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Influence of food handlers' compliance with procedures of poultry carcasses contamination: A case study concerning evisceration in broiler slaughterhouses

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ABSTRACT

Campylobacter remains the most commonly reported zoonotic agent worldwide. Reducing the concentration of *Campylobacter* on chicken meat is seen as the most efficient strategy to diminish the number of human campylobacteriosis cases. Analysis of risk factors related to characteristics of broiler batches and processing conditions could, however, not fully explain differences in impact of processing on contamination levels between slaughterhouses. Our study aimed at investigating whether compliance of food handlers with procedures on setting and controlling evisceration process parameters could explain differences in microbial concentrations on carcasses between slaughterhouses. The study was conducted in two commercial broiler chicken slaughterhouses. Analysis of documentation provided insight in the adequacy of procedures, and observational studies revealed insight in compliance with procedures by using a set of criteria for evisceration control. The frequency of carcasses with visible faecal contamination was counted and *Escherichia coli* concentrations on carcasses classified based on visible contamination was analysed. *E. coli* was found to be a valid indicator for *Campylobacter* during evisceration. Food handlers' knowledge, attitude and practices related to evisceration control tasks were analysed based on a validated questionnaire. Documentation analysis revealed obvious differences in the procedures between slaughterhouses. The observation study revealed that in the slaughterhouse with advanced procedures, the food handlers more often complied with these procedures and a lower frequency of carcasses with visible faecal contamination was observed. Carcasses contaminated with visible faecal spots, even at a low level, carried significantly higher concentrations of *E. coli* than visibly clean carcasses. Food handlers in both slaughterhouses revealed a good knowledge level. The attitude of food handlers differed between slaughterhouses. In one slaughterhouse, where food handlers complied more frequently with procedures their attitude was at a good level, and practices at good and moderate levels. In the other slaughterhouse the attitude of food handlers was at moderate level and practices at moderate and poor levels. In conclusion, the results from our case study suggest that management factors like availability of adequate monitoring procedures and food handlers' compliance with these procedures may influence the bacterial concentrations on carcasses. Our study demonstrated that compliance with procedures differed between slaughterhouses, and might be associated with faecal contamination of carcasses and thus with higher bacterial concentrations. These results suggest that managerial improvements, supervising and motivating food handlers could be an important control point. To validate the observed relation between compliance with procedures and contamination of carcasses, an intervention study is needed.

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1. Introduction

Campylobacter remains the most commonly reported zoonotic agent worldwide. A high fraction of campylobacteriosis cases in humans is accounted to the poultry reservoir and 20–30% of the cases to the handling, preparation and consumption of broiler meat (European Food Safety Authority, 2010). Risk assessment studies indicate that compliance of broiler meat batches with a *Campylobacter* microbiological criterion is the most efficient strategy to diminish human infection (European Food Safety Authority, 2011). Setting a hygiene target based on *Escherichia coli* concentrations of carcasses after chilling was proposed to be useful as an indirect sanitary tool for reducing the level of *Campylobacter* contamination of post-chilled broiler carcasses (European Food Safety Authority, 2012a; European Food Safety Authority, 2012b). In addition, changes in concentrations of *Campylobacter* and *E. coli* throughout the processing are similar (Pacholewicz et al., 2015). *Campylobacter* as well as *E. coli* concentrations on broiler chicken carcasses after chilling vary between slaughterhouses (Anonymous, 2011; Habib, De Zutter, Van Huffel, Geeraerd, & Uyttendaele, 2012; Pacholewicz et al., 2015; Seliwiorstow, Baré, Van Damme, Uyttendaele, & De Zutter, 2015). Identifying the causes of variation in the bacterial concentration between slaughterhouses could support the development of strategies to reduce the bacterial concentrations on chicken meat and thus the number of campylobacteriosis cases in humans.

The impact of processing steps on *Campylobacter* and *E. coli* contamination levels was reported to vary between two slaughterhouses (Pacholewicz et al., 2015). These slaughterhouses have similar equipment and operational food safety management systems based on HACCP principles and prerequisite requirements, and comparable contamination levels of *Campylobacter* and *E. coli* in the incoming batches. The effect of processes such as evisceration on bacterial concentration on carcasses has frequently been reported to differ between slaughterhouses, causing either an increase or no change in concentrations (Pacholewicz et al., 2015; Rosenquist, Sommer, Nielsen, & Christensen, 2006; Seliwiorstow et al., 2015). These differences might stem from processing parameters or characteristics of incoming batches, which will be reported separately (Pacholewicz, Swart, Wagenaar, Lipman, & Havelaar, in preparation). Also such differences might be influenced by factors related to food handlers.

Luning and Marcelis (2006) hypothesized that food quality is not only affected by the behaviour of the food systems (i.e. the properties of the product and processes), but could also be affected by the decision making behaviour of people operating the food production system within a certain company context. Moreover it was observed that food handlers did not always follow prescribed hygiene practices (Baş, Şafak Ersun, & Kıvanç, 2006; Jianu & Chiş, 2012; Walker, Pritchard, & Forsythe, 2003). Variable compliance of food handlers with procedures may impact product safety parameters as demonstrated in the case of concentration of acrylamide in French fries (Sanny, Jinap, Bakker, van Boekel, & Luning, 2012; Sanny, Luning, Jinap, Bakker, & van Boekel, 2013). Compliance with adequate procedures is necessary to produce food products that do not contain bacteria above an acceptable level (Luning, Bango, Kussaga, Rovira, & Marcelis, 2008).

Despite the high automation level in poultry processing (Barbut, 2014), certain activities still need to be executed by food handlers, e.g. adjusting the equipment to the size of the carcasses and taking corrective actions in case processes do not perform properly. Proper adjustment of equipment prevents the leakage of faecal contamination and thus prevents an increase in bacterial concentration on carcasses. Presence of visibly contaminated carcasses after evisceration was previously reported (Burfoot & Allen, 2013; Cason, Berrang, Buhr, & Cox, 2004; Cibin et al., 2014; Smith et al., 2007). Based on our literature survey, the compliance of food handlers with hygiene and food safety procedures in broiler chicken slaughterhouses and its impact on microbiological concentration has not yet been studied.

This study aimed to investigate whether compliance of food handlers with procedures on setting and controlling evisceration equipment could explain differences in the impact of the evisceration process on *E. coli* concentrations between slaughterhouses. To reach this goal, the structure of available procedures related to the evisceration process in the slaughterhouses was analysed against Good Manufacturing Practices. Furthermore, a set of criteria for optimal control of evisceration was developed and it was observed whether the available procedures and food handlers complied with these criteria. The frequency of carcasses with visible faecal contamination after evisceration was calculated and the *E. coli* concentration on the contaminated carcasses was analysed. *E. coli* was chosen because its concentration after evisceration changes in a similar way as *Campylobacter* (Pacholewicz et al. 2015). The quantification of *E. coli* is more rapid and cost effective than quantification of *Campylobacter*. In addition *E. coli* occurs frequently on carcasses, whereas presence of *Campylobacter* is seasonal.

