Developing nudges as an intervention to improve compliance of food handlers to procedures during broiler processing

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Summary

Evisceration is one of the key steps during processing of broilers at which carcasses may become contaminated with faecal material, a major source of *Campylobacter*. Faecal leakage typically occurs through damage of intestines when processing equipment is improperly adjusted. It has been shown that the number of carcasses contaminated with faeces varies between slaughterhouses and is associated with the compliance of food handlers with procedures on setting and controlling of the evisceration equipment. Improved compliance with these procedures could thus reduce faecal contamination, but interventions addressing this approach are currently lacking. Nudges, defined amongst other as changes in the presentation of various choice alternatives in such a way that makes the desired choice easier, automatic or default, are frequently used in marketing to guide consumer choices. Such strategies could guide behaviour and choices of food handlers during broiler processing towards handlings that reduce faecal contamination.

This study explored the use of nudges as cost-effective interventions to direct behaviour of food handlers (operators and post mortem inspectors) during broiler processing. Nudges were designed specifically for this study with the aim to improve controlling and adjusting of the evisceration equipment as well as to improve treatment of carcasses with visible faecal contamination.

During an inventory field study, at two processing lines the behaviour of food handlers at the evisceration process was observed. In addition, percentages of carcasses with visible faecal contamination at either high or low levels were observed and skin samples for *Campylobacter* and *E. coli* enumeration were collected. Through interviews and questionnaires, the reasons for non-compliance with procedures on the evisceration process were explored. This information was used to develop a set of nudges according to the iNudgeyou framework. These nudges addressed 1) attention, by placing reminders and priming (i.e. providing cues that create awareness); 2) determination by addressing social commitment and providing feedback; 3) choice by activating social norms through reminding about behaviour of others, and by activating motives and affect through reminding of food handlers' contribution to public health. A selection of suggested nudges were implemented at the studied processing lines.

A set of reminders was placed in the production area and in the canteen. In addition, a meeting was organised to raise the commitment of the food handlers where various reminders were presented. With these strategies, the operators were nudged to observe the carcasses for sufficient amount of time and to adjust equipment if needed. Using visual aids the post mortem inspectors were nudged to cut away contaminated parts of carcasses or to reject carcasses with high faecal contamination.
To evaluate the effect of the applied nudges, a second field study was conducted to observe again the behaviour of food handlers, the presence of carcasses with visible faecal contamination, and to collect samples for microbiological investigation.

Results revealed changes in behaviour of food handlers with respect to behaviour for which they were nudged. Post mortem inspectors (PMIs) handled carcasses showing visible faecal contamination more frequently after implementation of nudges. A decrease was observed in the number of such carcasses after inspection, although not statistically significant.

Operators (who set and adjust evisceration equipment) did observe the carcasses for a longer period after implementation of the nudges. However, the setting and adjusting of the equipment was not always done more frequent. To illustrate, on Line 1, operators adjusted vent cutter equipment less frequently and the percentage of carcasses with high level of visible faecal contamination after this step showed a significant increase. On Line 2, operators adjusted more frequently some settings of evisceration process equipment, whereas they adjusted others less frequently. As a result, there were no statistically significant differences in percentage of carcasses with high level of visible faecal contamination after implementation of nudges. The percentage of carcasses at low level of visible faecal contamination decreased after vent cutter and opener, however it increased after the evisceration following nudges implementation.

With respect to microbiological contamination, at both lines the levels of *Campylobacter* and *E. coli* prior to evisceration were higher in the field trials following implementation of nudges, indicating a higher initial load compared to the inventory field trials. Despite this, the evisceration process affected both *Campylobacter* and *E. coli* levels similarly in trials before and after implementation of nudges.

In conclusion, after implementation of nudges the food handlers improved some behaviours for which they were nudged, but not all. Activities of the food handlers might be affected by characteristics of batches and equipment itself and nudges for adjusting the evisceration equipment may need further optimisation. Activities of the post mortem inspectors PMIs seem to be less dependent of such factors. Improvement in behaviour of PMIs after implementation of nudges confirms thus potential of such interventions during broiler processing.

1 Introduction

Campylobacteriosis is this decade's most commonly reported zoonosis in Europe (EFSA, 2018). Most of the human infections can be attributed to the chicken reservoir, while handling, preparation, and consumption of broiler meat accounts for one third of all cases. Although *Campylobacter* control would be the most effective in primary production, this is however not achievable in the short term and alternative measures are needed in processing plants. The major source of *Campylobacter* contamination of poultry meat is through leakage of faecal material. Carcasses contaminated with faeces were reported to carry higher number of *Campylobacter* (Berrang et al., 2004) and *E. coli* (Cibin, 2014; Pacholewicz, 2016).

Many studies investigated interventions to reduce *Campylobacter* in slaughterhouses, including e.g. hot water treatment (Berrang, 2000; James, 2007; Whyte, 2003), steam-ultra sound (Boysen, 2009; Musavian, 2014), crust freezing (Boysen, 2009; Haughton, 2012; James, 2007), and decontamination (Bashor, 2004; Bauermeister, 2008; Bolder, 2007; Burfoot, 2013; Kere Kemp, 2001; Nagel et al., 2013; Northcutt et al., 2005). The results showed either low reduction level, quality deterioration of carcasses or poor acceptability by consumers (Loretz, 2010). These limitations point to the need to investigate measures that prevent faecal contamination to occur.

Leakage occurs frequently during evisceration because of improperly adjusted processing equipment, which can cause damage of intestines (Rosenquist et al., 2006). The number of contaminated carcasses with faeces can vary between slaughterhouses and has shown to be associated with food handlers' compliance to procedures on setting and controlling of evisceration equipment (Pacholewicz, 2016; Pacholewicz et al., 2015). In addition, it was demonstrated that although the food handlers had knowledge how to control the equipment in order to prevent the occurrence of the contamination, they did not always follow the procedures (Pacholewicz, 2016). Other studies also reported non-compliance of food handlers with procedures and discrepancy between their knowledge and practices in various food businesses (Abdul-Mutalib, 2012; Angelillo et al., 2000; Ansari-Lari, 2010; Baş, 2006; Clayton et al., 2002; Tokuc, 2009). Compliance of food handlers with procedures to control and set the evisceration machines for each processed batch could minimize the faecal contamination, and thus reduce the carcass contamination with *Campylobacter*. Such reduction was observed by a poultry processor in New Zealand, who reported that regular adjustment and maintenance of the evisceration equipment contributed to this success (Biggs, 2015).

Changing human behaviour is a challenge and approaches as nudging are frequently used to direct it. Nudging was firstly defined by Thaler and Sunstein (Thaler, 2008) as *"any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives. Nudges are not mandates. Putting the fruit at eye level counts as a nudge. Banning junk food does not".* In other words, nudges can be defined as changes in the presentation of various choice alternatives in such a way that makes the desired choice easier, automatic or default (De Ridder, 2014). Nudging is defined as any attempt to influence people's behaviour in a predictable way, which is possible because of biases in individual and social decision-making. It is independent of forbidding or adding any rationally relevant choice options, changing incentives, providing information (Hansen, 2016). Some examples of nudges include: a lamp flashing in the car reminding to wear a seatbelt; releasing a citrus aroma to suggest cleanliness; placing the healthy snacks in easily achievable positions in a buffet (De Ridder, 2014). Nudging covers a wide variety of approaches that enable certain preferred behaviour. Nudging strategies include providing information about what others are doing (social norm feedback), or changing the defaults, or making certain behaviour easier to do e.g. altering the layout of buildings to cue physical activity, or making certain behaviour more attractive or providing an reminder (Lindhout, 2017). Nudges are frequently implemented in the marketing (Mont, 2014). However using nudges to direct behaviour of food handlers in order to improve hygiene during poultry processing has not been investigated before.

This study aimed at development of nudges as cost-effective interventions to direct behaviour of food handlers (operators and post mortem inspectors) during processing of broilers to improve compliance with procedures on controlling and adjusting the evisceration process and thus prevent faecal contamination of carcasses during the slaughter process.

2 Materials and Methods

The study was conducted in two processing lines of broilers in 2017 and 2018. It was divided in three stages, 1) inventory, 2) development of nudges, 3) implementation and evaluation. During the inventory field trials conducted in 2017 an insight was gained in *Campylobacter* and *E. coli* contamination on carcasses during selected stages of processing, in the number of carcasses with visible faecal contamination and also in behaviour of food handlers (both operators setting and controlling the evisceration equipment and post mortem inspectors). Gaining knowledge on performed behaviour is required to develop the nudges (Dreibelbis et al., 2016). In addition questionnaires and structured interviews with food handlers were conducted to support development of nudges (Vrancken, 2018). After their implementations the following field trials again concentrated on observation of behaviour of food handlers, as well as the presence of carcasses with visible faecal contamination and determining the levels of *Campylobacter* and *E. coli* on carcasses.

2.1 Characteristic of the processing lines

On Line 1 carcasses up to 2 kg were processed with a line speed of around 9000 birds per hour (bph), whereas on Line 2 birds heavier than 2 kg were processed with a line speed of around 11000 bph. Scalding was done on Line 1 at 51 °C , whereas on Line 2 at 52 °C. There was a gas stunning applied at both lines and the chilling on both lines was firstly done in the immersion water tanks followed by chilling in air with water sprays. The Line 2 was modernised just before starting the field trials to evaluate the implemented nudges. The key evisceration equipment as vent cutter and opener was replaced.

2.2 Data collection

The inventory field trials took place between July and September 2017. In total there were 7 visits, during which 3-5 batches were observed and/or sampled per visit. In total 34 batches were analysed; on 20 batches the observations of food handlers and carcasses were done, whereas from 24 batches the samples were collected. Due to logistic reasons not always the batches could be both observed and sampled. As a result of unforeseen delay at the slaughterhouse, the field trials post nudges implementation had to be postponed until October 2018. There were 6 visits arranged. Per each visit 2-5 batches were observed and sampled. In total 20 batches were analysed of which 10 per each line. A batch, defined as a group of chicken raised in one shed (EFSA, 2011), was an observational and microbiological sampling unit.

2.3 Sampling

Neck skin samples from carcasses were collected at the following locations: before evisceration (i.e. after defeathering), after evisceration (i.e. before post mortem inspection), and after chilling. Neck skins were cut from carcasses being on moving lines during regular processing. Skins from three carcasses were pooled into one sterile stomacher bag and processed as a single sample having around 26 grams, in line with sampling for evaluation of compliance with the *Campylobacter* Process Hygiene Criterion (Anonymous, 2017). The knives and gloves were sterilised/exchanged between each sample. For each processing step, five (pooled) samples were collected, thus 15 samples per batch.
In addition, per each batch 10 intestinal packages were collected at the post mortem inspection stage. These were used for examination of the content of the gizzards, whether they were filled or empty to provide an indication of gut content and thus chance of faecal leakage. In addition the caeca material was used to examine the *Campylobacter* presence.

2.4 Processing of the samples

During the inventory field trials (in 2017) there were 24 batches sampled of which 13 from Line 1 and 11 from Line 2. During field trials after implementation of nudges (in 2018) 20 batches were sampled of which 10 per each line. *E. coli* was enumerated in the neck skin samples on the Petri films (3M™ *E. coli* / *Coliform* Count Plate Petrifilm™ , product number 64140). Samples were incubated at 37 °C for 24 hours, followed by counting of the suspected colonies.

In addition caeca content was pooled from the 10 collected caeca into one sample and examined by the Recombinase Polymerase Amplification (RPA) protocol (Achterberg, 2016) to check for *Campylobacter* presence. In case of a positive result *Campylobacter* was enumerated both in the caeca and neck skin samples on mCCDA (Oxoid, reference number CM0739, SR0155) according to ISO 10272-2 (ISO_10272-2:2017). Samples were incubated at 41.5 °C for 44 ± 4 at the microaerobic conditions. Following this the suspected colonies were counted and confirmation was done by MALDI-TOF.

Further the content of gizzards was evaluated. Per batch 10 gizzards were collected, opened in the laboratory and scored based on visual aids as empty (no residues of feed: score 0), low content (~1-4 grams of feed, score 1), medium content (~5-9 grams of feed, score 2), high content (>10 grams of feed, score 3). This classification was prepared in the initial stage of research when the content was weighed, categorised and the visual aids were developed (Appendix 6.1). Per each batch the scores of 10 examined gizzards (from 0 to 3 depending on how full they were) were summed up and divided by 10 to obtain an overall score per batch.

2.5 Observational study

The observations of food handlers (both operators and post mortem inspectors) and carcasses (for presence of faecal contamination at high and low level) were conducted based on checklists developed in a previous study (Pacholewicz, 2016), with minor modifications. In total there were 40 batches observed, 20 in field trials before (in 2017) and 20 after implementation of nudges (in 2018), of which 10 per each line.

Food handlers i.e. operators were observed on how they were setting and controlling of the evisceration equipment during the first 15 min after entrance of each new batch into evisceration processing area. It was observed whether they appeared in the evisceration area in the mentioned time and whether they performed target behaviours at each of the key evisceration machines (vent cutter, opener and eviscerator). These behaviours included observation of carcasses, adjusting of the height of the equipment, adjustment of the shackles guides, re-observation of the carcasses. Attention was paid how long the operators observed and re-observed the carcasses, whether it was a short glance or longer time to enable observing at least 100 carcasses to examine presence of faecal contamination. This number of carcasses to be observed was specified in the internal procedures. The above-mentioned settings are needed to properly position the carcasses in the particular evisceration equipment in order to avoid damages of the carcasses and thus faecal leakage.

The post mortem inspectors were observed for handling of carcasses with visible faecal contamination during 9 min of processing of the selected batch. It was observed whether they rejected carcasses with high level of visible faecal contamination and whether they trimmed parts of the carcasses with low level of faecal contamination.

In addition to observation of the food handlers also the presence of visible faecal contamination on carcasses was observed. Carcasses with low level of visible faecal contamination (having a small spot of faecal contamination e.g. spot < 5 mg, < 3mm^2) were counted, as well as with high level (having a substantial leakage of faecal material, or big spot of faeces). Visual aids to judge the presence of faecal contamination are included in the Appendix 6.2. The carcasses were counted during 9 min at five locations, i.e. after defeathering (just before first evisceration machine called vent cutter), after vent cutter, after opener, after eviscerator and after post mortem inspections. Further the percentage of carcasses with visible faecal contamination at low and high level was calculated taking into account speed of each processing line. On Line 1 there were around 1260 carcasses observed after defeathering, vent cutter and opener, whereas around 630 after eviscerator and post mortem inspection (the lower number at these steps was due to splitting the line into two inspection stages). On Line 2 there were around 1320 carcasses observed after defeathering, vent cutter, and opener, whereas around 660 after eviscerator and post mortem inspector.

Furthermore the food handlers were asked to answer the questionnaires on their knowledge, attitude and practices as described in a previous study (Pacholewicz, 2016). In addition the food handlers, quality managers and top management answered a questionnaire on the Food Safety Climate (FSC) (De Boeck, 2015). The structured interviews with food handlers were conducted to determine the motives of their non-compliance with procedures on setting and controlling the evisceration process (Vrancken, 2018).
This outcome was used to develop nudges following the methodology according to the iNudgeyou company framework (https://inudgeyou.com).

2.6 Data analysis

Observation of activities performed by food handlers

During field trials both before and after implementation of the nudges the operators and post mortem inspectors were observed while processing 10 batches. In case of ten batches in inventory field trials (three on Line 1 and seven on Line 2) and five batches in trials after implementation of nudges (four on Line 1 and one on Line 2) two post mortem inspectors could be observed for a single batch. This was because each line has two post mortem inspection stages. For the number of mentioned batches it was possible to observe the inspectors at both stages.

The number of batches for which the operators showed targeted behaviour was summed up and visualised as percentage of batches with targeted behaviour. Similarly, for handlings of post mortem inspectors, batches were summed up and visualised as percentage of observation events with the targeted behaviour.

