CamCon

Campylobacter control - novel approaches in primary poultry production

Deliverable 4.5.2: Report on major outcomes of WP4
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The Major outcomes of CamCon project Workpackage 4 on Risk Assessment and Economics

The CamCon project WorkPackage 4 on Risk Assessment and Economics resulted in four research papers and three reports. The abstracts of the papers, deliverables 4.1.1, 4.3.1 and 4.4.1., summarize the main results and are given below in chapter 1.

In chapter 2 the selection of interventions for primary broiler production is presented and discussed. Most of these interventions were based on risk factors identified in the CamCon project WP 1 and further analysed in the paper summarized in abstract 1.2. below and a few were based on risk factors identified in other studies, analysed in deliverable 4.2.1.

In chapter 3 the CamCon results on cost-effectiveness of interventions at primary broiler production are compared with previously reported results on the cost effectiveness of interventions during processing. It shows that comparison is difficult due to differences in approach and differences in assumptions made. Generally speaking, the cost-effectiveness of the farm-level interventions shows a wider range of outcomes than the cost-effectiveness of interventions during slaughter and processing in previous studies.

Chapter 4 summarizes the main conclusions.

Chapter 1 Abstracts of research papers

1.1 The effect of reducing numbers of *Campylobacter* in broiler intestines on human health risk

M.J. Nauta, G. Johannessen. L. Laureano Adame, N. Williams and H. Rosenquist.

One option for *Campylobacter* control in broiler chickens is to reduce the concentration in the intestinal content of the birds prior to slaughter, for example by vaccination or phage therapy. It is however unsure how such a reduction in concentration can be translated into a reduction in concentration on the meat and a reduction in the human health risk of campylobacteriosis. In this study, two methods are presented and compared. The first is a linear regression model, based on count data from caecal contents and skin sample data, obtained after processing from the same flocks. Alternatively, a previously published risk assessment model is used, that describes the dynamics of transfer and survival of *Campylobacter* during broiler processing at the slaughterhouse. Data from five European countries are used as inputs for the models. For both approaches the analyses show that a one to two log reduction in concentration in the intestinal content has a large impact on the risk: a relative risk reduction between 44 and 95%. Therefore interventions aiming at a reduction of the concentration of *Campylobacter* in the broiler intestines seems promising. However, it is not possible to derive a generic rule that can be used to relate a reduction in concentration in broiler intestines into a reduction in human health risk: Regression models based on different data sets predict different relationships between bacterial count data from caeca and skins, whereas the risk assessment model requires data on contamination of the birds' exterior, which is not sufficiently available in combination with caecal concentration data. Simulations performed with the risk assessment model show that it can pretty well describe the observed correlation in the data and the variation in regression lines obtained.

1.2 Translation of risk factor estimates into effects of on-farm interventions on *Campylobacter* broiler flock prevalence

H.M. Sommer, B. Borck Høg, H. Rosenquist and M.J. Nauta

Before making risk management decisions to control *Campylobacter* prevalence in broiler flocks, it is important to identify effective interventions. Commonly, on-farm interventions are derived from risk factor studies. These risk factors may seem to have large effect, but in practice interventions related to these risk factors may have only limited effect, since it may only be feasible to implement the interventions on a relative small proportion of the farms. In general, the translation of risk factors into practical interventions and the subsequent estimation of the effect of these interventions in terms of reduced flock prevalence is challenging. We present a novel tool for risk assessors to obtain such estimates of the effect of interventions.

Previously, in a risk factor study based on data from six European countries, five risk factors were found to have a significant impact on *Campylobacter* flock prevalence in all countries. In the present study, these risk factors were translated into practical on-farm interventions. A statistical method was developed that allowed an estimation of the population flock prevalence after implementation of these interventions in broiler farms. The method is anchored in the ideas behind standardized population estimations. In order to obtain a country wise population estimate the predicted prevalence values are multiplied with elements from a reference population. In the present study, the reference population consisted of data from the risk factor study plus extra data from a large questionnaire survey to improve the representativeness of the reference population.

Based on the prevalence estimates obtained in the EU baseline study of 2008, changes in flock prevalence after implementation of the interventions were assessed. The results showed that some individual interventions only resulted in a limited reduction in prevalence if the biosecurity was not accounted for. Furthermore, the effect of the interventions differed between countries, depending on current farm management practices and *Campylobacter* prevalence. In general, the most effective interventions were “building new houses with strict biosecurity for all houses older than 15 years” and “apply drinkers with nipples without cups”.