In addition, the level of knowledge, attitude and self-reported practices were investigated among the food handlers to understand a relationship with their compliance with the criteria.

2. Materials and methods

2.1. Slaughterhouses

The study was performed in two commercial broiler slaughterhouses in which the evisceration process had different effects on bacterial concentrations as described previously (Pacholewicz et al., 2015). In Slaughterhouse A, both *Campylobacter* and *E. coli* concentrations increased after the evisceration process, whereas concentrations did not increase in Slaughterhouse B (Pacholewicz et al., 2015).

2.2. Development of the assessment criteria

A set of assessment criteria for evisceration process control was developed in order to conduct both a documentation analysis and observational study of food handlers. Food handlers included operators responsible for setting and controlling the equipment and post mortem inspectors. The criteria included activities that the food handlers should carry out in order to control the evisceration process and were based on a literature survey and preliminary observations as recommended by Martin, Bateson, and Bateson (1993). Moreover, quality managers were interviewed and the available procedures were analysed. This resulted in fifteen assessment criteria: ten criteria dedicated to operators and the other five dedicated to post mortem inspectors (Table 1). During observations, three scores were used to rate the actions performed by the food handlers: good, sufficient and poor compliance. These scores were prepared based on the notational coding method (Clayton & Griffith, 2004). A criterion was scored as good compliance when the food handlers completed the task in a consistent way within the specified time interval and took sufficient time to perform observations and activities. A sufficient score indicated that food handlers performed the activities as specified by the criteria incompletely, e.g. only a hasty evaluation, or performed actions inconsistently. A poor score was given when the food handler did not perform the tasks or was not present at the production site.

Table 1
Checklist with assessment criteria to observe food handlers involved in the evisceration process. The table includes a comparison of the procedures available in two slaughterhouses with the assessment criteria.

Assessment criteria	Degree of compliance *[filled during observations]* Good/Sufficient/Poor	Does the procedure comply with the assessment criterion?	
		Slaughterhouse	
		A	B
1. Equipment Setting			
Vent cutter			
1.1. Control performance of vent cutter by observing carcasses		yes	yes
1.2. Observe and adjust height		no	yes
1.3. Observe and adjust shackle guide		no	yes
1.4. Observe and adjust water nozzles		no	yes
Opener			
1.5. Control performance of opener by observing carcass		yes	yes
1.6. Observe and adjust height		no	yes
1.7. Observe and adjust shackle guide		no	yes
Eviscerator			
1.8. Control performance of eviscerator by observing carcasses		yes	yes
1.9. Observe and adjust height		no	yes
1.10. Observe and adjust shackle guide		no	yes
2. Visible Faecal Contamination Inspection			
2.1. Remove carcasses with high visible faecal contamination from the line		no	yes
2.2. Remove part of carcasses with low visible faecal contamination by trimming or cutting		no	yes
2.3. Sterilize/clean knife before and after each trimming or cutting		no	yes
2.4. Remove part of remaining viscera in carcasses which were not properly eviscerated		no	yes
2.5. Record number of bile contamination, visible faecal contamination and rejected carcasses per each batch		yes	yes
Percentage of compliance [*yes* score]		27%	100%

2.3. Analysis of existing procedures

We analysed the available procedures on the evisceration process against the assessment criteria as specified in Table 1. Compliance of procedures with the criteria was expressed as a percentage of the assessment criteria present in the existing procedures in each slaughterhouse. The structure of existing procedures was analysed according to requirements specified by Good Manufacturing Practices (Table 2). While collecting the results, we weighted each of the structure categories equally, giving a score "yes" for presence of indicated characteristics and score "no" for absence. This was done to indicate consistency of slaughterhouses in preparing the procedures according to GMP practices but not the relevance of the procedures' structure on food safety.

2.4. Observation of compliance of food handlers with assessment criteria

This observational study was designed based on previous observational studies of food handlers (Clayton & Griffith, 2004; Fischer et al., 2007; Green et al., 2006; Redmond & Griffith, 2003). Compliance of food handlers was observed according to the assessment criteria as described in Section 2.2. Both slaughterhouses were visited between April and July 2015 to observe the activities of the food handlers involved in the evisceration process. The observations were performed on three separate days in each slaughterhouse. A batch was used as an observational unit and defined as a group of chickens raised together in one shed (European Food Safety Authority, 2011). In total, twenty-six batches were observed, namely 14 in Slaughterhouse A and 12 in Slaughterhouse B. Compliance of operators was observed during the first 15 min of processing each new batch in the evisceration area. The compliance of post mortem inspectors was observed during the following nine minutes. Food handlers were not informed about the specific objectives of the study in order to assure reliability of the observation. The presence of observers may affect the behaviour of the person being observed, known as reactivity or the Hawthorne effect (Clayton & Griffith, 2004; Redmond & Griffith,

Table 2
Assessment of the procedures on evisceration provided by two slaughterhouses according to the requirements on the structure of procedures.

Requirements to the structure of the procedure on evisceration process		Slaughterhouse A	Slaughterhouse B
1	Are the procedures present	yes	yes
2	Information about who wrote the procedures	no	no
3	Procedure number	no	yes
4	Authorization	no	no
5	Effective date	no	yes
6	Purpose: Clear purpose of the procedure, **why** it is it is written and why it is performed	no	yes
7	Scope of the procedures: **when** (frequency) the procedures needs to be performed and **where** the procedure applies	yes	yes
8	Responsibility **who** performs the procedure **who** is responsible to see it is performed correctly	no	yes
9	Materials and equipment**: what** is needed to perform the test	no	yes
10	**How**: clear and concise description how to perform the procedure.	no	yes
11	Reporting: **Where** results should be **recorded?**	yes	yes
12	Specify corrective action	no	yes
	Criteria that were met [%]	25%	83%

2003). In order to prevent the reactivity influencing the outcome of observations, the results obtained from the first one to two observed batches were discarded. We discarded the first full batch and measured the next one. This approach enabled the food handlers to adjust to the presence of observers in the slaughterhouses. Moreover, the two researchers involved in the observational study were wearing protective clothing typical for the employees in the slaughterhouses to limit the effect of reactivity (Clayton & Griffith, 2004; Green et al., 2006).

2.5. Frequency of carcasses with visible faecal contamination

After completing the observations of food handlers, we observed the presence of visible faecal contamination on carcasses in the 26 batches studied and classified the carcasses as without visible faecal contamination, with low and high level of visible faecal contamination as shown in Fig. 1. A low level of visible contamination indicated a single spot of faecal material, whereas substantial leakage of the material on carcasses was classified as high level.

