Controlling Campylobacter in the chicken meat chain
Estimation of intervention costs

Marie-Josée J. Mangen (LEI/RIVM)
A.H. Havelaar (RIVM)
K.J. Poppe (LEI)

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Campylobacter infections are a serious public health problem in the Netherlands. As a part of the CARMA project, this study focus on the estimation of the potential direct costs related to the implementation of various intervention measures to control campylobacters in the chicken meat chain. Costs were estimated using a second-order stochastic simulation model. Treating only positively tested flocks is far cheaper than treating all flocks. The implementation of equipment to reduce faecal leakage would be the cheapest, while irradiation would be costliness. However, indirect costs for the various interventions, if occurring, would be far higher than the estimated direct costs.

Orders:
Phone: 31.70.3358330
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Information:
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Preface

This report is part of the CARMA (Campylobacter Risk Management and Assessment) project - a collaboration between the National Institute for Public Health and the Environment (RIVM), the Animal Science Group (ASG), the Agricultural Economics Research Institute (LEI), the Inspectorate for Health Protection and Veterinary Public Health (VWA) and the National Institute of Food Safety (RIKILT). The main focus of the project is on two key questions, namely:

- what are the most important routes by which the Dutch population is exposed to Campylobacter, and can the contribution of these routes is quantified?
- which measures/sets of measures can be taken to reduce the exposure to Campylobacter, and what is their expected efficiency and societal support?

For the Netherlands, chicken meat has been demonstrated to be a major route of human Campylobacter infections, but not the only one. It was therefore decided to focus in the first instance on the chicken meat production chain. In addition to a risk assessment, an economic evaluation is needed in order to answer the second key question. Within the CARMA project an economic evaluation of different interventions in the chicken meat chain to reduce human Campylobacter infections is performed in the form of a cost-utility analysis. The costs of the intervention applied in the chicken meat chain (reported on in this document) will be related to a reduced burden of disease and reduced costs of illness. This will result in a cost-utility ratio that should express the relative efficiency of several policy options to reduce the number of Campylobacter infections. More information on the CARMA project can be found at www.rivm.nl/carma.

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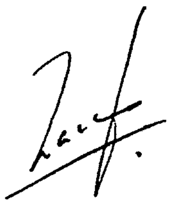

Prof. Dr. L.C. Zachariasse
Director General LEI B.V.

Summary

With an estimated disease burden of 1,200 DALYs (Disability Adjusted Live Years) and an estimated cost-of-illness of nearly €21 million per year, Campylobacter infections are a serious public health and socio-economic problem in the Netherlands. Within the multi-disciplinary CARMA (Campylobacter Risk Management and Assessment) project it was decided to focus on evaluation of interventions in the chicken meat chain, one of the major route. Apart from a farm to fork risk assessment an economic evaluation is necessary in order to advise decision makers which set(s) of measures might be taken to reduce the exposure to Campylobacter and what their costs are in relation to the expected effects. As a part of the CARMA project, this study focused on the estimation of the potential costs related to the implementation of various intervention measures to control campylobacters in the chicken meat chain.

Intervention costs were estimated using a second-order stochastic simulation model, with the year 2000 as baseline. To estimate potential losses of broiler farms when implementing an intervention measures, it was necessary to model a baseline, the estimated average labour income for the whole broiler farm sector, in total €12 million/year. The economic consequences of interventions were then modelled by changing the baseline and comparing the outcome with the baseline outcome. For other interventions, only additional annual costs, recurrent and non-recurrent costs, related to the implementation were considered. Non-recurrent costs (purchase costs and installation and reorganisation costs) are long-lasting investments that were depreciated following standard accounting principles. Under recurrent costs we considered annual maintenance costs, as well as some activity and volume dependent costs that recur with each application. Colonised broilers are not getting ill; consequently a direct benefit for investors was not given. Sensitivity analysis was applied to account for parameter uncertainty.

The lowest treatment costs would be incurred by implementing equipment to reduce the faecal leakage in the processing line, and educational campaign to promote improved kitchen hygiene and home freezing: approximately €1 million per year per intervention. While irradiation would result in the highest treatment costs of all analysed interventions, more than €60 million/year. In general, treating only positively tested flocks is far cheaper than treating all flocks, despite the additional testing costs incurred on the farm and in the processing plants. Losses due to potential price reductions for processing plants because of organoleptic changes, product changes, the non-acceptance by consumers and the additional costs related to scheduled treatment are, if occurring, far higher than the estimated treatment costs for the various interventions.

Samenvatting

Met een geschatte ziektelast van 1.200 DALY's (Disability Adjusted Live Years) en ziektekosten van bijna € 21 miljoen per jaar, zijn Campylobacter-infecties in Nederland een aanzienlijk volksgezondheidprobleem. Binnen het multidisciplinaire CARMA (Campylobacter Risk Management and Assessment) project is onderzoek gedaan naar de evaluatie van interventies in de kuikenvleesketen, een van de belangrijkste bronnen. Behalve van een 'boer tot vork'-risico-evaluatie, is ook een economische evaluatie nodig om na te gaan welke maatregelen genomen zullen moeten worden om de blootstelling aan Campylobacter te reduceren, door de kosten in relatie met het te verwachten effect te vergelijken. Als onderdeel van het CARMA-project richt deze studie zich onder andere op de schatting van potentiële kosten met betrekking tot de implementatie van verschillende interventies ter controle en bestrijding van Campylobacter in de kuikenvleesketen.

Interventiekosten zijn geschat met de hulp van een tweede orde stochastisch simulatiemodel, met het jaar 2000 als basis. Om de potentiële verliezen van vleeskuikenbedrijven te kunnen schatten bij interventies, zoals bijvoorbeeld het stoppen met uitladen, was het noodzakelijk om in eerste instantie de gemiddelde arbeidsopbrengst voor de hele vleeskuikensector te schatten, in totaal € 12 miljoen per jaar. De economische consequenties van deze interventies zijn vervolgens gemodelleerd door het veranderen van de aannames in het basismodel en het vergelijken van de uitkomsten met de basisuitkomsten. Voor alle andere interventies zijn alleen de jaarlijkse additionele kosten, eenmalige en terugkomende kosten voor de verschillende interventies berekend. Eenmalige kosten (aanschaffingskosten, installatie en reorganisatiekosten), zijn langdurende investeringen die volgens standaardboekhoudprincipes afgeschreven zijn. Terugkomende kosten zijn jaarlijkse onderhoudskosten, en de activiteit- en volumegebonden kosten die bij elke interventie ontstaan. Besmette kuikens zijn niet ziek; dientengevolge zijn geen directe baten voor de investeerder te halen. Gevoeligheidsanalyse is uitgevoerd op parameteronzekerheden.

De laagste behandelingskosten worden gerealiseerd bij de implementatie van een verminderde fecale lekkage in de slachtlijnen, verhoogde keukenhygiëne en het thuis invriezen van vers vlees, namelijk ongeveer € 1 miljoen per jaar. Bestraling daarentegen brengt de hoogste jaarlijkse behandelingskosten van alle onderzochte interventies met zich mee, namelijk meer dan € 60 miljoen. In het algemeen is het behandelen van alleen positief geteste koppels verreweg goedkoper dan wanneer alle koppels behandeld worden, ondanks extra kosten voor het testen op de boerderij en in de slachterij. Verliezen door een prijsreductie voor slachterijen vanwege organoleptische veranderingen, productverandering, de niet-acceptatie door de consument en extra kosten met betrekking tot kanalisatie zijn, als deze zouden optreden, veel hoger dan de geschatte behandelingskosten zelf.

1. Introduction

1.1 Background

Foodborne pathogens have been estimated to cause worldwide 70% of the roughly 1.5 billion annual episodes of diarrhoea and 3 million deaths of children under the age of 5 (WHO, 2003).

According to Blaser (1997), Campylobacter is among the most commonly recognised bacterial pathogens isolated from stool cultures of gastroenteritis patients in developed countries. Campylobacter infections and sequelae also pose an important public health problem in the Netherlands. It is estimated that each year approximately 80,000 persons (90% C.I.[1] 30,000-160,000) experience symptoms of acute gastroenteritis, and that 30 of them subsequently die as a result. Some 18,000 patients visit a doctor and 500 are hospitalised each year. Additionally, each year some 1,400 cases of reactive arthritis, 60 cases of Guillain-Barré syndrome and 10 cases of inflammatory bowel disease are associated with a previous Campylobacter infection (Mangen et al., 2004). These authors estimated the associated disease burden (including morbidity and mortality) to be 1,200 Disability Adjusted Life Years (DALYs) (90% C.I. 900-1,600 DALYs) per year, or 850 DALYs (90% C.I. 600-1,300 DALYs) per year when discounting by 4%. The associated costs for Dutch society, using cost estimates for the year 2000, included direct healthcare costs, direct non-healthcare costs and productivity losses from missed work, and were estimated to total €21 million (90% C.I. €11 million - €36 million) per year, or €19.5 million (90% C.I. €10 million - €35 million) per year when discounting by 4% (Mangen et al., 2004).

The most important reservoirs of campylobacters are found among animals (i.e. farm animals, wild animals and pets). Food products and the environment, including the domestic environment, undergo continuous contamination from these reservoirs, creating many pathways by which humans can come into contact with Campylobacter (Havelaar, 2002). Different research methods have been used, both nationally and internationally, to evaluate the relative importance of different exposure pathways. Poultry is often indicated as being an important source of contamination, although it is not the only one. In various case-control studies, 10 to 50% of human campylobacteriosis cases were associated with the ingestion of poultry (Rautelin & Hanninen, 2000). Based on limited Dutch data and the extrapolation of international data, poultry was estimated to be responsible for 40%, at the most, of all human cases of campylobacteriosis (Havelaar, 2002). A recent large-scale case-control study in the Netherlands indicates chicken meat to be responsible for at least 20% of all cases of human Campylobacter infections (Doorduyn et al., 2005). Other identified risk factors are the consumption of pork, beef or raw milk, direct contact with animals, contaminated surface water and foreign travel (Havelaar, 2002).

Infected animals are in general neither sick nor are their growth and reproduction abilities affected, even when excreting large numbers of campylobacters in the faeces (Corry and Atabay, 2001; Evans and Sayers, 2000), as opposed to humans, where a Campylobacter infec-

[1] 90% C.I.: 90% confidence interval for the estimated variable.

tion does result in clinical signs. Only very young animals, e.g. broiler chickens infected before the age of two weeks, do show excess mortality. But according to Corry and Atabay (2001), chicks which are held under normal commercial conditions are seldom colonised before two weeks of age. Consequently, for poultry farmers the eradication of Campylobacter would not result in a reduction of their production costs.

However, by producing and selling Campylobacter infected broilers and broiler meat, poultry farmers and the processing plants are indirectly responsible for broiler-related human Campylobacter infections and sequelae, and the associated costs-of-illness and disease burden, which in economic terms might be described as a negative production externality.

Infections of poultry and poultry products with Campylobacter are not visible, neither for the farmers and the processing plants, nor for the consumers. Only by testing are Campylobacters detectable and information of the Campylobacter status of poultry meat accessible. Processing plants would be in the position of penalising/remunerating broiler farmers for Campylobacter free broilers and differentiate their products from others by testing and signalling the results to farmers and consumers. However, a complicating factor in the Campylobacter problems is that, despite huge research efforts made in the last 10 years, only little is known on the pathways of infection of broilers and other poultry with Campylobacter. The precise source of infection of a poultry flock is seldom identified, except for unchlorinated water (Corry and Atabay, 2001). Furthermore, no control measures to reduce or to avoid Campylobacter infections in poultry are known. Despite asymmetric information on farmers' hygiene behaviour, imposing penalties for *positively* tested flocks might be questionable.

Properly applied hygiene practices in processing plants or in the consumer's kitchen when preparing the meal, respectively, could avoid cross-contamination, and consequently reduce human infections. Therefore, hidden information about the behaviour of the other players in the chain is a common effect and applies to all the players, from the farmers to the consumers.

Apart from Campylobacter infected poultry meat not being visible to the consumers, most consumers know nothing about this pathogen. Most Campylobacter infections in humans are sporadic. Consequently, media attention - a potential source of consumer information - is scarce or non-existent. Therefore processing plants that would like to differentiate their products by signalling the consumers that their products are Campylobacter-free would need first to invest substantially in information campaigns, before being able to sell off their differentiated products as an added-value product. But it is questionable if consumers are willing to pay for such products. Consumers in general assume that what they buy is safe. There are two examples where such added-value products, e.g. Salmonella-free broiler meat in the Netherlands and Campylobacter-free broiler meat in Denmark, have failed. Neither the Dutch consumers, nor the Danish consumers were willing to pay higher prices for the added-value products. But without the explicit questions from the market for Campylobacter-free products, the market will fail to solve this problem. Farmers and processing plants in general have no financial interest in changing their current production methods.

Given that food-borne pathogens, including Campylobacter, have a large impact on the total society in the form of disease burden, potential productivity losses and direct medical and non-medical costs, there is a rationale for government intervention as a guard of food safety, but this is a challenging task.

1.2 Motivation for and objectives of the study

The effective prevention of human campylobacteriosis requires a well-balanced set of measures. To establish such, in 2001 the CARMA (CAmpylobacter Risk Management and Assessment) project was started in the Netherlands. The goal of the project is to advise on the effectiveness and efficiency of measures aimed at reducing campylobacteriosis in the Dutch population. In the first phase, all available information was collected and summarised in an extensive risk profile (for more details, see Havelaar, 2002). This information is used to assess the relative contribution of different sources of contamination to the incidence of human Campylobacter infections. A risk model has been built for a major route of infection, namely the consumption of chicken meat. For making policy on reducing and controlling Campylobacter in the chicken meat chain[1], the national governments policymakers (risk managers) need certain knowledge and information. These risk managers want to know whether policy measures will have the desired results, whether and, if so, what unwanted side-effects of policy will occur, and whether the results will match the expectations of the target groups, such as chicken meat farmers, processing plants and consumers.

As a part of the CARMA project, this study focused on the economic evaluation of potential intervention measures that might be introduced in the chicken production chain to control Campylobacter. The main objectives were to estimate the costs of intervention measures that might be introduced at the farm level, in the processing plants and/or in the kitchen of the consumer to reduce Campylobacter infections associated with the consumption of chicken meat.

1.3 Outline of the report

A description of the model and the assumptions made are described in detail in the following sections. Section 2 explains the theoretical framework used. Section 3 focuses in more detail on the potential intervention measures at the farm level. Potential intervention measures in the processing plants are described in more detail in section 4. Potential intervention measures at the consumer level are described in section 5. The overall results are summarised and discussed in section 6.

[1] The term 'chicken meat chain' embraces all stakeholders in the chain, i.e. from the broiler farm level to the consumer and including the government, if it is taking action to control Campylobacter in this chain.

2. Methodology

2.1 Intervention measures to reduce Campylobacter in the chicken meat chain

According to Skirrow (1991), prevention measures could be applied at the farm level by preventing infection in broiler flocks, and at processing plants by reducing cross-contamination during the mass processing of broilers, as well as by a terminal disinfection of dressed birds. The packaging of poultry meat and poultry products could protect these foodstuffs from undesirable factors, and might also be used as a means of providing the consumer with information (Hafez, 1999). Finally, prevention measures at home to increase the kitchen hygiene of individuals (Anderson et al., 2003) might result in a less exposure of consumers to Campylobacter from fresh chicken meat.

The following sections present for each level within the chicken meat chain separately, the different intervention measures modelled. Model details, the assumptions made and specific details of the data sources used in order to estimate the intervention costs are also given.

2.2 Baseline

The year 2000 was used as the baseline in this economic evaluation. This is because in 2000 neither a food crisis nor any highly contagious animal disease epidemics - such as classical swine fever (CSF), foot-and-mouth disease (FMD) or highly pathogen avian influenza (AI) - affected the Netherlands directly or indirectly. And although England (CSF), Germany (CSF), Greece (FMD) and Italy (CSF, AI) - all EU member countries - had some problems with contagious animal diseases (OIE, 2004), their impact on the Dutch chicken meat sector was negligible, whereas the BSE crisis in 1996, the Belgian dioxin crisis in 1999, the Dutch CSF epidemic in 1997-8 and the FMD epidemic in 2001 in the Netherlands resulted in a temporary market disruption of at least one animal species with some spillover effects on other meat sectors. For example, the BSE crisis in 1996 resulted in a temporary switch from beef to other meat, for example poultry (Mangen and Burrell, 2001).

In order to monitor for Campylobacter, twice a year Dutch broiler farms submit faeces samples (five per broiler house), which are then pooled to form one test sample (PVE, 2002a). But apart from monitoring, good animal husbandry practice and good manufacturing practice, the agreement between the poultry industry in the Netherlands and the Dutch government does not foresee any other special measures to tackle the Campylobacter problem. This was the case in 2000 and is still the case today. In this study, we therefore assumed that every potential intervention measure implemented will result in additional costs for the chicken meat chain.

2.3 Estimating the costs

The objective of this study was to estimate the costs of potential intervention measures applied at different levels within the chicken meat chain. These levels are: the chicken producers, including all levels from the pedigree (elite) flocks to the commercial broiler chick flock; the transport industry; the slaughter and processing industry; the wholesalers and retailers; and the consumer.

In most cases, the affected level is also the primary affected stakeholder, who has to pay the additional industry costs triggered by the intervention measure taken. In the case of the consumer, however, public funds or chicken meat chain funds might have to be established to pay for, for instance, educational measures to teach the final consumer safer food handling.

Given our priorities, we therefore estimated the costs that are related to the various intervention measures under study. A list of the costs that might arise for the chicken meat chain by the application of the intervention measures under study are summarised in table 2.1. The details of the different intervention measures under study are discussed in more detail in sections 3, 4 and 5.

In order to estimate the potential losses of broiler farms when implementing an intervention measure such as the discontinuation of thinning flocks, it was necessary to model a baseline (see section 3.3.1 for details). The economic consequences of intervention measures were then modelled by changing the baseline and comparing the outcome with the baseline outcome.