Results from this translation method can be applied to describe the effectiveness in a study of the cost effectiveness of implementing specific interventions. The developed methodology can be applied for other pathogens and farm animals as well.

1.3 Impact of technical and economic farm performance on costs of *Campylobacter* interventions on broiler farms in six European countries

C.P.A. Van Wagenberg and P.L.M. Van Horne.

Campylobacter is one of the leading causes of acute diarrheal disease worldwide and can cause severe sequelae. Because broilers are an important reservoir for human *Campylobacter* infections, it is relevant to control *Campylobacter* on broiler farms. This study analysed the impact of a country’s average technical and economic farm performance and national economic factors on the costs of *Campylobacter* interventions on broiler farms. A farm calculation model based on the economic engineering-approach was developed to estimate costs of eight interventions in Poland, Spain, the United Kingdom, the Netherlands, Denmark, and Norway for the year 2009. Results showed that the costs of an intervention in the most expensive country were between 67% and 550% higher than in the cheapest country. Across interventions, Poland had the lowest costs, Denmark and Norway the highest. Across countries, the interventions building an anteroom with hygiene barrier, applying designated tools and applying fly screens (only cost estimate for Denmark) had the lowest costs and replacing old houses with new houses, slaughter at 35 days and a ban on thinning (partial depopulation) the highest, applying drink nipples without a cup and having a maximum downtime of ten days resulted in intermediate costs. We concluded that estimated costs of *Campylobacter* interventions on broiler farms varied substantially between countries due to differences in average technical and economic farm performance and in national economic factors.

1.4 Cost-effectiveness of Campylobacter interventions on broiler farms in six European countries

C.P.A. van Wagenberg, P.L.M. van Horne, H. M. Sommer, M.J. Nauta

Campylobacter is one of the leading causes of acute diarrheal disease worldwide and can cause severe sequelae. Because broilers are an important reservoir for human *Campylobacter* infections, it is relevant to control *Campylobacter* on broiler farms. Cost-effectiveness of eight *Campylobacter* interventions on broiler farms, selected on the basis of a European risk factor study and other risk

factor research, was analysed in the six European countries Poland, Spain, the Netherlands, the United Kingdom, Denmark and Norway. A calculation model was developed that considered differences between these countries in size of poultry production, import and export, in the effect of interventions on the prevalence of *Campylobacter* in broilers, in the disease burden of *Campylobacter* related human illness, and in technical and economic farm performance. Results showed that costs and cost-effectiveness of interventions differed substantially between interventions and for each intervention between countries. For each intervention, the cost-effectiveness in the country with the highest costs per avoided DALY was at least 9 times higher than in the country with the lowest costs per avoided DALY. Applying separate designated tools for each farm house and building an anteroom with hygiene barrier in each farm house were the interventions with the lowest costs and cost per avoided DALY across countries. A ban on thinning (partial depopulation), slaughter at 35 days, replacing old houses by new houses, and applying drink nipples without cup had the highest estimated costs and cost-effectiveness. Applying fly screens in Denmark resulted in an intermediate cost-effectiveness. A maximum downtime between crops of ten days showed the largest difference in cost-effectiveness between countries with high cost per avoided DALY in Denmark, the Netherlands and the United Kingdom, low costs per avoided DALY in Spain, and a benefit per avoided DALY in Poland. We conclude that the estimated costs and cost-effectiveness of on-farm *Campylobacter* interventions differed substantially between the six countries and that none of these interventions combined low costs and a large disease burden reduction.

Chapter 2 On-farm interventions

Identifying risk factors for the introduction of *Campylobacter* into broiler flocks is an important first step to decide upon on-farm interventions. The next and less explored step is the translation of risk factors into estimated effects of interventions in terms of a decrease in the overall population prevalence value for each country. The risk factors identified in the risk factor study in WP1 are listed in Table 1. Two risk factors *Temperature* and *Country* are not shown since these are factors that cannot be intervened upon. The two last risk factors in the table were not as such significant but played a role in the *Downtime* risk factor. Building anterooms and barriers in all houses was not an intervention in itself since the interaction term *Anteroom/barrier x Age of house* showed that this only had an effect for new and medium-new houses, that is, those that are less than 15 years old. The same applies for the risk factor *Tools* which also only had an effect in newer houses.