The number of carcasses with visible faecal contamination was counted at four locations including the key evisceration machines: 1) after the vent cutter, 2) after the opener, 3) after the eviscerator, and 4) after post mortem inspection. At each location, contaminated carcasses were counted three times for a three minute interval, adding up to nine minutes of counting per batch. All three were done in short time interval of one minute, in order to let observer's eyes rest. Further a frequency of carcasses with visible faecal contamination was calculated based on line speed in each slaughterhouse.

2.6. Microbiological sampling

After the observations of food handlers' practices and observations of the carcasses with and without visible faecal contamination, we collected samples to investigate whether carcasses with low and high level of visible faecal contamination had different concentrations of *E. coli* than visibly clean carcasses. In total 165 carcasses were collected, from five batches sampled in Slaughterhouse A and six in Slaughterhouse B. Per batch, 15 carcasses were sampled including five carcasses visibly clean, five with low and five with high contamination level. The samples were taken using the whole carcass rinse method and analysed for *E. coli* concentration as described in our previous study (Pacholewicz et al., 2015). The obtained results were transformed to the logarithmic scale. The limit of detection was 100 CFU/ml of rinse sample. In samples below the detection limit, the results were expressed as a half of the detection limit (Rosenquist et al., 2006).

2.7. Questionnaires on knowledge, attitude and practices

In July 2015, the slaughterhouses were visited again in order to identify possible reasons for inadequate compliance with procedures. Operators and post mortem inspectors were asked to fill in a questionnaire. One questionnaire was dedicated to the operators and the second to post mortem inspectors. Both questionnaires were divided into four parts covering food handlers' characteristics, knowledge, attitude and self-reported practices. The questionnaire was developed according to the guidelines provided by Tan, Bakar, Karim, Lee, and Mahyudin (2013).

Each questionnaire contained 35 questions. The food handlers' characteristics included gender, age, education level, training followed and years of employment in the studied slaughterhouse. The knowledge part contained ten statements for which the food handlers could choose answers ‘yes’, ‘no’, and ‘do not know’. The attitude part contained ten statements for which the food handlers were asked to specify the level of agreement as ‘strongly agree’, ‘agree’, ‘uncertain’, ‘disagree’ and ‘strongly disagree’. The section on self-reported practices contained ten statements for which the food handlers were asked to rate their practices based on the five point scale: ‘never’, ‘rarely’, ‘sometimes’, ‘often’, and ‘always’. This questionnaires contained negative statements, providing incorrect information without using negative words.

The questionnaires were translated into Dutch and German. Firstly, recruited native speakers with a background in veterinary medicine and animal sciences translated the questionnaires from English. Afterwards, two other native speakers with similar expertise as the first pair translated the questionnaires back to the English language in order to assure the equivalent interpretation of the questions (Young et al., 2010). Following both translations, we analysed the differences and if needed we implemented modifications. Experts in the field including veterinarians from Utrecht University verified the questionnaires for adequacy of their content.

Twelve food handlers in Slaughterhouse A participated in the study, including six operators and six post mortem inspectors. In Slaughterhouse B four operators and ten post mortem inspectors participated.

The answers given by food handlers in the questionnaires were scored. In the knowledge part the correct answer was scored with 4 points, whereas incorrect or ‘do not know’ with 0 points. In the

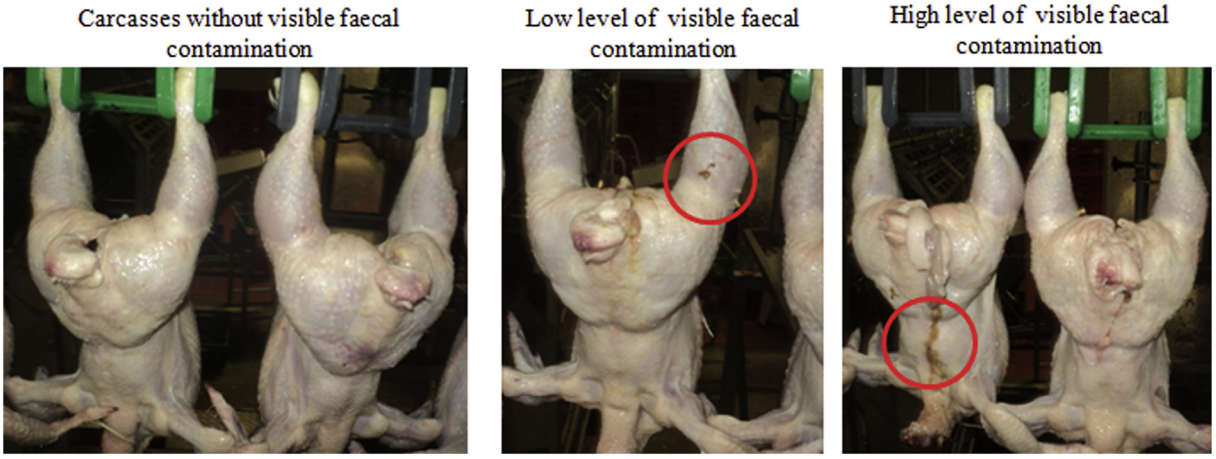

Fig. 1. Visual aids to judging the level of visible faecal contamination on carcasses.

attitude and practice parts a scale was used as follows, 4 for 'strongly agree' or 'always', 3 for 'agree' or 'often', 2 for 'uncertain' or 'sometimes', 1 for 'disagree' or 'rarely' and 0 for 'strongly disagree' or 'never'. For a negative statement the points were given in a reverse order. The maximum number of points that a food handler could gain in each part was forty. In each part an arbitrary scale was used to interpret the overall scores for knowledge, attitude and practice. If 80% and more questions were answered correctly by food handlers a score 'good' was assigned, between 50 and 79% 'moderate score', and below 50% 'poor'.

2.8. Pilot test

A pilot test was organized to check the reliability of the questionnaires. Thirty independent respondents were recruited by Wageningen University, including students with a background in veterinary medicine, animal science, food technology, food safety, and/or food quality management. Homogeneity of answers given by the responders was checked by computing Cronbach's alpha coefficient (Tan et al., 2013). The coefficient based on all questions in the pilot was 0.8, which is above 0.7 and indicates reliability of words, phrases, subjects and point of view.

2.9. Statistical analysis

Statistical analysis of the concentration of *E. coli* on carcasses with visible faecal contamination classified as low or high level and on clean carcasses was performed using a mixed effects model. Comparisons were made between groups (clean, low, and high) including a fixed effect of the slaughterhouse and random effect of batch.

The frequency of carcasses with visible faecal contamination was presented as a percentage. The frequency of fulfilling the actions specified in the assessment criteria on good, sufficient and poor level was calculated separately for each slaughterhouse and each group of food handlers.

The percentage of correct answers on knowledge, attitude, and practice parts was calculated for each slaughterhouse (Tan et al., 2013).