Visible faecal contamination

Changes in percentage of carcasses with visible faecal contamination were analysed by linear mixed effect models. The outcome variable was the percentage of carcasses with visible faecal contamination and the fixed variable the location during the evisceration, whereas a batch was a random variable. The analysis was performed to evaluate 1) after which step of evisceration the percentage of contaminated carcasses increased and decreased and 2) to compare the increases/decreases between field trials organised before and after implementation of nudges. While comparing results between the trials an interaction between the sampling location and a field trial was added to the model.

Microbiological data

The counts of the colony forming units (CFU) of both *Campylobacter* and *E. coli* were transferred to log10 scale. The samples with counts below the enumeration threshold were replaced by half of the enumeration threshold (Rosenquist et al., 2006). Several analyses were performed to evaluate whether 1) the changes in contamination during evisceration varied between batches, 2) whether contamination significantly changed after the evisceration and how it changed after the chilling, 3) whether changes in contamination during evisceration differed between field trials conducted before and after implementation of nudges. The analysis was performed separately for *Campylobacter* and *E. coli* data. The data were analysed using linear mixed effect models, the package lmer of R statistical software (3.5.0, 2018, R Development Core Team). In the models the processing step (i.e. sampling location) was modelled as a fixed effect, whereas the batch was a random effect. While comparing results between the field trials an interaction between the sampling location and a field trial was added.

2.7 Development of nudges

Nudges were developed based on the results from the inventory field trials, i.e. on observation of the behaviour of the food handlers, results from the questionnaires and the interviews. These revealed that the food handlers were aware of tasks that they need to perform, however the observations showed that not always it was actually put in practice (section 3.1).

Therefore the proposed nudges addressed 1) attention and salience, by placing reminders and priming (i.e. providing cues that create awareness) (Dolan, 2012; Sunstein, 2014; Thaler, 2008); 2) determination by addressing social commitment and providing feedback (Dolan, 2012; Thaler, 2008; Yiannas, 2008); 3) choice by activating social norms through reminding about behaviour of others, and by activating motives and affect through reminding of food handlers' contribution to public health (Dolan, 2012; Thaler, 2008; Yiannas, 2008).

To address the attention of food handlers, reminders were placed in the evisceration area for both groups of food handlers, i.e. operators and post mortem inspectors. The crucial tasks to be performed during the evisceration process (for the food handlers observing a sufficient number of carcasses for faecal contamination and adjusting the equipment if necessary, and for PMI trimming contaminated parts or removing heavily contaminated carcasses) were printed on 40x60 cm boards (Figure 1 and 3). In the canteen additional boards designed to raise attention were placed and priming technique was used (Figure 2 and 3). The cues were printed in order to remind the food handlers about the target behaviour. These cues addressed the social commitment of the food handlers and aimed at raising their determination.

Furthermore a meeting was organised with the food handlers to address their determination. It was arranged in August 2018 (week 34) and attended by operators (3 people) and production leader and post mortem inspectors. Furthermore a trusted person of the food handlers co-moderated the meeting together with the research team. Messenger is also a nudge, since it was reported that a person who communicates a messages influences other people (Dolan, 2012; Yiannas, 2008). During the meeting feedback was provided on the performance of the evisceration process and the results on presence of carcasses with visible faecal contamination from inventory field trails were presented. Various cues were shared with the food handlers that addressed social norms, for example some cues remained about behaviour of others. Additional cues remained about the role of food handlers to contribute to health of consumers, in order to increase their motivation. Moreover the cues were written using rhymes to simplify information and make it easy to remember (Yiannas, 2008). The cues used during the meeting are summarised in the Appendix 6.3.

In addition to improve the behaviour of making records by the food handlers, the research team proposed to change the place where the records sheets at Line 2 were positioned. As the inventory field trials revealed they were placed in a cabinet on the corridor and often the food handlers did not enter records immediately after examining the process, but rather with a delay. We proposed to place the records boards outside of the cabinet, on the right hand side in order to make entering the records more automatic activity. Studies have demonstrated that making changes in the physical environment or placing items on right hand side may improve executing of tasks (Marteau, 2011; Mont, 2014). Increasing the ease and convenience by a change in the physical environment may positively influence making records. Positioning of the recording boards differently and making them more accessible was expected to make the choice of entering the records easier. After inventory trials due to installation of a new hygienic barrier the cabinet was removed and indeed the recording sheets were placed on a table just in front of the exit from the Line 2.

In addition we proposed to place reminders to enter records on doors at both lines and to introduce an electronic system to enter records with defaults i.e. inability to move to next record sheet without entering the results to the current one. Defaults are commonly used nudge technique (Dolan, 2012; Mont, 2014; Sunstein, 2014; Thaler, 2008). The electronic system to enter records was implemented after our study, thus effect was not evaluated.

Furthermore additional nudges were proposed but not implemented at the processing lines. These included a feedback board to be placed in the canteen and used to regularly inform the employees on the presence of the faecal contamination. Also placing more reminders close to the key evisceration equipment were proposed: as for example stop signs at the spots where the operators should observe carcasses and adjust equipment, also indicating the key handlings: ob**S**erve, op**T**imise, rec**O**rd, **P**roceed.

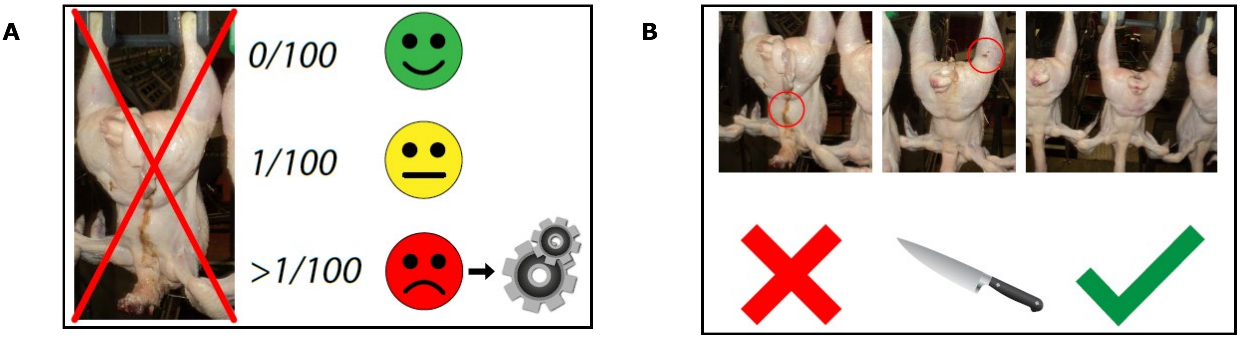


Figure 1. A. Reminder for operators placed next to the crucial equipment at the evisceration line (one at vent cutter, second at opener, third at eviscerator), B. reminder for post mortem inspectors.

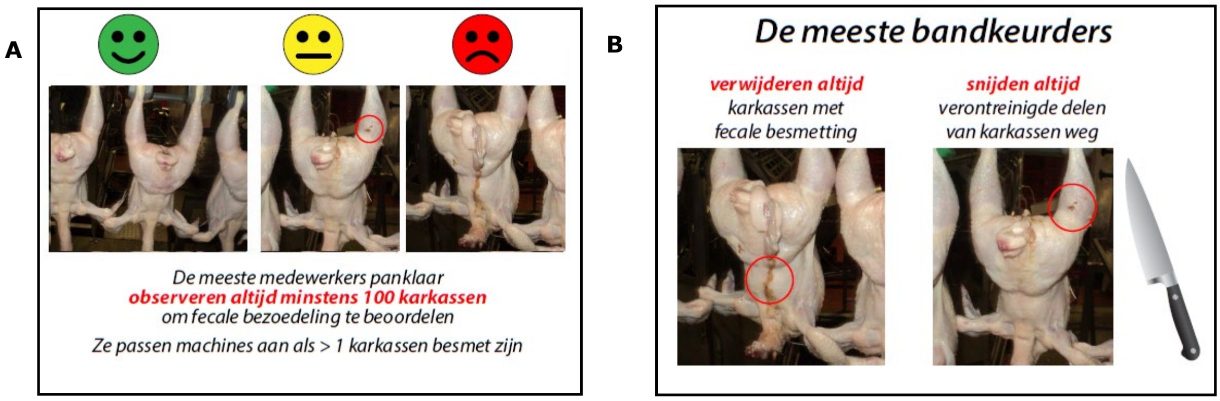


Figure 2. A. Reminder for operators and B. for post mortem inspectors placed in the canteen.

Figure 3. Implemented nudges in the processing area and in the canteen.

3 Results

3.1 Practices of food handlers

Figure 4 depicts the percentage of observation events for which the target behaviour (i.e. removing carcasses contaminated with faeces and trimming parts with visible contamination) of post mortem inspectors (PMIs) was observed.

These target behaviours were categorized as either done always during the 9 min of observation interval (in blue), sometimes during the 9 min (in green) or never (in red). Due to practical reasons the observations could not be conducted for longer time. Thus the results does not summarise the entire process and behaviour of the inspectors. It is important to notice that next to handling of contaminated carcasses with faeces the inspectors have to evaluate other characteristics of the carcasses, for e.g. diseases, process faults. Furthermore, the inspection is followed by cleaning of the carcasses from inside and outside what contributes to removal of visible contamination of carcasses.

The figure shows that during the field trials after implementation of nudges the PMIs performed more frequently the target behaviours for which they were nudged (i.e. removing contaminated carcasses, removing parts of contaminated carcasses with faeces), i.e. more green and blue fields in bottom panel on the Figure 4.

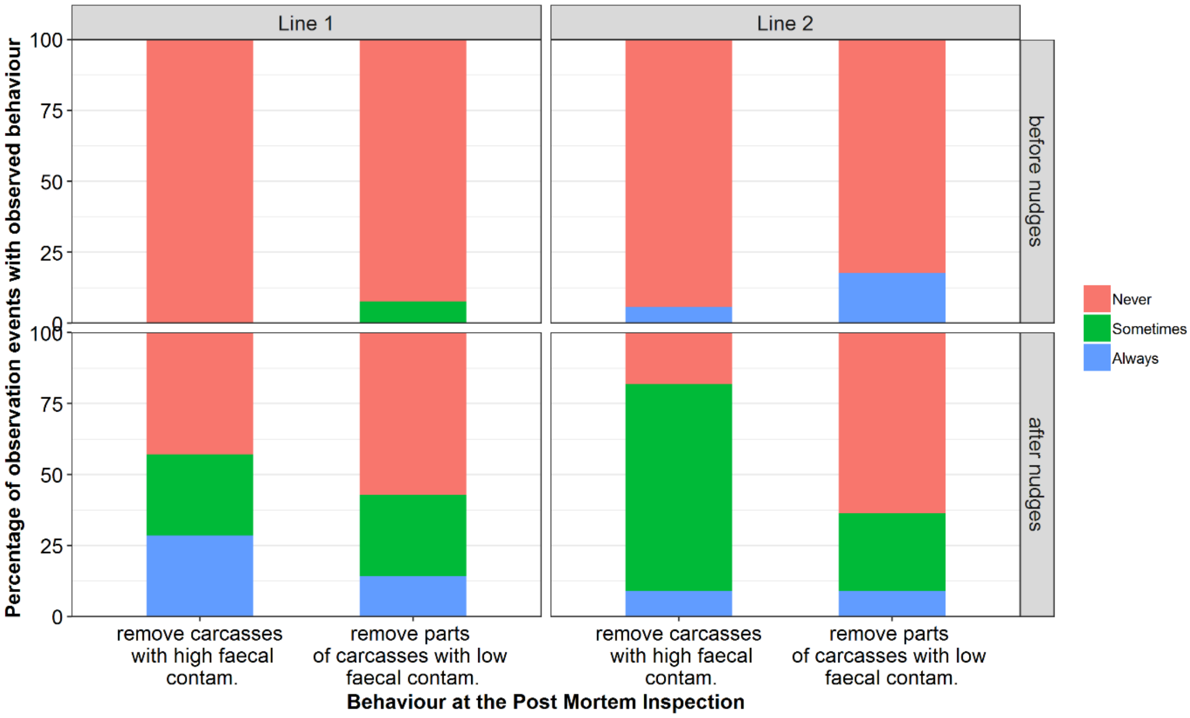


Figure 4. Target behaviour of the post mortem inspectors (PMIs) before and after implementation of nudges.

The behaviour of the operators during field trials before and after implementation of nudges is summarised in figures 5-8 and show the percentage of batches for which the target behaviours were performed. Target behaviours of operators at vent cutter are summarised in Figure 5, whereas at opener in Figure 6, and eviscerator in Figure 7. Different colours in the figure indicate to what extend procedures were followed for a certain behaviour (e.g. observation of carcasses); if it was performed as prescribed it is depicted in blue (observation for around 1 min enables evaluating around 100 carcasses), moderate in green (short observation a few seconds, or short glance on the carcasses), or not done in red.

In general, it can be concluded from the figures 5 to 7 that if the operators observed the equipment they spent more time on observations (more blue colour). However during the field trials following the implementation of nudges the operators on Line 1 occasionally failed to observe one of the batches during the time studied, which was slightly more often compared to trials before nudges. In general, equipment was less often adjusted in the field trials following the implementation of nudges compared to before. It is difficult to judge whether this behaviour was valid or not, as it is possible that adjustment was not needed for the particular batch.

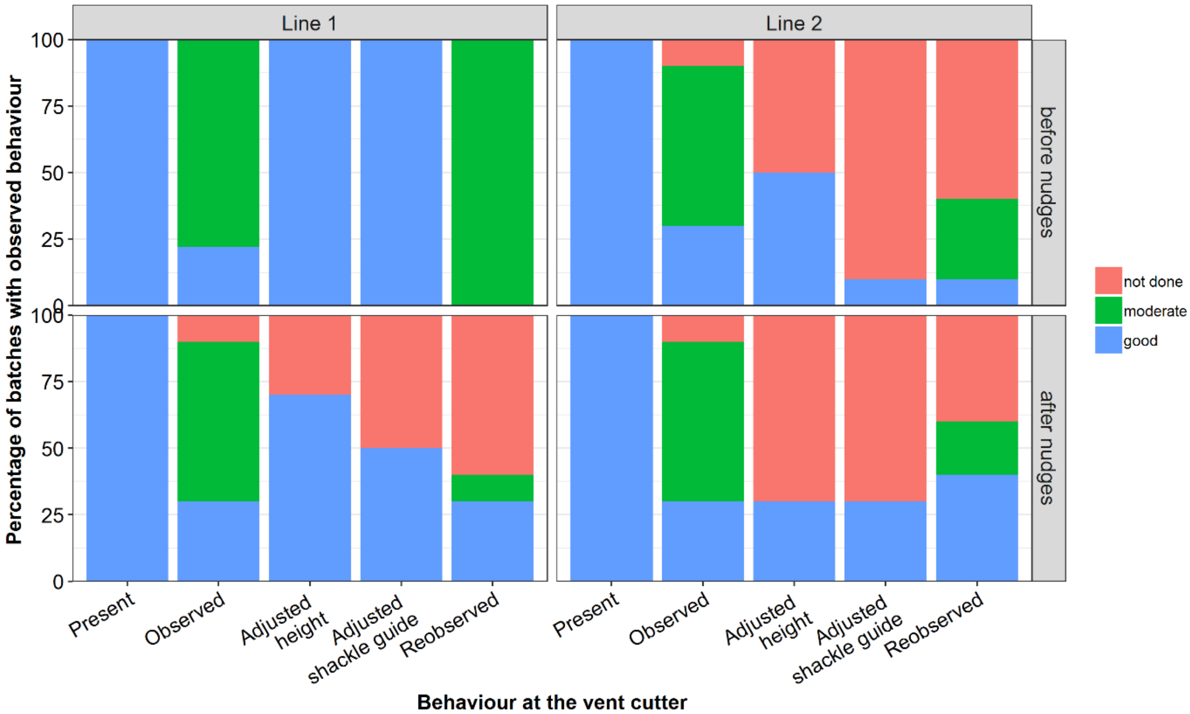


Figure 5. Percentage of batches with observed behaviour of the operators at vent cutter before and after implementation of nudges. The number of batches observed was 10 per line for each year.