Some of these intervention measures might require only a single but expensive investment, for example capital investments in a slaughterhouse. Capital investments are by definition long-lasting assets, which involve high financial costs. These costs remain unchanged in total for a given time period despite possible changes in the related level of total activity or volume (Horngren et al., 2000). Once a long-lasting asset is purchased or constructed, it is often difficult or costly to change, alter or reverse a capital investment decision (Kay and Edwards, 1994). These investment costs will be depreciated according to standard accounting principles. For other intervention measures, costs recur with each application (e.g. soap and disinfection materials when cleaning and disinfecting a broiler house before repopulating with the following flock). These latter costs change mostly in relation to the total applied volume or activity (Horngren et al., 2000). Consequently, not all costs will occur at the same time, and benefits might be realised at different moments in the future. In order to be able to compare the different intervention measures under study, we calculated the net present value for each of them and then compared the average annual costs and benefits of the different intervention measures. Present values were calculated by discounting a future value back to the present, in order to find the current or present value (Kay and Edwards, 1994). In the study, a discounting rate of 4% was used, in line with the Dutch recommendation for public sector investment (Oostenbrink et al., 2000). However, for sensitivity analysis, we also estimated the costs using a 2 and a 6% discounting rate, respectively.

For all preventive interventions to be modelled in the CARMA study, the costs of the intervention in the chicken meat chain to control Campylobacter are related to the reduced burden of disease and the reduced cost of illness. This results in a cost-utility ratio (CUR), expressing the relative efficiency of several policy options to reduce the number of Campylobacter infections. These results will be reported separately in Mangen et al. (2005).

Table 2.1 Costs included in the economic evaluation of intervention measures to reduce Campylobacter in the chicken meat chain

Cost category	Affected
Industry cost a)	
Direct costs related to animal production b)	Reduced number of cycles per year (additional time to disinfect broiler house between two flocks)
	Reduced number of chicken birds per cycle
Direct costs related to control costs for pathogens at all links in the food chain b)	Altered and new farm practices (testing, biosecurity measures, disinfection / sterilisation, phage therapy, etc.)
	New slaughterhouse procedures (logistic slaughtering, decontamination, etc.)
	New processing procedures (pathogen test, logistic processing, decontamination, product development, altered shelf-life of products, etc.)
Indirect costs c)	Losses due to e.g. lower selling prices because of e.g. product changes and non-acceptance by consumers;
	Losses of market shares
Direct costs related to outbreaks d)	
Regulatory and public costs for controlling Campylobacter e)	
	Information campaigns

a) A more complete list of industry costs can be found in Buzby et al. (1996). This table includes only costs that are appropriated for the intervention measures under study; b) Apart from direct costs related to intervention measures to reduce Campylobacter in the chicken meat chain, there might also be indirect benefits, such as better control of other foodborne pathogens, better management systems and control of whole production process, etc. However, these latter benefits are hard to quantify and are therefore in first instance not considered in the CARMA project; c) Indirect costs due to potential lower selling prices are only roughly estimated in the current study; Indirect costs due to losses of market shares are not considered in the CARMA project; d) According to Buzby et al. (1996) 'direct costs related to an outbreak' are also a part of the societal costs of foodborne illness. However, most human Campylobacter infections that are related to chicken meat, are sporadic cases. Therefore, we did not consider them in our economic evaluation; e) According to Buzby et al. (1996), regulatory and public health chain costs comprise another cost category of the societal costs of foodborne illness. However, some of these costs fall in the category of 'public health' costs and are therefore considered in the cost-of-illness study (section 2), whereas the other public costs are more closely related to the chain itself and might have to be even financed by the chain itself. In this list, we consider only the latter one. A more complete list on regulatory and public health chain costs can be found in Buzby et al. (1996).

2.4 Underlying assumptions

In our analysis, we made the assumption that both the Dutch chicken supply and the Dutch demand for Dutch chicken meat will be equal to those in 2000, our base year. This is an oversimplification and it assumes that none of the intervention measures under study would affect the Dutch supply of chicken meat or the Dutch domestic consumer demand for chicken meat.

In reality, however, the chicken meat production chain is strongly vertically integrated and there is high competition between countries in this sector (Bondt and Van Horne, 2002). Most of the intervention measures under study, however, would involve additional costs without a direct benefit for the investor. In order to survive, Dutch chicken meat producers and Dutch processing plants specialised in chicken meat might be forced to pass their additional production costs on to the final consumer. A higher product price for Dutch chicken meat, however, might have different effects on the consumer demand and as such on the long-term supply of Dutch chicken and chicken meat. Furthermore, consumers might also switch, for health and/or monetary reasons, to non-Dutch chicken meat or to other meat and fish (e.g. beef, pork, sheep, veal) due to the higher Dutch chicken meat prices, in which case the non-Dutch chicken meat production chain might benefit, as might stakeholders in other Dutch and non-Dutch meat markets (e.g. pig and cattle farmers). In this analysis, however, these effects are not quantified.

2.5 Modelling approach

2.5.1 General

The following is only a summary of the general modelling approach. The annual total costs (*TC*) for intervention *m* comprise the estimated annuity (*A*) of the non-recurrent costs (*NRC*) for intervention *m* and the recurrent costs (*RC*) of intervention *m*. Thus, the formula in basic notation for the total costs of intervention *m* is:

$$TC_m = A_m + RC_m$$

The non-recurrent costs (*NRC*) are mostly long-lasting investments. These investment costs will be depreciated following standard accounting principles. We included under non-recurrent costs the purchase costs (*PC*) for the required technology for intervention measure *m,* as well as the installation and reorganisation costs (*IC*). In some cases, costs for additional building facilities might be required, although in this study this latter category of non-recurrent costs was not required. Thus, the formula in basic notation for the non-recurrent costs for intervention *m* is:

$$NRC_m = PC_m + IC_m$$

In our case, most long-lasting investment would have a lifetime of at least eight years. For fiscal technical reasons, it might be attractive (and in fact appears to be the current practice) to depreciate such investment over a shorter period than the actual lifetime of the equipment. But in this study we considered the actual lifetime in years (*n*) to depreciate the non-recurrent costs (purchase costs and installation costs) when calculating the annuity (*A*). In this study, the lifetime *n* of technical equipment is assumed to be eight years. A shorter and a longer lifetime period of six and ten years, respectively, were analysed in the sensitivity analysis. The assumed interest rate *i* is 4%. But for the sensitivity analysis, 2 and 6% was used. The formula used in basic notation for the annuity of intervention *m* is:

$$A_m = NRC_m \times \left[\frac{i \times (1+i)^n}{(1+i)^n - 1} \right]$$

The recurrent costs (*RC*) change mostly in relation to the total applied volume or activity (Horngren et al., 2000). This category of costs comprises the annual maintenance costs plus some activity and volume dependent costs that recur with each application. Activity related costs are, for example, the costs of an additional tank filling each working day. Volume related costs are, for example, the costs of the additional water use per chicken slaughtered. In basic notation, the formula for recurrent costs for intervention *m* is:

$$RC_m = M_m + \sum_j \left[\sum_o \sum_k (CA_o) + \sum_p \sum_l (CV_p) \right]$$

Where:	Annual maintenance costs for equipment *m*	M_m;
	Working days per year *j*	for j = 1 to n
	Cost for activity *o*	CA_o; for o = 1 to n activities
	Activity units used per day *k*	for k = 1 to n activities units used/day
	Costs for volume *p*	CV_p; for p = 1 to n volume
	Volume units used/day *l*	for l = 1 to n volume units used/day

Given that intervention *m* is applied on all broiler farms and at all processing plants, respectively. The total costs for the sector (farm level or processing plants) for intervention *m* is equal to the sum of the total costs for intervention *m* applied on all broiler farms and at all processing plants. In basic notation, the formula for the total sector costs (SC) for intervention *m* is:

$$SC_m = \sum_v TC_m$$

for v = 1 to n number of broiler farms and number of processing plants, respectively.

2.5.2 Variability and uncertainty

The model used to estimate the intervention costs in the chicken meat chain in order to reduce campylobacters was built in Excel, using the add-in software program @Risk version 3.5.2 (Palisade Corporation, Newfield, NJ, USA). It is a second-order stochastic model. Given that real-life data are often limited and/or absent, every model builder has to deal with some degree of uncertainty and methodological controversy (Drummond et al., 1997). Total uncertainty is broken down into variability and uncertainty (Vose, 2000). Variability is defined as 'the inherent heterogeneity of a system', for example variations in the number of days needed to raise broilers to a certain weight. Uncertainty is usually defined as 'a lack of perfect knowledge about a factor in the model that represents the system' (Vose, 2000). Variability cannot be reduced. However, with the availability of more information on a system, the uncertainty might be reduced. For example, the farm-to-gate price for broilers is not known but is estimated from observational data from previous years. The uncertainty in the farm-to-gate price for broilers can be represented by a statistical distribution. The mean or median of this distribution represents our best estimate of the farm-to-gate price for broilers, whereas the range between for example the 5th and 95th percentile represents our variability about the farm-to-gate price for broilers over the years. Any value that is sampled from this distribution represents one possible value of the farm-to-gate price for broilers, and can be used as an input for a simulation of the variability of the farm-to-gate price for broilers over the years (for more details on second-order stochastic modelling, see Havelaar et al., 2003).

According to Vose (1997), sensitivity analysis might be applied for the 'scenario uncertainty' (e.g. descriptive errors, aggregation errors, etc.) and/or model uncertainty (e.g. uncertainty due to necessary simplification of real-world processes, miss-specification of the model structure, etc.). By performing sensitivity analysis, we aimed to identify those parameters that are of most influence on the obtained results and conclusions, and also be able to quantify the extent of their influence. In our study, we paid special attention to the parameters for which a possible change in parameter values might result in a different conclusion.

As many necessary data are lacking, uncertainty analysis was an important aspect of the work, and for some interventions only sensitivity analysis were possible.

2.5.3 Presentation of results

A useful way to represent the output data of a second-order stochastic simulation model is by a cumulative distribution plot. But given that the variability is less important from a decision-making point of view, we chose to present only the uncertainty in the mean cost in the results in our summary tables.

3. Intervention measures at the farm level

3.1 Background information

Most researchers found no evidence for a vertical transmission[1] of Campylobacter (Corry and Atabay, 2001). Horizontal transmission seems to be the most important route of infection (Anderson et al., 2003; Corry and Atabay, 2001; Evans and Sayers, 2000; Kist, 2002). We therefore analysed only intervention measures that might tackle horizontal transmission.

The main source of infection is unknown. Possible risk factors for a Campylobacter infection that are given in the literature are feed, water, staff and visitors, equipment, litter, wild birds, rodents, insects (e.g. house flies and litter beetles) and cross-contamination from the environment via farm operatives (Anderson et al., 2003; Corry and Atabay, 2001; Kist, 2002; Refregier-Petton et al., 2001; Pattison, 2001; Shane, 2000).

Other risk factors for the presence of Campylobacter are the presence of other farm animals on the farm, and the number of broiler houses on the farm (Bouwknegt et al., 2004; Refregier-Petton et al., 2001). Furthermore, the practice of harvesting part of the flock early ('thinning'[2]) has also been identified by various authors as a risk factor (Corry and Atabay, 2001; Hald et al., 2001; Jacobs-Reitsma et al., 2001; Kist, 2002; Pattison, 2001; Shane, 2000). According to some of these authors, the increased risk is related to the movement of personnel and equipment between broiler farms, and to the entry of catching crews to thin the flocks. However, Bouma et al. (2003) could not identify partial depopulation as a risk factor in their study, but explained the observed effects as solely a function of the increased age of the birds.

According to Corry and Atabay (2001), the main methods of control are biosecurity measures for workers and visitors, and the control of wild birds, rodents and flies. In most studies, biosecurity measures - in particular hygiene regulations requiring workers and visitors to disinfect or change their footwear (and other protective clothing) and to wash their hands when entering the growing house - are identified as the most important measures (Corry and Atabay, 2001). However, Refregier-Petton et al. (2001) found no significance for factors dealing with hygienic practices or biosecurity measures (boot-dip). These authors noted that biosecurity installations (e.g. changing room in two separated parts, change of clothes and presence of boot-dip) were not strictly used as they should be by the farmers during the rearing period. 'This explains why environmental contamination could be the main source of chicken contamination by Campylobacter' (Refregier-Petton et al., 2001). Bouwknegt et al. (2004) found, except for the use of broiler-specific clothes, no statistical association with Campylobacter presence and hygiene measures such as boot-dip disinfection, disinfection after depopulation and the presence of an anteroom. A large proportion of the surveyed Dutch broiler farms had already implemented 'optimal' hygiene, providing such facilities as anterooms, specific clothing, etc. However, no data were obtained on the stringency of the

[1] Vertical transmission occurs when a parent conveys an infection to its unborn offspring. Transmission occurring generally within a population, - but not including vertical transmission -, is called horizontal transmission.
[2] A house is 'thinned' once or twice, whereby a proportion of the birds are taken for slaughter before the remainders. The remainders are kept for heavier weights and form a separate slaughter group.

application of these measures. Also, boot-dip facilities were either not present or were refreshed infrequently on a majority of the farms.

Another prevention measure to reduce the load of Campylobacter on chicken meat might be the use of a phage therapy (Wagenaar et al., 2001). 'Generally, it was felt that even the most stringent biosecurity measures applied conscientiously would not be able to prevent infection occurring' (Pattison, 2001). And once infection has entered the broiler house, the infection spreads rapidly: 10-14 days after infection, more than 90% of the birds in a flock are infected (Katsma et al., 2004).

3.2 Selected interventions

By mutual agreement of the Steering Committee of the CARMA project - which includes risk managers at the Ministry of Public Health and the Ministry of Agriculture - and after discussion with the Industry Forum[1] and experts in the field, the following intervention measures concerning primary production were selected for evaluation:

- thinning: discontinuation of thinning flocks;[2]
- mono-species farms (i.e. absence of other farm animals);
- further improvement of hygiene at the farm: additional hygiene measures to reduce transmission between stables and between successive flocks[3]. In order to stop the transmission between successive flocks in the same house by increased cleaning and disinfection, the protocol developed to reduce Salmonella Java will be followed:
    - increased cleaning and disinfection is applied in each broiler house on *every* farm;
    - increased cleaning and disinfection is applied in broiler houses from positively tested flocks only;
- phage therapy:
    - all broilers are always treated.
    - only broilers from positively tested flocks are treated.

[1] The Industry Forum is composed of representatives of Dutch chicken farmers, Dutch slaughterhouses and processing plants, the Food and Consumer Safety Authority, the two Ministries (Public Health and Agriculture), as well as the research institutes involved.

[2] Based on microbiological evidence thinning is defined by different authors as a source of Campylobacter introduction in broiler flocks. But by using an analytical model, Katsma and colleagues (2005) demonstrated that the introduction of Campylobacter at thinning in a previous 'Camplobacter-free' flock would result only in a low within-herd prevalence with only few birds being infected. According to these authors the time between thinning and the slaughtering of the remaining birds is too short for infecting all birds within the remaining flock. For more details see Katsma et al. (2005). We calculated the costs for discontinuation of thinning in this study, but according to Katsma et al. (2005) the expected effect is negligible.

[3] We could not find any specific hygiene measures in the literature to tackle the Campylobacter problem. We used the Bolder approach as an example for 'potential' costs, not knowing if this approach would help or not to control Campylobacter infections in poultry. Please see also the discussion in section 3.3.4.

3.3 Interventions under study and assumptions made

3.3.1 Baseline

In order to estimate the potential losses of broiler farms when implementing an intervention measure such as the discontinuation of thinning flocks, it was necessary to first model a baseline. The baseline model is a stochastic simulation model build in Excel using @Risk. We used this model to simulate technical economic results for all Dutch broiler farms in 2000.

According to Statistics Netherlands (CBS, 2004a), in 2000 there were 1094 broiler farms with an average of approximately 58,200 birds per farm[1]. Based on CBS statistics (CBS, 2004b) and on the data collected by Bouwknegt et al. (2004), the average number of broiler houses per farm was estimated to be 2.23. About 39% of broiler farms have 1 broiler house, 28% have 2 broiler houses, 16% have 3, 9% have 4, 3% have 5, 2% have 6 and 3% have 7 or more. For simplification reason, this distribution was assumed to be the same for all production classes[2]. With an average number of 23.09[3] chicks per m^2, the average surface of a broiler house is estimated to be 1,130 m^2.

We distinguished four production classes, namely thinning, light broilers, mid-sized broilers and heavy broilers. The distinction for the different production classes was based on whether or not the flocks are thinned, and if not thinned then the distinction was made on the delivery weight at slaughter. Depending on the live weight at slaughter, broilers are classified as light broilers (< 1.7 kg), mid-sized broilers (1.7-2 kg) or heavy broilers (> 2 kg). Of the flocks that are thinned out, on average 22%[4] of the birds (first slaughter group) are delivered as light broilers. The remaining birds of a thinned flock (second slaughter group) are, at an average weight of 2.17 kg (S.D. 0.14 kg), mainly heavy broilers. The accounting data of 46 broiler farms (a total of 283 flocks[5]) were collected in the Dutch 'Informatienet'[6] data set of 1999/00. According to the Dutch FADN data set, only 47% of the flocks were thinned in 1999/00. But given the larger data set (i.e. 986 flocks analysed by the Marktgroep Pluimvee-

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[1] According to the CBS (2004), on 1 April 2000 the total number of broilers was 50,936,625 birds on 1094 farms. This is equal to an average of 46,560 broilers/farm. However, the CBS asked for the number of birds present on 1 April 2004, therefore a correction was necessary here. Approximately 20% of all broiler houses were assumed to be empty on the day of counting, resulting in approximately 58,200 birds.

[2] There is a tendency that a higher percentage of larger farms do thin their flocks than smaller farms, but this difference was not significant when analysing Dutch farm accountancy data network (FADN) from 1999/00 (for more details on FADN see footnote 6).

[3] Estimated based on FADN data from the year 1999/00 (for more details on FADN see footnote 6).

[4] Estimated based on FADN data from the year 1999/00 (for more details on FADN see footnote 6).

[5] A total of 278 records on broiler flocks could be used for the analysis. Some records had to be excluded either due to irregularities in the recorded data (e.g. probably a mistake in the recorded data), or due to exceptional farm practices (e.g. delivering chicks at a life age of 14 days to slaughterhouse).

[6] Various types of data from a random sample of Dutch agricultural and horticultural holdings are stored in 'het Informatienet', the Dutch farm accountancy data network (FADN). For a detailed description of the Dutch FADN, see Poppe (2004). 'Het Informatienet' is the Dutch partner within the European FADN (Farm Accountancy Data Network) and is collected by LEI (Agricultural Economic Institute). The European FADN was set up in 1965 as an instrument for evaluating the income of the agricultural holdings and the impact of the Common Agricultural Policy. For more information about the European FADN, see http://europa.eu.int/comm/agriculture/rica/index_en.cfm.

houderij (2001)[1] in 2000) and the findings of Horne (1999) and Jacobs-Reitsma et al. (2001), we assumed in our baseline that in the Netherlands 60% of the flocks are thinned. Based on the FADN data from 1999/00, we further assumed that broiler farms that do not thin their flocks produce 13% light broilers, 49% mid-sized broilers and 39% heavy broilers.