Furthermore, a coherence test (Ferreira, 2015; Rosenbaum, 2002) was performed for each slaughterhouse separately in order to test the presence of association between number of carcasses with visible faecal contamination and the compliance of operators with criteria to control the evisceration process at locations as vent cutter, opener, eviscerator and post mortem inspection. Based on a list of 15 criteria (Table 1) an overall compliance score was computed stratified by batch (b), location (m), and slaughterhouse (s). Although not all criteria apply for each location where the compliance was observed, an overall score for batch, location and slaughterhouse was computed by giving a score 0 when the criterion was not applicable, score 1 when performance was poor, score 2 when performance was sufficient and score 3 when performance was good. Score 0 was given in both slaughterhouses and the same criteria were relevant for the observed locations, i.e. vent cutter, opener, eviscerator, and post mortem inspection. These numbers were added up to arrive at the overall scores b, m, and s, denoted by $\boldsymbol{T}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$. Furthermore, the percentage of carcasses that were not scored as clean per batch, location and slaughterhouse, was calculated and denoted by $\boldsymbol{r}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$. However the food handler at location m (i.e. $\boldsymbol{T}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$) does not influence the level $\boldsymbol{r}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$ directly, but rather has influence over the increase in percentage of visibly contaminated carcasses with faeces, hence it is more applicable to study the difference $\boldsymbol{d}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}=\boldsymbol{r}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}-\boldsymbol{r}_{\boldsymbol{b},\boldsymbol{m}-1,\boldsymbol{s}}$. This implies that the compliance scores for the first location (vent cuter) cannot be used in the analysis. The null-hypothesis was formulated as: for fixed slaughterhouse (s) and location (m), the compliance score ($\boldsymbol{T}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$) is uncorrelated to $\boldsymbol{r}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$. Correlation was measured using Pearson's product moment correlation coefficient. The basic idea behind a coherent test is that under the null hypothesis, a permutation of b (say $\boldsymbol{\pi}(\boldsymbol{b})$) should not influence the correlation between T and R. Hence we may compare the data statistic

$$\boldsymbol{s}_{\boldsymbol{m},\boldsymbol{s}}=\sum_{\boldsymbol{b}=1}^{\boldsymbol{B}}\boldsymbol{R}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}\boldsymbol{T}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}$$

to the distribution of

$$\boldsymbol{S}_{\boldsymbol{m},\boldsymbol{s}}=\sum_{\boldsymbol{b}=1}^{\boldsymbol{B}}\boldsymbol{R}_{\boldsymbol{b},\boldsymbol{m},\boldsymbol{s}}\boldsymbol{T}_{\boldsymbol{\pi}(\boldsymbol{b}),\boldsymbol{m},\boldsymbol{s}}$$

arising from many permutations $\boldsymbol{\pi}(\boldsymbol{b})$ of b. Several terms of the Pearson correlation coefficient are unused, as they have no bearing on the result. Similar to the determination of a p-value in classical hypothesis testing, we may determine the fraction of values of S to the left of s, and if this value is small, the null-hypothesis is likely to be false. This procedure tests associations (Ferreira, 2015; Rosenbaum, 2002) and was computed for data from all locations pooled together. Validity of the model was checked and revealed that it performed as intended.

3. Results

3.1. Adequacy of procedures

In Slaughterhouse A, the existing procedures complied with 27% of the assessment criteria, whereas in Slaughterhouse B the procedures fully corresponded with the criteria (Table 1). Moreover, the structure of the procedures in Slaughterhouse A met 25% of the requirements, whereas this was 83% in Slaughterhouse B (Table 2).

3.2. Compliance of operators with assessment criteria to control evisceration process

Fig. 2 presents the number of batches for which the food handlers complied with the assessment criteria as specified in Table 1. It shows that food handlers from Slaughterhouse A complied less frequently with the criteria than food handlers from Slaughterhouse B.

3.3. Frequency of carcasses with visible faecal contamination

Fig. 3 presents the number of carcasses with visible faecal contamination assessed at four locations in the slaughter line. It shows that at most of the tested locations the number of carcasses with visible contamination was higher in Slaughterhouse A than in Slaughterhouse B. The results from the coherent test revealed that there was an association between compliance with control criteria and frequency of carcasses with visible faecal contamination based on combined results from all locations in Slaughterhouse A ($p = 0.003$) but not in Slaughterhouse B ($p = 0.2$).

3.4. E. coli concentration on carcasses visibly contaminated with faeces

Fig. 4 shows *E. coli* concentrations on carcasses with different levels of faecal contamination in the two slaughterhouses. The concentrations on carcasses with low visible contamination were higher than on visibly clean carcasses and differed on average by 0.4 log ($p = 0.001$). On the highly contaminated carcasses, the

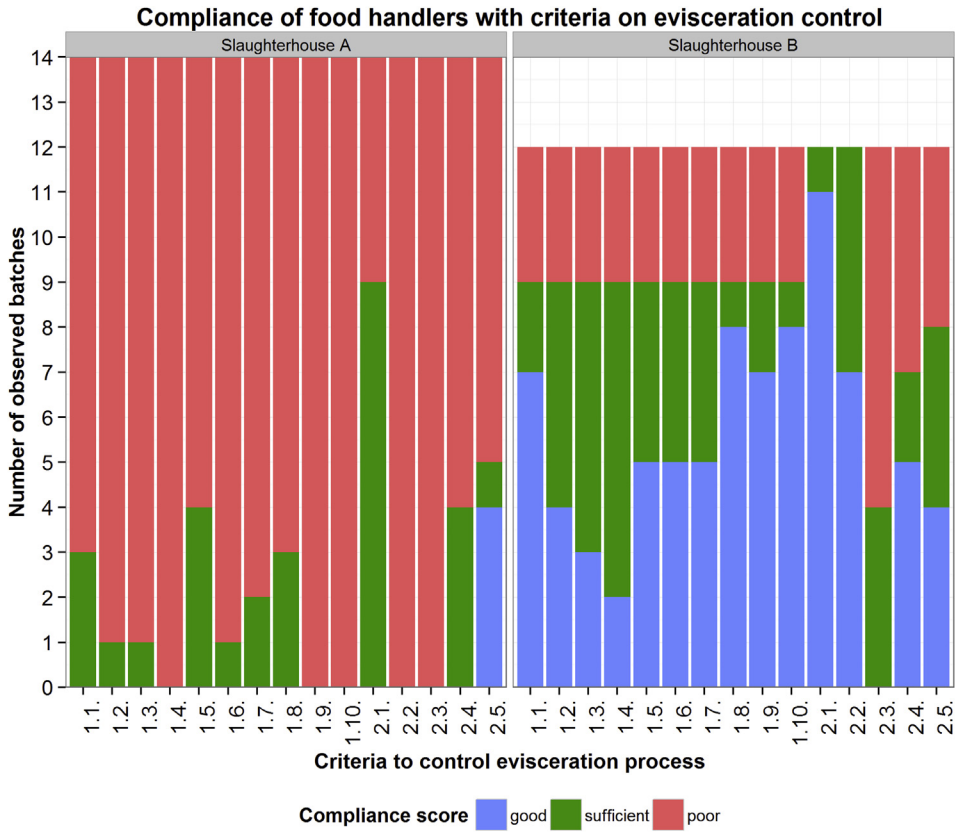

Fig. 2. Compliance of food handlers with criteria on evisceration control in two slaughterhouses on: good (blue), sufficient (green) and poor (red) levels.

concentrations were on average 1.5 log higher than on the visibly clean carcasses ($p < 0.001$). In Slaughterhouse A the concentrations on carcasses in all sampled groups were higher by 0.6 log than on carcasses in Slaughterhouse B ($p = 0.03$). The *E. coli* concentrations in all groups were significantly different between batches from which they originated. This was confirmed by the significance of the intercept in the mixed effect model used for the analysis ($p < 0.001$). These results are based on a model that had a random intercept on batch and fixed slope on both the slaughterhouse effect and the effect on the level of carcass contamination (clean, low, high). This model fitted data better compared to a model with an interaction between slaughterhouse and level of carcass contamination as the p value was 0.07.

