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Attitudes and opinions of the abattoir sector toward the control and prevention of microbiological foodborne pathogens

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Abstract

The abattoir sector plays a crucial role in controlling foodborne hazards, so insight in the incentives that motivate abattoirs to implement control measures is of great relevance to food safety risk managers and policy makers. Therefore, a cross-sectional telephone survey was conducted to assess the attitudes and opinions of abattoirs in Belgium and the Netherlands toward preventive measures for controlling microbiological pathogens. A total of 80 abattoirs participated, generally they seem to be aware of the most hazardous bacterial pathogens for public health and of their responsibility and potential role to control these hazards. However, significant differences were observed between animal species, company size, and countries.

Practical applications

The findings of this survey may help to specify and adjust the set-up and implementation of control strategies and measures to the diverse incentives and opinions of different food business operators.

1 | INTRODUCTION

The most commonly reported zoonotic diseases in the European Union (EU) are caused by *Campylobacter*, *Salmonella*, *Yersinia*, shigatoxigenic *Escherichia coli* (STEC), and *Listeria* (EFSA & ECDC, 2015). Each year, up to 10% of the human population of industrialized countries suffers from a foodborne zoonosis, which has large socio-economic consequences, such as labor productivity loss, costs for patient treatment, and hospitalization (Fosse, Seegers, & Magras, 2008). A study on the cost-of-illness and disease burden of food-related pathogens in the Netherlands in 2011, found that yearly €168 million and 5,510 disability-adjusted life years (DALY's) can be attributed to food, with 39% of these costs being attributed to exposure to beef, lamb, pork, and poultry meat (Mangen et al., 2015). Therefore, it is important that adequate strategies are developed and measures are taken to reduce the foodborne transmission of pathogens to humans (Fosse et al., 2008).

Meat and meat products are an important source for foodborne illnesses caused by *Campylobacter*, *Salmonella*, *Yersinia*, STEC, and *Listeria* (Nørrung & Buncic, 2008). Source attribution studies using foodborne outbreak data, showed that campylobacteriosis in the EU is mainly related to poultry products. For salmonellosis, transmission from eggs and poultry was indicated as the most common pathway of human infection (Greig & Ravel, 2009; Pires, Vigre, Makela, & Hald, 2010). The main source for human pathogenic *Yersinia enterocolitica* are pigs, and over 70% of yersiniosis cases are related to the consumption of contaminated pork (Batz, Hoffmann, & Morris, 2012; Fosse et al., 2008). A quantitative risk assessment model to explore the attribution of meat products to the risk of human STEC O:157 was conducted within the United Kingdom. Beef products were found to attribute the most to human STEC O:157 infections compared to lamb and pork products (Kosmider et al., 2010). The most important source for *Listeria monocytogenes* are ready-to-eat foods (Little, Pires, Gillespie, Grant, & Nichols, 2010). For all aforementioned bacterial foodborne pathogens, contamination of carcasses (and subsequently meat) may occur during slaughter, originating from the animal reservoir and/or the environment. Therefore, abattoirs play a critical role in the (prevention of) transmission of these pathogens to humans via meat (Greig & Ravel, 2009; Hill et al., 2016; Van Damme, De Zutter, Jacxsens, & Nauta, 2017).

Regulation (EC) no. 2073/2005 on microbiological criteria for foodstuffs imposes food business operator's (FBO's) compliance to the requirements for testing, sampling, and analyzing trends and aims to control *Salmonella* and other foodborne zoonotic pathogens in the EU. Abattoirs have to meet strict requirements regarding the microbiological quality of carcasses of food producing animals. In case of noncompliance, the slaughter process needs to be re-evaluated and adapted (European Commission, 2005).

As abattoirs play a crucial role in controlling foodborne hazards (EFSA, 2010), insight into the incentives that motivate abattoirs to implement preventive measures are of great relevance to risk managers. Meanwhile, the study by van Wezemael, Verbeke, Kügler, de Barcellos, and Grunert (2010) that focused on beef indicated that abattoirs were ranked by consumers from four EU countries among the distrusted actors in the meat chain with respect to safety, together with meat industries and packaging firms (van Wezemael et al., 2010). A recent study addressing stakeholder's perceptions, attitudes, and practices toward risk prevention in the food chain (Lupo, Wilmart, Van Huffel, Dal Pozzo, & Saegerman, 2016) showed that pathogenic microorganisms were seen as the largest risk that needs to be prevented. However, the participants of the study mainly included scientists and risk managers and only a limited number of FBOs. Yet, European consumers held mostly favorable attitudes toward interventions to improve meat safety in the beef chain at abattoir level, though this attitude depended on the levels of detail provided about the safety-improving interventions (van Wezemael, Verbeke, Kügler, & Scholderer, 2011). Therefore, the present study aims to obtain insight into the opinions of the abattoir sector toward microbiological hazards and preventive measures to control microbiological pathogens in meat. Hereby, differences between animal species, company size, and countries (Belgium and the Netherlands) were evaluated.