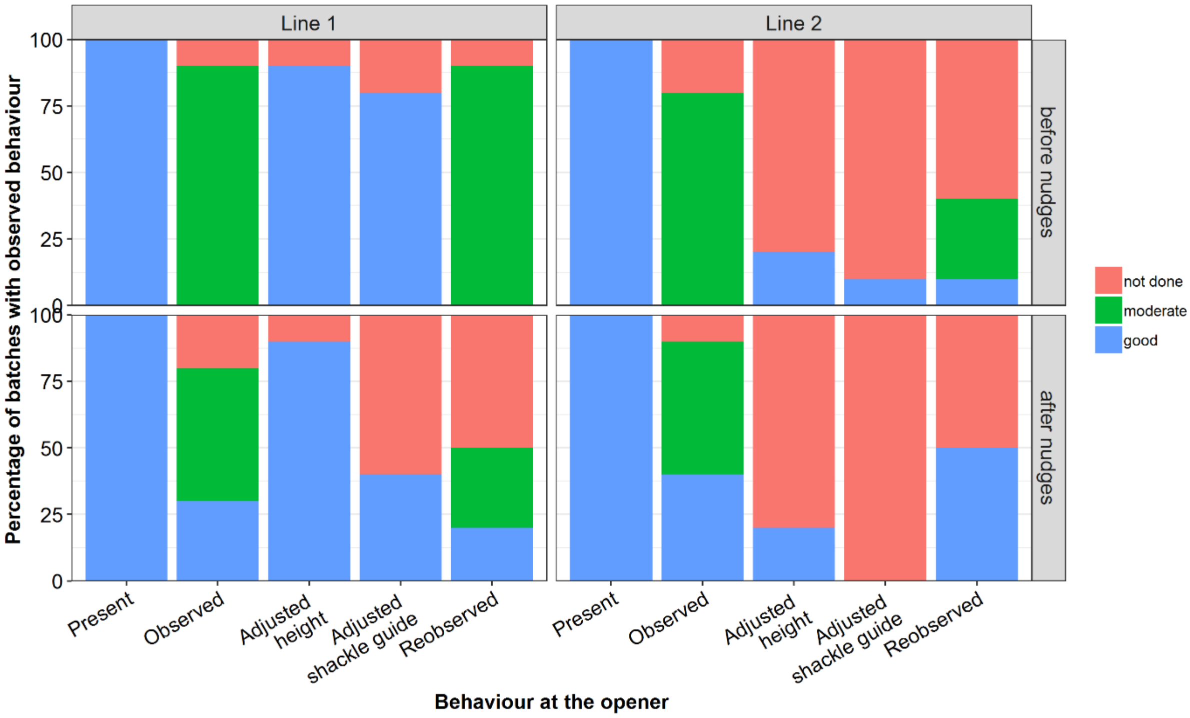


Figure 6. Percentage of batches with observed behaviour of the operators at opener before and after implementation of nudges. The number of batches observed was 10 per line for each year.

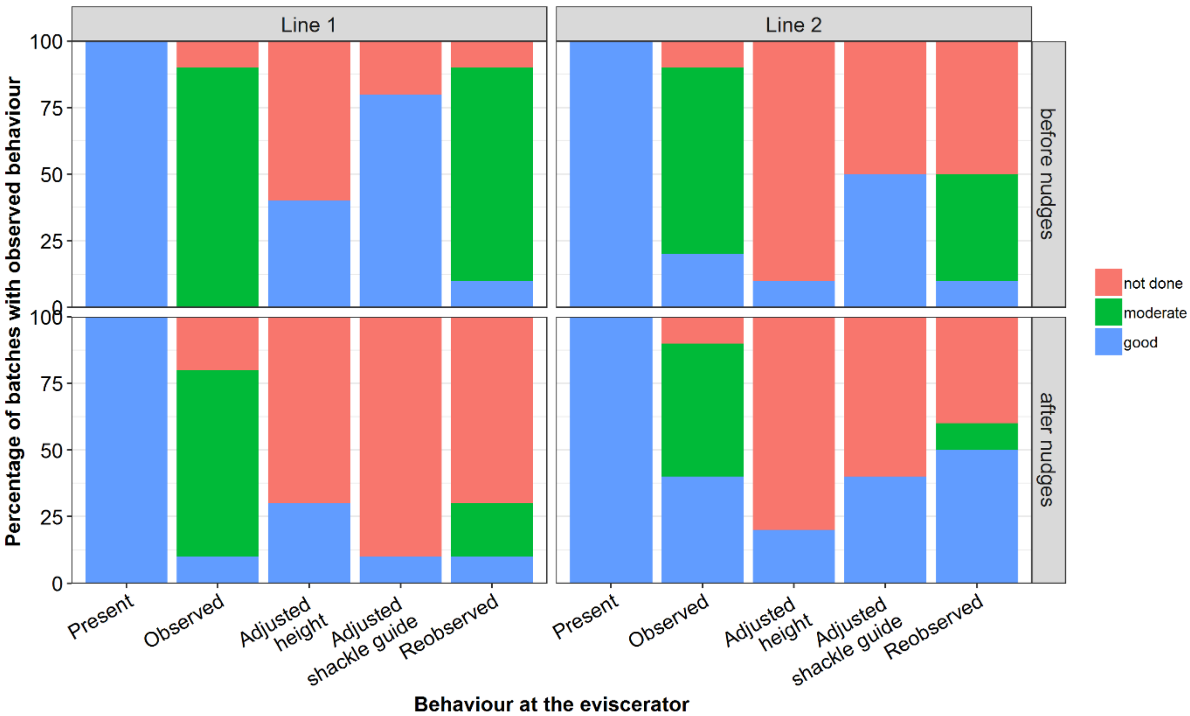


Figure 7. Percentage of batches with observed behaviour of the operators at eviscerator before and after implementation of nudges. The number of batches observed was 10 per line for each year.

Figure 8 summarises behaviour of operators on making records. The figure shows the percentage of batches for which the operators made records on controlling the evisceration equipment and on controlling the presence of faecal contamination. It shows that on Line 2 following implementation of nudges, the operators entered the records more frequently just after controlling the evisceration process (in blue) as compared to situation before the nudges (i.e. changing location of the record forms). No improvement was seen on Line 1 during the field trials post nudges, since no interventions were implemented on that line to improve making records (section 2.7).

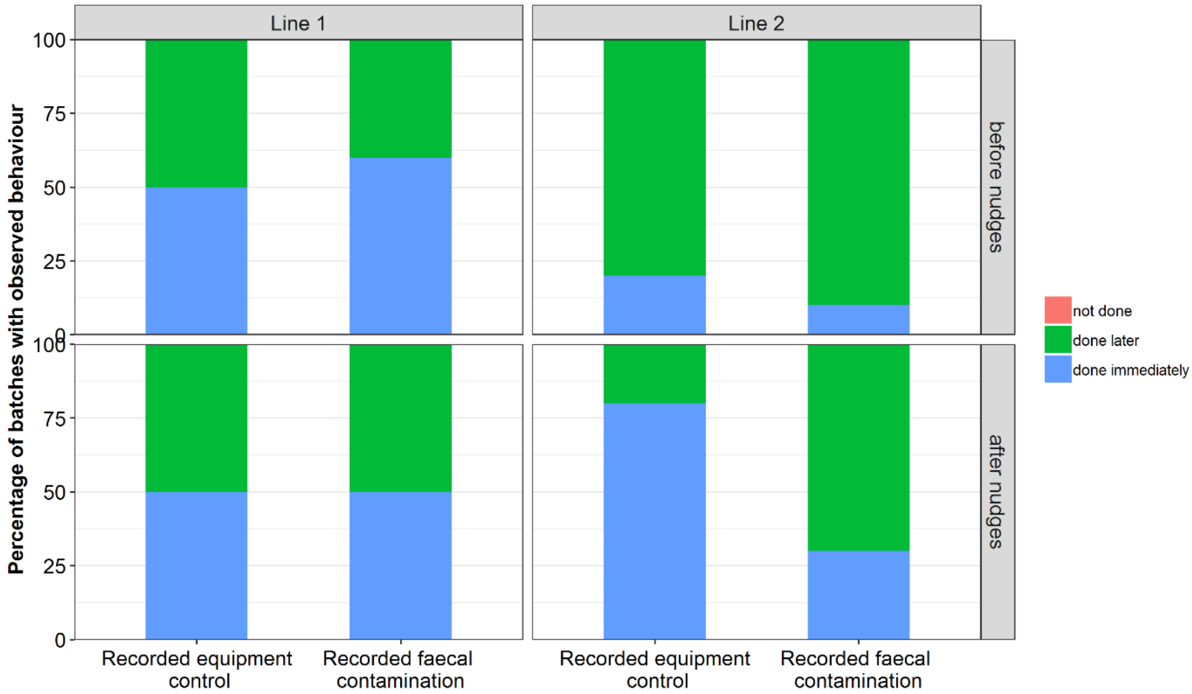


Figure 8. Percentage of batches with observed behaviour on making records observed before and after implementation of nudges.

3.2 Faecal contamination

The presence of carcasses with visible faecal contamination was observed at five steps in the evisceration department including after defeathering (just before evisceration), after vent cutter, after opener, after eviscerator and after post mortem inspection. Visibly contaminated carcasses were classified as having low or high levels of contamination (as visualised in Appendix 6.2). The descriptive statistics on percentage of carcasses with visible faecal contamination are presented in the Appendix 6.4.

Figure 9 and Table 1 summarise the results on the percentage of carcasses with visible faecal contamination on Line 1 before and after nudges implementation. The percentage of carcasses with low level of visible faecal contamination increased through all steps both before and after implementation of nudges. As Figure 10 and Table 1 show there were no statistically significant differences between changes in the percentage of contaminated carcases at low level before and after nudges.

The percentage of carcasses with high level increased at vent cutter and opener and decreased after eviscerator both before and after nudges (Figure 9, Table 1). Figure 10 and Table 1 reveal that after implementation of nudges there was higher increase (statistically significant) after vent cutter, no statistically significant change after opener, higher decrease (statistically significant) after eviscerator, and a higher decrease (statistically not significant) after post mortem inspection.

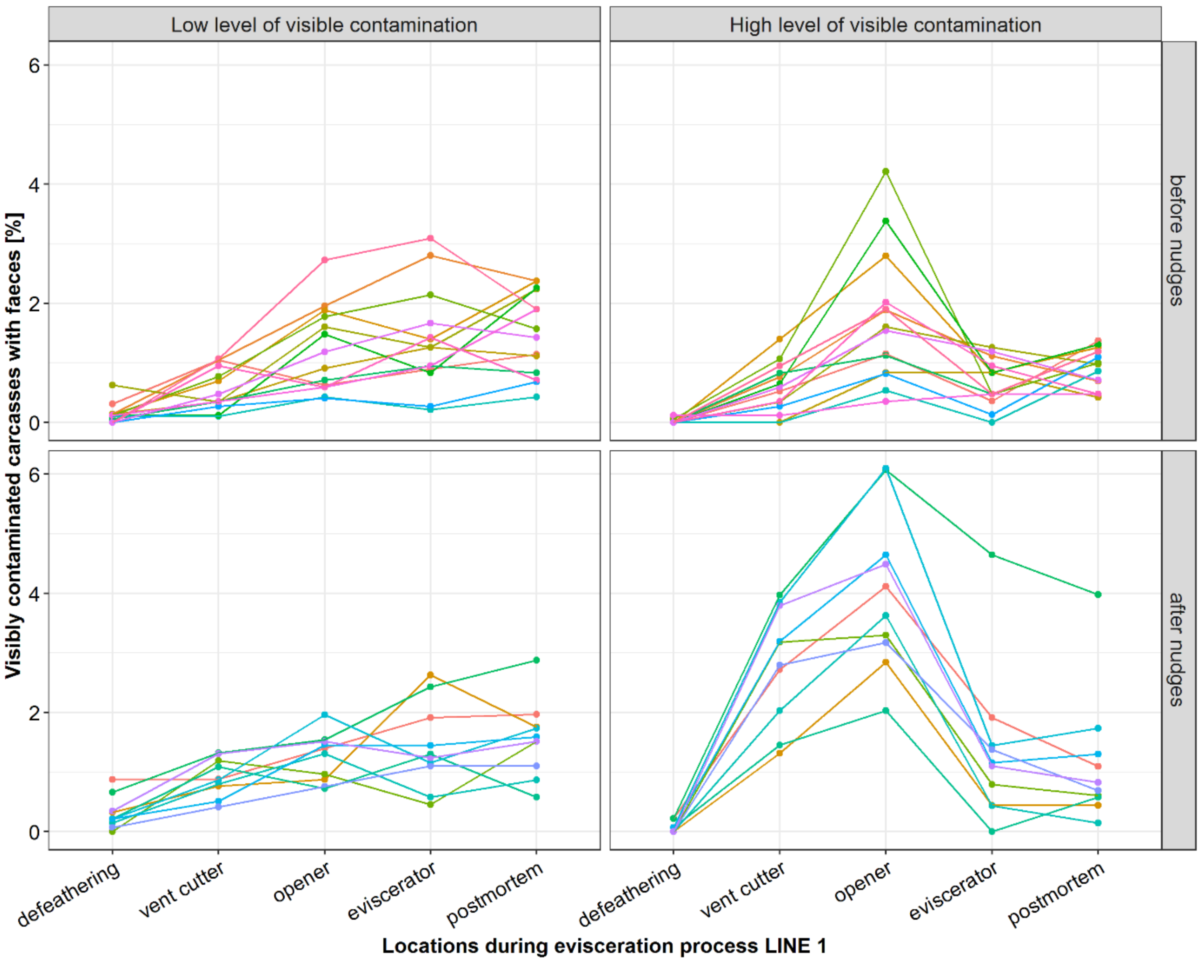


Figure 9. Percentage of carcasses with visible faecal contamination on low and high levels on Line 1, observed during the field trials conducted before implementation of nudges and after implementation. The points summarise percentage of carcasses with visible faecal contamination observed during nine minutes at each location: after defeathering, after vent cutter, after opener, after eviscerator and after post mortem inspection. Different colours of the points and lines visualise different batches.

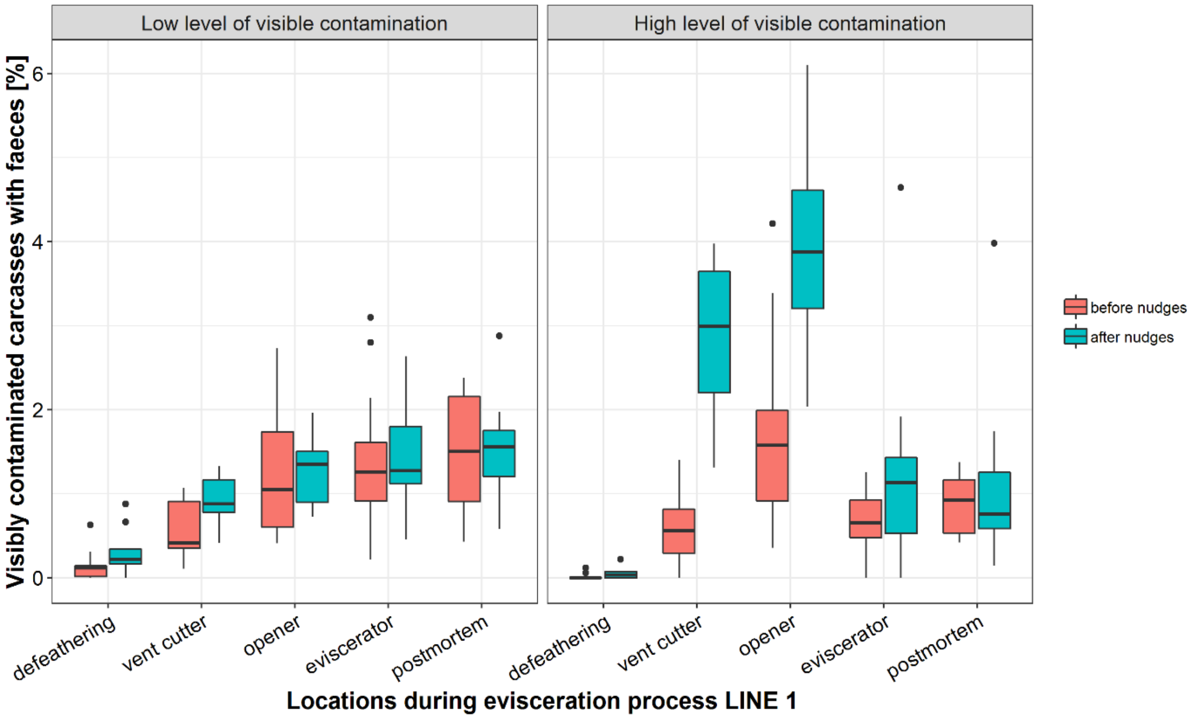


Figure 10. Results on percentage of carcasses with visible faecal contamination on Line 1 at each location: after defeathering, after vent cutter, after opener, after eviscerator and after post mortem inspection, observed before implementation of nudges (in red) and after implementation of nudges (in blue). The length of the boxplot indicates the interquartile range (IQR) of the data (50% of the data), the horizontal bar inside the boxes indicates the median value; black dots, outliers (> 1.5 ×IQR below the first quartile or above the third quartile); whiskers represent 1.5 × IQR or the maximum/minimum value of the dataset.