3.5. Food handlers' characteristics

Table 3 shows the overview of food handlers' characteristics in the two slaughterhouses. In Slaughterhouse A, most food handlers (9 out of 12) were male and 6 out of 12 food handlers were between 41 and 50 years old. The majority of food handlers (9 out of 12) had secondary school education and 2 food handlers followed training given by the slaughterhouse. One third of the food handlers (4 out of 12) worked there for 15–20 years and one quarter for more than 20 years. In Slaughterhouse B, 13 out of 14 food handlers were male. Five out of the 14 food handlers were between 41 and 50 years old and 5 out of 14 were between 31 and 40 years old. Almost all food handlers (13 out of 14) had followed training given within the slaughterhouse. One third of the food handlers (5 out of 14), worked there more than twenty years and 4 out of 14 for 10–15 years.

Tables 4–6 present the outcome of the questionnaires. Overall six answers were excluded, because the food handlers either did not give any answer or gave two contradictory answers. Overall, the knowledge level of food handlers on evisceration process control was good (80% and above) (Table 4). In Slaughterhouse A the level was 87% for operators and 98% for post mortem inspectors, whereas in Slaughterhouse B it was 80% for operators and 91% for post mortem inspectors. The attitude of food handlers in Slaughterhouse A was scored 'moderate' for both operators (77%) and post mortem inspectors (67%), whereas in Slaughterhouse B it was scored as 'good' for both operators (86%) and post mortem inspectors (86%). The score on self-reported practices was 'poor' in Slaughterhouse A for operators (47%) and 'moderate' for post mortem inspectors (70%), whereas in Slaughterhouse B it was scored as 'moderate' for operators (75%) and 'good' for post mortem inspectors (88%).

4. Discussion

This observational study aimed at investigating whether compliance of food handlers' with criteria on controlling and setting the evisceration process may contribute to differences in the impact of evisceration between slaughterhouses determined previously (Pacholewicz et al., 2015). The current study showed that in Slaughterhouse A carcasses with visible faecal contamination were observed more frequently than in Slaughterhouse B (Fig. 3). Also in Slaughterhouse A, non-compliance with the criteria on evisceration control was more frequent (Fig. 2). Knowledge of food handlers in both slaughterhouses was scored on a good level. The attitude was scored as moderate among both groups of food handlers in Slaughterhouse A, whereas good in Slaughterhouse B. The self-reported practices fulfilled by food handlers were scored 'poor' for operators in Slaughterhouse A and 'moderate' for the post

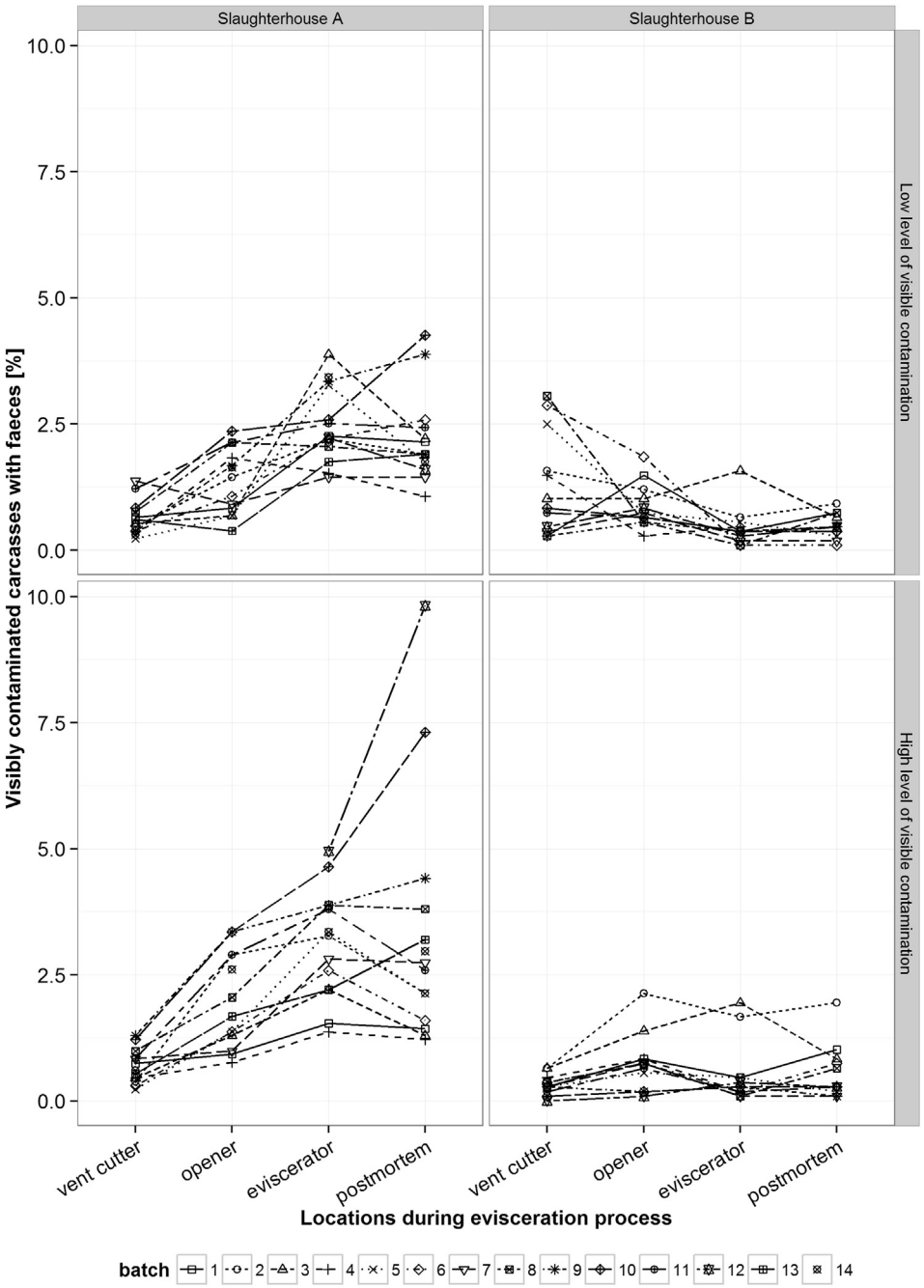

Fig. 3. Frequency of carcasses with visible faecal contamination at low and high levels measured at four locations in two slaughterhouses.

mortem inspectors. In Slaughterhouse B the practices were scores as moderate for both groups of food handlers.