Using the FADN data from 1999/00, the distribution of the age when the last broilers are slaughtered, the time between two flocks, the number of day-old chicks per m^2, the mortality rate, the weight of broilers when slaughtered, the feed conversion, the heating costs, other direct accountable variable costs, indirect variable costs and the fixed costs were estimated for farms producing light broilers, mid-sized broilers, heavy broilers and thinning broilers, respectively (see Appendix 1 for the details). For some of these parameters (e.g. mortality rate and time between two flocks), a distinction between the different groups was not made, because no significant difference was found between the means of the different groups when testing in SPSS. The estimated distribution for farm-to-gate price, the feed price and the day-old chick price was based on monthly LEI data from 1993 until 2003. The estimated distributions are summarised in appendix 1. The price for day-old chicks is not correlated with the feed price or with the farm-to-gate price. However, the feed price and the farm-to-gate price are highly correlated.

The variability of the different parameters, which might vary between farms, between years and within one year, was built into our model by the different distributions shown in appendix 1, and was simulated using a Monte Carlo simulation model. The assumed farm-to-gate price and the feed price (over 50% of all costs are feed costs) largely influence the estimated gross margin, and as such also the labour income of broiler farms. Farm-to-gate price and feed price, however, fluctuate greatly from year to year, rather than within one year. For example, a year with high farm-to-gate price results in high labour incomes for all broiler farms, whereas a year with low farm-to-gate prices mostly results in low or even negative labour incomes for all farmers. Given the large impact of the average yearly farm-to-gate price and the average yearly feed price on the annual labour income of broiler farms, and given that the limited impact of the single farmer on those two parameters, we split the variability into two variability components. The yearly farm-to-gate price and the yearly feed price - which are highly correlated (r=0.8) and affect all farms in that year - are modelled as one variability component. The second variability component is the variability of all other parameters, which might vary between farms and within a year.

The farm-to-gate price given in the statistics is often only for one live weight category, mainly the one that is considered to be the most representative. Broilers of different live weights are often produced for different markets, for example light broilers are mostly sold for roasting chickens, whereas heavy broilers are mainly for the fillet market. Farm-to-gate prices for the different live weight categories vary slightly. The only data that are available here are the annual average farm-to-gate prices of light, mid-sized, heavy and thinning broiler flocks as estimated by the DLV advice group for the years 1998-2002[2]. Setting the farm-to-

[1] Based on the annual results of the 'Technisch Economische Administratie vleeskuikens' of the DLV Adviesgroep in Deventer for the year 2000. Economic data of 986 flocks for the year 2000 were considered in the DLV (De Landbouw Voorlichtingsdienst) data set. Personal communication of Bijl (Wildering and Bijl). Bijl used to work for DLV Team Marktgroep Pluimveehouderij until the group was liquidated in 2003.

[2] Information received from A. Bijl (Wildering and Bijl, previously DLV Marktgroep Pluimveehouderij) for the years 1998-2002 from the corresponding annual technical economic DLV reports (see also footnote 1).

gate price for live broilers at 100, we defined the relative price indices for the other live weight categories (see appendix 1).

In addition to modelling the total labour income of all Dutch broiler farmers, we also estimated the number of light, mid-sized and heavy broilers produced per year. The simulated production of Dutch broilers is, at 420 million birds and 840 million kg live weight (average weight 2 kg), similar to the Dutch production of 838 million kg live weight in 2000 (PVE, 2002b).

Based on literature studies, Corry and Atabay (2001) and Evans and Sayers (2000) concluded that infection of poultry is not generally associated with clinical illness, even when large numbers of campylobacters are excreted in the faeces. Only broiler chickens that are infected naturally before the age of two weeks showed excess mortality (Neill et al., 1984). But according to Corry and Atabay (2001), chicks which are held under normal commercial conditions are seldom colonised before two weeks of age. But if infected chicks are not getting ill, a benefit resulting from, for example, lower mortality or better feed conversion by avoiding infection cannot be realised. Consequently, broiler farmers will have only costs when implementing intervention measures, and no economic benefit.

3.3.2 No thinning

Based on microbiological evidence, the practice of thinning was identified by different authors as a risk factor. Katsma et al. (2005), however, have shown, using an analytical model, that in most cases the time between thinning and slaughtering of the remaining birds would be too short to reach high prevalence levels of Campylobacter within the flock when infected at the moment of thinning. An potential intervention measure would be to forbid this practice, although the effectiveness of such an intervention is questionable. The economic consequences were modelled, using the farm model described in section 3.3.1, assuming that the number of farms that are thinning is equal to zero. However, in order to cover the different markets, we had to redefine the distribution of farms between the different live weight categories (production classes). Using the estimated average numbers of light, mid-sized and heavy broilers from the baseline scenario, the newly defined percentage of farmers producing light, mid-sized and heavy broilers was estimated to be 15.5, 24.3 and 60.2%, respectively. Everything else remained constant.

3.3.3 Mono-species farms

According to various authors, broiler flocks that are held on a farm with other farm animals have a significantly higher risk of contamination by Campylobacter than those held on specialist broiler farms. Given the significance of this risk factor, it was decided to analyse the effectiveness of having only mono-species farms (i.e. no other farm animals on the farm).

According to Statistics Netherlands, in 2000 only 543 (49.6%) of the 1,094 Dutch farms with broilers were actually considered to be specialists broiler farms. Seventy-three (6.7%) Dutch broiler farms earned a second income from agriculture or horticulture. For the remainder (43.7%) of Dutch broiler farms (multi-species farms), other farm animals such as other poultry, cattle and/or pigs mostly constitute a second income source (CBS, 2004).

In order to obtain only mono-species broiler farms, multi-species farms would have to stop holding other farm animals. However, that would mean losing a part of their income, as well as reducing their production portfolio with as a consequence an increased income risk. Multi-species farms often have deliberately chosen a diversification in their production portfolio in order to minimise their income risk due to price and production risks. However, by losing their diversification benefits ex-multi-species farmers would in return benefit from economies of scale. We therefore assumed that multi-species farmers will be willing to stop with one of their multiple animal species only if they have the possibility to enlarge their production of one of the different animal species held on their farm. When enlarging the production of an animal species there are two main factors to consider in the Netherlands. First of all there is the investment required for new buildings (e.g. stables, broiler houses) and secondly the purchase of production quotas. Both are capital-intensive investments. The limiting factors for the extension of dairy, poultry and pig production in the Netherlands are production quotas[1] for dairy cattle milk quota and manure quotas for poultry and pig production.

We therefore assumed that multi-species broiler farms would exchange their production quotas, and thus avoid purchase costs. For example, one farmer would stop raising pigs and enlarge his broiler production, while another would stop raising broilers and enlarge his pig production. The consequence would be that there would be fewer but more specialised broiler farms with on average more broiler houses per farm. However, the number of broiler houses has been identified as another important risk factor for Campylobacter infection (Bouwknegt et al., 2004; Refregier-Petton et al., 2001).

The first step in the CARMA project, therefore, was to analyse the effectiveness of this intervention measure.[2] Only if the intervention measure of mono-species broiler farms turned out to be effective - taking into account the increased risk due to an increased number of broiler houses per farm - would we then estimate the costs for this intervention measure, especially because, apart from the willingness to exchange production quotas, the necessary investments are enormous and hard to quantify.

Based on data from Statistics Netherlands (CBS, 2004) and on the data collected by Bouwknegt et al. (2004), the average number of broiler houses on a multi-species farms only was estimated to be 1.59 before the intervention, and 3.55 after the intervention. The total number of broiler farms would decrease to 811.[3] Based on this assumption, Katsema et al. (2005) estimated the effect, using a statistical transmission model.[4] According to these authors, the positive effect of having only mono-species farms is cancelled out by the increased number of broiler houses on the remaining farms. Consequently, no costs were estimated for this intervention scenario.

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[1] Milk quotas were introduced in the EU in the 1980s in order to guarantee farmers a reasonable milk price and to limit milk production. The poultry and pig manure quotas (a typical Dutch intervention) were introduced to prevent environmental pollution. Especially in the Netherlands, poultry and pig producers often do not have sufficient land to use the manure produced by their animals in a good agriculture practice on their own land. The main idea behind these manure quotas is to promote the trade in manure. This should result in a responsible distribution of manure over the whole Netherlands, thereby preventing environmental pollution.

[2] This work was done by the Animal Science Group in Lelystad, mainly by Elly Katsma and Aline de Koeijer, in close cooperation with Wilma Jacobs-Reitsma. Details can be found in Katsma et al. (2005).

[3] A detailed description is available on request from the first author.

[4] More details on the risk modelling can be found in Katsma et al. (2005).

3.3.4 Further improvement of hygiene at farm

With the help of a farm risk assessment model Katsma et al. (2005) have shown that theoretically additional or improved hygiene measures might be very effective in reducing the number of human Campylobacter infections. A complicating factor is that *no single* specific measure is known to be able to control Campylobacter infections of broiler flocks effectively, despite all research efforts that were made during the last years. Reducing the infection or transmission of broiler flocks might be possible by the application of additional or improved hygiene measures, - whatever measures those might be. However, it is hard to say something about costs if it is not known which measures ought to be applied.

In the last years much focus was put on the reduction of Salmonella and Campylobacter prevalence in broiler flocks. Then the main focus was put on bio-security measures on broiler farms during the presence of broilers on the farm. Consequently, most farms now apply at least a certain level of bio-security measures. This is in line with the observation of Bouwknegt et al. (2004), who observed that on the surveyed Dutch broiler farms hygiene provisions were mostly already implemented. However, the authors had collected no information on the stringency of the application of these measures. Nevertheless, these biosecurity measures worked for Salmonella, as the decreasing prevalence of Salmonella in broiler flocks has shown over the last years. But these measures did not affect the Campylobacter prevalence. The prevalence of *positively* tested Campylobacter flocks has hardly decreased since the introduction of the action plan against Salmonella and Campylobacter. Therefore, putting focus on further bio-security measures, of which we did not know whether they would work, seemed questionable to us. Furthermore, according to Katsma et al. (2005) the reduction of Campylobacter transmission from the previous flock to the successive flock might be the most effective measure. Reducing the infection of the successive flock by the previous flock might be possible by applying additional or improved hygiene measures, whatever measures these might be.

Although the prevalence of Salmonella decreased, there are some broiler farms left that still have problems eradicating Salmonella Java from their farms and consequently from their successive flocks. The Bolder approach[1] for eradicating Salmonella Java turned out to be the only approach that seemed to work on these farms.

In the absence of any information on potential hygiene measures and in order to get an idea about 'potential' costs for additional hygiene measures on broiler farms, we decided at the beginning of this project - at the beginning of 2003 - to use the Bolder approach, hoping this approach might also work against Campylobacter, and not only against Salmonella Java.[2]

The Bolder approach focuses mainly on the cleaning and disinfection of broiler houses between two successive flocks. Farmers are not forced to apply all the measures described in the Bolder approach, but might use only one or two. Furthermore, not every measure described in the approach is suitable to control Campylobacter. There are mainly three possible

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[1] Nico Bolder (ASG) has defined a set of intervention measures to eliminate Salmonella java on positively tested farms. A description of the different measures, including a possible cost estimate for each measure individually, is given in Bolder (2003). In the field this set of measures is known as the Bolder approach.

[2] Based on first results from the field, we now know (January/February 2005) that the Bolder approach is probably not the right solution. But, in the absence of any other potential measures, we will not restart doing new calculations.

measures that might help to control Campylobacter, namely additional cleaning and disinfection by a specialist; sealing cracks and holes (every third flock rotation) and disinfecting them (every time); and applying both measures (i.e. the additional cleaning and disinfecting by a specialist, and the sealing and disinfecting of cracks and holes).

The costs per measure and the chosen measures are uncertain factors. According to Bolder (2003), the additional cleaning and disinfection per broiler house costs between €1,000 and €3,000. The material costs for sealing of cracks and holes costs between €1,000 and €1,500 per broiler house, but renewing the sealing is necessary only after every third flock.[1] The disinfection of cracks and holes, which would be applied every time, costs approximately €0.005/chick. We have therefore performed some sensitivity analysis.

The additional cleaning and disinfection would be applied by a specialist. However, the sealing of cracks and holes, as well as the disinfecting of cracks and holes would be applied by the farmer. In order to seal all cracks and holes in a broiler house, a minimum of 4 and a maximum of 12 (though most likely 8) hours per broiler houses are assumed to be needed to perform this task. For disinfecting the cracks and the holes, a minimum of 2 and a maximum of 6 (though most likely 4) hours per broiler house would be required.[2] The required time differs from farm to farm, and probably from broiler house to broiler house. We therefore simulated the required time as being variable, using a pert distribution. Given that broiler farmers are independent entrepreneurs, the additional working time required to seal and disinfect cracks and holes in the broiler houses implies less leisure time. Opportunity costs of €18 per hour were considered, assuming the 'salary' that farmers might make when working in an alternative enterprise. There are two alternative scenarios: either each broiler house is always treated, or the flocks are tested[3] and only the broiler houses of positively tested flocks are treated.

3.3.5 Phage therapy

Another prevention measure might be the use of a phage therapy. Here too there are two alternative scenarios: either birds of each broiler house are always treated, or the flocks are tested[4] and only birds from positively tested flocks are treated. The phage therapy would be given two days before slaughtering in order to reduce the Campylobacter load in the faeces. To avoid resistance, only the last slaughter group of thinned flocks would receive a phage therapy treatment. In flocks not thinned out, every bird would receive a phage therapy treatment.

No phage therapy for Campylobacter is yet on the market. According to Wagenaar,[5] the costs for phage therapy should be comparable to an antibiotic cure that is given via water. The potential costs of an antibiotic cure vary between €0.0027 and €0.036 per treated chick, with the most likely value €0.02 per treated chick[6]. We therefore performed some sensitivity analysis when estimating the costs.

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[1] According to J. Obdam (Plukon), personal communication; September 2004.
[2] After discussion with Wilma Jacobs-Reitsma (ASG) and Nico Bolder (ASG).
[3] For details about testing, see section 3.3.6.
[4] For details about testing, see section 3.3.6.
[5] Jaap Wagenaar (ASG), personal communication; July 2004.
[6] Based on information from Twan van Gerwe (University of Utrecht), personal communication; July 2004 and from G.J. Bouwhuis (secr. Nederlandse pluimveedierenartsen), personal communication; July 2004.

3.3.6 Testing

Testing is applied shortly before slaughtering in order to identify Campylobacter infected flocks. If testing is applied, only positively tested flocks would undergo a treatment to reduce Campylobacter infection in chicken meat.

Three different tests were analysed: a dipstick test, a PCR test and the currently applied culture test. The most likely sensitivity and specificity of the different tests, as assumed for this study, are summarised in table 3.1. Assuming 2 days in order to organise logistic slaughtering and scheduled treatment, the dipstick test, the PCR test and the culture test for transport and testing is applied 3, 5 and 7 days before slaughtering, respectively, depending on the time required by the laboratory. Dipstick tests are assumed to be applied by the farmers themselves, and results are obtained within a few hours. PCR and culture tests are applied in laboratories, taking less than 1 day and a minimum of 2 days, respectively.

Table 3.1 The most likely value of sensitivity and specificity for the used dipstick test, PCR test and culture test, respectively, and the estimated fraction of positively tested flocks

Test	Sensitivity	Specificity	Fraction of positively tested flocks a)
Dipstick	80	95	0.291
PCR	95	100	0.286
Culture	75	90	0.282

a) As estimated by Katsma and Koeijer (2005).

We assume that five samples are taken per broiler house flock, which are then pooled to form one test sample. The costs for the dipstick test, PCR test and culture test are assumed to be €10 to €30 per pooled sample tested[1]. Sensitivity analysis was applied here. A dipstick test is applied by the farmer himself, therefore only testing costs were calculated. However, if a PCR test or a culture test is used, additional costs per submission would be €22 for the courier[2] and €7.80 for administration tasks.

When modelling the costs, we had to consider the fact that farms with more broiler houses have a higher risk of becoming infected than do farms with only one broiler house. Using the statistical transmission model (see footnote 19 on page 2), the estimated prevalence is: 0.188; 0.367; 0.472; 0.544; 0.596; 0.635 and 0.664 for 1, 2, 3, 4, 5, 6 and ≥7 broiler houses, respectively[3].

[1] Based on the tariff list of the Gezondheidsdienst voor dieren (Animal health service) and after discussion with Jaap Wagenaar (ASG) and Wilma Jacobs-Reitsma (ASG).
[2] Tomas Miedema (Miedema), personal communication; October 2004.
[3] Aline de Koeijer (ASG), personal communication; October 2004.

3.4 Results

3.4.1 All flocks

The cumulative distribution of the estimated annual labour income for Dutch broiler farmers in the baseline scenario is shown in figure 3.1. Note the variability within years has less effect on the total variability than does the variability between years. The mean and the attendant yearly variability for the average Dutch broiler farms and for all Dutch broiler farms, respectively, is summarised for the baseline scenario in table 3.2. The estimated mean represents the labour income in an average price year for an average broiler farmer and for all Dutch broiler farmers, respectively. The simulated 5th percentile represents the labour income in case of a low farm-to-gate price year, and the simulated 95th percentile represents the labour income in case of a high farm-to-gate price year.

Table 3.2 Estimated mean and attendant yearly variability of the average annual labour income/farm, the total labour income for all Dutch broiler farms and the percentage of farms with a positive labour income, respectively, for the baseline scenario

	Estimated annual labour income			
	Mean	5% a)	50%	95% b)
Labour income (in €)/average farm/year	10,500	-31,300	13,600	46,700
Labour income (in €m) for all Dutch farms/year	11.5	-34.3	14.9	51.1
% of farms with positive labour income	61	10	70	96

a) The 5th percentile represents a year with low farm-to-gate prices; b) The 95th percentile represents a year with high farm-to-gate prices.