Table 1 Identified risk factors from the risk factor study of Sommer et al., workpackage 1.

Risk factors	Categories	Target situation	Intervention
Anteroom/ barrier	anteroom+barriers in all houses: yes no	both physical barrier and anteroom in all houses	-
Anteroom/ barrier x Age of house (interaction term)	anteroom+barriers in all houses x age of house: yes x <5, 6-15, >15 no x <5, 6-15, >15	both physical barrier and anteroom in all houses < 15 years	build anteroom and barrier in all houses < 15 years
Downtime	0 1-9 10-19 20-29 ≥30 days	downtime <10 days	reduce downtime to < 10 days + rodent control > 5 times a year + disinfection (improved cleaning) between all crops at the end of downtime
Age of house	<5 6-15 >15 years	< 15 years of age	build new house if > 15 years + anteroom and barrier + nipples without cups+ designated tools
Drinkers	nipple nipple with cup bell	nipples without cups	apply nipples without cups in all farms
Tools	designated tools per house: yes no	each house has its own tools (basic equipment)	-
Tools x Age of house (interaction term)	designated tools x age of house: yes x <5, 6-15, >15 no x <5, 6-15, >15	each new house (<15 years) has its own tools (basic equipment)	have designated tools in each house younger than 15 years
Cleaning	yes no	disinfection between all crops	-
Frequency of rodent control	>5 times a year 3-5 times 1-2 times	farmer applies rodent control (either by hired company or by themselves)	-

Three risk factors that were previously identified as being important, but could not be analysed in CamCon WP1, are listed in Table 2 and are included as potential interventions. These risk factors were not identified in the risk factor study from Camcon WP1 of several reasons: *Fly screen* was removed from the risk factor model (even though significant) due to at that time only three farms in the data set had screened houses. *Thinning* was included in the questionnaire performed in CamCon WP1 but most samples were only collected at the first depopulation, which ruled out the possibility of estimating an effect of thinning. *Age of chicken at slaughter* was not included in the questionnaire and thus it was not possible to relate flock contamination with slaughter age in the risk factor study.

Table 2 Additional risk factors identified in the literature as being important.

Risk factors	**Categories**	**Target situation**	**Intervention**
Fly screen	yes no	fly screens on all inlets for houses and < 15 years	apply fly nets in houses < 15 years and with high biosecurity
Thinning	yes no	no thinning	stop thinning
Age of chicken at slaughter	< 35 days ≥ 35 days	35 days or less	slaughter at 35 days

The effect of the risk factors from Tables 1 and 2 were translated into estimated of the effect of the given intervention. However, the methods to achieve these results were different depending on the origin of the risk factor, whether they originated from the risk factor study with detailed parameter estimates for all combinations of the significant factors or they originated from the literature (Bahrndorff et al 2013, EFSA 2010). The method applied for the risk factors identified in CamCon WP1, Table 1 are described in the manuscript of Sommer et al, Deliverable 4.1.1. (abstract 1.2 in Chapter 1) and the methods applied for the risk factors in Table 2 are described in CamCon Deliverable 4.2.1 ”Data collected for risk assessment and economics”.

Table 3 provides the percentages of farms involved in the intervention, that is the proportion of farms in which it was possible to apply the given interventions. The flock prevalence estimates for different countries are given, before (baseline situation, based on the EU baseline study 2008) and after interventions. The relative risk reductions indicate the change in prevalence due to the interventions, as a percentage.

The effects of the interventions, given in Table 3, show that there is not a single intervention that has a large effect of flock prevalence in all countries. For most interventions the absolute reduction of prevalence is less than five percent. In general, looking at the reduction in terms of relative risk reduction the building of new houses and the application of drinkers with nipples without cups stand out as most effective. There are however differences between countries, which are related to their current farm management practices. In Norway the reduction of downtime comes out as most effective, because the downtime periods in that country are currently long. In Spain building new houses for all houses older than 15 years has a large effect on the flock prevalence, because there are relatively many farmhouses older than 15 years.

Table 3. Impact of interventions. For explanation see text The most effective interventions in the different countries are given in bold.