Differences in the control of the evisceration step between the studied slaughterhouses observed in the current study may potentially explain the differences in the occurrence of visibly contaminated carcasses (Fig. 3). Our results demonstrate that the visibly contaminated carcasses after evisceration have higher *E. coli* concentrations than visibly clean carcasses (Fig. 4). This is in agreement with previous studies (Burfoot & Allen, 2013; Cibin et al., 2014). In the present study, carcasses with even small spots of faecal and caecal content after evisceration carried on average a significantly higher load of *E. coli* ($p = 0.001$). Similar findings were reported with respect to *Campylobacter* (Berrang, Smith, Windham, & Feldner, 2004). Visibly clean carcasses in the current study carried *E. coli* in concentrations between 1.6 and 3.6 log CFU/ml (Fig. 4). In Slaughterhouse A the concentrations on visibly clean carcasses were higher than in Slaughterhouse B, which is in agreement with previous findings (Pacholewicz et al., 2015) where in one slaughterhouse carcasses carried higher *E. coli* concentration after evisceration than in another. The variation observed in *E. coli* concentration on carcasses within a category of visibly contaminated carcasses (Fig. 4) suggests that even if carcasses fall in one category based on visual assessment, they may carry variable concentrations of *E. coli*.

Our study shows the importance of procedures that should document all activities that food handlers need to do in order to

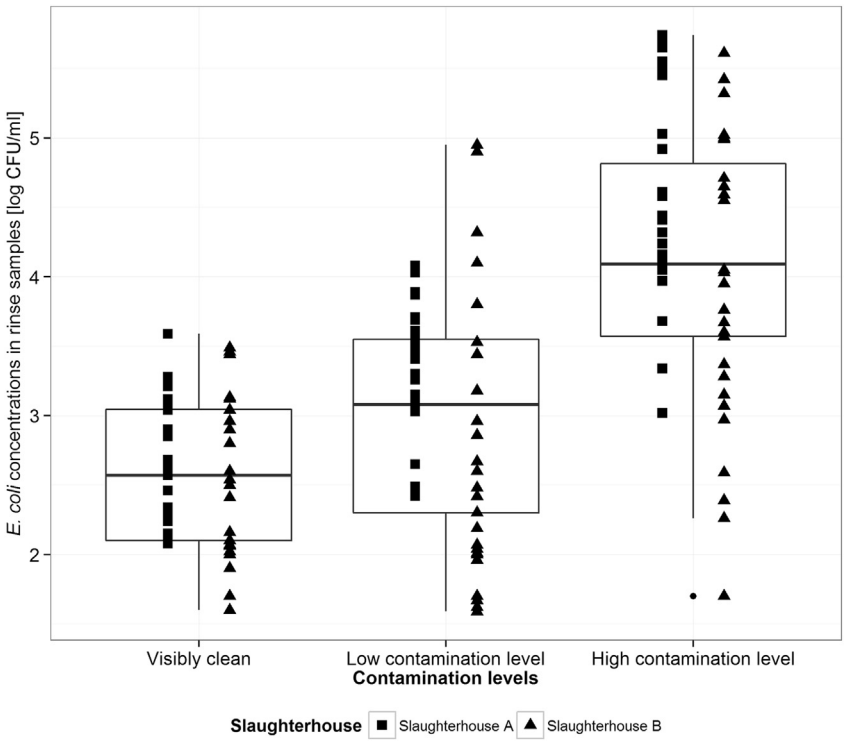

Fig. 4. *E. coli* concentrations (log CFU/ml) on carcasses with different levels of faecal contamination. Samples were obtained from two slaughterhouses. The squares indicate concentrations in the samples obtained in Slaughterhouse A, whereas triangles in B. The line inside each box indicates the median, the upper whiskers indicate 75th percentiles and the lower whiskers indicate 25th percentiles.

Table 3
Characteristics of food handlers in two slaughterhouses. In total 26 food handlers participated in the study.

Demographic characteristics	Category	Slaughterhouse A		Slaughterhouse B	
		Operators n =	Inspectors n=	Operators n=	Inspectors n=
Gender	Male	6	3	4	9
	Female	0	3	0	1
Age (years)	Under 21	0	0	0	0
	21–30	0	0	1	0
	31–40	2	0	1	4
	41–50	4	2	1	4
	51–60	0	3	1	2
	Over 60	0	1	0	0
Education	Primary school	0	0	0	0
	Secondary school	5	4	4	9
	High school	0	1	0	1
	University	0	2	0	0
Training	Yes	2	0	3	10
	No	4	3[a]	1	0
Duration working in a slaughterhouse (years)	Under 1	0	1	0	0
	1–5	0	1	2	0
	5–10	1	0	0	1
	10–15	2	0	0	4
	15–20	2	2	0	2
	Over 20	1	2	2	3

[a] Answers given by three remaining inspectors were invalid.

assure that they know their tasks and responsibilities to prevent deviations (Yiannas, 2008). The role of procedures is to support food handlers in taking appropriate and consistent decisions to meet food safety goals (Luning & Marcelis, 2007).

The compliance of food handlers with the criteria on evisceration control differed between slaughterhouses e.g. setting of the evisceration equipment and removing carcasses or their parts with visible faecal contamination in Slaughterhouse A was hardly ever carried out, whereas in Slaughterhouse B it was frequently carried out (Fig. 2). Data analysis in our study revealed an association between the presence of visibly contaminated carcasses and the compliance of food handlers with the criteria on evisceration control only in Slaughterhouse A. Lack of association between compliance with evisceration controls and contamination of carcasses in Slaughterhouse B suggests that the contamination may occur also due to other factors as e.g. uniformity of batch because the evisceration equipment cannot be adjusted to an individual carcass.

Table 4
Knowledge of the food handlers on the assessment criteria to set and control the evisceration process obtained in two slaughterhouses. An asterisk next to the number of question indicates negatively coded statements, an hashtag indicates statements in which some answers were excluded.