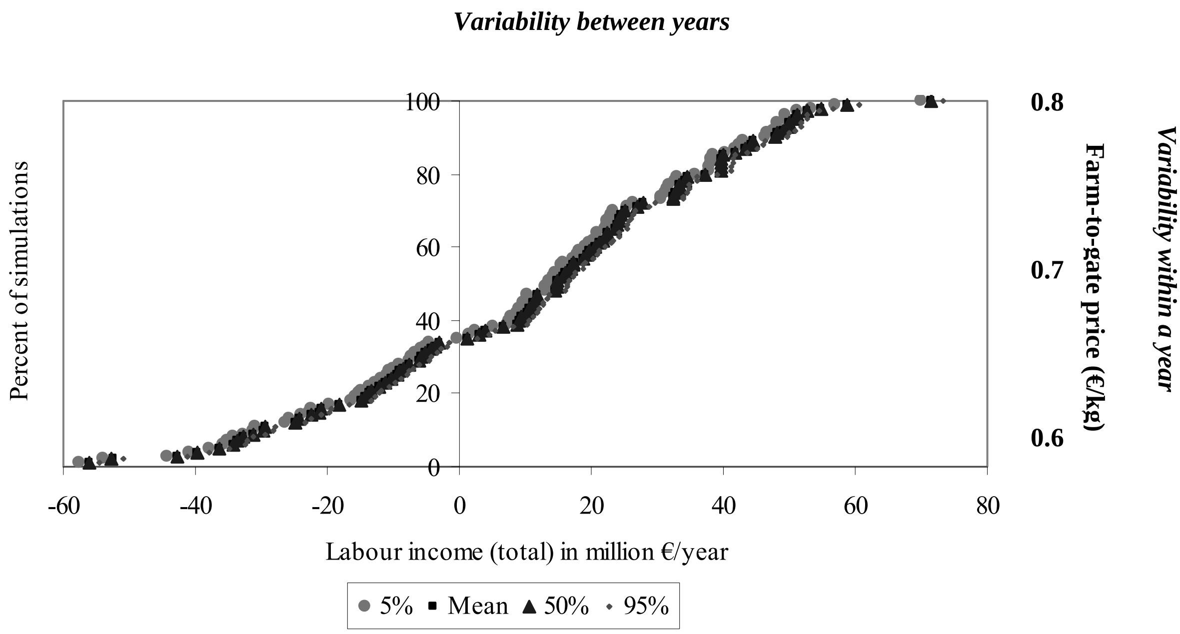

Figure 3.1 Cumulative distribution of the mean, 5th, 50th and 95th percentile of the estimated annual labour income (in € million per year) of all Dutch broiler farmers, breaking down the total variability into variability within a year, holding farm-to-gate price and feed price fixed, and variability between years, assuming different yearly farm-to-gate prices and feed prices

The estimated mean and the attendant yearly variability for the average Dutch broiler farms and for all Dutch broiler farms, respectively, for the alternative scenario whereby thinning is forbidden is summarised in table 3.3. As in the baseline scenario, the estimated mean represents the estimated labour income in an average price year for an average broiler farmer and for all Dutch broiler farmers, respectively. The simulated 5th percentile represents the labour income in the case of a low farm-to-gate price year, and the simulated 95th percentile represents the labour income in case of a high farm-to-gate price year. The reduced annual labour income is on average €800 per farm and €0.9 million for the whole sector. But apart from the reduced labour income, the number of broilers produced per year is also slightly decreased (by 8 million) from 420 to 412 million broilers/year.

Table 3.3 *Estimated mean and attendant yearly variability of the average annual labour income/farm, the total labour income for all Dutch broiler farms and the percentage of farms with a positive labour income, respectively, for the alternative scenario whereby thinning is forbidden*

	Estimated annual labour income			
	Mean	5% a)	50%	95% b)
Labour income (in €)/average farm per year	9,700	-31,100	12,800	45,100
Labour income (in €m) for all Dutch farms per year	10.6	-34.0	14.0	49.4
% of farms with positive labour income	61	9	69	96

Campylobacter infected chicks are not getting ill, consequently broiler farms incur costs when implementing intervention measures, and no economic benefits.

Table 3.4 *Average additional annual cost estimates (in €m) if applying hygiene on the farm and phage therapy, respectively, to all flocks and positively tested flocks only, respectively*

	Estimated average additional annual costs (in €m)	
	All flocks	Positively tested flocks b)
Hygiene on the farm		
Add. disinfection by specialist (minimum cost estimate)	17	5
Add. disinfection by specialist (maximum cost estimate)	50	15
Seal & disinfect cracks and holes (min. cost estimate)	8 a)	2 a)
Seal & disinfect cracks and holes (max. cost estimate)	13 a)	4 a)
Both measures (minimum cost estimate)	24 a)	7 a)
Both measures (maximum cost estimate)	63 a)	19 a)
Phage therapy		
Assuming €0.0025/chick (minimum cost estimate)	1	0.3
Assuming €0.02/chick (most likely cost estimate)	7	2
Assuming €0.035 /chick (maximum cost estimate)	13	4

a) The sealing of the holes and cracks as well as the disinfection of the holes and cracks in broiler houses is assumed to be applied by the farmers themselves. In total more than 92,500 hours are on average necessary to perform this task, which were included as a monetary costs (opportunity costs) in our cost estimate. The average opportunity costs for additional required working hours would be €1.7 million when applied to all flocks, and €0.6 million when applied to positively tested flocks
b) Not including the testing costs (see table 3.5).

Intervention measures such as additional cleaning and disinfection (further improvement of hygiene on farm) and the application of a phage therapy therefore lead only to additional costs, and in the case of hygiene on the farm also to an increasing unpaid working load for farmers. Given that no or only vague information was available concerning the potential costs for additional hygiene on the farm and for phage therapy, respectively, some what-if scenarios were performed. The minimum and maximum additional costs for these different what-if scenarios are summarised in table 3.4. The results of all the different what-if scenarios are shown in figure 3.2 for the phage therapy, and in figure 3.3 for additional cleaning and disinfection.

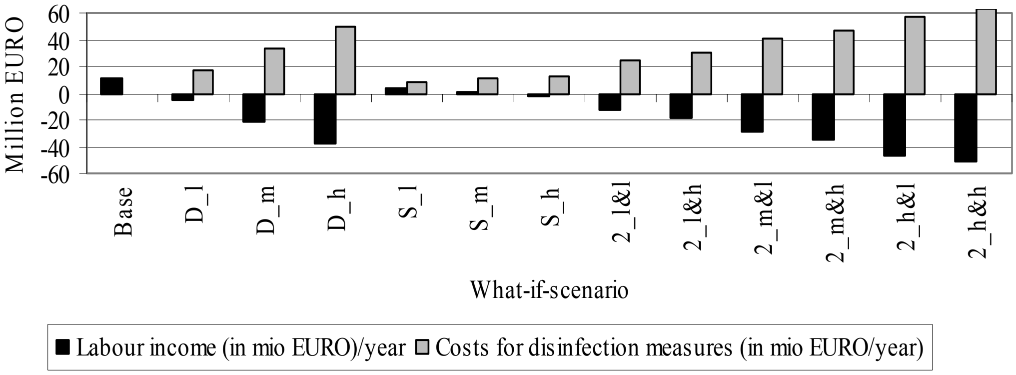

Figure 3.2 *The average annual labour income (in €m) and additional annual costs (in €m) for on-farm hygiene measures at all broiler farms, depending on the assumed measures applied. (D = cleaning and disinfecting broiler house by a specialist; S = seal and disinfect cracks and holes; 2 = both measures are applied), whereby assuming a low cost estimate (l), a medium estimate (m) and a high cost estimate (h), respectively.*

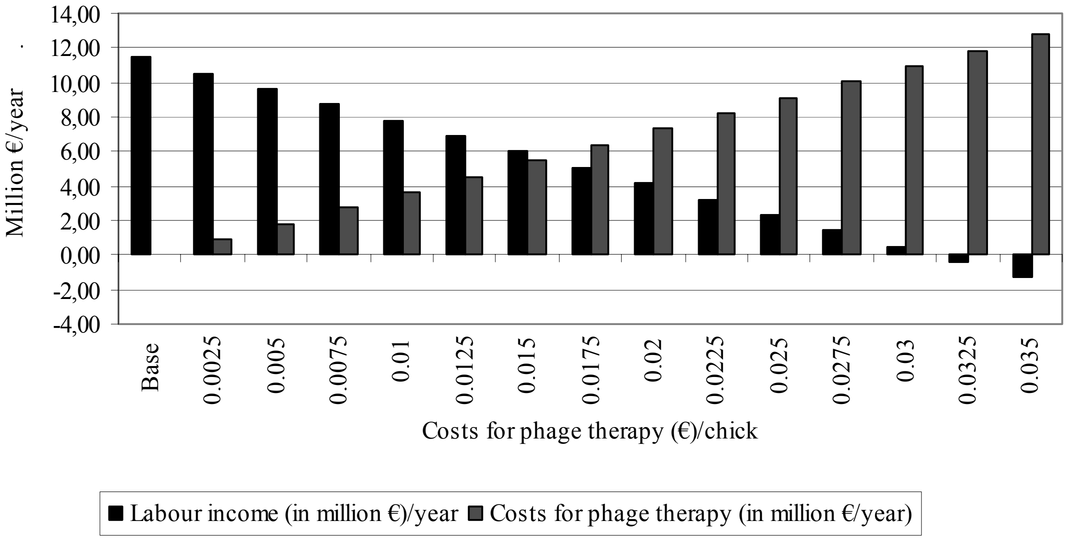

Figure 3.3 *The average annual labour income (in €m) and the additional costs (in €m) for application of the phage therapy in all flocks, depending on the assumed costs per treated chick*

3.4.2 Testing and treating only positive flocks

The estimated average annual costs for testing using a dipstick test, a PCR test and a culture test, respectively, are summarised in table 3.5. They vary between €0.3 million and €1 million for a dipstick test, and between €0.7 million and €1.4 million for a PCR and culture test, depending on the assumed costs per tested sample.

Table 3.5 Average annual cost estimate for testing (in €m), using a dipstick test, PCR test and culture test, respectively, depending on costs (in €) per tested sample

	Estimated average annual testing costs (in €m)
Dipstick test	
Assuming €10/tested sample	0.3
Assuming €15/tested sample	0.5
Assuming €20/tested sample	0.6
Assuming €25/tested sample	0.8
Assuming €30/tested sample	0.9
PCR / culture test	
Assuming €10/tested sample	0.7
Assuming €15/tested sample	0.9
Assuming €20/tested sample	1.0
Assuming €25/tested sample	1.2
Assuming €30/tested sample	1.4

By first testing and then treating only positively tested flocks, the additional costs for on-farm hygiene measures and for phage therapy, respectively, are only approximately 30% of the estimated costs for testing all flocks (see table 3.3.). But annual testing costs of between €0.3 million and €1 million for the dipstick tests, and of between €0.7 million and €1.4 million for the PCR/culture tests need to be added to the annual intervention costs given in table 3.3.

3.4.3 The different interventions at farm-level in short

For the various interventions at farm-level, we have summarised in figure 3.4, the mean and the attendant uncertainty of the estimated intervention costs in € million per year, including

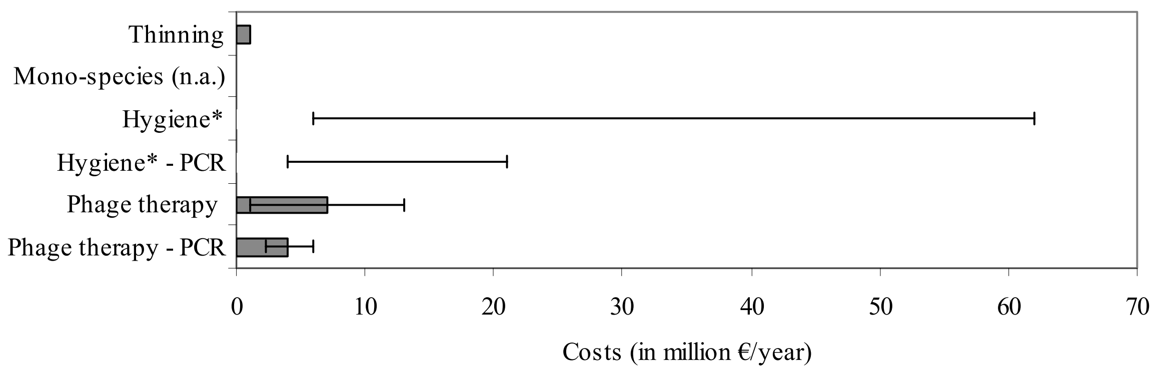

Figure 3.4 The average costs (in €m) for the different interventions at farm-level, and the uncertainty, assuming treating all carcasses and carcasses of positively tested flocks (PCR) only, respectively. Given the uncertainty of additional costs related to further improvement of hygiene at farm, only the minimum and the maximum cost estimates are shown

testing costs, if applied. For testing costs, we assumed the application of a PCR test on farm-level, in total €1 million per year. Further, we assumed for control the application of a culture test at slaughterhouse (see section 4.3.9 and table 4.3), in total €1 million per year.

3.5 Discussion

3.5.1 The baseline

Although the year 2000 was defined as the base year, we used an average farm-to-gate price and an average feed price based on the years 1993-2003. Farm-to-gate prices and feed prices fluctuate considerably over the years, see figure 3.5. By choosing only the prices from one year, income might be strongly overestimated or underestimated, depending on the year chosen. We therefore opted to use a 10-year average farm-to-gate price and feed price, rather than the 2000 prices.

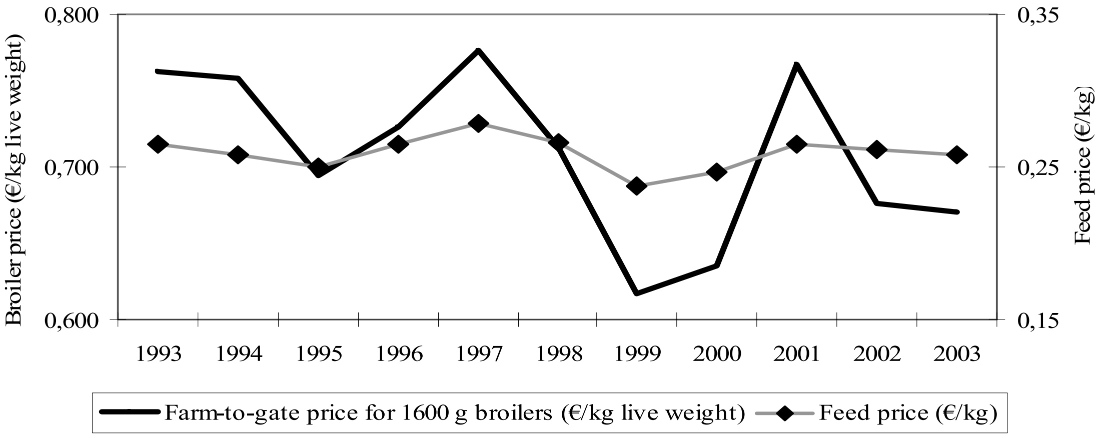

Figure 3.5 The farm-to-gate broiler price and the broiler feed prices for the years 1993-2003
Source: LEI.

Our estimated annual labour income of €10,500 farm/year is slightly below the calculated average 'family farm' income of €13,000 for a specialised broiler farm of 60,000 chicks for the years 1992 until 2002[1]. Nevertheless, the simulated labour income does match well enough with reality to be used as baseline. Family farm income is not exactly the same as labour income. Apart from labour income also interest earned from farm capital investment are considered in this economic indicator. Consequently, family farm income is always slightly higher than labour income. Furthermore, Horne used the 1992 to 2002 data. We, however, based our farm-to-gate prices on the 1993 to 2003 data. But in 1992 the average yearly farm-

[1] Based on Dutch FADN data from 1992 until 2002, P. van Horne (LEI) personal communication, has calculated the average annual family farm income for a farm with 60,000 chicks to be €13,000.

to-gate price was €0.8 per kg, whereas in 2003 this price was only €0.7 per kg, according to LEI data, with as consequence a slightly lower average farm-to-gate price.

3.5.2 Intervention measures under study

The discontinuation of thinning results in a slight decrease in Dutch broiler production, namely from 420 million to 412 million birds/year. The labour income for the whole broiler production sector would decrease by nearly €1 million per year, which is equal to an income decrease of approximately 8%. But apart from the monetary losses for the farmers, also the animal welfare would decline, due to higher stocking density in kg per m^2 at slaughter. Thinned flocks have on average a lower stocking density measured in kg per m^2 at slaughter than do not-thinned flocks.

Based on theoretical farm risk assessment modelling, reducing transmission or infection between successive flocks seems to be the most effective measure. As previously mentioned, no specific hygiene measures to tackle the Campylobacter problem are known. We used the Bolder approach as an example for 'potential' costs for additional or improved hygiene measures that might be applied to control infection between successive flocks. The Bolder approach is currently applied to control and eliminate, mainly between successive flocks, Salmonella Java on Salmonella Java positively tested farms. The estimated additional annual costs vary from €8 million to €64 million, depending on the combination of chosen and assumed costs. Applying these intervention measures on all farms and always, without being able to pass the additional production costs on to the next stage, would imply that with the assumed costs, the majority of Dutch broiler farmers would be out of business within no time. With approximately 30% positively tested flocks, hygiene applied to only positively tested flocks would still be too costly for most broiler farms to bear them over a longer period. The Bolder approach might be applicable and financially bearable for the Salmonella Java control, with a flock prevalence of less than 5%. But with an observed flock prevalence of approximately 30%, too many farms would have to apply these measures.

Flies and insects have been identified as a potential source of infection (Hald et al., 2004). The sealing and disinfection of cracks and holes should help to avert this problem, although it is certainly not the only measure to apply. But even the sealing and disinfection of cracks and holes between successive flocks costs €8-14 million per year, if applied on all farms.

According to Bouwknegt et al. (2004), a large proportion of Dutch broiler farms have already implemented 'optimal' hygiene by providing such facilities as anterooms, specific clothing, etc. Nevertheless, consistent and correct use of the current on-farm bio-security barriers and hygiene measure is the first step to assure. Additional hygiene costs seem to be quite costly and time consuming. Therefore, before forcing broiler farmers who do have 'optimal' hygiene measures to invest in additional measures, their efficiency in controlling Campylobacter should be proven. More research is needed here.

Phage therapy, if effective in controlling Campylobacter infection and assuming low costs per chick treated, might be a promising intervention measure. But cost estimates per chick treated are very uncertain. Under the current circumstances, and assuming that the additional production costs cannot be passed on to the next stakeholder, the phage therapy might work if costs per chick treated are close to the minimum cost estimate. At this cost estimate, it is cheaper to treat all birds than to test and treat only positively tested flocks.