Intervention	**involved in intervention (% of all farms)**						**Campylobacter prevalence after control (%)**						**Relative risk reduction (%)**					
	DK	*ES*	*NL*	*NO*	*PL*	*UK*	*DK*	*ES*	*NL*	*NO*	*PL*	*UK*	*DK*	*ES*	*NL*	*NO*	*PL*	*UK*
Baseline situation							19.2	87.7	24.2	3.3	79.2	75.8						
Anteroom/ barrier in new houses	*27.5*	*30.6*	*48.8*	*37.2*	*39.9*	*36.8*	17.4	84.2	21.0	2.9	77.0	71.5	9.4	4.0	13.2	12.1	2.8	5.7
Downtime	20.6	89.3	25	96.3	84.1	15.4	17.8	79.0	22.5	**1.9**	72.9	74.3	7.3	9.9	7.0	42.4	8.0	2.0
New houses	42.2	66.3	34.4	30.5	49.0	48.7	**14.9**	**38.1**	**17.9**	2.4	76.0	**55.5**	22.4	56.6	26.0	27.3	4.0	26.8
Drinkers	85.3	81.1	50.8	68.9	67.8	78.6	**14.5**	80.3	20.9	2.5	75.1	67.0	24.5	8.4	13.6	24.2	5.2	11.6
Designated tools per house in new houses	2.0	25.5	32.8	7.9	8.2	36.8	18.9	82.4	20.3	3.1	78.7	67.3	1.6	6.0	16.1	6.1	0.6	11.2
Stop thinning	24.8	49.1	42.2	3.3	49.4	63.4	16.5	80.4	18.4	3.2	69.6	60.0	14.1	8.3	24.0	3.0	12.1	20.8
Slaughter at 35 days	85.0	94.6	85.3	5.1	97.4	80.2	17.2	75.5	19.0	3.3	**66.5**	66.9	10.4	13.9	21.5	0.0	16.0	11.7
Fly nets in houses < 15 years and with high biosecurity	33.0						16.6						13.5					

3. Comparison of the cost effectiveness of interventions at primary production and interventions during processing

Several interventions for *Campylobacter* control during slaughter and processing have been proposed in previous studies (Mangen et al., 2007, Elliot et al., 2012) and a summary is presented in Table 1.

Table1 : Cost-effectiveness of Campylobacter interventions during slaughter and processing from some previous studies

Intervention	Cost-effectiveness (€/ averted DALY)	Country	Source
Limiting fecal leakage	-15,000 – -14,000	Netherlands	Mangen et al., 2007
Decontamination carcass	37,000 – 64,000	Netherlands	Mangen et al., 2007
Irradiation	204,000 – 466,000	Netherlands	Mangen et al., 2007
freezing	72,000 – 239,000	Netherlands	Mangen et al., 2007
Best practice hygiene	1,487 – 3,347	EU-27	Elliot et al., 2012
Chemical decontamination	1,078 – 3,235	EU-27	Elliot et al., 2012
Freezing (2-3 weeks)	2,710 – 4,291	EU-27	Elliot et al., 2012
Hot water	2,248 – 6,068	EU-27	Elliot et al., 2012
UV irradiation	2,536 – 3.804	EU-27	Elliot et al., 2012

The cost-effectiveness of interventions presented by Elliot et al. (2012) is lower than the cost-effectiveness presented by Mangen et al. (2007). Differences in definition of the intervention, in size of poultry production, in reduction in cost-of-illness and in disease burden reduction in DALY explain the different values for the cost-effectiveness between these studies.