	Knowledge of operators	Correct answer	Slaughterhouse A				Slaughterhouse B			
			Yes	No	Do not know	Score	Yes	No	Do not know	Score
			n=	n=	n=	[%]	n=	n=	n=	[%]
1	Bacterial contamination can occur during processing in a slaughterhouse	yes	5	0	1	83	4	0	0	100
2	Proper setting of evisceration equipment may prevent damage of intestine	yes	6	0	0	100	3	1	0	75
3	Change of evisceration equipment setting may be needed after change of each batch	yes	6	0	0	100	3	1	0	75
4*	Proper adjustment of evisceration equipment settings may cause rupture of intestine and increase bacterial contamination	no	1	3	2	50	1	3	0	75
5	Setting of the height of vent cutter depends on the size of carcasses	yes	6	0	0	100	2	2	0	50
6*	Proper adjustment of spraying nozzles in the vent cutter may increase faecal contamination	no	6	0	0	100	1	3	0	75
7	Setting of shackle infeed guide in the opener depends on the size of carcasses	yes	6	0	0	100	4	0	0	100
8*	Correct position of carcasses in the opener may cause rupture of intestine	no	1	5	0	83	1	3	0	75
9*	Controlling the setting of eviscerator may cause bacterial contamination	no	1	4	1	67	0	3	1	75
10	Adjusting shackle infeed guide in the eviscerator can reduce visual faecal contamination on carcasses	yes	5	0	1	83	4	0		100
	Average score of correctly answered knowledge questions					87				80
Knowledge of post mortem inspectors										
1	Bacterial contamination on carcasses can be caused by presence of faecal material on carcasses	yes	6	0	0	100	10	0	0	100
2	Rupture of intestine may cause visual faecal contamination on carcasses	yes	6	0	0	100	10	0	0	100
3	Correct Post Mortem Inspection after evisceration may reduce the presence of visual faecal contamination on carcasses	yes	6	0	0	100	6	3	1	60
4*	Carcasses with diseases and deficiencies may continue to chilling step	no	6	0	0	100	0	10	0	100
5#	Faecal contamination can be visible as dirty marks or spots on carcasses	yes	6	0	0	100	8	0	0	80
6*	Carcasses with bile contamination may continue after post mortem inspection to the following step	no	6	0	0	100	0	10	0	100
7#	Visual faecal contamination can be eliminated by trimming, cutting, extra washing and removing contaminated carcasses	yes	6	0	0	100	7	2	0	70
8*	Cleaning or sterilizing knife after trimming and cutting can be ignored during inspection	no	6	0	0	100	0	10	0	100
9*	Remained viscera or part of viscera may stay in carcasses after post mortem inspection	no	1	5	0	83	0	10	0	100
10	Number of rejected carcasses per each batch and the cause of rejection can be reported to manager	yes	6	0	0	100	0	10	0	100
	Average score of correctly answered knowledge questions					98				91

In both slaughterhouses the scores of knowledge level were good (>80%). However in Slaughterhouse A operators reported fulfilling 47% control tasks during the evisceration process and post mortem inspectors 70% of the tasks, whereas in Slaughterhouse B operators reported 75% and post mortem inspectors 85% (Table 6). This was confirmed by actual observations, showing that food handlers in Slaughterhouse A complied with fewer tasks than in Slaughterhouse B (Fig. 2). Likewise in a study of Clayton, Griffith, Price, and Peters (2002) food handlers had knowledge about their tasks, but they have not always implemented it into practice. Such a discrepancy in behaviour of food handlers who have the knowledge but do not implement it in actual practices was reported in various food premises (Abdul-Mutalib et al., 2012; Angelillo, Viggiani, Rizzo, & Bianco, 2000; Ansari-Lari, Soodbakhsh, & Lakzadeh, 2010; Baş et al., 2006; Clayton et al., 2002; Tokuç, Ekuklu, Berberoğlu, Bilge, & Dedeler, 2009). Adoption of knowledge in practice is a challenge, even after providing training, as demonstrated by Sanny et al. (2013). In our study, only 2 out of 12 food handlers in Slaughterhouse A reported that they had training provided by the slaughterhouse, whereas the majority of food handlers (13 out of 14) from Slaughterhouse B reported this. Despite lack of training, the knowledge of food handlers in Slaughterhouse A scored evenly with that of food handlers in Slaughterhouse B, i.e. as good in both cases. In principle, theoretical training can improve the knowledge level of food handlers, but it can only have a limited effect on food handlers' attitude and practices (da Cunha, Stedefeldt, & de Rosso, 2014). Various researchers suggested that training can influence practices of food handlers only if it employs adequate strategies to change attitude and motivation (da Cunha et al., 2014; Rennie, 1994; Tokuç et al., 2009). Ko (2013) reported that the attitudes of food handlers mediate the relationship between their knowledge and practices. More attention should be thus given to enhancing the attitude of food handlers. Additional measures beyond training were suggested to potentially influence the practices of food handlers, such as e.g. routine inspection (Bolton, Meally, Blair, McDowell, & Cowan, 2008), strict monitoring of compliance with procedures (Sanny et al., 2013) or incentives for food handlers to reward practical implementation of knowledge (Mitchell, Fraser, & Bearon, 2007).

Another explanation of the discrepancy between knowledge and practices can be seen in an “optimistic bias effect” (da Cunha et al., 2014; Wilcock, Pun, Khanona, & Aung, 2004) meaning that people perceive that the risk of a negative event is lower for them than for other people.

Furthermore, it was reported that the practices of food handlers can change only if the food safety culture changes and if the organization provides the necessary resources (Clayton et al., 2002). Food safety culture was thus proposed to be considered as an “emerging risk factor” contributing to an increase in the likelihood of food poisoning (Griffith, Livesey, & Clayton, 2010). Recently, food safety culture has been defined as an interaction between two routes, the human route and the techno-managerial route (De Boeck, Jacxsens, Bollaerts, & Vlerick, 2015). The human route was defined as a food safety climate perceived by employees and managers in a company. The techno-managerial route was defined as the context in which the company operates. The components of the food safety climate (human route) include leadership, communication, commitment, environment, and risk perceptions (Griffith et al., 2010). These components should be further compared between broiler slaughterhouses to determine additional factors influencing practices of food handlers and thus bacterial concentrations on broiler meat.

The methods developed for the purpose of our case study could be applied across the poultry sector to recognise in depth the role of food handlers and organisations in *Campylobacter* control. Also these methods can be used to revise procedures available in the

Table 5
Attitude of the food handlers on the assessment criteria to set and control the evisceration process obtained in two slaughterhouses. Asterisk next to the number of question indicate negative coded statements, hashtag indicates statements in which some answers were excluded.