3.5.3 Conclusion

Given that Campylobacter infected broiler flocks do not show clinical signs or growth reduction, controlling Campylobacter does not result in reduced production costs. But with an average annual labour income of €10,500 per farm per year, or €12 million per year for the whole sector, the resources of broiler farmers to bear increased production costs resulting from the implementation of additional intervention measures, without being able to pass these costs onto the next stage in the chain, are rather limited. These conclusions apply as long as no additional bonus is paid for Campylobacter-free flocks. But even then, it has to be demonstrated that such intervention measures as on-farm hygiene and the discontinuation of thinning are effective in controlling Campylobacter. Because otherwise the bonus paid (or the penalty to pay, if positive) do not cover the additional costs incurred. Furthermore, in the case of a bonus for Campylobacter-free flocks, the phage therapy is not the intervention measure to chose, as it would lead to a reduction but not the elimination of Campylobacter.

4. Intervention measures at the processing plants

4.1 Background information

There are nine main stages in chicken processing (Anderson et al., 2003), namely:

- stun & kill;
- scald;
- defeather;
- evisceration;
- wash;
- chill;
- portioning;
- grading & packing;
- distribution.

In a fully automated poultry processing plant it is impossible to isolate individual carcasses from others or from equipment, employees and other materials essential for processing, resulting in possible cross-contamination at all stages of the process (Hafez, 1999). Within the CARMA project, Nauta et al. (2005) developed an analytical risk model to simulate the different steps in a processing line. This risk model is used to compare the different intervention measures under study to control Campylobacter. For details, see Nauta et al. (2005).

Food safety technologies to reduce foodborne pathogens are based on either thermal or non-thermal treatments (Majchrowicz, 1999). Thermal decontamination technologies rely on heat, either dry or steam, to dehydrate or injure micro-organisms, while non-thermal decontamination technologies kill pathogens by affecting the composition and cellular activity of pathogens (Majchrowicz, 1999).

Heat, particularly through cooking, has long been the principal method of eliminating pathogens in food (Majchrowicz, 1999). Various forms of heat have been suggested for decontaminating poultry and other raw meats, for example hot water treatment of poultry carcasses (dipping or spraying), steam at atmospheric, high or reduced pressure, high intensity dry heat or microwave heating. In the case of hot water, significant reduction in numbers of bacteria can be achieved only after a relatively long contact times and high temperatures, resulting in an unacceptable (cooked) appearance (Corry and Atabay, 2001). Also other forms of thermal decontamination have some residual effects on the appearance. Furthermore, both steam decontamination and microwave heating cannot treat the surface of poultry meat without causing some surface cooking (Corry and Atabay, 2001; Göksoy et al., 2000).

Chemical rinses, irradiation, ozonisation and ultra-high pressure are different non-thermal decontamination technologies (Majchrowicz, 1999). The reduction of micro-organisms might be achieved by treating the scald water with for example organic acids (acetic or lactic), ozonisation and homogenisation (Corry and Atabay, 2001, Hafez, 1999). Chlorine, chlorine dioxide and other chlorine derivatives, trisodium phosphate and organic acid (e.g. lactic acid) in water sprays and in chill water are also used to reduce foodborne pathogens. Also the use of chlorinated water, trisodium phosphate or a lactic acid solution as a dip immediately after water chilling or before air chilling reduces contamination (Corry & Atabay, 2001, Hafez, 1999; Kist, 2002). The use of a low-voltage electrical current with a low concentration of salt in the chill water has been shown to eliminate Campylobacter from chillier water and to reduce the contamination on chicken skin (Hafez, 1999). All these measures reduce foodborne pathogens but do not eliminate them completely from the final product and may have a negative impact on the organoleptic properties of the product.

The application of gamma rays or electron beams is an effective method of eliminating Campylobacter from poultry meat and products (Corry and Atabay, 2001; Shane, 2000). Irradiation is the most effective because it can be applied to warm, chilled or frozen carcasses, and affects appearance and organoleptic properties the least. Gamma irradiation is very effective, and has the added advantage of penetrating the surface (Corry and Atabay, 2001). But this method is relatively expensive and is unpopular with consumers (Corry and Atabay, 2001).

Storage under refrigeration or freezing conditions will reduce the prevalence and quantity of contamination on chicken products after processing (Anderson et al., 2003, Þorkelsson et al., 2003; Shane, 2000). Iceland, for example, tried to solve the Campylobacter problem by freezing positively tested lots. But the substantially lower prices paid to producers for frozen lots has been an important factor, according to Stern et al. (2003), to reinforce prevention measures on farm-level such as broiler house clean-out, disinfection and the practice of biological security measures.

In summary, all methods of decontamination have some disadvantages.

4.2 Selected interventions

By mutual agreement of the Steering Committee of the CARMA project - which includes risk managers at the Ministry of Public Health and the Ministry of Agriculture - and after discussion with the Industry Forum and experts in the field, the following intervention measures concerning processing plants were selected for evaluation:

- all broilers are treated:
  - reduction of faecal leakage: reduction of the birth of faeces during scalding and defeathering;
  - decontamination of scald water: decontamination of scald water by;
    - adding lactic acid; assumed concentration is 2.5%;
    - adding trisodium phosphate (TSP); assumed concentration is 10%;
  - decontamination of carcass: decontamination of the carcass by;
    - dipping carcass before chilling in an additional scald tank with lactic acid; assumed concentration is 2.5% (lactic acid 1x);
    - adding lactic acid to the washing and chilling water, as well as dipping after defeathering; applied concentration is 2.5% (lactic acid 3x);
    - dipping carcass before chilling in an additional scald tank with trisodium phosphate (TSP); assumed concentration is 10% (TSP 1x);
    - adding TSP to the washing and chilling water, as well as dipping after defeathering; applied concentration is 10% (TSP 3x);

- crust-freezing;
- irradiation: assuming gamma irradiation of chicken meat;
- freezing: assuming freezing of chicken meat and carcasses for 2 weeks at - 20°C;

- only broilers from positively tested flocks are treated;
  - decontamination of carcass: decontamination of the carcass by;
    - dipping the carcass before chilling in an additional scald tank with lactic acid; assumed concentration is 2.5% (lactic acid 1x);
    - adding lactic acid to the washing and chilling water, as well as dipping after defeathering; applied concentration is 2.5% (lactic acid 3x);
    - dipping the carcass before chilling in an additional scald tank with trisodium phosphate (TSP); assumed concentration is 10% (TSP 1x);
    - adding TSP to the washing and chilling water, as well as dipping after defeathering; applied concentration is 10% (TSP 3x);
  - crust-freezing;
  - irradiation: assuming gamma irradiation of chicken meat;
  - freezing: assuming freezing of chicken meat and carcasses for 2 weeks at - 20°C;
  - for prepared meat use only: assuming that meat originating from positive flocks will not be sold as fresh meat, but as processed and prepared meat and/or meal.

4.3 Interventions under study and assumptions made

4.3.1 Reduction of faecal leakage

In order to reduce carcass contamination in the scalding and the defeathering process, a new technology was developed and patended by one of the leading manufactures of poultry processing equipment in the Netherlands. The underlying goal of this technology is to reduce the birth of faeces (faecal leakage) in the scalding and defeathering process and as such reduce the contamination of processed birds, and the environment (e.g. scald water and defeathering equipment) with intestinal pathogens.

In 2000, none of the 23 Dutch slaughterhouses would have had this technology. Consequently every slaughterhouse would have to buy and to install such technology on each of their slaughterlines. The purchase costs for such equipment are assumed to vary between €85,000 to €95,000 per unit[1], depending on the speed of the slaughter line[2]. The installation costs per unit are assumed to be €5,000 and €15,000, respectively, depending on the problems encountered when installing the equipment on the current line. However, no information was available about how many and which slaughterhouses would have more or fewer problems when installing this new technology in their slaughter lines. In consultation with people from the field, it was decided to model that 0 to 25% (uniformly distributed) of the slaughterhouses would have more problems to install the technology, and that the remaining slaughterhouses would have fewer problems. Depreciation of these non-recurrent costs is applied over 8 years, whereby considering an interest rate of 4% (see section 2.5.1 for more details).

[1] The prices and costs given here are only indications, which we received from manufactures.
[2] Information about the number of slaughterlines per slaughterhouse, and the speed of the slaughterlines were made available by Ate Jelsma and colleagues from the VWA for each of the 23 slaughterhouses.

We considered the annual maintenance (2-3% of the purchase costs[1]) as a part of the recurrent costs. Other recurrent costs are costs for additional water (0.3 l per slaughtered chick), cleaning water and the additional sewage water. The costs for sewage water are assumed to be somewhere between €1.3/m^3 and €1.6/m^3 (uniformly distributed).[2] The costs for water were in 2000 on average €1.01/m^3 if drinking water quality and €0.46/m^3 if industry water quality (lower quality than drinking water quality).[3] It is assumed that drinking water quality would be used. However, for sensitivity analysis, we also estimated the costs for the use of industry water quality. The costs of additional electricity and other operational costs are negligible and were therefore not considered in the cost estimates.

4.3.2 Decontamination of scald tank

A 2.5% lactic acid solution and a 10% TSP solution, respectively, in the scald tank in order to reduce the cross-contamination via contaminated scald water was the intervention measure under study. These concentrations were chosen in accordance with the concentrations reported by Stekelenburg and Logtenberg (2004). In order to apply this intervention measure, a dose unit with control apparatus would have to be installed on the slaughter line. The assumed costs are approximately €35,000 per installed unit.[4] However, as one of the manufactures quoted a much lower price, we performed some sensitivity analyses. Installation costs are assumed to be about 5-8% (uniformly distributed) of the purchase costs.[5]

Depreciation of these non-recurrent costs is applied over 8 years, whereby considering an interest rate of 4% (see section 2.5.1 for more details).

The annual maintenance costs are assumed to be 2-3% of the purchase costs (see footnote 1 on page 2). The additional electricity use per dose unit and control apparatus is approximately 0.12 kWh. Further, additional variable costs are the costs for lactic acid and TSP. The concentration in the scald water is assumed to be 2.5% for lactic acid and 10% for TSP. Apart from the initial scald tank filling, it was assumed that 0.15-0.25 l water per kg product is dragged and needs to be refilled.[6] The purchase price for lactic acid, at a concentration of 80%[7], is according to Smits[8] €1.5 to €2.5 per kg. We assumed a similar purchase price

[1] According to Willem Heemskerk (Meyn) and Pieter-Klaas Hopma-Zijlema (Stork), 2-3% of the purchase costs could be taken as a guideline for the estimation of the annual maintenance costs of a piece of machinery in the slaughter line. We therefore assumed for each piece of new equipment installed in the slaughterline in order to apply intervention *i* that the annual maintenance costs would be somewhere between 2 and 3% (uniformly distributed) of the assumed purchase costs of equipment *i*.

[2] Eric Vierenga (Waterschap Vallei&Em), personal communication; October 2004.

[3] P. Geudens (VEWIN), personal communication; October 2004.

[4] Cost indications as received from manufactures.

[5] According to Pieter-Klaas Hopma-Zijlema (Stork), 5-8% of the purchase costs could be taken as a guideline for the estimation of the installation costs of new equipment in the slaughter line. If not indicated otherwise, we therefore assume that the installation costs of equipment *i* are about 5-8% (uniformly distributed) of the purchase costs of equipment *i*.

[6] Based on information received from manufactures Stork and Meyn.

[7] In order to obtain a lactic acid concentration of 2.5%, [(100%/80%)x2.5%]=3.125% lactic acid, at a concentration of 80% is required.

[8] Koen Smits (PURAC), pers. communication; September 2004.

for TSP.[1] Technical changes might result in a lower concentration of lactic acid or TSP.[2] We analysed this in our sensitivity analysis.

4.3.3 Decontamination of the carcass during washing and chilling and by dipping

Recently, researchers in the Netherlands studied the effectiveness of carcass washing systems as regards removing Campylobacter (Snijders et al., 2004; Stekelenburg and Logtenberg, 2004). Their results suggest that carcass washer systems consisting of multiple washers provide minimal reduction of campylobacters. It was therefore assumed that decontamination of the carcass with lactic acid and trisodium phosphate would occur at three places on the slaughter line. Consequently, three dose units with the necessary control apparatus are required. The assumed purchase costs and installation costs per dose unit are the same as given in section 4.3.2. For all scenarios an additional scald tank in order to dip the carcasses is required. This additional tank is placed in the slaughter line after defeathering and before evisceration. The purchase costs are somewhere between €110,000 and €150,000 per additional tank[3], depending on the speed of the slaughter line. In order to decontaminate the carcasses during chilling, a spraying cabinet has to be installed in downflow chilling tunnels. The assumed cost for the spray cabinet is €38,000 per cabinet. In the case of a spray chilling system, only a dose unit is required. There are three Dutch slaughterhouses that do have a spray chilling system. Installation costs are assumed to be about 5-8% of the purchase costs. Depreciation of all non-recurrent costs is applied over 8 years, whereby considering an interest rate of 4%.

The annual maintenance costs are assumed to be 2-3% of the purchase costs. Additional water is required for the additional scald tank (a tank filling per day, and 0.1 l per slaughtered chick) and, if applied, for the additional spray cabinet (0.1 l per chick). Consequently, the quantity of sewage water produced increases. The costs per additional m^3 water and sewage water are €1.01 and €1.3-1.6, respectively (see section 4.3.1). Assuming room temperature for the water in the additional scald tank, no additional electricity is required to heat the water. The additional electricity use per dose unit and control apparatus is assumed to be 0.12 kWh.

The assumed concentration is 2.5% lactic acid[4] and 10% TSP, respectively (Stekelenburg and Logtenberg, 2004). The costs for lactic acid and TSP are assumed to be between €1.5 and €2.5 per kg product used. Apart from the initial scald tank filling for the additional scald tank, it was assumed that per kg of product about 0.1 l water per slaughter chick is dragged out and refilled. During washing, approximately 0.44 l per slaughtered chick is used.

[1] To consider TSP as chemical substance for decontamination was only decided towards the end of the project. It was not possible to find in the remaining time a purchase price for TSP, if applied on a large scale. We could only obtain the purchase price for 97% TSP for laboratory purposes. The price per kg of 97% TSP was more than 100 times cheaper than the price per kg of 98% lactic acid. However, these were the prices for TSP and lactic acid for laboratory purposes (i.e. small quantities, high concentration and high purity).

[2] Some manufactures are already working on new technologies, whereby a lower lactic acid concentration might be compensated for by a higher temperature. But no information concerning the impact of these technologies on campylobacters reduction on poultry carcasses/meat is available.

[3] Cost indications as received from manufactures.

[4] Or 3.125% lactic acid, at a concentration of 80% (see section 4.3.2 for details).

In the chilling system, approximately 0.1 l for the spray cabinet and 0.4 l for the spray chilling system are required per slaughtered chick[1].

In order to analyse the impact on the costs, a sensitivity analysis was applied to the assumed concentration of lactic acid and TSP and the assumed purchase price. Further, according to Stekelenburg and Logtenberg (2004) lactic acid and TSP might have a negative impact on the organoleptic properties of the meat, depending on the concentration of lactic acid and TSP, respectively, used. A negative impact on the organoleptic properties of the meat, however, might result in indirect costs for the processing industry due to potential lower selling prices. Sensitivity analysis was applied here.

A further point considered in our sensitivity analysis is the discussion around the possible corrosion of some parts of the equipment in the slaughter line when using lactic acid. In the baseline scenario, we assume no corrosion. However, some people from the industry were afraid that some of the installed equipment might be of a less corrosive-resistant material. Consequently, the earlier replacement of some parts of the equipment is required together with an extended overhaul of the whole equipment. After a onetime renewal, a normal lifetime is assumed for the replaced equipment. In our sensitivity analysis, we assumed that 20-25% of the slaughterhouses would have no problem because they have relatively new equipment. Some 20-25% of the slaughterhouses would have major problems, because of elderly equipment made of a less corrosive-resistant material. And all remaining slaughterhouses would have some corrosion problems with some parts of their equipment.

4.3.4 Decontamination of the carcass by dipping only

Carcasses are decontaminated by dipping them in an additional scald tank just before chilling in a 2.5% lactic acid solution and a 10% trisodium phosphate solution, respectively. Here, an additional scald tank and a dose unit with control apparatus is required. Purchase costs and installation costs are the same as described in section 4.3.3 for this type of equipment.

Apart from the maintenance costs, additional costs are made for additional water use and additional sewage water produced, in total one initial tank filling/day and 0.1 l per slaughtered chick (same as in section 4.3.3). The additional electricity use per dose unit and control apparatus is assumed to be 0.12 kWh. The assumed concentration is 2.5% lactic acid[2] and 10% TSP (Stekelenburg and Logtenberg, 2004). The cost of lactic acid and of TSP is assumed to be between €1.5 and €2.5 per kg. Apart from the initial scald tank filling for the additional scald tank, it was assumed that per kg product about 0.1 l water per slaughtered chick is dragged out and refilled.

In order to analyse the impact on the costs sensitivity analysis is applied on the assumed concentration of lactic acid and TSP and the assumed purchase price. As in section 4.3.3, the applied concentration of lactic acid might have a negative impact on the organoleptic properties of the meat, resulting in indirect costs for the processing industry due to potential lower selling prices. We therefore performed some sensitivity analysis with respect to lower selling prices for the processing industry.

[1] Based on information received from manufactures.

[2] Or 3.125% lactic acid, at a concentration of 80% (see section 4.3.2 for details).

4.3.5 Crust-freezing

The first results of Corry et al. (2003) indicate that crust-freezing - a new technology developed in England for chilling and maturing poultry meat -has a positive side-effect, namely it reduces Campylobacter in poultry meat. We therefore opted to analyse this intervention measure.

The non-recurrent costs, purchase costs, installation and reorganisation costs are somewhere between €1.5 million and €3 million per piece of equipment[1] when installed in the current chilling system. Depreciation of all non-recurrent costs is applied over 8 years, whereby considering an interest rate of 4%.

Apart from the maintenance costs, there are only additional electricity costs.[2] The most likely value of a regular air chilling system without crust freezing is around 490 kW per hour, with a variation of 50 kWh.[3] Implementing 'crust freezing' in a regular air chilling system was estimated to increase the energy use for chilling up to 200%. We therefore assumed that on average the additional electricity use would be 490 kWh, with a minimum of 440 kWh and a maximum of 540 kWh. For sensitivity reasons, however, we played it safe and assumed an increase up to 300% and 400% opposite to a regular air chilling system.