Figures 11 and Table 1 summarise the results on the percentage of carcasses with visible faecal contamination on Line 2.

The percentage of carcasses with low level of visible faecal contamination increased through subsequent steps before nudges, it fluctuated during the trials after implementation of nudges with increase after vent cutter and eviscerator and decrease after opener and post mortem inspection. Not all of these increases and decreases were statistically significant (Table 1). As Figure 12 and Table 1 summarise after implementation of nudges the percentage of carcasses with low level of visible faecal contamination showed a lower increase after vent cutter (statistically significant) and opener (statistically not significant), higher increase after eviscerator (statistically significant) and decrease after post mortem inspection (statistically not significant).

The number of carcasses with high level of faecal contamination increased after the vent cutter and decreased after the eviscerator, and the post mortem inspection before and after implementation of nudges. Not all of these increases and decreases were statistically significant (Figure 11, Table 1). Percentage of contaminated carcasses decrease slightly after opener before nudges, whereas it increased after nudges implementation. The increase at vent cutter was lower post nudges implementation as compared to before, however not statistically significant (Table 1). While comparing the increases and decreases before and after nudges at all tested locations there was no statistically significant difference (Figure 12, Table 1).

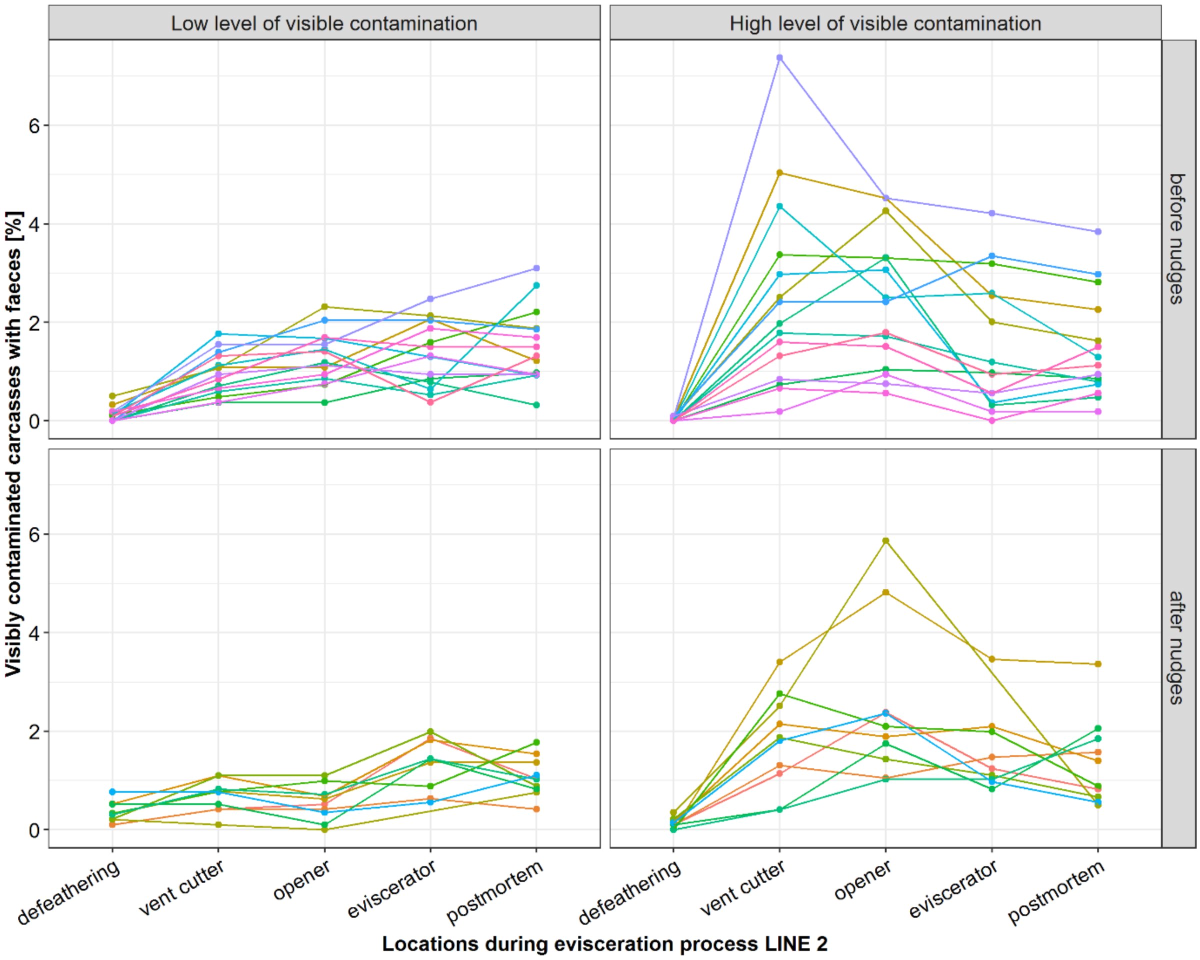


Figure 11. Presence of carcasses with visible faecal contamination on low and high level on Line 2 observed during the field trials conducted before and after implementation on nudges. The points summarise percentage of carcasses with visible faecal contamination observed during nine minutes at each location: after defeathering, after vent cutter, after opener, after eviscerator and after post mortem inspection. Different colours of the points and lines visualise different batches.

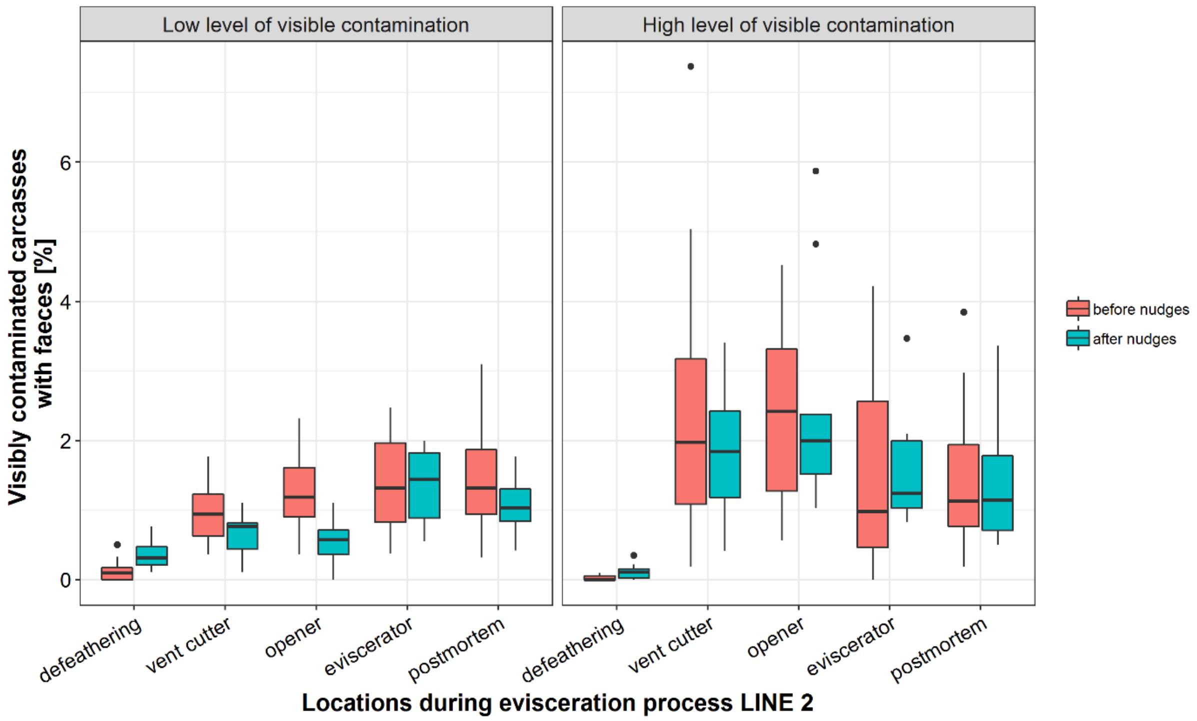


Figure 12. Results on percentage of carcasses with visible faecal contamination on Line 2 at each location: after defeathering, after vent cutter, after opener, after eviscerator and after post mortem inspection, observed before (in red) and after implementation of nudges (in blue). The length of the boxplot indicates the interquartile range (IQR) of the data (50% of the data), the horizontal bar inside the boxes indicates the median value; black dots, outliers (> 1.5 ×IQR below the first quartile or above the third quartile); whiskers represent 1.5 × IQR or the maximum/minimum value of the dataset.

Internal data on faecal contamination

In addition to results obtained during the study, internal data from the slaughterhouse on number of carcasses with visible faecal contamination at the processing lines were analysed. Typically, employees observe 50 carcasses just before chilling for the presence of faecal contamination. Results from 10 weeks before implementation of nudges (weeks 25-34 in 2018) and 10 weeks after their implementation (weeks 40-49 in 2018) were compared. On Line 1 there were 0.1% carcasses with visible faecal contamination prior nudges implementation, whereas 0.3% after implementation. On Line 2 before the nudges implementation there were 0.3%, whereas after 0.1% carcasses with faecal contamination. There were no statistically significant differences between these results comparing data prior and after implementation of nudges on each line.

Table 1. Results on changes in percentage of carcasses with visible faecal contamination with low and high level after selected location during the evisceration process. An asterisk indicate significant p values (<0.05).

			Before implementation of nudges		After implementation of nudges		Comparison before minus after implementation of nudges	
		Sampling location	Difference [log10]	p value	Difference [log10]	p value	Difference [log10]	p value
Line 1	low level of faecal contamination *	defeathering					-0.28	0.18
		vent cutter - defeathering	0.43	0.01*	0.61	<0.01*	-0.17	0.53
		opener - vent cutter	0.64	<0.01*	0.33	0.051	0.30	0.28
		eviscerator - opener	0.16	0.33	0.18	0.31	-0.01	0.96
		post mortem - eviscerator	0.13	0.43	0.12	0.47	0.01	0.98
	high level of faecal contamination	defeathering					-0.04	0.89
		vent cutter - defeathering	0.55	<0.01*	2.77	<0.01*	-2.21	<0.01*
		opener - vent cutter	1.16	<0.01*	1.21	<0.01	-0.04	0.92
		eviscerator - opener	-1.05	<0.01*	-2.71	<0.01*	1.65	<0.01*
		post mortem - eviscerator	0.21	0.27	-0.19	0.51	0.40	0.34
Line 2	low level of faecal contamination	defeathering					-0.24	0.19
		vent cutter - defeathering	0.83	<0.01*	0.34	0.01*	0.49	0.046*
		opener - vent cutter	0.33	0.04*	-0.13	0.33	0.46	0.07
		eviscerator - opener	0.08	0.59	0.75	<0.01*	-0.71	<0.01*
		post mortem - eviscerator	0.14	0.37	-0.23	0.09	0.41	0.1
	high level of faecal contamination	defeathering					-0.06	0.87
		vent cutter - defeathering	2.45	<0.01*	1.66	<0.01*	0.79	0.11
		opener - vent cutter	-0.06	0.84	0.69	0.052	-0.75	0.13
		eviscerator - opener	-0.88	<0.01*	-0.83	0.02*	-0.06	0.91
		post mortem - eviscerator	-0.07	0.83	-0.27	0.46	0.20	0.68

* changes in number of carcasses with visible faecal contamination at selected locations compared before (in 2017) and after (in 2018) implementation of nudges were statistically not significant

3.3 *Campylobacter* contamination

During the field trials before and after implementation of the nudges the neck skin samples were collected at the following steps: after defeathering (just before evisceration) after evisceration and after chilling. When the RPA results revealed the presence of *Campylobacter* in the caeca, enumeration of *Campylobacter* was performed on the neck skin samples. During the field trials prior implementation of nudges there were 7 positive batches on Line 1 and 9 on Line 2, whereas in the trials after the implementation there were 3 positive batches on Line 1 and 6 on Line 2. In the trials post nudges one batch on Line 2, although negative by RPA was positive by culture. This might be explained by limitation in the RPA sensitivity.

In the data set collected before implementation of nudges there were five samples below the limit of quantification (i.e. 10 CFU/g), whereas in data set collected after implementation of nudges there were two samples below the limit.

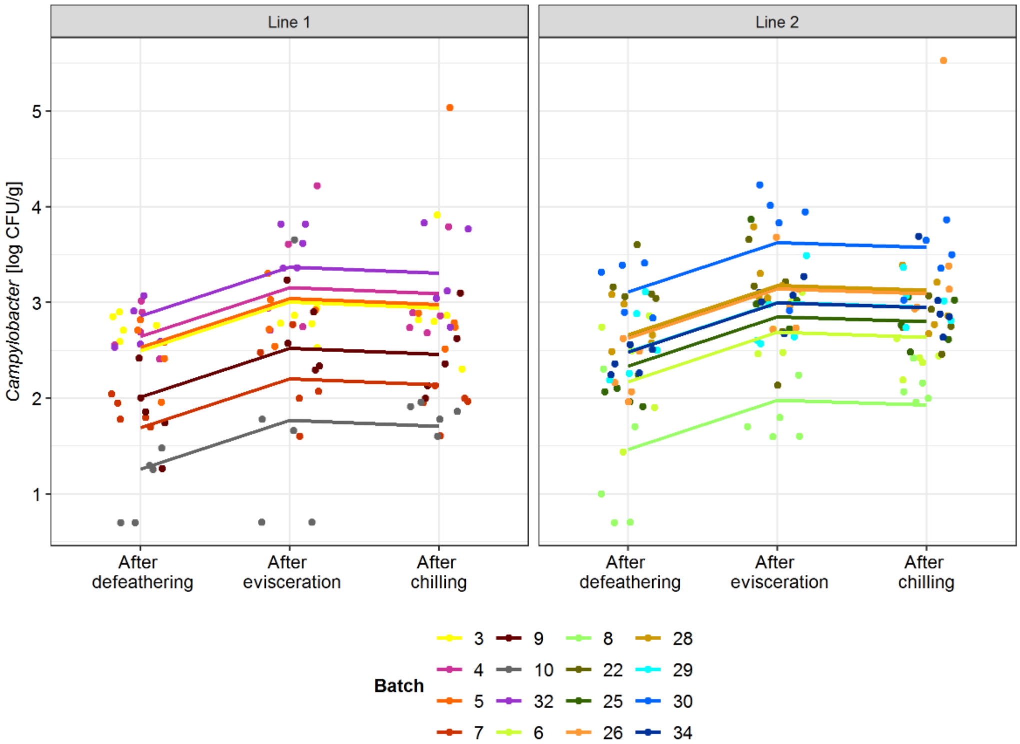
Figures 13 and 14 and Tables 2 and 3 summarise results on *Campylobacter* enumeration in the neck skin samples analysed before and after implementation of nudges. Before nudges on both lines there was an increase in *Campylobacter* concentration after evisceration by 0.5 log ($p<0.01$) and slight but not statistically significant decrease after chilling (0.05 on Line 1 and 0.06 on Line 2, $p=0.6$) as compared to after evisceration. The effect of evisceration and chilling did not differ between batches (parallel lines) before implementation of nudges. It varied after implementation (variable lines) what points to more variation in the effect of processing on microbiological contamination. After implementation of nudges there was a slight but statistically not significant increase after evisceration on Line 1 (by 0.2 log, $p=0.5$), and a significant increase on Line 2 (by 0.76 log, $p=0.02$), on both lines. On average the concentration after chilling decreased (Line 1 by 0.06 in 2017 and by 0.07 in 2018, whereas on Line 2 by 0.05 in 2017 and 0.3 in 2018) but it was not statistically significant (Figures 13 and 14, Table 3).