2 | METHODS

2.1 | Study design and questionnaire design

The data were collected through a cross-sectional telephone survey (n = 80). The self-designed questionnaire with nine straightforward and open-ended questions took 5–10 min to answer. The first two questions concerned general information while the seven remaining questions addressed the awareness of microbiological quality and the opinions toward preventive measures (Table 1).

2.2 | Data collection

The study population consisted of Dutch-speaking abattoir representatives in Belgium and the Netherlands. A list of abattoirs was obtained from the Belgian Federal Agency for the Safety of the Food Chain and the Dutch Food and Consumer Product Safety Authority. The abattoirs were contacted by telephone between February and May 2016 with the question to participate. If possible, the survey was held immediately. If not, the abattoirs were called at a more convenient time or the survey was sent by email. Reminders were done by phone or, when the survey was sent by email, per email after three to 4 weeks. The survey data were processed anonymously using randomly assigned ID numbers.

2.3 | Data analysis

The response data were collected in a Microsoft Excel spread sheet (MS Office version 2016) and were categorized, after which the data were transferred to STATA/IC 11.0 (StataCorp LP, College Station, TX) for statistical analysis.

The categorized variables were respondent's function in the company, main animal species that was slaughtered, company size, main contributor for meat of low microbiological quality, main pathogens, and the attributed responsibility for the implementation of preventive measures (Table 1). For abattoirs slaughtering more than one animal species, only the main species was taken into consideration. Based on company size, the participants were divided in two categories (large and small companies) based on the number of animals (of the main animal species) that were slaughtered and a set of guidelines based on expert opinion. For pig abattoirs, a slaughter speed of more than 100 animals per hour and more than 5,000 animals per week were the criteria to be classified as a large company. The ruminants' category contained cattle (beef and dairy), calves, and sheep. The threshold for a large ruminant abattoir was 20 animals per hour and 400 animals per week. For poultry and rabbits, abattoirs with a line speed of more than 2,000 animals per hour or 30,000 animals/week were classified as large companies.

For each question, differences in response (binary variable) between animal species, country, abattoir size, and respondent's function within the company were analyzed using multivariate logistic regression. Backward elimination was used, by which each time the variable with the largest p-value was dropped until only significant variables ($p < .05$) remained. Confounding factors were also retained in the final model. All possible two-way interactions between significant main effects were tested and were included in the final model when significant ($p < .05$). Only significant variables and interactions ($p < .05$) are mentioned in the text, findings are presented as odds ratios (OR). The lagomorph abattoirs were not included in the analyses due to the low number of observations (n = 2).

3 | RESULTS

3.1 | Survey response

Overall, 80 out of the 151 abattoirs (53%) participated. The main reasons for declining participation were a lack of time and a company policy against any participation in research. The animal category “ruminants” were the largest group with 34 abattoirs (42%), followed

TABLE 1 Overall results of the abattoir respondents (n = 80)

	Question	Category	Number of respondents[a]
1	Respondent's function within the company	Quality manager	46
		(General) manager/owner	29
		Company veterinarian	3
		Administrative personnel	2
2	Main animal species slaughtered in the abattoir	Ruminants	34
		Pigs	21
		Poultry	23
		Lagomorphs	2
3	Main contributor for meat of low microbiological quality	Primary production	39
		Abattoir level	34
		Consumer level	20
4	Can the microbiological risk be prevented?	Yes	74
		No	6
5	Main pathogens	*Salmonella*	72
		Campylobacter	27
		(Pathogenic) *E. coli*	40
		Listeria	37
		Other	14
6	Can preventive measures at abattoir level reduce pathogens?	Yes	49
		No	31
7	Who should be responsible for the implementation of preventive measures	Abattoir and/or entire sector	49
		Government (national government or EU)	20
		Both	11
8	Are additional control measures necessary?	Yes	52
		No	28
9	Are you prepared to implement additional measures at slaughterhouse level?	Yes	69
		No	11