4.3.6 Irradiation

It was assumed that gamma irradiation would not be applied in the processing plants, but would be applied by specialists. This means that processing plants would not need to invest in new technology. Depending on the quantities of chicken meat irradiated, the specialist industry might be forced to increase its capacity. But the costs of a possible expansion should be covered by the costs they charge the processing plants for irradiation. We therefore considered only the costs for irradiation that processing plants would have to pay and the related logistic costs.

In the Netherlands, there is only one firm (with two plants) applying gamma irradiation. Depending on the quantity irradiated, the price would be a minimum of €35 and a maximum of €60 per pallet treated (though most likely €55/palet treated).[4] A pallet is assumed to be approximately 975 kg of meat, plus 25 kg for the pallet itself. The price was considered as being uncertain and was modelled as a pert distribution. Apart from the treatment costs, there are costs for loading and discharging, transporting to and from the irradiation plant, and the waiting time of the lorry at the irradiation plant (the two irradiation plants in the Netherlands do not have a cold store; this problem is currently solved by using the truck as a cold store). It was assumed that gamma irradiation would be applied daily; a maximum of 20 pallets would fit in a lorry[5]; the cost for charge and discharge, respectively, would be a minimum of €1, most likely €2.5 and a maximum of €3 per pallet (uncertain); transport costs would be a

[1] Cost indication received from Neil Hannay (Airproducts, UK), pers. communication; March 2005.
[2] The developing manufacturer of the crust freezing system could not give us an indication of the potential additional electricity costs.
[3] Peter Kragtwijk (Meyn), pers. communication; March 2005.
[4] G. Eijsermans (ISOTRON), pers. communication; July 2004.
[5] P. Hullegie (Hays Logistics); pers. communication; October 2004.

minimum of €150, most likely €250 and a maximum of €500 per ride (variable)[1]; and the waiting costs is assumed to be €15 per pallet treated (time to treat a pallet is assumed to be 0.35 hours[2] times €42.8/hour[3]).

4.3.7 Freezing

Freezing and storing chicken meat for two weeks at -20°C might be applied by the processing plant itself or could be performed by an external specialist. If it were cheaper for a processing plant to do itself, it would invest in freezing and storage technologies and capacities. But if it were cheaper to do it externally, processing plant managers would opt for this. We assumed that processing plants would not invest in this technology, but contract out the freezing and storing. Depending on the quantities of chicken meat frozen the specialist industry might be forced to increase its capacity. But the costs of a possible expansion should be covered by the price they charge processing plants for freezing and storing. We therefore considered only the costs for freezing and storing paid by processing plants and the related logistic costs. This cost estimate can be seen as an upper limit estimate.

The costs for freezing and storing for two weeks at -20°C costs are €0.03 per kg (€0.02/kg for freezing and approximately €0.01/kg for storing)[4]. Apart from the freezing and storing costs, there are costs for loading and discharging and the transport to and from the specialist. Here we made the same assumption as explained in section 4.3.6.

Freezing meat results in lower selling prices, which are indirect costs for the processing industry. Sensitivity analysis was applied here.

4.3.8 For prepared meat use only

As explained in section 4.1, there are different sorts of thermal treatment. However, nearly every treatment, if it is effective, results in an unacceptable (cooked) appearance. Selling this meat as 'fresh' meat would be very problematic. We therefore decided that it might be better to test for Campylobacter. Chicken meat originating from positively tested flocks would not enter the fresh meat market, but would go into the market sector of processed and prepared meat and meat products. No additional 'heat treatment' as described in section 4.1 would be required. The applied 'heat treatment' (cooking) is not an additional process step, but a necessity in order to produce the processed meat and prepared meat. Therefore, apart from testing and scheduled treatment (see section 4.3.9), no additional costs would be incurred.

But when selling chicken meat to the industrial market sector of processed and prepared meat, Dutch slaughterhouses would have to compete with chicken meat from Brazil and Thailand, two important chicken exporting countries. However, according to Bondt and Van Horne (2002), production costs of broilers from Brazil are 30-40% lower than those of broilers produced in the European Union. Therefore the main 'cost' for processing plants would be indirect costs due to reduced selling prices. Sensitivity analysis was applied here.

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[1] Costs for loading and discharging, respectively, as well as the costs per transport ride are based on a questionnaire sent to slaughterhouses; there were, however, only four respondents.
[2] Based on information received from G. Eijserman (ISOTRON), pers. communication; July 2004.
[3] P. Hullegie (Hays Logistics); pers. communication; October 2004.
[4] Based on information received from Jan Tjalling Bakker (Storteboom) and Frits Hermans (Astenhof) in November 2004.

4.3.9 Testing and scheduled treatment

In order to treat only positively tested flocks, testing and scheduled treatment is a must. Testing is applied on the broiler farms as explained in section 3.3.6. Three different tests are analysed, namely a PCR, a dipstick test and a culture test. It is assumed that farmers pay these costs. However, for verification purposes a second testing is applied when slaughtering (culture method of cloacal samples). These testing costs are charged to the processing plants. We assume that per slaughter group, five samples are taken and pooled to form one test sample. The costs for a test are assumed to be €10-30 per test. These costs are very uncertain, we therefore apply sensitivity analysis. The time needed to take the samples, prepare the pool sample and to do the administration work is assumed to be 0.5 hours per slaughter group. Horne (2002) assumed 0.75 hours per flock, but that seems to be on the upper limit. Sensitivity analysis was applied here too. Along with Horne (2002), we assume that the additional time for slaughterhouse personnel costs €18 per working hour. The transportation of samples to slaughterhouses is assumed to be applied once a day and to be included in the related additional working time for testing.

Testing and consequently applying logistic slaughter and scheduled treatment might lead to additional operational costs (e.g. extra cleaning in between), inefficient production and not being able to deliver on time. For example, a flock of light broilers destined for England is tested positive two days before slaughtering. In order to allow for decontamination, the flock is slaughtered in the late afternoon instead of the early morning. Consequently, the ship to England, which leaves every day at 12.00 hrs, is missed. Delivery a day later means dissatisfied clients, risking losing clients, and a shorter shelf-life for retailers. Inefficient production (resulting in e.g. higher production costs) and not being able to deliver on time (resulting in e.g. reduced selling prices, which are indirect costs) are potential costs that are hard to quantify. In agreement with slaughterhouses managers, we therefore decided to perform some what-if scenarios,[1] whereby assuming that scheduled treatment would lead to a) no additional costs (direct and indirect); b) €5 cts/kg; c) €10 cts/kg and c) €20 cts/kg.

4.4 Results and sensitivity analysis

4.4.1 Main results

The mean and the attendant uncertainty of the total additional costs in € million per year and in €cts per chicken, respectively, for the various intervention measures under study are summarised in table 4.1. Figure 4.1 is a summary of the yearly non-recurrent 'treatment' costs (in € million) and the yearly recurrent 'treatment' costs (in € million) for the various intervention measures.

[1] We tried to quantify these costs by sending questionnaires to slaughterhouse managers. Four managers replied, representing nearly 50% of the 23 slaughterhouses in 2000 in the Netherlands. The answers we received were inconclusive. We therefore discussed the outcomes of these questionnaires with the managers themselves and a representative of the industry. The conclusion of this meeting was that we should perform some what-if scenarios, because nobody was able to quantify these costs.

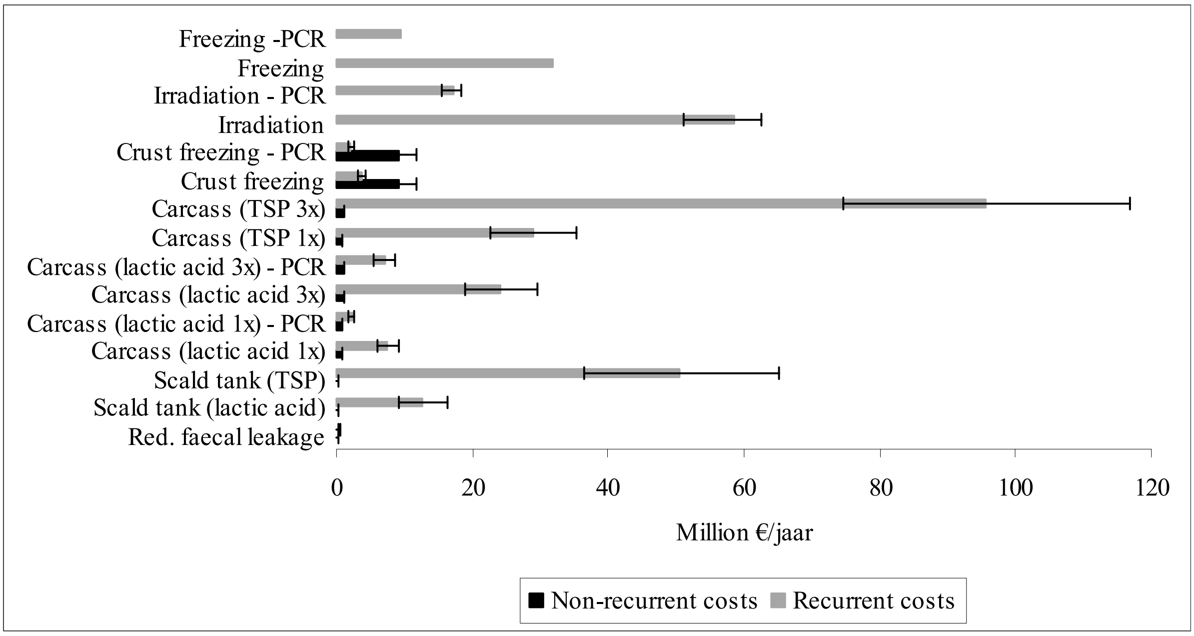

Figure 4.1 *Average yearly non-recurrent costs and yearly recurrent costs, and the attendant uncertainty for the different intervention measures in the processing plant, assuming treating all carcasses and carcasses of positively tested flocks (PCR) only*

Organoleptic changes (e.g. soft and pale meat), product changes (e.g. frozen meat and prepared meat in place of fresh meat) and non-acceptance on the part of the consumer (e.g. gamma irradiation) might result in indirect costs for processing plants, such as e.g. a reduction of the selling price. Potential indirect costs for different price reductions are summarised in table 4.2, if all carcasses are treated and if carcasses from positively tested flocks are treated only, respectively.

The testing costs in processing plants are summarised in table 4.3, depending on the assumed costs per tested sample. The total testing costs comprise the costs for testing on farm (see table 3.5) and the costs for testing in processing plants (see table 4.3).

Testing and treating positively tested flocks only, might result in additional scheduled treatment costs. These scheduled treatment costs might be due to higher operational costs (direct costs). But scheduled treatment costs might also be the consequences of reduced selling prices (indirect costs). Due to delivery problems, and consequently the loss of fix clients relations, processing plants might be forced to sell larger quantities on the open market, leading to a lower selling price. Due to a lack of data, an estimate of these costs was not possible. In agreement with managers from Dutch chicken processing plants, some what-if scenarios were performed. The results of these scenarios are summarised in figure 4.2.

Table 4.1 The mean and attendant uncertainty of annual total treatment (in €m) and the treatment costs (in €cts) per kg slaughter weight (SW), respectively, for the different intervention measures

	Total treatment costs (in €m)/year				Treatment costs (in €cts)/kg SW			
	Mean	5%	Median	95%	Mean	5%	Median	95%
Treating all carcasses and meat a)								
Reduction of faecal leakage	0.81	0.79	0.81	0.83	0.12	0.12	0.12	0.12
Decontamination of scald tank (lactic acid)	12.82	9.31	12.42	16.49	1.89	1.37	1.83	2.43
Decontamination of scald tank (TSP) b)	50.74	36.72	49.15	65.43	7.48	5.41	7.25	9.65
Decontamination of carcass (lactic acid 3x)	25.51	20.29	25.97	30.82	3.76	2.99	3.83	4.55
Decontamination of carcass (TSP 3x) b)	96.82	75.97	98.61	118.15	14.28	11.21	14.55	17.43
Decontamination of carcass (lactic acid 1x)	8.23	6.65	8.37	9.82	1.21	0.98	1.23	1.45
Decontamination of carcass (TSP 1x) b)	29.73	23.44	30.27	36.15	4.36	3.44	4.44	5.31
Crust-freezing	12.86	9.64	13.00	15.90	2.83	2.12	2.86	3.50
Irradiation	58.56	51.00	58.71	62.63	8.64	7.75	8.69	9.24
Freezing	31.88 c)	-	-	-	4.70 c)	-	-	-
Testing and treating only carcasses and meat originating from positively tested flocks a), d)								
Decontamination of carcass (lactic acid 3x)	8.33	6.82	8.47	9.84	1.23	1.01	1.25	1.45
Decontamination of carcass (TSP 3x) b)	27.19	21.15	27.75	33.23	4.01	3.12	4.09	4.90
Decontamination of carcass (lactic acid 1x)	2.98	2.52	3.02	3.42	0.44	0.37	0.45	0.51
Decontamination of carcass (TSP 1x) b)	8.21	6.37	8.37	9.97	1.21	0.94	1.23	1.47
Crust-freezing	11.25	7.99	11.38	14.32	2.47	1.76	2.50	3.14
Irradiation	17.23	15.51	17.33	18.40	2.54	2.29	2.56	2.71
Freezing	9.59 c)	-	-	-	1.41 c)	-	-	-
For prepared meat use only	- e)	-	-	-	- e)	-	-	-

a) Only direct costs are considered here. A price reduction of the treated meat (indirect costs), if applied, is not considered in these costs; b) Assuming same cost price/kg for TSP as for lactic acid; c) The costs for freezing and storing are considered to be fixed. But the logistic costs were considered to be variable (attendant variability is not shown here); d) Only 'treatment' costs considered. Costs for testing on farm (table 3.5) and in the processing plant (table 4.3) are not included in the cost estimates shown here, nor are indirect costs due to a possible price reduction (see table 4.2) and/or scheduled treatment related costs (see figure 4.2). Furthermore, we show here only the costs of positively tested flocks using a PCR. The 'treatment' costs for positively tested flocks using a dipstick test and a culture test hardly differ from those shown in this table. The difference is negligible; e) No 'treating' costs assumed. The potential 'costs' of this intervention are the testing costs (direct costs) on the farm and in slaughterhouse (see table 3.5 and table 4.3) plus a significant potential price reduction (indirect costs) (see table 4.2).

Table 4.2 Estimated indirect costs in € million/year and in €/kg, respectively, due to a potential price reduction, depending on assumed reduction and depending on base sale price, respectively

Assumed price reduction (in €/kg meat)	Treating all carcasses		Treating only carcasses from positively tested flocks	
	Losses (in €m) per year	Losses in €/ kg SW	Losses (in €m) per year	Losses in €/ kg SW
€ 0.2/kg	136	0.2	39	0.06
€ 0.3/kg	203	0.3	59	0.09
€ 0.4/kg a)	271	0.4	79	0.12
€ 0.5/kg	339	0.5	98	0.15
€ 0.6/kg	407	0.6	118	0.17
€ 0.7/kg	475	0.7	138	0.20

a) The production cost difference between Dutch and Brazil meat is €0.4-0.5/kg (Bondt and Van Horne, 2002). A price reduction of approximately €0.4/kg therefore seems to be realistic if Dutch processing plants have to compete with Brazil broiler meat on the non-fresh broiler meat market.

Table 4.3 Estimated average total testing costs in processing plants, laboratory costs and working costs, respectively, in € million/year and total testing costs in €cts/kg, depending on assumed costs per tested sample a)

Assumed costs (€)/ test	Total testing costs (€m)/year	Laboratory costs (€m)/year	Working costs (€m)/year b)	Total testing costs in €cts/ kg SW
10	0.61	0.34	0.26	0.09
15	0.78	0.52	0.26	0.11
20	0.95	0.69	0.26	0.14
25	1.12	0.86	0.26	0.17
30	1.30	1.03	0.26	0.19

a) Costs for testing on farm (see table 3.5) have to be added in order to get the total annual testing costs; b) Assuming 0.5 hour working time/slaughter group tested.

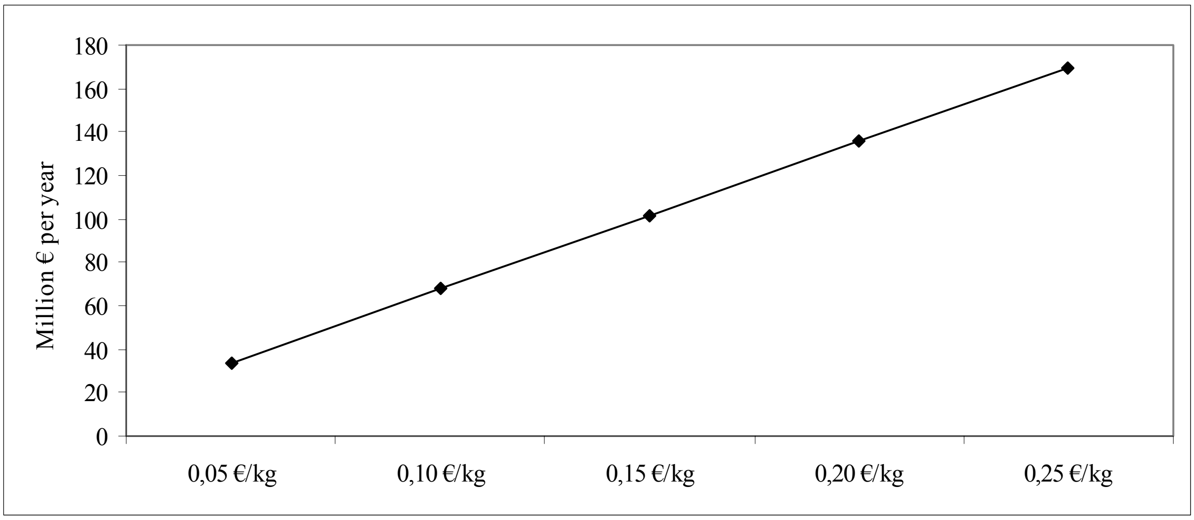

Figure 4.2 Estimated potential additional costs (direct or indirect costs) due to scheduled treatment (in €M), depending on the assumed additional costs/losses per kg broiler meat

4.4.2 Additional results

More than 90% of the annual treatment costs for the decontamination of the scald tank and of the carcass, respectively, with 2.5% lactic acid are purchase costs for lactic acid (see figure 4.3). Decontamination with TSP shows a similar result.