The cost-effectiveness in our study is presented in Table 2. Applying separate designated tools for each farm house and building an anteroom with hygiene barrier in each farm house were the interventions with the lowest cost per avoided DALY across Poland, Spain, Netherlands, United Kingdom, Denmark and Norway (€14 – €6,753 per averted DALY). A ban on thinning (partial depopulation), slaughter at 35 days, replacing old houses by new houses, and applying drink nipples without cup had the highest estimated cost-effectiveness across the countries (€1,472 – €1,332,268 per averted DALY). Applying fly screens in Denmark resulted in an intermediate cost-effectiveness (€5,333 per averted DALY). A maximum downtime between crops of ten days showed the largest difference in cost-effectiveness between countries with high cost per avoided DALY in Denmark, the Netherlands and the United Kingdom, low costs per avoided DALY in Spain, and a benefit per avoided DALY in Poland (- €4,179 to €137,782 per averted DALY). The cost-effectiveness in our study is excluding a reduction in cost-of-illness of campylobacteriosis. With an estimated cost-of-illness of €6,857 per averted DALY (Elliot et al., 2012), the cost-effectiveness including cost-of-illness in our study ranged across all interventions from -€11,036 to €1,325,411 per averted DALY. Generally speaking, the cost-effectiveness of the farm-level interventions in our study show a wider range than the cost-effectiveness of interventions during slaughter and processing in previous studies. The interventions designated tools for each farm house, building an anteroom with hygiene barrier in each farm house, and applying fly screens were relatively cost-effective measures also compared to interventions during slaughter and processing. The cost-effectiveness of the least cost-effective interventions in this study, i.e. a ban on thinning (partial depopulation), slaughter at 35 days, replacing old houses by new houses and applying drink nipples without cup, were in the range of the less cost-effective interventions during slaughter and processing or worse.

Table 2: Estimated cost-effectiveness of on-farm *Campylobacter* interventions in Poland, Spain, United Kingdom, Netherlands, Denmark and Norway.

	Estimated cost-effectiveness (€/avoided DALY)					
Intervention	**Poland**	**Spain**	**United Kingdom**	**Nether--lands**	**Denmark**	**Norway**
Designated tools	60	14	87	237	416	1,013
Anteroom with hygiene barrier	31	34	372	378	836	6,753
Fly screens [a]	-	-	-	-	5,333	-
Maximum downtime ten days [b]	-4,179	240	22,583	29,152	137,782	-
Drink nipples without cup	3,516	2,032	25,467	43,513	189,330	213,880
New houses	15,944	1,472	59,164	48,997	634,303	567,446
Stop thinning	3,894	10,341	159,402	189,940	1,332,268	-
Slaughter at 35 days [c]	44,433	97,998	229,487	316,427	381,996	390,148

[a] Only estimated for Denmark, because the relative risk of this intervention was not available for the other countries; [b] Not estimated for Norway, because of the legal maximum number of broilers per farm that can be delivered per year. Negative costs indicate gains; [c] Not estimated for Norway, because the average delivery is at 33 days, which is below 35 days.

4. Main Conclusions

- Biosecurity is crucial to prevent *Campylobacter* infection of broiler flocks. This is not a new finding, but it is confirmed by the result of the risk factor study which indicates that combinations of interventions are most efficient in reducing the prevalence in *Campylobacter* flocks. Overall, the effect of control measures largely depend on the strict implementation, which is hard to control and cannot be measured in studies like the 20 farm study performed in WP1 of CamCon. Also, the implementation of a control measure like fly screens, can only be expected to be efficient if the biosecurity is in place.

- Relatively simple control measures like the use of drinkers without cups and the use of designated tools for each farmhouse do significantly reduce the Campylobacter flock prevalence. They are however not sufficient, and will not be effective if biosecurity is not in place.

- It is not possible to establish a simple relationship that predicts the decrease in concentrations on the broiler skin or broiler meat on the basis of a reduction of the concentration in the chicken faeces (e.g. as measured in the caeca). Data sets obtained in different countries show different regression lines for neck skin counts and caecal concentrations. Data analysis is complicated due to the presence of censored data and extrapolation issues. It seems the dynamics of transmission of *Campylobacter* through slaughter and processing cannot be described by a linear model.

- However, the risk assessment study shows that a 1-2 log reduction will probably have a large impact on the risk reduction for humans, with a relative residual risk between 17 and 56% (1 log) or less than 40% (2 log). Hence, intervention measures aimed at reducing the concentration in the intestinal content may be very effective.

- For the potential effect of control measures like vaccination and the application of phage therapy, it is important to not only know the effect in terms of mean log decrease in concentration in the faeces, but also the variation in the effect. A larger variation decreases the impact of the interventions.

- The national costs of interventions differ considerably between countries, with in general the highest costs in Norway and Denmark, and the lowest costs in Poland and Spain.

- The cost effectiveness of interventions also differs largely between countries. In general it is found that building an anteroom with hygiene barrier in all farms and the use of designated tools for each house are interventions with low cost per averted DALY. A ban on thinning, building new houses, reducing the slaughter age to 35 days and the use of drinkers without cups are interventions with a high cost per averted DALY.

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