While comparing the effect of processing steps on *Campylobacter* concentration before and after implementation of nudges there was significant difference at defeathering only on Line 2 but not on Line 1 (Figure 14, Table 3). The carcasses after defeathering on Line 2 carried higher level of *Campylobacter* by 0.8 log as compared to data collected before implementation of nudges. This is important, because it indicates higher levels of *Campylobacter* prior to the evisceration process in trials after implementation of nudges as compared to situation before. The increase after the evisceration processes was similar before and after nudges. Although the increase was higher by 0.2 log after nudges implementation this difference was not statistically significant ($p=0.2$) compared to the increase prior nudges (Table 3).

With respect to compliance with the PHC in the neck skin samples collected after the chilling, before implementation of nudges on Line 1 22% (8 samples out of 35) of the samples exceeded the level of 1000 CFU/g (specified by PHC), whereas on Line 2 40% (18 out of 45) of the samples exceeded the limit. After nudges on Line 1 27% (4 samples out of 15) of the samples exceeded the level of 1000 CFU/g that is specified by PHC, whereas on Line 2 50% (15 out of 30) of the samples exceeded the limit. There were no statistically significant differences in these results while comparing between the years per line.

In practice the criterion should be monitored in a window of 10 weeks and in this period 50 samples should be collected of which 20 might exceed the limit. The field trials conducted in the current study were rather limited to a few batches tested per each line each year. To gain a broader insight in the *Campylobacter* compliance to the PHC the data available at the slaughterhouse were analysed. These data are not divided per line however. Two time windows were analysed. The first window included 10 weeks before implementation of nudges (i.e. between the week 25-34 in 2018). The second window included 10 weeks following implementation of nudges (week 40-49 in 2018). While in the first window there were 13 samples of neck skin out of 50 above the 1000 CFU/g specified by the PHC, in the second window there were 11 out of 50 samples exceeding this limit. This data confirm compliance with PHC and show slightly more samples complying with the criterion after implementation of nudges. The difference was however not statistically significant.

A.



B.

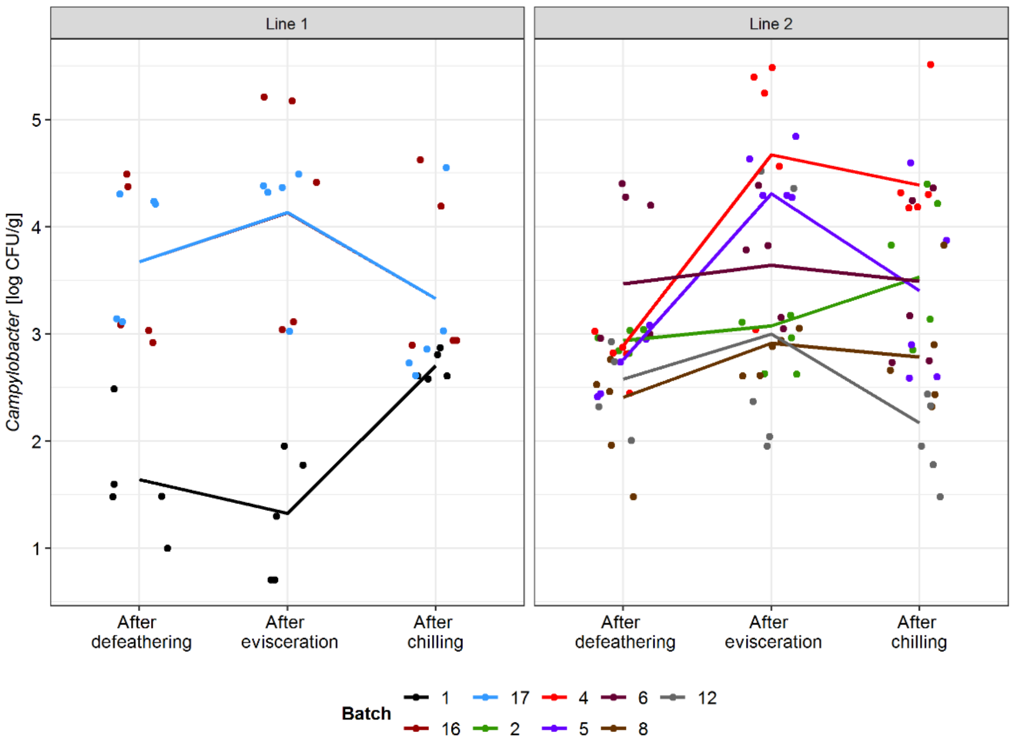


Figure 13. *Campylobacter* contamination in the neck skin samples collected before and after evisceration and after chilling on Line 1 and Line 2 during field trials before (13A) and after implementation of nudges (13B). The lines summarise the average concentration per batch, while each dot concentration in each collected samples. Different colours indicate different batch. Lines are based on the model that the best fitted the data. Model with random intercept and fixed slope (the effect of a processing step) fitted the data collected before nudges (parallel lines figure 13A), whereas a model with random intercept and random slope fitted the data collected after nudges implementation (variable lines figure 13B).

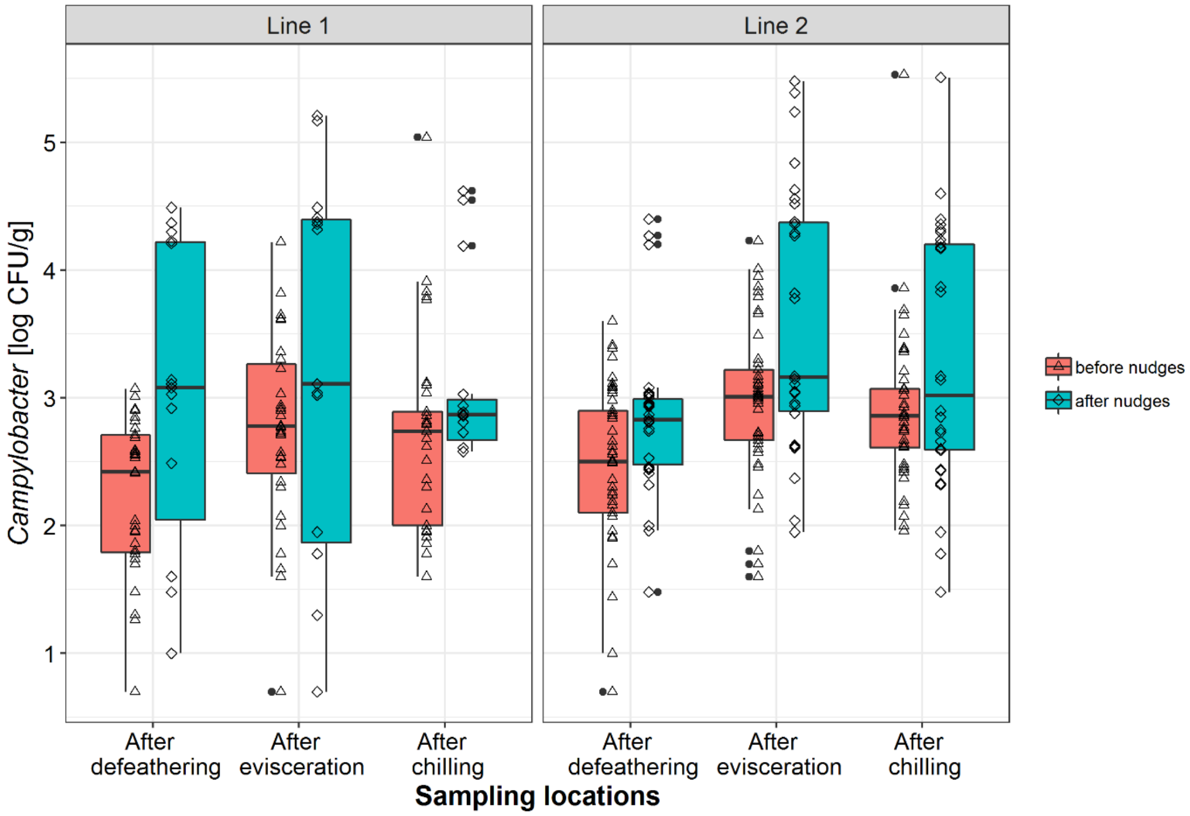


Figure 14. Comparison of *Campylobacter* [log CFU/g] in neck skin samples collected after defeathering, after evisceration and after chilling in the samples obtained in the field trials before (in red colour) and after (in blue). The results are from 7 batches of broilers for Line 1 and 9 batches for Line 2 before nudges, while the results after nudges are from 3 batches for Line 1 and 6 batches for Line 2. The length of the boxplot indicates the interquartile range (IQR) of the data (50% of the data), the horizontal bar inside the boxes indicates the median value; black dots, outliers (> 1.5 ×IQR below the first quartile or above the third quartile); whiskers represent 1.5 × IQR or the maximum/minimum value of the dataset. The triangles indicate *Campylobacter* concentration [log CFU/g] in each sample collected during the trials before implementation of nudges (in 2017), whereas diamonds in the field trials after implementation of nudges (in 2018).

Table 2. Descriptive statistics on *Campylobacter* (log10 CFU/g of neck skin and caeca) in the neck skin samples collected after selected locations during broiler processing.

		Line 1				Line 2			
Field trials	Sampling location	Mean	SD	Min	Max	Mean	SD	Min	Max
Before nudges	after defeathering	2.21	0.65	0.70	3.07	2.44	0.66	0.70	3.60
	after evisceration	2.72	0.80	0.70	4.22	2.96	0.62	1.60	4.23
	after chilling	2.66	0.75	1.60	5.04	2.91	0.60	1.96	5.53
	caeca	8.25	0.55	7.77	9.08	8.32	0.68	7.37	9.66
After nudges	after defeathering	3.00	1.18	1.00	4.49	2.84	0.61	1.48	4.40
	after evisceration	3.20	1.58	0.70	5.21	3.60	1.02	1.95	5.48
	after chilling	3.12	0.71	2.58	4.62	3.29	0.99	1.48	5.51
	caeca	8.22	2.11	6.60	10.61	6.99	1.21	6.00	9.00

Table 3. Results from the comparison of *Campylobacter* concentration (log10 CFU/g of neck skin) between sampled locations before and after implementation of nudges. An asterisk indicate significant p values (<0.05).

Sampling location	Before nudges		After nudges		Comparison before minus after nudges	
	Difference [log10]	p value	Difference [log10]	p value	Difference [log10]	p value
Line 1						
defeathering					0.08	0.74
after evisceration - after defeathering	0.51	<0.01*	0.2	0.53	0.31	0.30
after chilling - after evisceration	-0.06	0.58	-0.07	0.91	0.01	0.98
after chilling-after defeathering	0.45	<0.01*	0.13	0.78	0.31	0.29
Line 2						
defeathering					-0.82	<0.01*
after evisceration - after defeathering	0.52	<0.01*	0.76	0.02*	-0.24	0.21
after chilling - after evisceration	-0.05	0.59	-0.31	0.25	0.26	0.18
after chilling-after defeathering	0.47	<0.01*	0.45	0.14	0.01	0.95

3.4 *E. coli* contamination

Figures 15 and 16 and Tables 4 and 5 show results on *E. coli* [log CFU/g] in the samples collected during the field trials before and after implementation of nudges. Before nudges implementation there were 27 neck skin samples below the limit of quantification, whereas in trials after implementation of nudges none of the samples were below the limit. The samples below the limit [i.e. 100 and 1000 CFU/g] were replaced by half of the enumeration threshold.

The results show that more variation in the effect of the processing step on *E. coli* concentration on carcasses was observed on Line 2, since the model with random intercept and random slope fitted the best the data from both field trials before and after implementation of nudges (variable lines on Figure 15). On Line 1 there was less variation in the contamination pattern since the model with random intercept and fixed slope fitted the data. Before implementation of nudges on Line 1 the *E.coli* concentration increased after evisceration and after chilling on average by 0.2 log (p=0.01) at each step. Whereas on Line 2 it increased by 0.3 log (p<0.01) after evisceration and decreased after chilling by 0.2 log what was not statistically significant (p=0.07) (Table 5). After implementation of nudges on Line 1 the *E.coli* increased by 0.4 log on average (p<0.01), whereas decreased after chilling 0.1 log (p=0.9). On Line 2 *E. coli* levels increased on average by 0.2 log after evisceration (p=0.1) and a decreased after chilling by 0.03 on average (p=0.9) (Table 5).

While comparing the data before and after implementation of nudges only after defeathering the *E. coli* concentration differed significantly and was higher in batches sampled after implementation of nudges on both lines (Figure 16, Table 5). Although contamination prior evisceration after implementation of nudges was higher (by 0.8 log on Line 1 p<0.01 and by 0.3 log on Line 2, p=0.03) the evisceration processes showed similar trends. The increase in concentration of *E. coli* after evisceration did not differ before and after implementation of nudges on both lines (Table 5).

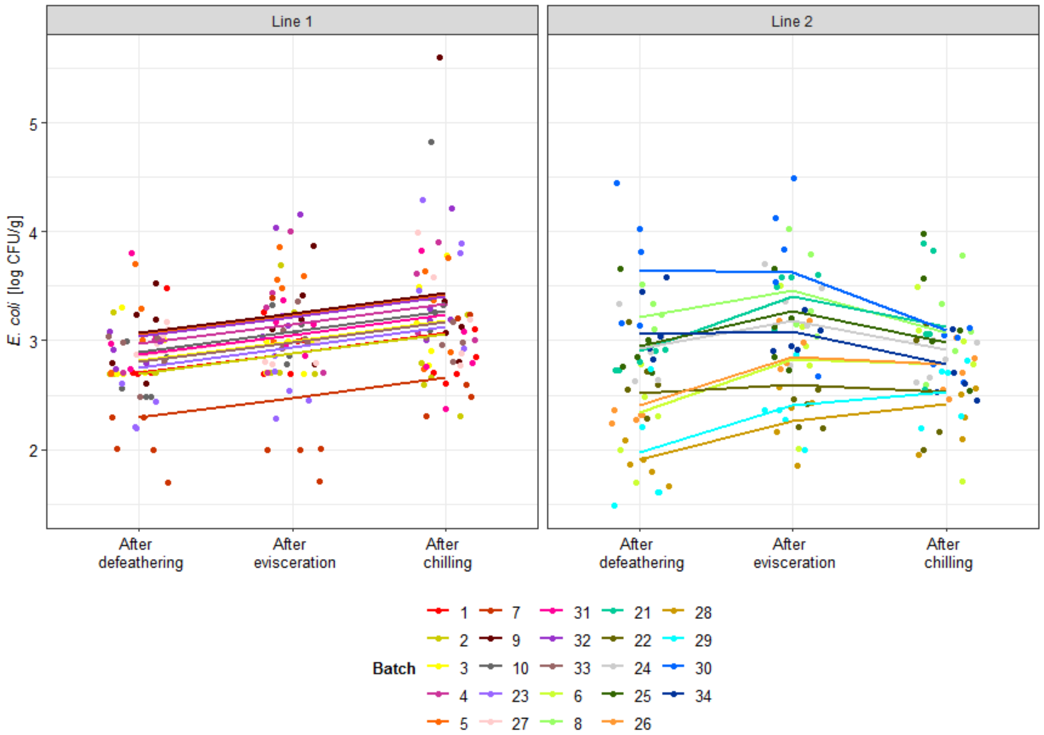
Table 4. Descriptive statistics on *E.coli* (log10 CFU/g of neck skin and caeca) in the neck skin samples collected after selected locations during broiler processing.

