Modelling the effect of logistic slaughter and/or germicidal treatment on the contamination of broiler meat with Campylobacter

A. HAVELAAR, E. EVERS, M. NAUTA and W. JACOBS-REITSMA

1National Institute for Public Health and the Environment, PO box 1, 3720 BA Bilthoven, The Netherlands
2Wageningen UR, RIKILT Institute of Food Safety, PO box 230, 6700 AE Wageningen, The Netherlands
*wilma.jacobs@wur.nl

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Summary
The goal of the CARMA project, within which logistic slaughter was studied here, is to advise the Dutch government on the effectiveness and efficiency of measures aimed at reducing campylobacteriosis in the Dutch population. Logistic slaughter is a method aimed at reducing the health risk to consumers of Campylobacter spp. on chicken meat. Testing all broiler flocks and processing all positively tested flocks either at the end of the day or at another location is one method to reduce cross-contamination in the processing plant. However, only one-third of all infected flocks at the age of slaughter is currently tested positive. This is due to the long delay (two weeks or more) between sampling done on broiler flocks at the farm and delivery of these flocks to the processing plant. As a consequence, the expected effect of logistic slaughter on the prevalence of Campylobacter spp. on chicken carcasses is limited. Furthermore, since the number of campylobacters on a cross-contaminated carcass is considerably lower than on a carcass from a flock that was contaminated upon arrival at the processing plant, this will have little effect on public health. Public health risks could, however, be considerably reduced through a combination of logistic slaughter and germicidal treatment after processing of carcasses from positively tested flocks. This combined strategy is only effective when a highly sensitive test is used with a minimum delay between sampling and processing.

Introduction
The contamination of chicken meat with Campylobacter spp. is unacceptably high. Despite intensified hygiene measures in primary production, the prevalence of infection of broiler flocks in the Netherlands has not decreased in recent years and it is not likely that this situation will change in the near future. To reduce the health risk to consumers, interventions in the production chain are necessary. The CARMA (Campylobacter Risk Management and Assessment) project is aimed at advising the Dutch government on the effectiveness and efficiency of measures aimed at reducing campylobacteriosis in the Dutch population. Further details can be found at www.rivm.nl/carma.

One possible intervention that is evaluated in the project is logistic slaughter of broilers. Testing all broiler flocks and processing all positively tested flocks either at the end of the day or at another location is one method to reduce cross-contamination in the processing plant. Additionally, positively tested flocks can be subjected to germicidal treatment. We present estimates of the effectiveness of these interventions, alone or in combination, based on mathematical modelling.

Effect of logistic slaughter on flock prevalence
To illustrate the effect of logistic slaughter, we simulate a hypothetical processing plant on which 6 flocks per day are processed. We define an “infected flock” as a flock that is colonised with Campylobacter at the farm. A “cross-contaminated flock” is a flock that is not infected at the farm, but a number of carcasses are contaminated after processing due to cross-contamination from a previously processed infected flock. The distribution of infected flocks arriving at the processing plant on different days is strictly random; one possible realisation is shown in Figure 1 (red bars).
example assumes a prevalence of infected flocks of 26% and that cross-contamination to carcasses from non-infected flocks is limited to one subsequent flock (baseline scenario, yellow bars).

![Figure 1 Cross-contamination due to processing in random order.](image1)

In case of logistic slaughter, flocks are tested for infection before delivery to the processing plant, and are processed at a separate location or at the end of the day if found positive. The effect of separate processing depends strongly on the sensitivity of the test protocol, here assumed to be 52%. In Figure 2, infected flocks that are detected before processing are shown in orange (e.g. flock 5 on day 4 is detected and processed last, no cross-contamination occurs; compare Figures 1 and 2). However, if an infected flock is tested negative, it will still be processed at its original position, and cross-contamination will occur (for example flock 4 on day 1).

![Figure 2 Reduced cross-contamination due to logistic slaughter (reordering of flocks).](image2)

In the Netherlands, 11% of all flocks was tested positive at the farm (faecal droppings) in the year 2000, but 35% was tested positive upon arrival at the processing plant (cloacal samples). Hence, the sensitivity of the test protocol was only 31%, mainly due to the long delay (two weeks or more) between sampling at the farm and delivery of the flock to the processing plant. We have developed a mathematical model to calculate the change in flock prevalence due to processing, in relation to the apparent prevalence at the farm and the sensitivity of the test protocol (Evers et al., submitted for publication). Figure 3 shows that in the baseline scenario (only the next flock is contaminated), random processing is expected to lead to an increase of flock prevalence from 35% to 55%. If the test results would be used to guide logistic slaughter, a reduction to 50% flock prevalence would be obtained, only 5% lower than without intervention. In an alternative scenario, we assume that not only one, but all flocks processed on the same day after an infected flock will be cross-contaminated. In that case, flock prevalence after random processing would be 72%, reduced to 64% by logistic slaughter.
Figure 3  Effect of logistic slaughter on flock prevalence, using data from the Netherlands, 2000.

