animal Feed (2006). *Evaluatie aanpak Salmonellabeheersing in de diervoedersector 2006*. The Hague: Product Board Animal Feed. Kwaliteitsreeks nr. 120.

PDV, Product Board Animal Feed (2008). *GMP+ certification-scheme 2006*. Retrieved July 2, 2008 from http://www.pdv.nl/english/kwaliteit/GMP_2006/index.php.

Pelt, W., van, Notermans, D., Mevius, D.J., Vennema, H., Koopmans, M.P.G., Duynhoven, Y.T.H.P., van. (2008). Trends in gastro-enteritis van 1996-2006: Verdere toename van ziekenhuisopnames, maar stabiliserende sterfte. *Infectieziekten bulletin, 19,* no. 1*,* 24-31.

Pouliot, S., Sumber, D.A. (2006). *Traceability, Liability and Incentives for Food Safety and Quality*. University of California: Agricultural Issues Center.

PVE, Boards for Livestock, Meat and Eggs (2002). *Actieplan Salmonella en Campylobacter pluimveevlees 2000+.* Retrieved August 2, 2008, from https://wic5.wur.nl/VERRE004_verre004/My%20Documents/ACTIEPLAN_PLUIMVEESECTOR.pdf.

PVE, Boards for Livestock, Meat and Eggs (2006). *Huishoudelijke aankopen pluimveevlees Nederland. 2006 – 2^e kwartaal*. Retrieved July 2, 2008, from https://bedrijfsnet.pve.agro.nl/pls/pbs/docs/folder/BEDRIJFSNET_US_CA/MARKT/HHA_NL/PLUIM_NL/HHA_PLUIMVEE2006-KW2.PDF.

PVE, Boards for Livestock, Meat and Eggs (2008). *Pluimveevlees en Eieren, Statistisch Jaarrapport - Het jaar 2007 definitief.* Retrieved August 28, 2008, from http://www.pve.nl/wdocs/dbedrijfsnet/up1/ZipmrayHeI_pluimvee_eieren_2007.pdf.

PVE, Product Board for Livestock, Meat and Eggs (n.d. a). *IKB: kwaliteit met een pre*. Retrieved July 2, 2008 from https://bedrijfsnet.pve.agro.nl/pls/pbs/docs/FOLDER/BEDRIJFSNET_US_CA/HOOFDTHEMAS/KWALITEIT_VOEDSELVEILIGHEID/IKB/IKB_KIP/80.1517+IKB+FOLDER+KIP.PDF.

PVE, Product Board for Livestock, Meat and Eggs (n.d. b). *Aanpassingen in de Actieplannen SaCa.* Retrieved July 2, 2008 from https://bedrijfsnet.pve.agro.nl.

Rodenburg, T.B., Hulst-van Arkel, M.C., van der, Kwakkel, R.P. (2004). *Campylobacter* and *Salmonella* infections on organic broiler farms*. Netherlands Journal of Agricultural Science, 52,* no. 2, 101-108.

Roest, J., van der, Bokma-Bakker, M., Bondt, N., Ipema, A.H., Houwers, H.W. (2004). *Toets risicobeoordeling PDV en overzicht bestaande bedrijfseigen borgingssystemen in de diervoedersector*. Wageningen: RIKILT - Instituut voor Voedselveiligheid, report 2004.003.

Safe Feed (n.d.). *Welkom*. Retrieved July 22, 2008, from: http://www.safefeed.nl/desktopdefault.aspx?panelid=1andtabindex=0andtabid=74.

Tacken, G.M.L., Horne, P.L.M., van. (2006). *Handelsstromen van Pluimveevlees.* Den Haag: LEI, report 5.06.03.

Trouw (2000). *Bedrijfsnieuws*. Retrieved July 30, 2008, from: http://archief.trouw.nl/artikel?REC=ed07bee30607b81c3f74fba7aeca2e1ce.

TrusQ (n.d.), *Over TrusQ*. Retrieved July 22, 2008, from: http://www.trusq.nl/pages.php?cID=2.

Vries, J., de. (2002). *Monitoring dioxine-gehalte in eieren afkomstig van biologische bedrijven*. Keuringsdienst van Waren – Oost, report OT0105A.

VWA, Dutch Food and Consumer Product Safety Authority (2007). *Surveillance en monitoring van pathogene bacteriën in voedingsmiddelen van dierlijke oorsprong, jaar 2006.* Den Haag: VWA, report OT06C2.

VWA, Dutch Food and Consumer Product Safety Authority (2008a). *HACCP*. Retrieved Jully 22, 2008 from: http://www.vwa.nl/portal/page?_pageid=119,1640187and_dad=portaland_schema=PORTAL

VWA, Dutch Food and Consumer Product Safety Authority (2008b). *Campylobacter spp*. Retrieved July 29, 2008, from: http://www.vwa.nl/portal/page?_pageid=119,1639827and_dad=portaland_schema=PORTALandp_file_id=29392.

VWA, Dutch Food and Consumer Product Safety Authority (2008c). *Salmonella* spp. Retrieved July 29, 2008, from: http://www.vwa.nl/portal/ page?_pageid=119,1639827and_dad=portaland_schema=PORTALandp_file_id=29430.

Wageningen UR projectteam, Veerkrachtige Pluimveevleesproductie (2004). *Verkenningen voor een veerkrachtige pluimveevleesproductie.* Wageningen – Lelystad: Wageningen UR, report AandF 308.

Website Wikipedia (n.d.a). *ISO 9000.* Retrieved July 2, 2008 from http://en.wikipedia.org/wiki/ISO_9000

Willems, M.J.M.H. (2007). *Productaansprakelijkheid in de agrarische sector.* Den Bosch: Scriptie ter HBO Rechten - Juridische Hogeschool Avans-Fontys.

Yeung, R.M.W., Yee, W.M.S. (2002). Multi-dimensional analysis of consumer-perceived risk in chicken meat. *Nutrition and Food Science, 32,* no. 6, 219-226.

Yeung, R.M.W., Morris, J. (2001). Consumer perception of food risk in chicken meat. *Nutrition and Food Science, 31*, no. 6. 270-278.

Zee, H., van der, Wit, B., Boer, E., de. (2004). *Monitoring Pathogenen in Kip en Kipproducten, Jaar 2004.* Zutphen: KEURINGSDIENST VAN WAREN OOST, report OT 04 H005.

Personal Communication October 2008

a) Marianne Koebrugge, owner parent animal farm, Ambt-Delden.
b) Paul Grefte, owner broiler farm, Hengevelde.
c) Peter de Bont, head of division juridical advice, Interpolis NV, Tilburg.
d) Ernest Olde-Scheper, product specialist AVB / CAR / MSV / RB, Interpolis NV, Tilburg.
e) Rene Welpelo, manager quality and information, Plukon Poultry, Wezep.