[a]Since some abattoirs gave more than one answer for certain questions, the total number may be higher than the total number of respondents (n = 80).

by 23 poultry (29%), and 21 pig abattoirs (26%). Only two lagomorph abattoirs participated in the survey (2%). From the 80 abattoirs and following the previously described criteria, 49 companies were categorized as large companies, and 31 as small companies. Most respondents in both countries were quality manager (n = 46; 58%), followed by general managers (n = 29; 36%). In both countries, one administrative employee participated (n = 2, 2%). In Belgium, three company veterinarians (4%) participated. The survey was mainly completed by telephone (n = 63; 79%). Out of the 17 respondents (21%) that answered per email, nine were located in Belgium and eight were from the Netherlands (Table 2).

3.2 | Largest risk and preventability

First, the opinion of the abattoirs on which level in the food chain contributed the most to a decreased microbiological quality of meat was addressed (Table 1, question 3). Abattoirs that responded one category, indicated mostly that the largest contribution to microbiological risk was situated at primary production (n = 29; 36%), followed by the abattoir (n = 25; 31%) and consumers (n = 15; 19%). Several participants addressed more than one category: primary production and abattoir (n = 6), primary production and consumer (n = 2), abattoir and consumer (n = 1), all actors in the production chain (n = 2). Quality managers mentioned the abattoir level more frequently than (general) managers ($OR_{adjusted}$ = 5.1 [95% CI 1.6–16]; p = .006). Respondents from ruminant abattoirs indicated the abattoir more frequently than poultry abattoirs ($OR_{adjusted}$ = 4.1 [95% CI 1.1–16]; p = .040) when adjusting for country. Poultry abattoirs indicated the consumer level significantly more as the largest contributor to microbiological risk than ruminant abattoirs ($OR_{adjusted}$ = 5.0 [1.2–22]; p = .030), and participants from abattoirs in the Netherlands implied the consumer level significantly more than participants from Belgian abattoirs ($OR_{adjusted}$ = 5.4 [95% CI 1.5–20]; p = .010) when controlling for respondent's function within the company. General managers expressed the consumer level significantly more than quality managers ($OR_{adjusted}$ = 4.3; 95% CI 1.2–15; p = .022).

TABLE 2 Overview of the abattoirs that participated in the study (*n* = 80) according to the main animal species that was slaughtered, country, and company size

	Belgium			The Netherlands			
Animal species	Large abattoirs	Small abattoirs	Total	Large abattoirs	Small abattoirs	Total	Total
Poultry	10	6	16	7	0	7	23
Pigs	10	3	13	3	5	8	21
Ruminants							
Cattle	8	7	15	7	7	14	29
Sheep	1	0	1	2	2	4	5
Lagomorphs	1	0	1	0	1	1	2
Total	30	16	46	19	15	34	80

Note: Numbers indicate the number of abattoirs within each category.

TABLE 3 Overview of the main pathogens that were mentioned by the abattoir respondents according to the main animal species, that is, slaughtered and the size of the abattoir

	Salmonella	*E. coli*	*Listeria*	*Campylobacter*
Pigs	20/21	11/21	11/21	1/21
Small	7/8	2/8	2/8	0/8
Large	13/13	9/13	9/13	1/13
Ruminants	28/34	23/34	15/34	3/34
Small	11/16	10/16	4/16	1/16
Large	17/18	13/18	11/18	2/18
Poultry	22/23	5/23	10/23	21/23
Small	6/6	1/6	2/6	5/6
Large	16/17	4/17	8/17	16/17
Rabbits	2/2	1/2	1/2	2/2
Small	1/1	0/1	0/1	1/1
Large	1/1	1/1	1/1	1/1
Total	72/80	40/80	37/80	27/80

Note: Numbers represent the number of abattoir respondents that mentioned the pathogen relative to the total number of abattoirs within the category.

Out of the 34 respondents indicating the abattoir as the main contributor to microbiological risk, 30 mentioned one or more measures to prevent microbial contamination: hygiene (*n* = 21), training of personnel (*n* = 15), frequent inspection (*n* = 9), cleanness of incoming animals (*n* = 6), temperature control (*n* = 6); evisceration technique (*n* = 4); cleaning and disinfection (*n* = 3), fasting of animals prior to slaughter (*n* = 3), reducing the slaughter speed (*n* = 2), and renewal of machinery/slaughter line (*n* = 1).