		Line 1				Line 2			
Field trials	Sampling location	Mean	SD	Min	Max	Mean	SD	Min	Max
Before nudges	after defeathering	2.83	0.38	1.70	3.80	2.71	0.64	1.48	4.45
	after evisceration	3.02	0.48	1.70	4.16	3.00	0.58	1.85	4.49
	after chilling	3.20	0.58	2.30	5.60	2.82	0.48	1.70	3.98
	caeca	8.01	0.82	6.69	9.11	7.96	0.48	7.10	8.74
After nudges	after defeathering	3.32	0.71	2.16	5.33	3.11	0.72	1.91	4.50
	after evisceration	3.68	0.88	2.34	5.51	3.31	0.79	2.07	5.44
	after chilling	3.67	0.83	2.36	5.60	3.27	0.72	2.33	5.30
	caeca	8.94	1.06	7.58	10.44	7.75	0.44	7.04	8.50

Table 5. Results from the comparison of *E. coli* concentration (log10 CFU/g of neck skin) between sampled locations before and after implementation of nudges. An asterisk indicate significant p values (<0.05).

	Before nudges		After nudges		Comparison before minus after nudges	
	Difference [log10]	p value	Difference [log10]	p value	Difference [log10]	p value
Line 1						
defeathering					-0.75	<0.01*
after evisceration - after defeathering	0.18	0.01*	0.36	<0.01*	-0.18	0.23
after chilling - after evisceration	0.19	0.01*	-0.01	0.93	0.20	0.18
after chilling-after defeathering	0.37	<0.01*	0.35	<0.01*	0.02	0.9
Line 2						
defeathering					-0.31	0.03*
after evisceration - after defeathering	0.29	<0.01*	0.2	0.14	0.09	0.53
after chilling - after evisceration	-0.18	0.07	-0.03	0.88	-0.15	0.3
after chilling-after defeathering	0.11	0.45	0.17	0.47	-0.06	0.68

A.



B.

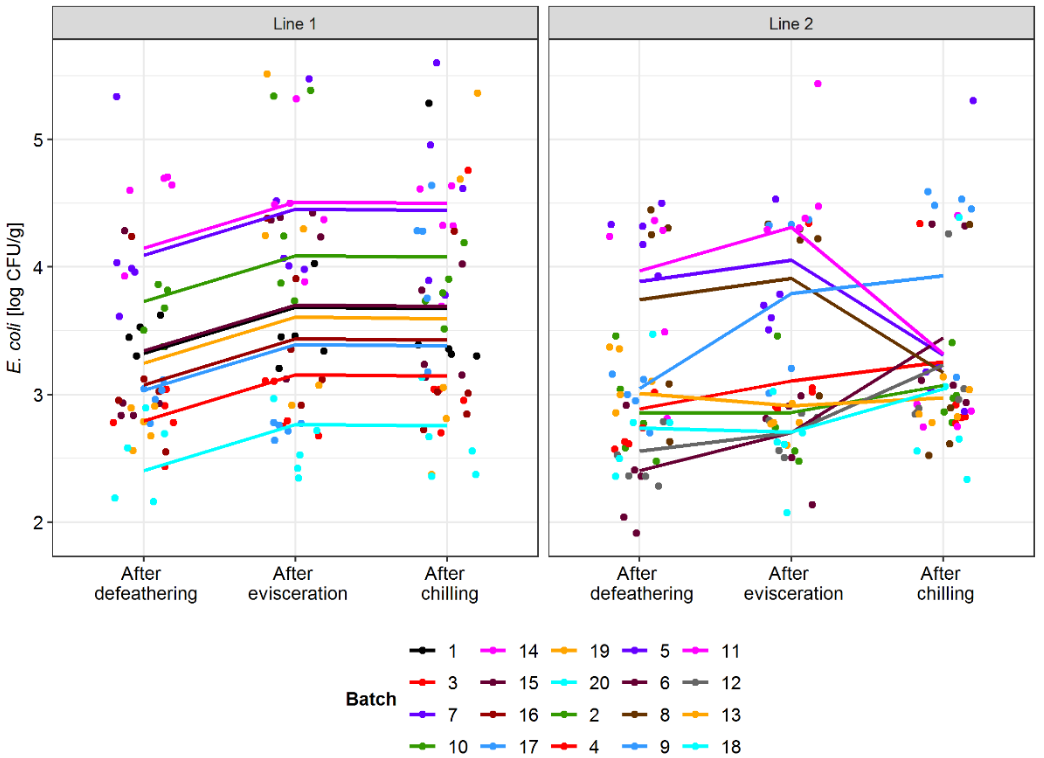


Figure 15. *E. coli* contamination in neck skin samples collected before and after evisceration and after chilling on Line 1 and Line 2 during field trials before (15A) and after implementation of nudges (15B). The lines summarise the average concentration per batch, while each dot concentration in each collected samples. Different colours indicate different batch. Lines are based on the model that the best fitted the data. Model with random intercept and fixed slope (the effect of a processing step) fitted the data on Line 1 collected both before and after nudges (parallel lines on Figure 15A and 15B for Line 1), whereas a model with random intercept and random slope fitted the data from Line 2 collected both before and after nudges (variable lines on Figure 15 A and 15B Line 2).

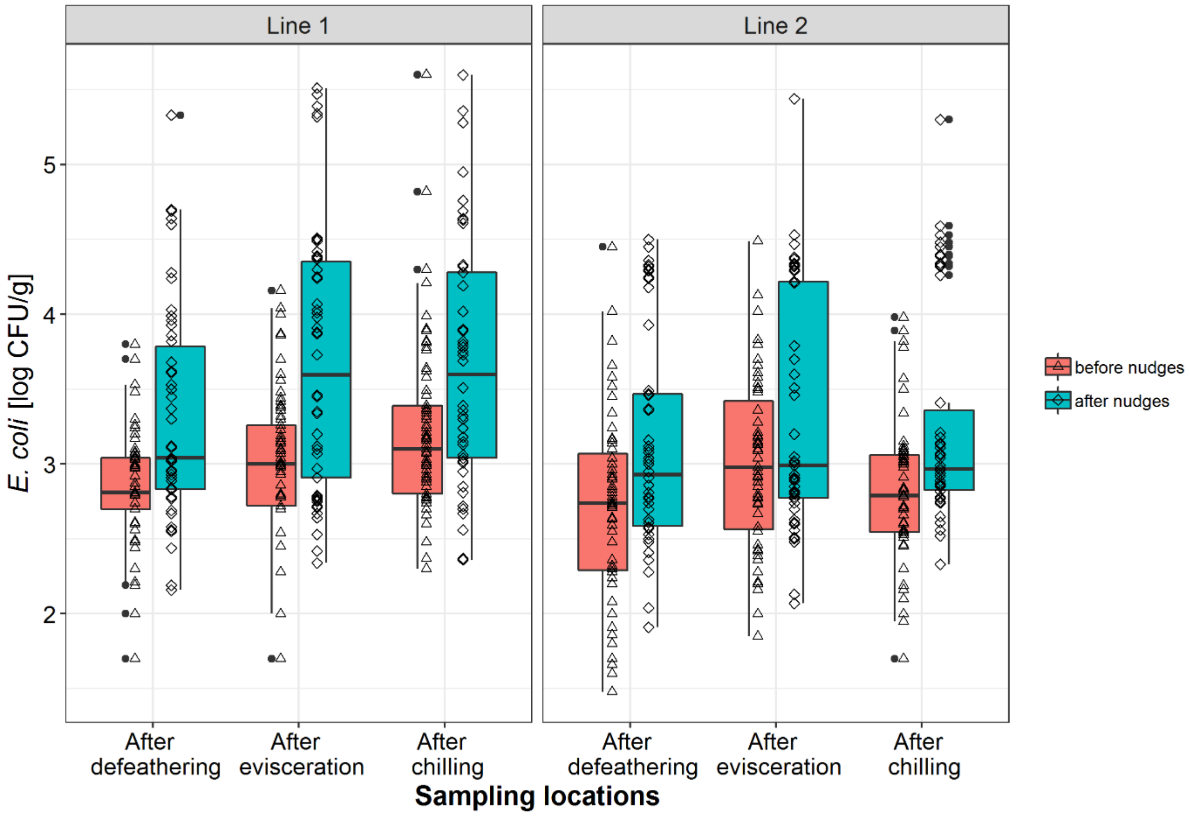


Figure 16. Comparison of *E.coli* [log CFU/g] in neck skin samples collected after defeathering, after evisceration and after chilling in the samples obtained in the field trials before (in red) and after (in blue) implementation of nudges. The results are from 13 batches of broilers for Line 1 and 11 batches for Line 2 before nudges, while the results after nudges are from 10 batches for Line 1 and 10 batches for Line 2. The length of the boxplot indicates the interquartile range (IQR) of the data (50% of the data), the horizontal bar inside the boxes indicates the median value; black dots, outliers (> 1.5 ×IQR below the first quartile or above the third quartile); whiskers represent 1.5 × IQR or the maximum/minimum value of the dataset. The triangles indicate *E.coli* concentration [log CFU/g] in each sample collected during the trials before implementation of nudges, whereas diamonds in the field trials after implementation of nudges.

3.5 Characteristics of the sampled batches

The content of the gizzards was evaluated as an indication of the feed withdrawal time. Feed is withdrawn to reduce the content of guts and thus limit the faecal leakage during slaughter (Warriss et al., 2004).

Table 5 and Figure 17 below summarise the scores assigned to the content of the gizzards in the batches samples on Line 1 and 2 in field trials before and after implementation of nudges. It showed that the scores were higher (i.e. gizzards more filled) in batches tested after implementation of nudges.

Table 6. Summary of the mean scores of the content of the gizzards

Line	Field trials	Mean	SD	Min	Max
Line 1	Before nudges	2.0	0.4	0.8	2.6
	After nudges	2.4	0.6	1.3	3.0
Line 2	Before nudges	1.8	0.6	0.4	2.6
	After nudges	2.3	0.8	1.0	3.0

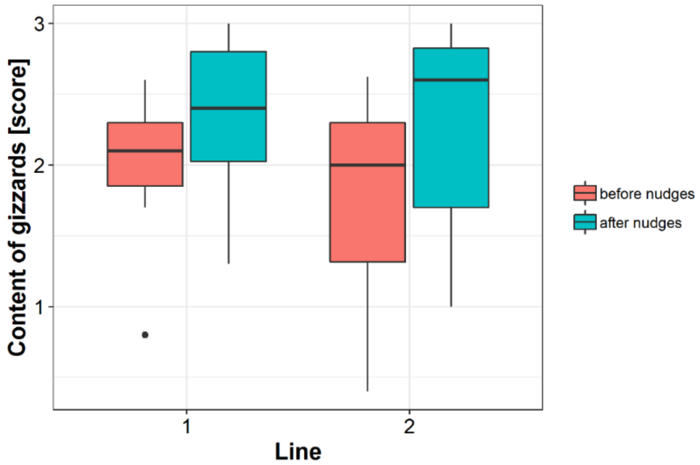


Figure 17. Summary of the scores indicating filling of gizzards of the batches sampled before (in red) and after implementation of nudges (in blue). The higher the score the more filled the gizzards.

In addition uniformity of the sampled batches was evaluated based on internal documentation available at the processing lines. There uniformity was categorised by the employees at the processing liens as good, reasonable, mediocre and bad. We assigned scores from 4 to 1 respectively to calculate the overall score of batches samples before and after implementation of nudges per each line. Thus the higher the score the more uniform the batch. While on Line 1 the score for the batches sampled in before nudges was 3.1 and 3 after nudges implementation, it was 2.8 for batches sampled from Line 2 both before and after nudges implementation. Thus the uniformity according to the internal documentation did not differ between the batches samples before and after nudges and was slightly better on Line 1.

With respect to the bacterial levels in caeca, it was observed that *Campylobacter* concentration in caeca on Line 1 was comparable between trials before and after implementation of nudges (8.3 log/g prior nudges vs 8.2 log/g post nudges), whereas lower on Line 2 after implementation (8.3 log/g prior nudges vs 7.0 log/g post nudges). *E. coli* levels in caeca on Line 1 were higher post nudges (8.0 log/g prior vs 8.9 log/g post nudges), and comparable on Line 2 (8.0 log/g prior vs 7.8 log/g post nudges) (Tables 2 and 4). These quantitative results are based on one pooled sample per batch only.

4 Discussion/conclusions

Control of *Campylobacter* contamination during broiler processing remains a challenge. While various interventions related to processing technology were studied, hardly any addressed the management of processing where human behaviour play a role. This study aimed at exploring a preventive approach to control the occurrence of the faecal leakage, a major source of *Campylobacter* contamination, during evisceration that is one of the key step where such leakage occurs.

Developed nudges addressed attention, social norms, commitment and motives of food handlers
During the study a number of nudges were developed and tailored to direct the behaviour of food handlers working at the evisceration department including operators and post mortem inspectors. Nudges are defined as any attempt influencing people's behaviour in a predictable way as for e.g. changes in the presentation of various choice alternatives in such a way that makes the desired choice easier, automatic or default (De Ridder, 2014; Hansen, 2016). Thus in the study several visual aids were placed at production lines and in the canteen. They aimed at reminding the food handlers about controlling and adjusting of the evisceration equipment and handling of the carcasses with visible faecal contamination. In addition to these reminders, a meeting was organised by the research team in cooperation with a member of the quality management aiming at raising the commitment of the food handlers. This was an important meeting in the concept of nudges implementation during which various reminders and cues to address attention, social norms and motives were presented. In addition the food handlers were provided with feedback on the performance on the evisceration process.

Food handlers improved some of the behaviours for which they were nudged
Results revealed changes in behaviour of food handlers with respect to handlings for which they were nudged. Post mortem inspectors (PMIs) handled the carcasses with visible faecal contamination more frequently after implementation of nudges. A decrease in the number of such carcasses following the inspection was higher post nudge implementation, although not statistically significant. It should be noted that the majority of the PMIs attended the meeting mentioned above. This was in contrast to operators. Unfortunately only 3 operators attended the meeting dedicated to raising their commitment. The operators that did not attend the meeting were informed individually or in small groups by the quality management at a later time (without presence of people from the research team).

The operators (who set and adjust evisceration equipment) were nudged through visual aids to remind them to observe the carcasses for a sufficient amount of time and adjust the equipment if needed. After implementation of reminders they indeed observed the product and process longer. However not always the setting and adjusting of the equipment was done more frequent after implementation of nudges. On Line 1 adjustment at the vent cutter equipment was less frequent. Subsequently a significantly higher increase was observed in the percentage of carcasses with high level of visible faecal contamination after this step in the trials following implementation of nudges as compared to the trials before. There were no differences in increases/decreases in the percentage of carcasses with low level of visible faecal contamination at examined evisceration steps on that line before and after implementation of the nudges. On Line 2, depending on equipment some settings were done with higher or lower frequency after implementation of nudges. While comparing the increases and decreases in the percentage of carcasses with high level of visible faecal contamination between trials before and after nudges implementation there was no statistically significant differences. A lower increase in the percentage of carcasses with the low level of visible faecal contamination was observed after vent cutter and opener, however a higher increase was found after evisceration in the trials post nudges implementation as compared to before.

Furthermore, on Line 2 an improvement was observed in making records by the operators for what they were nudged. In the field trials before implementation of the nudes the sheets for making records on Line 2 were placed in a cabinet in the corridor, thus not easy to access. The research team suggested to move the records sheets from the cabinet. The company made this change and replaced the records sheets from a cabinet to a table, positioned just in front of the exit doors from the production area. Besides nudging there was another reason for implementing this, i.e. installation of a hygienic barrier at the place where the cabinet with records sheets was placed during trials before implementation of nudges. In addition we suggested to nudge food handlers on both lines for making records by placing a reminder at the doors as a short term solution, and by implementing an electronic system for making records as a long term solution. The reminders were however not implemented. Implementation of an electronic system for entering records was foreseen at both processing lines, however implemented after the field trials. Thus nudges for making records were partly implemented on Line 2 as suggested in our proposal, whereas no nudges were applied on Line 1. This might explain the lack of improvement on Line 1 towards making records.