	Attitude of operators	Answer with maximum score	Slaughterhouse A						Slaughterhouse B					
			Strongly agree	Agree	Uncertain	Disagree	Strongly disagree	Score	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree	Score
			n=	n=	n=	n=	n=	[%]	n=	n=	n=	n=	n=	[%]
1	Preventing bacterial contamination during slaughtering is part of my responsibility	strongly agree	4	2	0	0	0	92	2	1	0	1	0	75
2*	Learning how to prevent bacterial contamination is crucial only for manager	strongly disagree	0	0	1	1	4	88	0	0	1	1	2	81
3	Setting of the evisceration equipment is part of my responsibility	strongly agree	2	1	0	0	3	46	3	1	0	0	0	94
4*	Adjusting the setting of the evisceration equipment is less essential to avoid rupture of intestine and visual faecal contamination	strongly disagree	2	0	2	2	0	42	0	0	0	2	2	88
5	Adjusting the setting of the evisceration equipment is needed while changing of each batch	strongly agree	3	3	0	0	0	88	3	1	0	0	0	94
6*#	Monitoring if the evisceration equipment runs well during processing is only manager's responsibility	strongly disagree	0	0	0	3	3	88	0	0	1	0	2	63
7*	Adjusting the height of vent cutter is necessary only at the beginning of day	strongly disagree	0	1	0	1	4	83	0	0	0	1	1	94
8*	Adjusting the height of opener is only important to do at the beginning of day	strongly disagree	0	1	0	2	3	79	0	0	0	1	3	94
9*	Checking the setting of eviscerator is only manager's responsibility	strongly disagree	0	0	0	3	3	88	0	0	1	1	2	81
10*	Controlling and monitoring the setting of eviscerator is done once per day	strongly disagree	0	1	0	2	3	79	0	0	0	1	3	94
	Average score of correctly answered attitude questions							77						86
Attitude of post mortem inspectors														
1	Preventing bacterial contamination during slaughtering is part of my responsibility	strongly agree	0	3	0	0	3	88	6	4	0	0	0	90
2	Learning how to prevent bacterial contamination is crucial only for manager	strongly disagree	1	1	1	1	2	58	0	0	0	1	9	98
3	Inspection on visual faecal contamination on carcasses is part of my task	strongly agree	4	2	0	0	0	92	7	3	0	0	0	93
4*	Visible faeces on carcasses are acceptable	strongly disagree	0	1	1	2	1	54	0	0	1	1	8	93
5	Carcasses with diseases and deficiencies are allowed to continue to chilling step	strongly disagree	0	0	0	0	6	100	1	0	0	1	8	88
6	The acceptable number of carcasses with visual faecal contamination is 1%	strongly agree	0	0	3	2	1	33	1	2	2	1	4	38
7*	Broiler carcasses with visual faecal contamination was continued to next step	strongly disagree	0	2	0	2	1	50	0	0	0	2	8	95
8	Removing visual faecal contamination from carcasses is important to be done during inspection	strongly agree	2	3	0	1	0	75	6	4	0	0	0	90
9	Removing remained viscera or part of viscera from carcasses is manager's responsibility	strongly disagree	2	1	0	1	2	50	0	0	0	4	6	90
10	Recording and reporting number of visual faecal contamination per each batch to manager is part of my task	strongly agree	1	4	0	1	0	71	6	3	0	1	0	85
	Average score of correctly answered attitude questions							67						86

slaughterhouses. Similarly, the assessment criteria could be developed for other steps during poultry processing such as defeathering, which also has inconsistent effects between slaughterhouses (Pacholewicz et al., 2015). In addition, implementation of the questionnaires in many slaughterhouses would enable managers to recognise how compliance could be improved. The questionnaires could be extended not only to food handlers but also to the management level. This could provide a picture of food safety culture in organisations that might influence the safety of broiler meat.

In summary, this case study demonstrates that procedures and food handlers' compliance with these procedures differed between slaughterhouses. The level of compliance was statistically associated with the frequency of carcasses with visible faecal contamination. It was demonstrated that visibly contaminated carcasses carry significantly higher concentration of *E. coli*. These findings suggest that adequate procedures to control the evisceration process and compliance of food handlers with these procedures may contribute to the reduction of the number of carcasses with visible faecal contamination, and to the prevention of an increase in bacterial concentrations on carcasses after this processing step. These findings suggest that managerial aspects of the organisation might influence food safety. However in order to demonstrate the influence of the compliance with procedures on contamination of poultry carcasses an intervention study needs to be performed.

Table 6
Practices of food handlers on setting and controlling the evisceration process obtained in two slaughterhouses.

	Practices of operators	Answer with maximum score	Slaughterhouse A						Slaughterhouse B					
			Never	Rarely	Sometime	Often	Always	Score	Never	Rarely	Sometime	Often	Always	Score
			n=	n=	n=	n=	n=	[%]	n=	n=	n=	n=	n=	[%]
1	Do you adjust the height of vent cutter after change of each batch?	Always	1	0	3	2	0	50	0	0	1	1	2	81
2	Do you change the vent cutter setting if carcasses are too small?	Always	0	0	0	4	2	83	2	0	0	1	1	44
3	Do you count number of missed carcasses after vent cutter?	Always	5	0	0	0	1	17	0	0	1	2	1	75
4	Do you adjust the shackle infeed guide of opener after change of each batch?	Always	1	1	2	2	0	46	0	0	2	1	1	69
5	Do you change the height of opener after change of each batch?	Always	1	0	2	2	1	58	0	0	0	3	1	81
6	Do you count number of carcasses with damaged intestine after opener?	Always	3	1	0	1	1	33	0	0	1	1	2	81
7	Do you adjust the shackle guide of eviscerator after change of each batch?	Always	1	0	4	1	0	46	0	0	1	2	1	75
8	Do you adjust the height of eviscerator after change of each batch?	Always	1	1	3	1	0	42	0	0	0	2	2	88
9	Do you check feed withdrawal time of the carcasses per batch?	Always	2	1	0	2	1	46	0	0	1	0	3	88
10	Do you count the number of carcasses with visual faecal contamination after eviscerator?	Always	3	0	0	1	2	46	0	1	0	2	1	69
	Average score of correctly answered knowledge questions							47						75
Practices of post mortem inspectors														
1	Do you inspect faecal contamination inside of carcasses?	Always	0	0	3	3	0	63	0	0	0	5	5	88
2	Do you check the presence of faecal spots outside of carcasses?	Always	0	0	0	2	4	92	0	0	1	3	6	88
3	Do you check the presence of diseases and deficiencies of carcasses?	Always	0	0	0	0	6	100	0	0	0	1	9	98
4	Do you check the presence of bile contamination on carcasses?	Always	0	0	0	2	4	92	0	0	0	3	7	93
5	Do you allow carcasses with faecal spots to continue to next steps?	Never	1	0	2	1	1	38	6	3	1	0	0	88
6	Do you remove carcasses with visual faecal contamination from conveyor?	Always	0	0	4	0	1	50	0	0	2	2	6	85
7	Do you remove visual faecal contamination by trimming, cutting, extra rinsing?	Always	2	1	2	1	0	33	0	1	2	3	4	75
8	Do you sterilize or clean your knife before and after trimming and cutting?	Always	0	2	0	1	2	54	0	0	1	3	6	88
9	Do you record number of visual faecal contamination on carcasses per each batch?	Always	0	0	0	0	6	100	0	0	0	2	8	95
10	Do you report rejected carcasses to manager?	Always	1	0	0	0	5	83	1	0	0	2	7	85
	Average score of correctly answered knowledge questions							70						88

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