In both countries and for each of the animals species, over 90% of the respondents believed that the risk they saw as the largest risk was preventable (data not shown).

3.3 | Knowledge on the main public health hazards

To obtain an overview of the awareness of abattoirs toward foodborne hazards, respondents were asked which human pathogens they knew (Table 1, question 5). One respondent (from a pig abattoir) was not able to name any, 13 respondents mentioned one hazard, 25 respondents mentioned two hazards, and 40 mentioned three or more hazards. The most frequently mentioned hazards were *Salmonella*, *Escherichia coli*, *Listeria*, and *Campylobacter* (Table 3).

Almost all participants (90%) mentioned *Salmonella*, followed by *E. coli* (50%), *Listeria* (44%), and *Campylobacter* (34%; Table 3). *Salmonella* was mentioned more frequently by large abattoirs (47/49) than by small abattoirs (25/31; OR = 5.8 [95% CI 1.1–31]; *p* = .041). Half of the participants mentioned *E. coli*, though the respondents of poultry abattoirs mentioned *E. coli* less frequently (5/23) than the respondents of ruminant abattoirs (23/34; OR = 0.13 [95% CI 0.04–0.45]; *p* = .001) and pig abattoirs (11/21; OR = 0.25 [95% CI 0.07–0.95]; *p* = .039). Six abattoirs specifically mentioned enterohemorrhagic *E. coli* (EHEC), shigatoxigenic *E. coli* (STEC), or verocytotoxigenic *E. coli* (VTEC) and all of these were cattle and/or veal abattoirs (three cattle abattoirs, two veal abattoirs, and one abattoir slaughtering cattle, veal, and sheep). *Listeria* was the third most frequently reported pathogen, mentioned by almost half of the respondents (Table 3). Quality managers mentioned *Listeria* more often (32/46) than (general) managers (4/29; OR = 13 [95% CI 4–46]; *p* < .001). Almost all poultry abattoirs (91%) mentioned *Campylobacter*, whereas the pig and ruminant abattoirs mentioned *Campylobacter* less (OR = 0.005 [95% CI 0.0004–0.06] and OR = 0.01 [95% CI 0.001–0.06]; *p* < .001; Table 3).

Other hazards mentioned were (methicillin resistant) *Staphylococcus aureus* or staphylococci (*n* = 7), *Streptococcus* (2), *Pseudomonas* (1), *Trichinella* (1), *Clostridium* (1), tuberculosis (1), foot and mouth disease (1), and blue tongue (1).

3.4 | Preventive measures in the abattoir and willingness to implement control measures

A total of 61% (*n* = 49) of respondents thought that additional preventive measures in the abattoir could decrease the presence of pathogens (Table 1, question 6). Quality managers (37/46) indicated this more than (general) managers (11/29; $OR_{adjusted}$ = 8.6 [95% CI 2.6–29]; *p* < .001) when controlling for animal species. Poultry abattoirs (9/23) shared this belief less compared to ruminants (22/34; *p* = .077) and pigs (17/21; $OR_{adjusted}$ = 0.09 [95% CI 0.02–0.52]; *p* = .007).

A total of 69 respondents (86%) indicated to be willing to implement additional control measures in the abattoir (Table 1, question 9). All large ruminant and pig abattoirs were willing to implement additional preventive measures, whereas poultry abattoirs were significantly less eager to do so than ruminant abattoirs ($OR_{adjusted}$ = 0.08 [95% CI 0.012–0.58]; *p* = .012) when controlling for abattoir size. Significantly more participants from large abattoirs (45/49; 92%) were willing to implement control measures than the participants from small abattoirs (24/31; 77%; $OR_{adjusted}$ = 0.11 [95% CI 0.02–0.60]; *p* = .011) when controlling for animal species.

Forty-seven of the respondents (59%) provided information about the conditions before they would implement prevention measures. Thirty respondents mentioned that the effectiveness of the control measures needs to be (scientifically) proven (54%); 17 (30%) mentioned that control measures need to be proven applicable and feasible, and 9 (16%) mentioned that control measures should be economically feasible.

3.5 | General preventive measures and responsibility

From the total sample of respondents, 65% (*n* = 52) indicated that additional preventive measures are necessary (Table 1: question 8). Poultry abattoirs were significantly more in favor of additional measures (19/23, 83%) than ruminant abattoirs (18/34, 53%; OR = 4.2 [95% CI 1.2–15]; *p* = .026).