Increase in *Campylobacter* and *E. coli* levels after evisceration did not change after implementation of nudges
With respect to microbiological contamination, on both lines the levels of *Campylobacter* and *E. coli* were higher prior to evisceration in the field trials following implementation of nudges, indicating a higher initial load. This might be due to differences in characteristics of the sampled flocks. Our findings showed that the batches slaughtered after implementation of nudges had in general more filled gizzards. This might imply that the intestinal were also more filled and the potential of faecal leakage might have been higher. Nevertheless no difference in the effect of evisceration was observed post nudges implementation. Whether this had been affected by nudging can only be speculated.

Challenges approached during the study suggest potential for nudges improvement
There were some limitations of the current study, one of which was the time of the field trails. There was a long gap between the inventory trials (in 2017) and the evaluation field trials (in 2018). There were delays in implementing the nudges caused by various circumstances at the processing lines, as management change, various level of commitment and involvement of employees. The field trials before implementation of nudges were conducted between July and September, while those after implementation in October, when in general the percentage of *Campylobacter* positive flock is lower as compared to July-September (Anonymous, 2018). Therefore after implementation of nudges less sampled flocks were positive for *Campylobacter*. In addition just before the field trials in 2018 the evisceration equipment i.e. vent cutter, opener on Line 2 were replaced. Also during the chilling an additional ventilation was implemented in the period between the two field trials.

Additional nudges dedicated to operators were proposed in the current study, however not implemented by the management of the processing lines. They included for example a feedback board that could be placed in the canteen to provide to the employees information on performance of the evisceration in terms of presence of carcasses with visible faecal contamination. It has been shown that receiving feedback can reduce mistakes. Also such a tool could introduce a competition between shifts and thus activate ego motive, since people like to feel better about themselves (Dolan, 2012; Thaler, 2008; Yiannas, 2008). Although the need for regular feedback to employees was agreed by the management of the processing lines, at the time of implementation of the study they were not open for such approach.

The field trials conducted in the current study were rather limited to a few batches tested per each line each year. Additional slaughter plant data showed a slight reduction in the number of samples exceeding the PHC post nudges implementation. The difference was however not statistically significant. It is difficult to judge whether or to what extend this difference can be attributed to the sampling season. In general in October there are less *Campylobacter* positive broiler batches and the *Campylobacter* levels on skin samples are lower as compared to summer (Anonymous, 2018). However the PHC criterion is based on a relatively large window of sampling (10 weeks of time), implying that the results from the field trials before implementation of nudges (in 2017) are based on results from the summer/autumn period, while those after implementation (in 2018) from autumn only. Importantly, the management of the processing lines reported that they noticed an improvement post nudge implementation. In their opinion, this study raised attention of the food handlers and various discussions even several weeks following the study.

In conclusion, after implementation of nudges the behaviour of food handlers improved for some activities for which they were nudged. Nudges for adjusting the evisceration equipment may need further optimisation. These activities of the food handlers might have been influenced by characteristics of batches and equipment itself. Activities of the PMIs might be less dependent of such factors. Improvement in behaviour of PMIs post nudges implementation confirms thus potential of this cost-effective intervention during broiler processing.

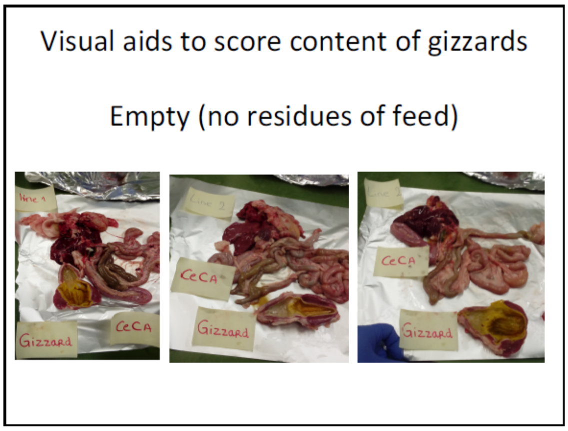
5 References

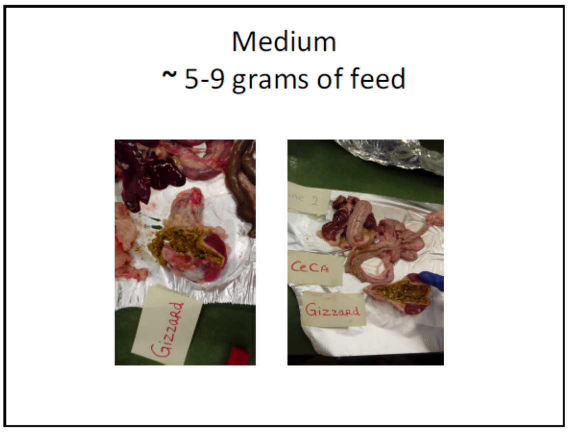
- Abdul-Mutalib, N., Abdul-Rashid, M., Mustafa, S., Amin-Nordin, S., Hamat, R. A., Osman, M., 2012. Knowledge, attitude and practices regarding food hygiene and sanitation of food handlers in Kuala Pilah, Malaysia. Food Control 27, 289-293.
- Achterberg, R., Pacholewicz, E., Stamatelou, G., Woning, van der, M., Wal, van der, F., J., Koene, M. , 2016. Using Recombinase Polymerase Amplification for the detection of Campylobacter in chicken faeces. Poster presented during the 11th Conference on Rapid Methods Europe, Amsterdam, The Netherlands, 7-9 November 2016.
- Angelillo, I.F., Viggiani, N.M., Rizzo, L., Bianco, A., 2000. Food handlers and foodborne diseases: knowledge, attitudes, and reported behavior in Italy. J Food Prot 63, 381-385.
- Anonymous, 2017. Commission regulation (EU) 2017/1495 of 23 august 2017 amending regulation (EC) No 2073/2005 as regards *Campylobacter* in broiler carcases. http://eur-lex.europa.eu/eli/reg/2017/1495/oj last access: March 2018.
- Anonymous, 2018. Rapportage Campylobacter monitoring 2017 op Nederlandse vleeskuikenslachterijen. NEPLUVI internal report. Available online: https://www.nepluvi.nl/dynamic/media/1/documents/Campylobacter/2018-030_eindrapportage_campylobactermonitoring_2017_NL_vleeskuikenslachterijen.pdf.
- Ansari-Lari, M., Soodbakhsh, S., Lakzadeh, L., 2010. Knowledge, attitudes and practices of workers on food hygienic practices in meat processing plants in Fars, Iran. Food Control 21, 260-263.
- Baş, M., Şafak Ersun, A., Kıvanc, G., 2006. The evaluation of food hygiene knowledge, attitudes, and practices of food handlers' in food businesses in Turkey. Food Control 17, 317-322.
- Bashor, M.P., Curtis, P.A., Keener, K.M., Sheldon, B.W., Kathariou, S., Osborne, J.A., 2004. Effects of carcass washers on Campylobacter contamination in large broiler processing plants. Poultry Science 83, 1232-1239.
- Bauermeister, L.J., Bowers, J.W., Townsend, J.C., McKee, S.R., 2008. The microbial and quality properties of poultry carcasses treated with peracetic acid as an antimicrobial treatment. Poultry Science 87, 2390-2398.
- Berrang, M.E., Dickens, J.A., Musgrove, M.T., 2000. Effects of hot water application after defeathering on the levels of Campylobacter, coliform bacteria, and Escherichia coli on broiler carcasses. Poultry Science 79, 1689-1693.
- Berrang, M.E., Smith, D.P., Windham, W.R., Feldner, P.W., 2004. Effect of intestinal content contamination on broiler carcass Campylobacter counts. J Food Prot 67, 235-238.
- Biggs, R., 2015. Tegel Foods Ltd. presentation during conference. The 18th International workshop on Campylobacter, Helicobacter and related organisms, Rotorua, New Zealand, 1-5 November 2015.
- Bolder, N., 2007. Microbial challenges of poultry meat production. World's Poultry Science Journal 63, 401-411.
- Boysen, L., Rosenquist, H., 2009. Reduction of thermotolerant Campylobacter species on broiler carcasses following physical decontamination at slaughter. J Food Prot 72, 497-502.
- Burfoot, D., Allen, V., 2013. Relationship Between Visible Contamination and Campylobacter Contamination on Poultry. The 17th International Workshop on Campylobacter, Helicobacter and Related Organisms, Aberdeen, Scotland, UK, 15-19 September.
- Cibin, V., Mancin, M., Pedersen, K., Barrucci, F., Belluco, S., Roccato, A., Cocola, F., Ferrarini, S., Sandri, A., Lau Baggesen, D., Ricci, A., 2014. Usefulness of Escherichia coli and Enterobacteriaceae as Process Hygiene Criteria in poultry: experimental study. Available online: http://www.efsa.europa. eu/en/supporting/doc/635e.pdf; Last accessed: January 2016.
- Clayton, D.A., Griffith, C.J., Price, P., Peters, A.C., 2002. Food handlers' beliefs and self-reported practices. Int J Environ Health Res 12, 25-39.
- De Boeck, E., Jacxsens, L., Bollaerts, M., Vlerick, P., 2015. Food safety climate in food processing organizations: development and validation of a self-assessment tool. Trends in Food Science & Technology 46, 242-251.
- De Ridder, D., 2014. Nudging for beginners. The European Health Psychologist 16, 2-6.
- Dolan, P., Hallsworth, M., Halpern, D., King, D., Metcalfe, R., & Vlaev, I. , 2012. Influencing behaviour: The mindspace way. Journal of Economic Psychology 33, 264-277.
- Dreibelbis, R., Kroeger, A., Hossain, K., Venkatesh, M., Ram, P.K., 2016. Behavior Change without Behavior Change Communication: Nudging Handwashing among Primary School Students in Bangladesh. Int J Environ Res Public Health 13.
- EFSA, 2011. Scientific Opinion on Campylobacter in broiler meat production: control options and performance objectives and/or targets at different stages of the food chain. EFSA Journal 9(4):2105.
- EFSA, 2018. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2017. EFSA Journal 16(12):5500.
- Hansen, P.G., 2016. The Definition of Nudge and Libertarian Paternalism: Does the Hand Fit the Glove? . The European Journal of Risk Regulation. EJRR.

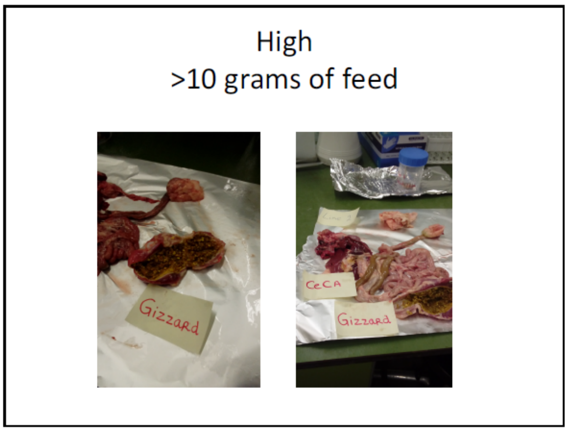
- Haughton, P.N., Lyng, J., Cronin, D., Fanning, S., Whyte, P., 2012. Effect of crust freezing applied alone and in combination with ultraviolet light on the survival of Campylobacter on raw chicken. Food Microbiology 32, 147-151.
- ISO_10272-2:2017, Microbiology of the food chain - Horizontal method for detection and enumeration of *Campylobacter* spp. - Part 2: Colony-count technique. International Organization for Standardization, Geneva, Switzerland.
- James, C., James, S.J., Hannay, N., Purnell, G., Barbedo-Pinto, C., Yaman, H., Araujo, M., Gonzalez, M.L., Calvo, J., Howell, M., 2007. Decontamination of poultry carcasses using steam or hot water in combination with rapid cooling, chilling or freezing of carcass surfaces. International Journal of Food Microbiology 114.
- Kere Kemp, G., Aldrich, M., Guerra, M., Schneider, K., 2001. Continuous online processing of fecal- and ingesta-contaminated poultry carcasses using an acidified sodium chlorite antimicrobial intervention. J Food Prot 64, 807-812.
- Lindhout, P., Reniers, G. , 2017. What About Nudges in the Process Industry? Exploring a new safety management tool. Journal of Loss Prevention in the Process Industries
- 50, 243-256.
- Loretz, M., Stephan, R., Zweifel, C., 2010. Antimicrobial activity of decontamination treatments for poultry carcasses: a literature survey. Food Control 21, 791-804.
- Marteau, T.M., Ogilvie, D., Roland, M., Suhrcke, M., & Kelly, M. P., 2011. Judging nudging: can nudging improve population health? BMJ 342, d228–d228.
- Mont, O., Lehner, M., Heiskanen, E., 2014. Nudging A tool for sustainable behaviour? Report 6643, Swedish EPA, Stockholm, Sweden.
- Musavian, H.S., Krebs, N.H., Nonboe, U., Corry, J.E., Purnell, G., 2014. Combined steam and ultrasound treatment of broilers at slaughter: a promising intervention to significantly reduce numbers of naturally occurring campylobacters on carcasses. International Journal of Food Microbiology 176, 23-28.
- Nagel, G.M., Bauermeister, L.J., Bratcher, C.L., Singh, M., McKee, S.R., 2013. Salmonella and Campylobacter reduction and quality characteristics of poultry carcasses treated with various antimicrobials in a post-chill immersion tank. Int J Food Microbiol 165, 281-286.
- Northcutt, J.K., Smith, D.P., Musgrove, M.T., Ingram, K.D., Hinton, A., Jr., 2005. Microbiological impact of spray washing broiler carcasses using different chlorine concentrations and water temperatures. Poult Sci 84, 1648-1652.
- Pacholewicz, E., Barus, S. A. S., Swart, A., Havelaar, A. H., Lipman, L. J. A., Luning, P. A. , 2016. Influence of food handlers’ compliance with procedures of poultry carcasses contamination: a case study concerning evisceration in broiler slaughterhouses. . Food Control 68, 367-378.
- Pacholewicz, E., Swart, A., Schipper, M., Gortemaker, B.G., Wagenaar, J.A., Havelaar, A.H., Lipman, L.J., 2015. A comparison of fluctuations of Campylobacter and Escherichia coli concentrations on broiler chicken carcasses during processing in two slaughterhouses. Int J Food Microbiol 205, 119-127.
- Rosenquist, H., Sommer, H.M., Nielsen, N.L., Christensen, B.B., 2006. The effect of slaughter operations on the contamination of chicken carcasses with thermotolerant Campylobacter. Int J Food Microbiol 108, 226-232.
- Sunstein, C.R., 2014. Nudging: a very short guide. Journal of Consumer Policy 37, 583-588.
- Thaler, R.H., Sunstein, C.R., 2008. Nudge: Improving decisions about health, wealth, and happiness. Yale University Press.
- Tokuc, B., Ekuklu, G., Berberoğlu, U., Bilge, E., Dedeler, H., 2009. Knowledge, attitudes and self-reported practices of food service staff regarding food hygiene in Edirne, Turkey. Food Control 20, 565-568.
- Vrancken, B.J.A., 2018. Compliance behaviour of food handlers in broiler processing: exploring the possibilities of nudges. MSc Thesis Report.
- Warriss, P.D., Wilkins, L.J., Brown, S.N., Phillips, A.J., Allen, V., 2004. Defaecation and weight of the gastrointestinal tract contents after feed and water withdrawal in broilers. Br Poult Sci 45, 61-66.
- Whyte, P., McGill, K., Collins, J., 2003. An assessment of steam pasteurization and hot water immersion treatments for the microbiological decontamination of broiler carcasses. . Food Microbiology 20, 111-117.
- Yiannas, F., 2008. Food safety culture: Creating a behaviour-based food safety management system. Springer Science & Business Media.