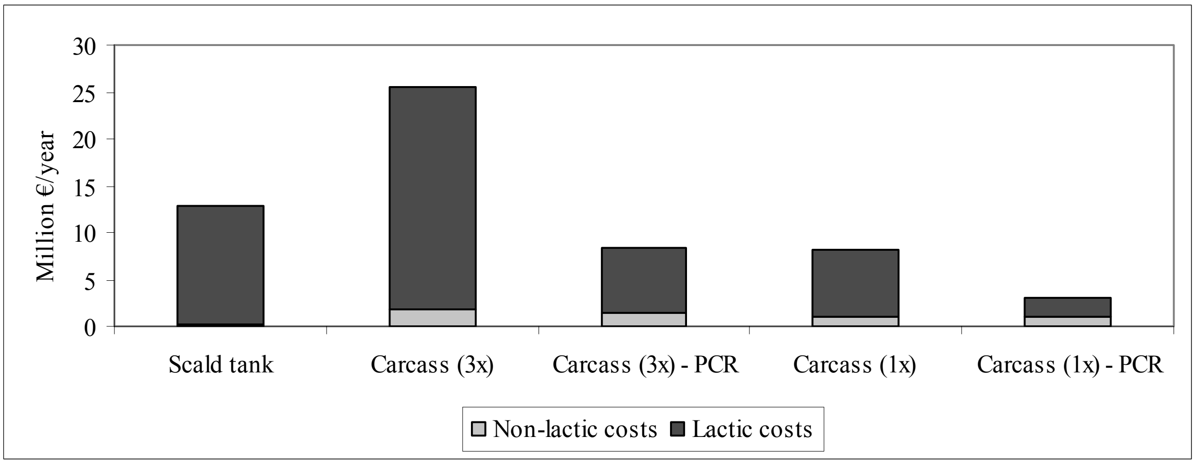

Figure 4.3 *Splitting up the average annual treatment for decontamination of scald tank, decontamination of carcass by dipping and washing (3x), decontamination of carcass by dipping only (1x) in non-lactic costs and lactic costs, assuming a concentration of 2.5% lactic acid*

In the case of irradiation and freezing, about 40% of the annual average costs are logistic costs, given that we assume that both interventions would be applied by specialised industries, see figure 4.4.

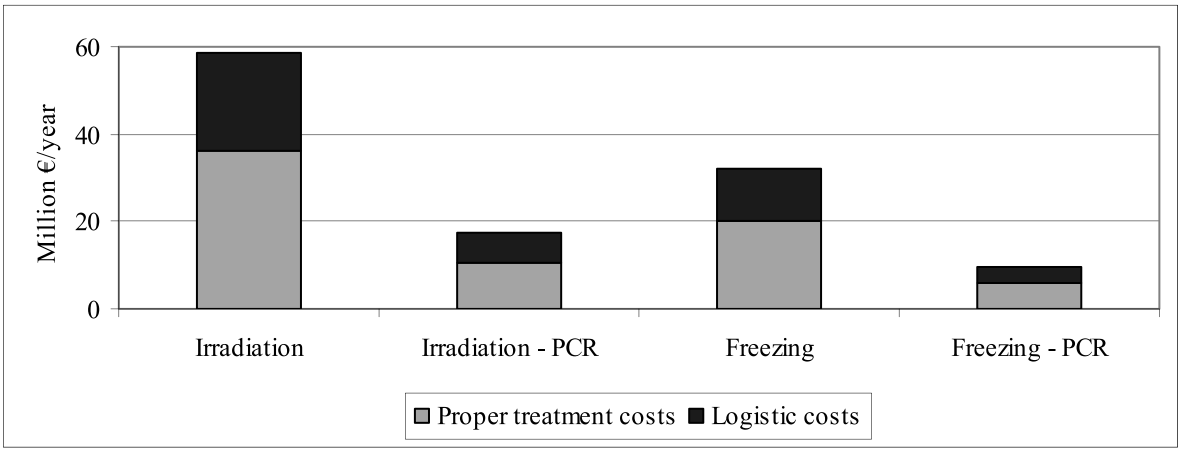

Figure 4.4 *Splitting up the average annual 'treatment' costs for freezing and irradiation, respectively, into logistic costs and 'proper' treatment costs. 'Proper' treatment costs are the costs for irradiation only or for freezing only, no costs for logistics*

4.4.3 Sensitivity analysis

Assuming a shorter and a longer lifetime, respectively, for new equipment hardly affects the estimated total treatment costs for all analysed intervention measures. Furthermore, using an interest rate of 2 and 6%, respectively, rather than 4% only slightly affects the estimated total treatment costs. Results are summarised in appendix 2.

Using water of industry quality instead of drinking water for the equipment to reduce faecal leakage would only slightly reduce the total costs, namely from €0.81 million to €0.73 million per year.

The annual costs for the dose unit (necessary to decontaminate the scald tank and the carcass) are so low that a cheaper dose unit than the one used in the baseline would hardly affect the total treatment costs for these different intervention measures.

However, the assumed concentration of a chemical substance used to decontaminate the scald tank and the carcass, respectively, has a huge impact on the total estimated annual treatment costs (see figure 4.5). Furthermore, the assumed purchase price per kg chemical substance has an important impact on the total estimated annual treatment costs. Assuming an average purchase price of €2/kg, the total annual treatment costs would decrease (increase) by €1.4 million to €25 million, depending on the concentration used and on the decontamination method chosen (see figure 4.5 for more details).

If the decontamination of carcasses were to lead to the corrosion of processing line equipment, the total costs would be approximately €2 million, resulting in €0.3 million per year if depreciated at 4% and over a lifetime of 8 years.

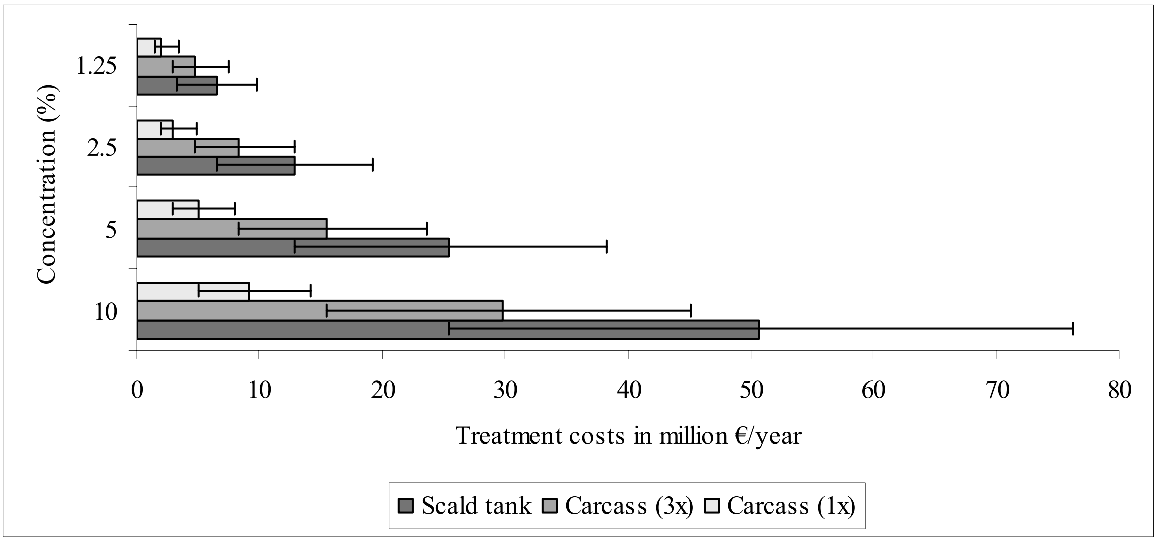

Figure 4.5 Estimated average annual treatment costs for decontamination methods, depending on the concentration used and the assumed purchase price of €2/kg. The bars shows estimated treatment costs if assuming a purchase price of €1/kg and €3/kg, respectively

The annual non-recurrent costs for crust-freezing are €9 million. At an average of €13 million per year (mainly electricity costs), non-recurrent costs make up the greatest part of total annual treatment costs for crust-freezing. However, the actual electricity use in kW/hour for the crust-freezing equipment was uncertain. Assuming an increased electricity use for the crust-freezing equipment of 490 kW per hour, results in an increase of annual treatment costs by €2.3 million.

Assuming an increase (decrease) in the working time required per slaughter group tested by 0.25 working hours would result in an increase (decrease) of the testing costs in processing plants by €0.13 million per year.

4.5 Discussion

4.5.1 The intervention measures under study

The reduction of faecal leakage, the decontamination of scald tanks, the decontamination of carcasses, and crust-freezing are intervention measures that presume long-lasting investments. The estimated annuities vary between €0.15 million and €9.1 million, with decontamination of scald tank being the lowest and crust-freezing the highest annuity to consider. Once implemented, the annuities would have to be paid by the industry over the assumed lifetime, which in this study this was 8 years.

Freezing and irradiation were assumed to be contracted out to specialist industries. Consequently, processing plants have only recurrent costs. However, specialist industries might have to increase their current capacity in order to cope with the increased demand. They, therefore, would have to make long-lasting investments.

Although we assumed that freezing and irradiation would be contracted out to specialist industries, if less costly in the long run when applied in own plants, processing managers would certainly invest in the relevant technology. Therefore, the cost estimates for freezing and irradiation are an over- rather than an underestimation of treatment costs for freezing and irradiation.

In the case of decontamination of the scald tank and decontamination of the carcass with a chemical substance, the concentration used and the purchase price per kg chemical substance determine the total treatment costs. In this study, we focussed on lactic acid as the chemical substance for decontamination, because of the available knowledge within the Netherlands. But apart from lactic acid, there are other chemical substances available, for example other organic acids, chlorine, chlorine dioxide and TSP. Although these different chemical substances might control pathogens, their application is not always allowed by law.

The cheapest treatment costs would be made by implementing equipment to reduce the faecal leakage in the processing line, while irradiation would result in the highest treatment costs of all analysed intervention measures at the processing level. Treating only positively tested flocks is in general cheaper than treating all flocks, despite the additional testing costs made on farm and in the processing plant.

4.5.2 Potential indirect costs

By implementing intervention measures such as crust-freezing and the reduction of faecal leakage, treated broiler meat could be sold as fresh chicken meat and would not be recognised as being treated by the consumer. However, some people from the field were sceptical about the appearance of fresh chicken meat after having undergone crust-freezing. Their fear was that chicken meat would appear 'pale', 'soft' and 'watery'. But, James and colleagues from the University of Bristol (James, pers. communication; September 2004) did not observe in their experiments any change in the appearance of fresh meat.

Decontaminated meat - whether decontaminated in the scald tank or later in the processing line - might have to be labelled as being decontaminated fresh meat. Consequently, consumers would realise that the 'fresh' meat had been decontaminated with a chemical substance. It is questionable whether consumers would accept these products. Furthermore, depending on the chemical substance used and on its concentration, organoleptic changes might occur.

Irradiated meat - whether it has been subject to gamma irradiation or to e-beam - has to be labelled as being irradiated fresh meat. Again, it is questionable whether consumers would accept these products. For example, in the United States only a few food processors and retailers offer irradiated products because they fear that consumers will not buy such products (Buzby and Mentzer-Morrison, 1999), despite scientific evidence of the effectiveness of irradiation. Nayga et al. (2004) analysed the willingness to purchase irradiated food products in the United States. Their study suggests that once individuals are informed about the nature of food irradiation technology, they are willing to pay for the reduced risk of foodborne illness. But in order to inform the consumers, large efforts might be required when implementing irradiation as an intervention measure.

Freezing meat and preparing meat results in a product change, with as a consequence indirect costs for the processing plants due to considerable lower selling prices. For example, in Iceland, where the freezing of positively tested flocks was applied as a control measure, the substantially lower prices paid to producers for frozen lots have been an important factor to reinforce hygiene at farm level (Stern et al., 2003).

Scheduled treatment and treating only positively tested flocks might carry the risk of resulting in two separate channels, whereby treated meat might be considered less valuable than non-treated meat. Indirect costs due to a decreased selling price of treated meat for processing plants and/or farmers might be the consequence.

Organoleptic changes, product changes and non-acceptance by consumers might force processing plant to sell their treated meat at a lower price than fresh meat, all indirect costs related to the implementation of an intervention. These potential indirect costs might vary from €140 to €480 million per year if all carcasses are treated, and from €40 million to €140 million per year if only carcasses of positively tested flocks are treated, depending on the assumed price reduction.

4.5.3 Conclusion

If additional direct and indirect costs related to the implementation of intervention measures cannot be passed on to other stakeholders - either downwards to the farmers or upwards to retailers and consumers - then the estimated direct costs (treatment and testing costs), the potential indirect costs due to price reduction and the additional costs (direct and indirect) due to scheduled treatment would have to be borne by Dutch broiler processing plants, resulting in lower margins.

However, higher production costs, resulting from national intervention measures, would weaken the competitiveness of the Dutch broiler processing sector in and outside the Netherlands, leading in the long-term to a potential important shrinking of the Dutch broiler processing sector. Increased imports of less safe meat might be one of the consequence.

5. Intervention measures at the consumer level

5.1 Background information

The foods contaminated with Campylobacter or other emerging pathogens usually look, smell and taste normal, and therefore visual identification is not possible (Tauxe, 1997). During meal preparation at home, individuals can be exposed to Campylobacter from fresh chicken through a variety of pathways (Anderson et al., 2003). The widespread dissemination of campylobacters or other foodborne pathogens via the hands and work surfaces during the preparation of meals has been demonstrated in different studies (e.g. Gorman et al., 2002; Humphrey et al., 2001). In a study conducted in 1995/96, Altekruse et al. (1999b) investigated the food handling and/or food consumption practices of 19,356 adults in eight states in the US. In this study, 19% of respondents were found to inadequately wash their hands and/or cutting boards after contact with raw meat or chicken, 20% ate pink hamburgers, 50% ate undercooked eggs, 8% ate oysters and 1% drank raw milk.

According to Allos (2001) and Peterson (1994), chicken should be adequately cooked. And cutting boards and utensils used in handling uncooked chicken or other meats should be washed with hot soapy water before being used for the preparation of salads or other foods that are eaten raw. A careful food preparation habit in the kitchen is therefore an important prevention measure to decrease campylobacteriosis cases in the Netherlands. Nauta et al. (2005) simulates, with the help of an analytical risk model, the different steps during the preparation of chicken meat and the potential cross-contamination of salads in the kitchen. For more details, see Nauta et al. (2005).

Another possible intervention measure is the freezing of fresh meat at home by the consumer themselves. Freezing has a damaging effect on Campylobacter, resulting in fewer organisms in frozen birds (Stern et al., 1985).

5.2 Selected interventions

By mutual agreement of the Steering Committee of the CARMA project - which includes risk managers at the Ministry of Public Health and the Ministry of Agriculture - and after discussion with the Industry Forum and experts in the field, the following intervention measures concerning consumer level were selected for evaluation:

- kitchen hygiene: hand washing and the use of separate cutting boards and utensils for the preparation of meat and for the preparation of salads or other foods that are eaten raw are promoted;
- home freezing: the home freezing and storing of chicken meat for between several days and a week is promoted.

Details on risk assessment modelling of the different interventions measures are given in Nauta et al. (2005).

5.3 Interventions and assumptions made

Both intervention measures presume a change in consumer behaviour. Such a change might be realised by increasing the awareness and knowledge of effective hygiene procedures in the domestic kitchen. Information or advice to consumers can be given in several ways: information campaigns (television, radio, handouts, Internet, etc.), advertisements, education at schools and universities, courses, labelling, etc.

Information campaigns such as *Maak je niet dik!* (Don't make yourself fat!) and *Eerlijk over eten*[1] (Honest about food) aim to increase awareness and knowledge of the given problem, whereby the underlying goal in the long term is change in consumer's behaviour. The requirements of both information campaigns are comparable with the requirements of an information campaign that should increase the use of separate cutting boards and utensils for the preparation of meat and of other foods, and an information campaign that should increase the home freezing and storing of fresh chicken meat for between several days and a week. For both intervention measures under study, we consider information campaigns as the most appropriate method to increase awareness and knowledge.

The annual costs[2] for this type of information campaign are somewhere between €0.75 million and €1.5 million. It is widely recognised that a permanent behaviour change in the consumer can only be achieved if such a campaign is conducted over several years.

Despite recognising that information campaigns and education are important instruments, which might and should be used to change consumer behaviour, no information was available to quantify a) when people would change their behaviour, b) for how long they would change their behaviour, and c) how many would change their behaviour. Given that not only the costs for, but also the effects of such an information campaign would occur over several years, we made the simplified assumption that the annual effects would be the same over the years, and that these effects would start from the first year onwards. We therefore could consider the annual information campaign costs only as direct yearly costs. We assumed a uniform distribution of the annual costs with as a minimum €0.75 million and as a maximum €1.5 million. By conducting such information campaigns over several years, consumers would be reminded to change their behaviour until a permanent behaviour change would be achieved.

Such a campaign might be paid either by the industry or by public funds. Given that the campaign's benefactors would mainly be individuals, employers and health insurers, rather than the food industry, we assumed that such information campaigns would be promoted and financed with public funds.

[1] Information on the campaigns *Maak je niet dik!* and *Eerlijk over eten* is given on the website of the Netherlands Nutrition Centre (www.voedingcentrum.nl). In October 2004 information on both campaigns was directly accessible. This was: www.voedingscentrum.nl/mirakel/pageViewer.jsp?id=1154 for *Maak je niet dik!* and www.voedingscentrum.nl/mirakel/pageViewer.jsp?id=4150 for *Eerlijk over eten*.

[2] J. Satter (Voedingscentrum), pers. communication; October 2004.

5.4 Results

The mean and the attendant uncertainty of the estimated annual expenses (costs) and the costs per kg of chicken meat consumed, and for an information campaign are summarised in table 5.1.

Table 5.1 Mean and attendant uncertainty of estimated annual costs and annual costs/kg chicken meat consumed in the Netherlands for an information campaign

	Minimum	5^{th} percentile	Mean/ median	95^{th} percentile	Maximum
Total costs (in €m)/ year	0.75	0.79	1.13	1.46	1.50
Costs (in €cts)/ kg chicken meat consumed in the Netherlands a)	0.28	0.30	0.42	0.55	0.57

a) Assuming a Dutch consumption of poultry meat of 265 million kg in the year 2000 (PVE, 2002).

The costs in table 5.1 are for one information campaign only. Such a campaign could either increase the use of separate cutting boards and utensils for the preparation of meat and of other foods, or increase the home freezing and storing of fresh chicken meat. If the choice is to apply both interventions, then two separate information campaign would need to be set up; consequently, the costs would double.

5.5 Discussion

Campylobacter in Dutch and in imported broiler meat could be tackled by informing and educating the Dutch consumer, whereas intervention measures applied on Dutch farms or in Dutch processing plants only would control only a fraction of all broiler meat consumed in the Netherlands.