Out of the 52 abattoirs who indicated that additional control measures were needed, 40 addressed at which point in the meat production chain they thought this would be the most necessary. Seventeen indicated primary production, 11 at consumer level, 6 both primary production and consumer level, three at all levels, two at abattoir level and one at retail level.

Regarding the responsibility for the implementation of preventive measures (Table 1, question 7), 61% responded the abattoir or the entire sector (*n* = 49), 25% governmental bodies (national government or EU; *n* = 20), and 14% mentioned both the abattoir/sector and government (*n* = 11; Table 4). The abattoir/sector was more frequently mentioned as responsible for the implementation of preventive measures by ruminant and pig abattoirs compared to poultry abattoirs ($OR_{adjusted}$ = 6.5 [95% CI 1.4–30]; *p* = .016 and $OR_{adjusted}$ = 12 [95% CI 1.6–83]; *p* = .014, respectively), and more so by quality managers than by general managers ($OR_{adjusted}$ = 9.4 [95% CI 2.3–39]; *p* = .002). The government was mentioned significantly more among poultry abattoirs than ruminant abattoirs (OR = 3.2 [95% CI 1.1–9.8]; *p* = .036) and pig abattoirs (OR = 3.9 [95% CI 1.1–14]; *p* = .035; Table 4).

TABLE 4 Responsibility for the implementation of preventive measures according to abattoirs (*n* = 80) by animal species

Animal species	Abattoir or entire sector	Governmental bodies	Both
Poultry	9	12	2
Pigs	15	2	4
Ruminants	23	6	5
Rabbits	2	0	0
Total	49	20	11

4 | DISCUSSION

To our knowledge, this is the first study describing both the awareness of abattoirs on microbiological human pathogens and their attitudes and opinions toward preventive measures concerning these pathogens. Possible limitations of this study are selection bias, response bias, and social desirability bias. Out of the 151 contacted abattoirs, only 53% participated. Although this is a good response rate overall, it is possible that specific types of abattoirs systematically refused to participate (e.g., those with a poor awareness of microbiological risks and a low interest in the study topic), and vice versa for other abattoirs (e.g., those with a high awareness of microbiological risks, a strong interest in the study topic, and a high involvement in preventive measures). This may imply that the insights obtained are rather optimistic and provide for a kind of best-case situation. To limit response bias, only one interviewer was involved in the study, using exactly the same questions and accompanying explanations to participants. Social desirability bias is presumably small as only a few of the abattoirs had previously cooperated with the researchers. Yet, if present, this would also mean that the data describe a best-case situation.

4.1 | Knowledge of abattoirs toward the most relevant foodborne pathogens

Salmonella spp. is mostly found in poultry, pig, and bovine meat (EFSA & ECDC, 2015). Almost all respondents mentioned *Salmonella* spp., which is likely related to the mandatory tests of carcasses on *Salmonella* according to the European Commission regulation (EC) no. 2073/2005. Further, *Y. enterocolitica*, *T. gondii*, and *Trichinella* were identified as relevant hazards related to pigs and pork (EFSA Panel on Biological Hazards (BIOHAZ), 2012). Yet, these were mentioned by less than 4% of respondents. Although *Y. enterocolitica* is often present on pig carcasses and pork and is indicated to be responsible for over 70% of human yersiniosis cases (Batz et al., 2012; Fosse et al., 2008), European microbiological criteria for this pathogen in pork are lacking, and our findings confirm that also the awareness of these hazards among abattoirs is poor. Further regulation and controls might raise the awareness of the public health issues related to the most relevant hazards, as abattoirs mainly mentioned those hazards, which they are obliged to test for.

For poultry, the most relevant microbiological hazards are *Campylobacter* spp., *Salmonella* spp., and ESBL/AmpC gene-carrying *E. coli* (EFSA Panel on Biological Hazards (BIOHAZ), 2012). The majority of poultry abattoir respondents mentioned *Campylobacter* spp. and *Salmonella* as one of the main biological hazards, which are regulated by national and EU legislation, respectively. *Escherichia coli* was mentioned by 22% of the poultry abattoirs, though ESBL/AmpC producing *E. coli* was never mentioned in specific.