6 Appendix

6.1 Visual aids to judge the content of gizzards



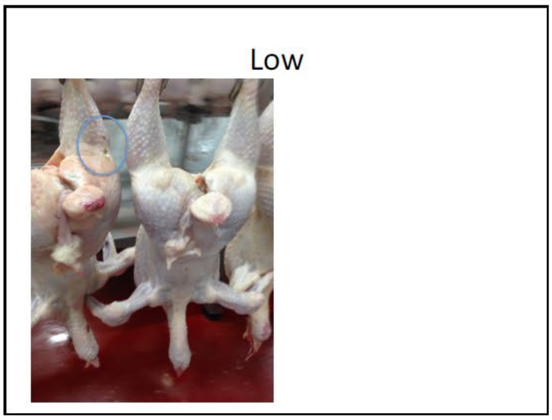


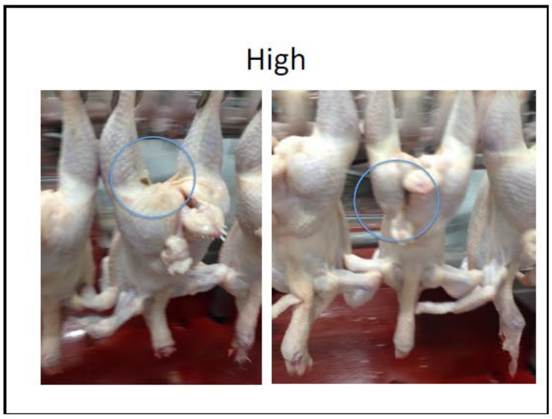


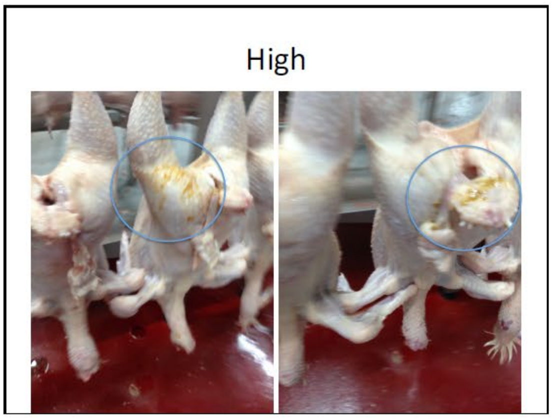
6.2 Visual aids to judge the presence of faecal contamination

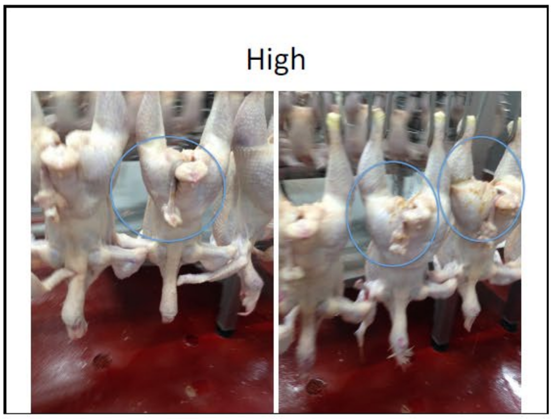
Visual aids to judging the level of visible faecal contamination on carcasses

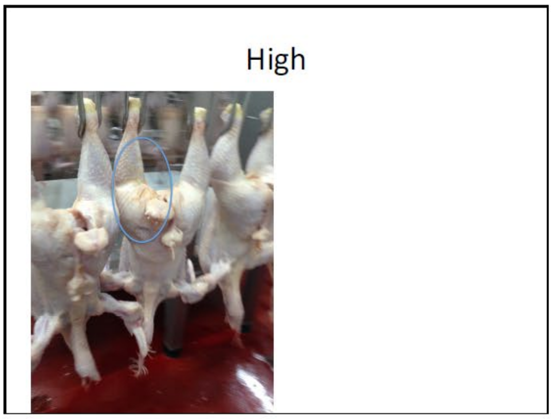
- Low level: spot of faecal contamination (for e.g. spot < 5 mg, < $3mm^2$)
- High level: substantial leakage of faecal material, or big spot of faeces (as big as for e.g. little finger nail, or bigger)



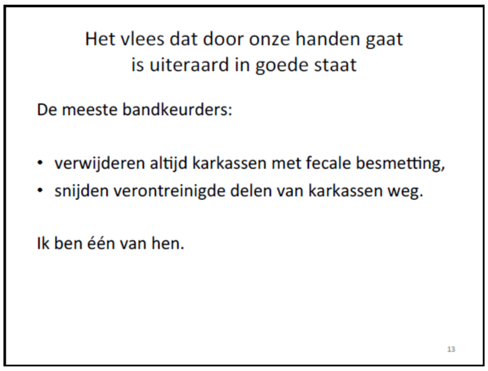








6.3 Example of nudges-cues to raise commitment



6.4 Descriptive statistics on visible faecal contamination

Table A. Descriptive statistics on visible faecal contamination during the evisceration process. The data show percentage of carcasses with visible faecal contamination observed on Line 1 and Line 2 during field trials before and after implementation of nudges.

Line	Contamination	Descriptive	Nudges	defeathering	vent cutter	opener	eviscerator	post mortem
Line 1	Low	Mean	before	0.13	0.57	1.21	1.37	1.50
			after	0.31	0.92	1.25	1.43	1.55
		SD	before	0.17	0.35	0.71	0.84	0.69
			after	0.27	0.31	0.40	0.71	0.63
		Min	before	0.00	0.11	0.41	0.22	0.43
			after	0.00	0.41	0.73	0.45	0.58
		Max	before	0.63	1.07	2.73	3.10	2.38
			after	0.88	1.32	1.96	2.63	2.88
	High	Mean	before	0.01	0.56	1.73	0.67	0.88
			after	0.07	2.83	4.04	1.33	1.14
		SD	before	0.03	0.41	1.10	0.39	0.34
			after	0.09	0.97	1.33	1.29	1.10
		Min	before	0.00	0.00	0.36	0.00	0.42
			after	0.00	1.31	2.03	0.00	0.14
		Max	before	0.12	1.40	4.22	1.26	1.37
			after	0.22	3.97	6.10	4.65	3.98
Line 2	Low	Mean	before	0.12	0.95	1.28	1.36	1.50
			after	0.34	0.68	0.55	1.33	1.07
		SD	before	0.14	0.43	0.53	0.66	0.76
			after	0.21	0.32	0.35	0.53	0.40
		Min	before	0.00	0.37	0.37	0.38	0.32
			after	0.10	0.10	0.00	0.56	0.42
		Max	before	0.50	1.77	2.32	2.48	3.10
			after	0.76	1.10	1.10	1.99	1.77
	High	Mean	before	0.02	2.48	2.42	1.53	1.47
			after	0.12	1.78	2.47	1.58	1.37
		SD	before	0.04	1.93	1.37	1.34	1.06
			after	0.11	0.98	1.61	0.84	0.89
		Min	before	0.00	0.19	0.56	0.00	0.19
			after	0.00	0.41	1.03	0.82	0.50
		Max	before	0.09	7.37	4.52	4.21	3.84
			after	0.35	3.41	5.87	3.47	3.36

6.5 *Campylobacter* raw results per batch

Figure A. *Campylobacter* results obtained during field trials before implementation of nudges on Line 1.

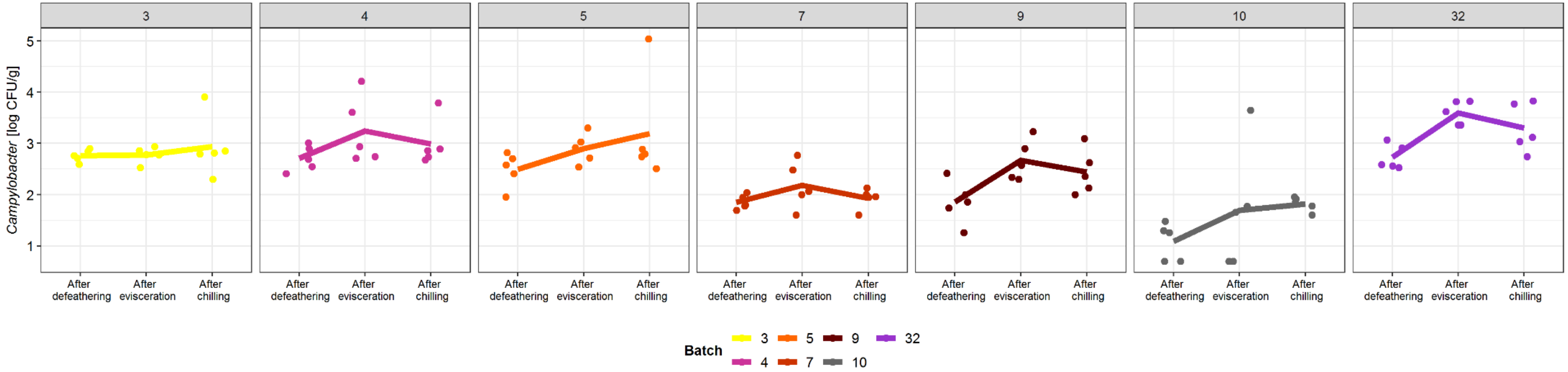


Table A. Results on characteristics of batches positive for *Campylobacter* processed on Line 1 before implementation of nudges.

Batch	3	4	5	7	9	10	32
Uniformity	reasonable	reasonable/good	reasonable	reasonable	reasonable	reasonable/good	reasonable/good
Gizzards	2.3	2.6	2.2	1.9	1.8	2.3	2.0

Figure B. *Campylobacter* results obtained during field trials before implementation of nudges on Line 2.

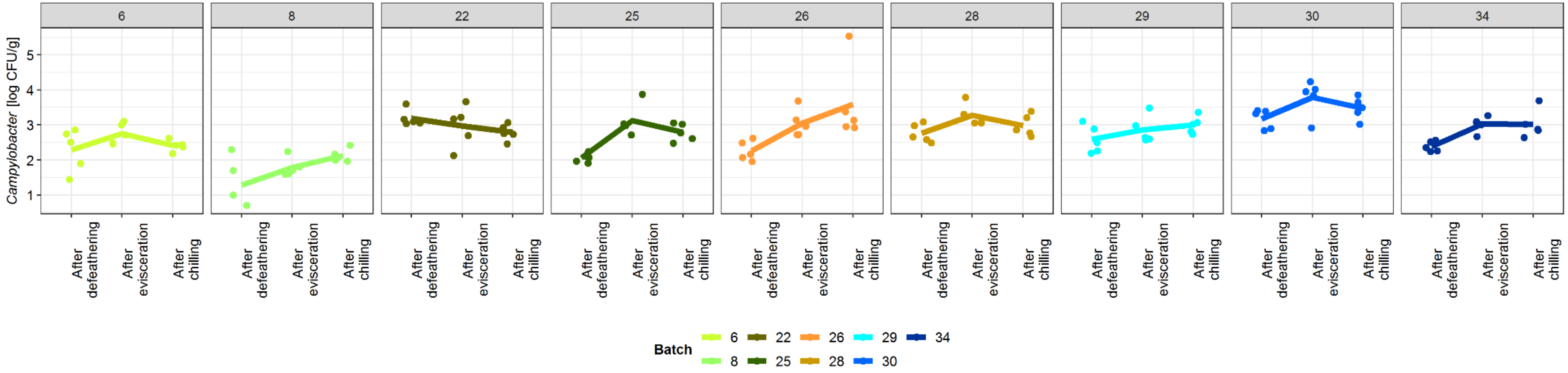


Table B. Results on characteristics of batches positive for *Campylobacter* processed on Line 2 before implementation of nudges .

Batch	6	8	22	25	26	28	29	30	34
Uniformity	reasonable	reasonable	reasonable	reasonable	reasonable / mediocre	NA	NA	mediocre	reasonable /good
Gizzards	2.3	1.3	1.3	2.0	2.3	1.33	0.4	1.0	1.90

Figure C. *Campylobacter* results obtained during field trials after implementation of nudges on Line 1.

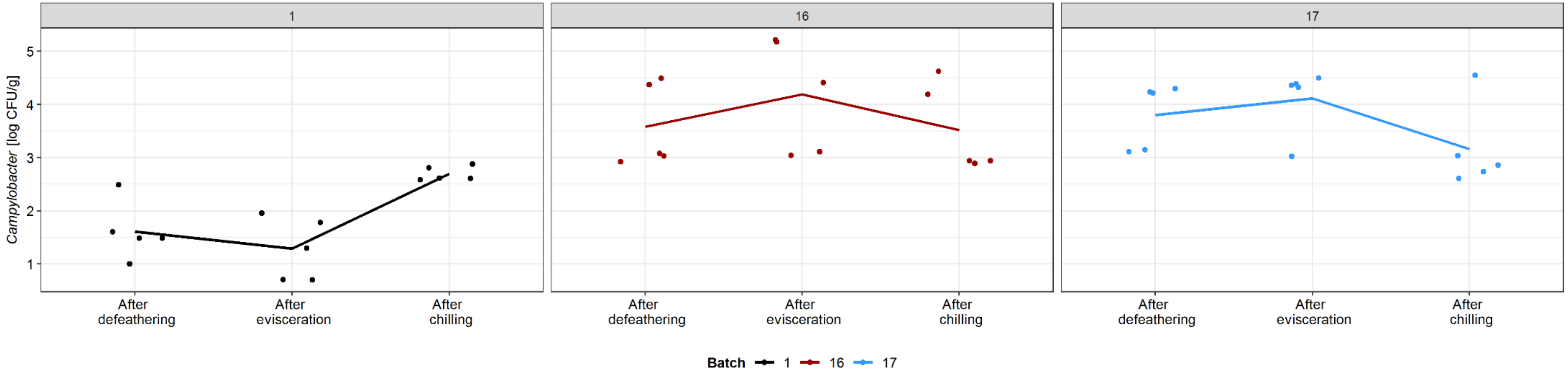


Table C. Results on characteristics of batches positive for *Campylobacter* processed on Line 1 after implementation of nudges .

Batch	1	16	17
Uniformity	reasonable	reasonable	good
Gizzards	2.8	1.8	2.1

Figure D. *Campylobacter* results obtained during field trials after implementation of nudges on Line 2.

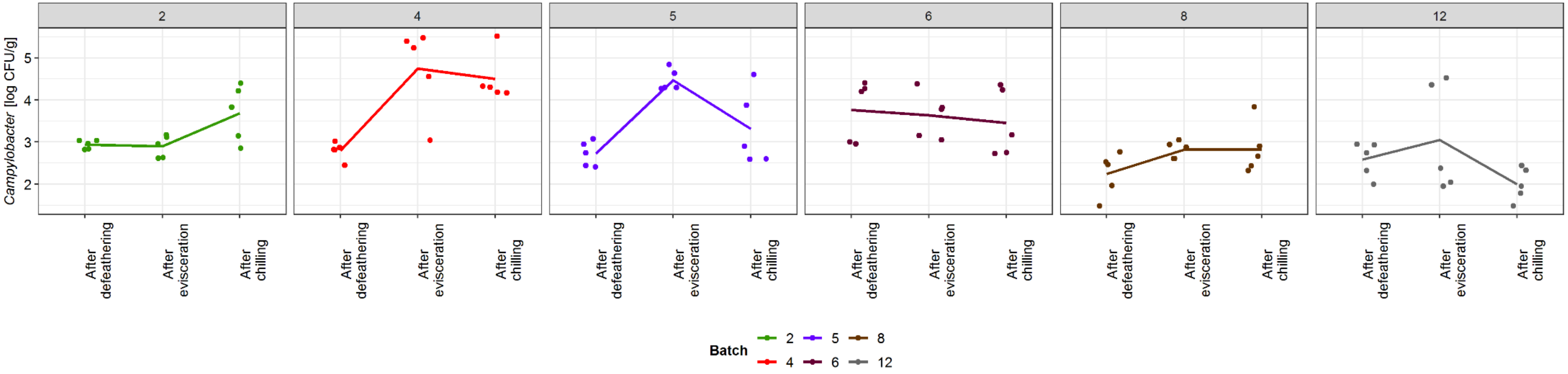


Table D. Results on characteristics of batches positive for *Campylobacter* processed on Line 2 after implementation of nudges .

Batch	2	4	5	6	8	12
Uniformity	reasonable	mediocre	mediocre	reasonable	reasonable	mediocre
Gizzards	1.4	3.0	2.9	1.8	1.0	NA