However, measuring the effect of information campaigns is a recognised problem. To our knowledge, there have been no long-term studies (if any at all) into the impact of such campaigns.

Apart from information campaigns, there are also other methods to influence consumer behaviour, for example via education in schools. However, again no information was available about the effectiveness of the different potential information and communication methods. Independent of the methods chosen, experts argue that campaigns and education programmes would have to be conducted over several years in order to bring about a permanent change in consumer behaviour.

6. Summary and general discussion

6.1 The main results in short

Before starting with the general discussion, we have summarised in table 6.1 for all interventions under study the intervention costs estimates, both total and divided into which stakeholder bears the costs. Table 6.1 provides only the main results. Details of the assumptions made and the results themselves have been described in previous sections and will therefore not be repeated here.

Table 6.1 Mean estimates of total annual intervention costs, annual costs for farmers, annual costs for industry and annual expenses for government for all intervention measures under study

Intervention	Annual intervention costs in €million/year			
	Total	Farmers	Industry	Government
Intervention costs applied on broiler farms a)				
Thinning - all	1	1	-	-
Hygiene on the farm - all	8-64 b)	8-64 b)	-	-
Phage therapy - all	7	7	-	-
Phage therapy - PCR c)	4	3	1	-
Intervention costs applied at processing level				
Red. faecal leakage - all	1	-	1	-
Decontamination of scald tank :lactic acid - all	13 f)	-	13 f)	-
Decontamination of scald tank: TSP d) - all	51	-	51	-
Decontamination of carcass: lactic acid (1x) - all	8 f)	-	8 f)	-
Decontamination of carcass: lactic acid (1x) - PCR c)	5 f)	1	4 f)	-
Decontamination of carcass: lactic acid (3x) - all	26 f)	-	26 f)	-
Decontamination of carcass: lactic acid (3x) - PCR c)	10 f)	1	9 f)	-
Decontamination of carcass: TSP d) (1x) - all	30	-	30	-
Decontamination of carcass: TSP d) (1x) - PCR c)	11	1	10	-
Decontamination of carcass: TSP d) (1x) - all	97	-	97	-
Decontamination of carcass: TSP d) (1x) - PCR c)	31	1	30	-
Crust-freezing - all	13	-	13	-
Crust-freezing - PCR c)	13	1	12	-
Irradiation - all	59 f)	-	59 f)	-
Irradiation - PCR c)	19 f)	1	18 f)	-
Freezing - all	32 f)	-	32 f)	-
Freezing - PCR c)	12 f)	1	11 f)	-
For prepared meat use only - PCR c)	79 e)	1	78 e)	-
Intervention costs applied at consumer level				
Kitchen hygiene	1	-	-	1
Home freezing	1	-	-	1

a) Mono-species farms was estimated to be not effective (Katsma et al. (2005) for details). No cost estimate was made; b) The intervention costs for hygiene on the farm are the minimum and maximum estimated costs, if applying the Bolder approach between successive rotations, as an example for potential additional hygiene measures; c) Additional costs for positively tested and treated flocks, using a PCR test and assuming no costs for scheduled treatment. Similar cost estimates for dipstick and culture. Not considered are potential scheduled treatment costs (see section 4); d) We had no information of the purchase price for TSP. We therefore used the price for lactic acid; e) Apart from the testing costs, the main costs for this scenario is a reduction of the selling price for slaughterhouses (indirect costs). It is therefore not realistic to consider testing costs as the *only* costs. Assumed price reduction is €0.4 cts/kg; f) Assuming no indirect costs. If there were to be, the total costs and the costs for industry would increase (see section 4).

In each of the previous chapters we described the different sensitivity analyses applied. In this short summary we therefore only discuss assumptions that have an important impact on our final outcomes. These were:

- the cost estimate for hygiene on the farm is very uncertain, mainly because it is unknown which potential hygiene measure(s) to apply and in what frequency, in order to control Campylobacter introduction in broiler flocks;
- in the case of phage therapy, the assumed cost per chicken treated is an important factor for the total cost estimate for phage therapy;
- at the processing level, mainly the concentration of the chemical substance used and the assumed purchase price of that substance have a huge impact on estimated costs for the decontamination of scald tanks and the decontamination of carcasses.

6.2 General discussion

The reduction of faecal leakage, the decontamination of scald tanks, the decontamination of carcasses, and crust-freezing are intervention measures that presume long-lasting investments for processing plants. Irradiation and freezing might force specialist industries to apply long-lasting investments. Once a long-lasting asset is purchased or constructed, it is often difficult or costly to change, alter or reverse a capital investment decision. It is also attractive to plan such investments far ahead, as they then can be integrated in normal investment projects and maintenance schedules. These facts should not be forgotten when deciding on potential interventions to implement in the chicken meat chain.

The lowest treatment costs would be incurred by implementing equipment to reduce the faecal leakage on the processing line, and possibly chemical decontamination, depending on the concentration chosen, while irradiation would result in the highest treatment costs of all analysed intervention measures at the processing level.

The average annual prevalence of positively tested broiler meat is over 30%. Scheduled treatment and treating in general, only positively tested flocks is far cheaper than treating all flocks, despite the additional testing costs incurred on the farm and in processing plants. However, when scheduled treatment would result in two different meat streams, whereby positively tested meat would be considered less valuable than negatively tested meat, the indirect costs due to e.g. reduced selling prices might be enormous.

It is the fresh broiler meat market in the EU in particular where the Dutch broiler meat sector gets its surplus value, and consequently its ability to compete with such nations as Brazil and Thailand. But with an average annual prevalence of over 30% positively tested broiler flocks in the Netherlands, some of the interventions, - if treated meat is than not recognised as fresh meat -, result in a shortage of fresh meat, and consequently in the potential loss of market shares. Especially in the summer months, with an increase in prevalence of up to 60%, the supply of fresh meat cannot cover the demand. Therefore the recognition and acceptation of treated meat as 'fresh' meat is crucial for the Dutch broiler industry.

However, only roughly estimated, we could show that potential indirect costs due to e.g. potential price reductions for processing plants because of organoleptic changes, product changes, the non-acceptance by consumers would be far higher for the various intervention measures under study than the estimated direct costs, such as treatment and testing costs. For a more precise estimation of the potential indirect costs, however, other economic studies would be required, which were beyond the scope of this study.

Campylobacter control in broilers does not result in savings or a reduction of the production costs on farms and processing plants. Assuming no pass-on of increased production costs due to the implementation of interventions in the chicken meat chain to other stakeholders implies that the costs for interventions applied at farm level, processing level and consumer level would have to be borne by farmers, processing plants and government, respectively. In reality, however, costs occurring in the industry and at retail level are often spill-through either to farmers or to consumers. But, with an average labour income of €10,500/farm/year or €12 million/year for the whole broiler farm sector, the resources of Dutch broiler farmers to bear higher production costs are rather limited. Furthermore, the level of price-based competition between countries in this sector is high. Therefore, if intervention measures would only be applied in the Netherlands, additional costs could not be spilled-through to consumers without losing market shares, letting processing plants and farmers bear them. Consequently, financial margins of processing plants and farmers would decrease.

One complicating factor is that over two thirds of all chicken meat produced in the Netherlands is exported. By carrying out a national action to control Campylobacter in chicken meat, the production costs for only Dutch-produced broilers and broilers slaughtered in the Netherlands would increase. It has to be recognised that Campylobacter is only one of several potential pathogens which might be found in chicken meat. If foreign and Dutch consumers are not willing to pay more for safer broiler meat, the competitiveness of the Dutch broiler processing sector both in and outside the Netherlands would weaken. In the long term, the Dutch broiler sector would undergo an important shrinking. Furthermore, increased demand for cheaper but not necessarily safer imported meat, might be the consequence. The Dutch broiler sector might profit from such a national action if, and only if, it somehow succeeds in convincing consumers both in and outside the Netherlands that it is worth paying higher prices for safer broiler meat, and that Dutch broiler meat is safer than any other. This might be possible if Dutch broiler meat were to be recognised by consumers as being a high-quality rather than a bulk product. But before any pay-off from the efforts would be seen, large efforts - including monetary efforts - would need to be made, especially in product development and marketing. It is unlikely that all business involved can make this change in strategy and in an optimistic case a restructering of the industry would happen. Such a strategy and restructering however would be in line with suggestions for the future of the troubled industry, as a results of changing agricultural policy and environmental policy (e.g. Backus, 2004).

The interventions under study in CARMA have economic implications for the partners in the food production chain. But the majority of effects - such as the reduction of gastroenteritis and associated days of paid work lost - will be effectuated in other parts of society.

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Appendix 1 Parameters used in the farm model

Parameter	No thinning - producing:			Thinning		Remarks
	Light broilers	Mid-sized broilers	Heavy broilers	First slaughter group	Second slaughter group	
Age when slaughtered (in days)						Modelled as truncated normal distribution; based on FADN data
Average	37.5	39.32	43.78	44.38		
S.D.	1.89	1.99	2.09	2.18		
Minimum	35.0	36.0	39.0	38.0		
Maximum	41.0	45.0	49.0	50.0		
Time in between two rotations						Modelled as truncated lognormal distribution; based on FADN data; no difference between the groups
Average		← 11.43 →				
S.D.		← 5.58 →				
Minimum		← 3 →				
Maximum		← 40 →				
Number of rotations per year a)						Modelled as truncated normal distribution; estimated
Average	7.43	7.16	6.62	6.54		
S.D.	0.3	0.3	0.25	0.26		
Minimum	6.35	6.07	5.76	5.61		
Maximum	8.35	8.09	7.31	7.31		
Surface in m^2 per farm	*Number of broiler houses x 1130 m^2 per broiler house*					Calculated
Number of day-old chicks per m^2						Modelled as truncated normal distribution; based on FADN data
Average	23.88	22.70	21.36	23.87		
S.D.	1.68	2.10	2.30	1.59		
Minimum	20.53	19.40	17.78	20.27		
Maximum	26.60	27.56	27.89	27.86		
Number of day-old birds bought per farm flock	*Surface in m^2 per farm x number of day-old chicks per m^2*					Calculated
Mortality rate (in %)						Modelled as truncated lognormal distribution; based on FADN data; no difference between the groups
Average		← 4.4 →				
S.D.		← 2.6 →				
Minimum		← 0.03 →				
Maximum		← 15.4 →				
Number of birds delivered / farm flock	*Number of day-old chicks bought per farm flock, corrected for mortality*					Calculated
Percentage of birds delivered per slaughter group	100	100	100	22	78	Based on FADN data (using the average)
Number of birds per slaughter group	*Number of delivered broilers per farm flock x percentage of birds that are delivered per slaughter group*					Calculated
Weight of broilers when slaughtered (in g)						Modelled as truncated normal distribution; based on FADN data
Average	1,633	1,844	2,180	1,560	2,174	
S.D.	56	84	127	102	139	
Minimum	1,507	1,701	2,006	1,292	1,833	
Maximum	1,699	1,995	2,490	1,966	2,548	

a) In order to save some calculation time, we modelled the number of rotations per year separately and used the estimated distribution in our final model only.

Parameter	No thinning - producing: Light broilers	Mid-sized broilers	Heavy broilers	Thinning: First slaughter group	Second slaughter group	Remarks
Total delivered broilers (in kg) per farm flock	*For each slaughter group individually (and sum up): Number of delivered broilers/slaughter group x weight of birds when slaughtered*					Calculated
Farm-to-gate price (€/kg) b)						Modelled as truncated normal distribution and correlated to the feed price (r=0.76); considered as being *variable over the years*
Average			← 0.71 →			
S.D.			← 0.06 →			
Minimum			← 0.59 →			
Maximum			← 0.79 →			
Live weight broiler prices (=100) in relation to other category broiler prices c)						Modelled as a uniform distribution
Minimum	100	97	96	98		
Maximum	100	100	100	101		
Return per farm flock	*Total delivered broilers (in kg) per farm flock x (farm-to-gate price/kg x difference in farm-to-gate price)*					Calculated
Price for chicks (€/chick) d)						Modelled as truncated normal distribution; based on FADN data
Average			← 0.25 →			
S.D.			← 0.01 →			
Minimum			← 0.24 →			
Maximum			← 0.27 →			
Costs for chicks (€/farm flock)	*Number of day-old chicks bought x price for chicks*					Calculated
Price for feed (€/kg) e)						Modelled as truncated normal distribution and correlated to the feed price (r=0.76); considered as being *variable over the years*
Average			← 0.23 →			
S.D.			← 0.01 →			
Minimum			← 0.20 →			
Maximum			← 0.25 →			
Feed conversion (kg feed/kg delivered broiler)						Modelled as truncated normal distribution; based on FADN data
Average	1.67	1.74	1.79	1.79		
S.D.	0.04	0.07	0.07	0.09		
Minimum	1.61	1.60	1.64	1.61		
Maximum	1.73	1.97	1.93	2.09		
Feed costs (€/farm flock)	*Feed conversion x kg delivered broilers x price for feed*					Calculated

b) Farm-to-gate prices fluctuate over the years. We therefore opt to use a larger dataset than only prices in 2000. The current distribution is based on the monthly broiler prices €/kg of 1600 g broilers from 1993 until 2003 as registered by LEI (Jan Bolhuis, pers. communication; Augustus 204); c) The farm-to-gate price for broilers varies, depending on the live weight of broilers. However, price statistics are mostly collected only for one production type. We used the average farm-to-gate price of the different production types of the years 1998-2002 as estimated by Arie Bijl (pers. communication) for DLV clients (not public); d) The current distribution is based on the monthly day-old chick price in €/kg from 1993 until 2000 from LEI. No data was collected after 2000 (Jan Bolhuis, pers. communication; Augustus 204); e) Feed price fluctuates over the years. The feed price is highly correlated with the farm-to-gate price. The current distribution is based on monthly data from 1993 until 2003 for 8-ton orders (Jan Bolhuis, pers. communication). But given that broiler farms order larger amounts, a downward correction of the prices was applied. The correction was based on the difference found between the LEI feed price and the average DLV feed prices for the years 1998-2003.

Parameter	No thinning - producing:			Thinning		Remarks
	Light broilers	Mid-sized broilers	Heavy broilers	First slaughter group	Second slaughter group	
Heating costs (in €cts/day-old chicks)						Modelled as truncated lognormal distribution; based on FADN data
Average			← 0.79 →			
S.D.			← 3.08 →			
Minimum			← 0.24 →			
Maximum			← 8.96 →			
Heating costs (€/farm flock)	*Number of day-old chicks x heating costs/chick*					Calculated
Other variable costs accountable to broiler production (€cts/day-old chick) f)						Modelled as truncated normal distribution; based on FADN data
Average	10.1	10.4	11.2	11.6		
S.D.	1.2	1.7	1.8	2.1		
Minimum	6.8	7.5	9.0	7.5		
Maximum	17.2	18.8	14.4	18.8		
Other variable costs (€/farm flock)	*Number of day-old chicks x other variable costs/chick*					Calculated
Gross margin (€/farm flock)	*Return - chick costs - feed costs - heating costs - other variable costs*					Calculated
General costs not directly accountable to broiler production (€cts/day-old chick) g)						Modelled as truncated normal distribution; based on FADN data
Average	2.2	3.1	4.6	4.6		
S.D.	0.8	1.6	1.5	1.9		
Minimum	1.2	1.2	1.6	1.0		
Maximum	3.5	10.5	9.4	11.1		
General costs (€/farm flock)	*Number of day-old chicks x other variable costs/chick*					Calculated
Corrected gross margin (€/farm flock) h)	*Gross margin - general costs*					Calculated
Corrected gross margin (€/farm/year)	*Corrected gross margin per farm flock x number of rotations/year*					Calculated
Fixed costs (€cts/m^2/day) i)						Modelled as truncated normal distribution; based on FADN data
Average	6.0	5.1	4.0	4.0		
S.D.	1.1	1.9	1.3	1.3		
Minimum	3.8	1.4	1.4	1.0		
Maximum	7.4	8.2	7.6	6.5		
Labour income (€/farm/year)	*Corrected gross margin per year - fixed costs*					Calculated

f) Other variable costs include health costs, straw, hired labour, electricity, etc.; g) General costs include costs for accounting, manure, telephone, water, etc. The proportion of the general costs at the expense of the broiler production is estimated in the beginning of an accounting year; h) Fixed costs comprise the depreciation of the broiler house(s) and the inventory, interest, maintenance and insurance of broiler houses and the inventory; i) Labour income is the money the farmer has left over after having subtracted his variable and fixed costs, but excluding his own labour.

Appendix 2 Sensitivity analysis - annual treatment costs

Table A2.1 Estimated annual treatment costs for the different intervention measures under study, depreciating the average costs over a lifetime of 6, 8 and 10 years, respectively, and using an interest rate of 2, 4 and 6%, respectively

	6 years			8 years			10 years		
	2%	4%	6%	2%	4%	6%	2%	4%	6%
Treating all carcasses									
Reducing faecal leakage	0.9	0.9	0.9	0.8	**0.8**	0.8	0.7	0.7	0.8
Decont. scald tank a)	12.8	12.9	12.9	12.8	**12.8**	12.8	12.8	12.8	12.8
Decont. carcasses (3x) a)	25.8	25.9	26.0	25.4	**25.5**	25.6	25.2	25.3	25.4
Decont. carcasses (1x) a)	8.4	8.5	8.5	8.2	**8.2**	8.3	8.0	8.1	8.2
Crust-freezing	14.7	15.5	16.2	12.1	**12.9**	13.6	10.6	11.3	12.1
Irradiation	-	-	-	-	**58.6**	-	-	-	-
Freezing	-	-	-	-	**31.9**	-	-	-	-
Testing and treating only birds from positively tested flocks									
Decont. carcasses (3x) a)	8. 6	8.7	8.8	8.2	**8.3**	8.4	8.0	8.1	8.2
Decont. carcasses (1x) a)	3.1	3.2	3.3	2.9	**3.0**	3.0	2.8	2.8	2.9
Crust-freezing	13.1	13.8	14.6	10.5	**11.3**	12.0	9.0	9.7	10.5
Irradiation	-	-	-	-	**17.0**	-	-	-	-
Freezing	-	-	-	-	**9.4**	-	-	-	-

a) Only costs shown for decontamination with 2.5% lactic acid. If using a 10% TSP solution, the non-recurrent costs are the same. The recurrent costs (≥ 90% of total costs), however, would quadruple, assuming same purchase costs/kg for TSP and lactic acid.