Obviously, the effect of logistic slaughter depends strongly on the sensitivity of the test protocol. If the sensitivity of the test protocol could be raised to 95%, the final flock prevalence would be 37%, which is only 2% higher than the prevalence of infection upon arrival at the processing plant.

Effect of logistic slaughter on the level of carcass contamination

The health risk to consumers depends on both the prevalence and the level of contamination of carcasses, and ultimately of the ready-to-eat food. At low levels, there is a linear relationship between ingested dose and risk of illness. We have developed a model to quantify the effect of cross-contamination in the processing plant on the bacterial counts on individual carcasses (Nauta et al., accepted for publication). Parameter values for the cross-contamination model were mainly based on expert interviews (Van der Fels – Klerx et al., accepted for publication), and are uncertain. The model predicts that the average number of campylobacters on a carcass after processing an infected flock is \(3.5 \times 10^6\) cfu/carcass (90% confidence interval \(3 \times 10^5 - 2 \times 10^8\)). If we assume that flock prevalence is 35% and that 6 flocks of 10,000 birds are slaughtered on a single day, a total flux of campylobacters from infected flocks of \(7.4 \times 10^{10}\) cfu/day is found. The model predicts that as a result of cross-contamination, only 500 birds (median; 90% confidence interval 230 – 3000) of the next flock will be contaminated, resulting in an additional flux of \(7.7 \times 10^6\) cfu/day. This is only a fraction of the total flux! Hence, the health risk associated with cross-contamination is negligible in comparison to the risk from infected flocks.

Logistic slaughter in combination with germicidal treatment

If logistic slaughter is to result in any significant reduction of health risks, it should be combined with germicidal treatment of carcasses from infected flocks (e.g. decontamination, freezing, irradiation). The final effect of such a procedure will depend on the reduction in bacterial numbers as well as on the accuracy with which infected flocks are detected. We have simulated the effects of a combination of logistic slaughter and germicidal treatment, assuming hypothetical methods with a relatively low effect (reduction factor 20 x) or a relatively high effect (reduction factor 1000x). Figure 4 demonstrates that the effect of a combined approach depends strongly on the sensitivity of the test protocol and much less on the reduction factor. If many flocks go undetected, and consequently are not treated, a high flux will result, even if a highly efficient germicidal treatment is employed for detected flocks. In order for a combined approach to be effective, a test sensitivity of at least 95% is necessary.
Logistic slaughter and Campylobacter contamination: A. Havelaar et al.

Figure 4  Effect of logistic slaughter and germicidal treatment on Campylobacter flux.

Discussion
Two newly developed mathematical models were used to evaluate the effect of logistic slaughter on cross-contamination in broiler processing. The models demonstrate that sensitivity of the test protocol is of critical importance for the success of this procedure. But even employing a highly sensitive test protocol, the potential reduction of health risks by logistic slaughter is negligible because the total flux of campylobacters from a cross-contaminated flock is expected to be low. According to the experts who provided information for parameter estimates, removal and inactivation of campylobacters in the processing environment occurs at such a rate that the effect of cross-contamination is limited. By sensitivity analysis, we were able to demonstrate that there are no realistic combinations of parameter values that would change this conclusion. Hence, despite the uncertainties in parameter values, our conclusions are valid over a wide range of conditions. The effectiveness of a combined procedure of logistic slaughter and germicidal treatment was found to be effective only if infected flocks could be detected with high sensitivity. This places high demand on the organisation and performance of the testing procedure and the communication of results between different parties involved. Germicidal treatment of all flocks, regardless of their infection status, circumvents the need for testing, thereby reducing costs and complexity. However, product quality or acceptability may be negatively influenced and the treatment itself incurs costs. Optimising the combination of logistic slaughter and germicidal treatment, while also taking legal aspects into consideration, will be the subject of further studies in the CARMA project.

References
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