In food producing animals, *Listeria* spp. is detected mostly in ruminants, followed by pigs and poultry (EFSA & ECDC, 2015). However, less than half of the respondents mentioned *Listeria*. The most relevant pathogens for cattle are *Salmonella* spp. and STEC, whereas for sheep and goats *T. gondii* and STEC are the main pathogens of concern (EFSA Panel on Biological Hazards (BIOHAZ), 2013a; EFSA Panel on Biological Hazards (BIOHAZ), 2013b). Half of the respondents mentioned *E. coli*, which may be interpreted as an indicator for fecal contamination (EC/2073/2005) or as a pathogen, though this differentiation was rarely made by the study participants. However, six respondents specifically mentioned STEC, VTEC, EHEC, or *E. coli* O157. All sheep and goat abattoirs mentioned *E. coli*, though none specifically referred to its possible pathogenicity.

In addition, 15 abattoirs mentioned *Enterobacteriaceae* (nine ruminants, four pigs, and two poultry abattoirs) and two of the ruminant abattoirs also mentioned total aerobic bacteria (data not shown). A potential explanation is that *Enterobacteriaceae* as well as total aerobic count might be applied as process hygiene indicators (Baylis, Uyttendaele, Joosten, Davies, & Heinz, 2011), and are therefore known within some abattoirs.

4.2 | Main risk along the farm to fork chain

Ninety-three percent of the participants mentioned that the factor they perceived as contributing the largest risk for a decreased microbiological meat quality was preventable. However, the largest risk differed among animal species, countries, and the respondent's function within the company. Forty-nine percent perceived the primary production stage as contributing the largest risk. A study among Flemish pig, cattle, and poultry farmers with known interest in research indicated that there are not enough motivators to implement preventive measures as no real incentives were perceived. All farmers had similar ideas on disease prevention: veterinarians acted as the main information provider and cost–benefit evaluations were the most important motivation (Laanen et al., 2014).

The second largest contributor to risk mentioned was the abattoir (42%). Additional prevention measures in the abattoir were believed to entail the potential of decreasing pathogens by 61% of respondents, although poultry abattoirs were significantly less convinced of this potential compared to pig and ruminant abattoirs. This might be related to the highly automated slaughter process for poultry compared to pigs and ruminants; poultry slaughter is more automated because of the size and uniformity of broilers (Barbut, 2014). As an example, several studies have shown a strong association between poultry carcass contamination with *Campylobacter* and the colonization level of incoming birds, which makes control of these pathogens during slaughter very challenging (Seliwiorstow et al., 2016; Seliwiorstow, Baré, Van Damme, Uyttendaele, & De Zutter, 2015). However, from a short-term perspective, intervention measures reducing *Campylobacter* contamination levels are considered more practical and effective during broiler slaughter and further processing, than in primary production (Nauta et al., 2009; Seliwiorstow et al., 2016). By contrast, a study on the reduction of pork-related salmonellosis suggests that abattoir interventions are more reliable and cause a larger decrease in human illness, and in a shorter timeframe than farm interventions (Hill et al., 2016). Examples of possible abattoir interventions that were associated with a lower presence of *Salmonella* on pig carcasses in small abattoirs in Spain were reducing the turbidity of scalding water, strict cleaning, and disinfection protocols on polishing equipment and avoiding the use of pressurized water in the intermediate cleanings (Sánchez-Rodríguez et al., 2018). However, a study determining the prevalence and diversity of *Salmonella* spp., *Campylobacter* spp., and *L. monocytogenes* among two free-range pig abattoirs in Spain addressed the importance of strategies along the pork production chain and implementation of hygiene strategies on the farm, during transport and slaughter (Morales-Partera et al., 2018). Koohmaraie et al. (2005) reported that slaughterhouse-level interventions would be most effective to reduce *E. coli* O157:H7 and other pathogens in beef. It was suggested that the costs of these interventions should be shared among chain actors rather than solely lie with the concerned actor.

Consumers were regarded as the largest contributor to risk by 25% of respondents. Further, several respondents mentioned that consumers could decrease the risk of an infection by correct handling of the meat. This is in line with a study of Sargeant et al. (2007), where stakeholders of the industry from the United States and Canada stated that consumers are (too) distant from the farm to fork processes (Sargeant et al., 2007). Abattoirs in the Netherlands mentioned consumers more than Belgian abattoirs, which might be related to several factors such as demographics and culture, which have been indicated to influence consumer behavior (Al-Sakkaf, 2015). Interestingly, when exposed to the question “Who do you think should be responsible for beef safety” in the study by van Wezemael et al. (2010), consumers from four EU countries did not mention themselves. They almost exclusively put the responsibility for beef safety with actors situated early in the including primary producers and abattoirs, together with veterinarians, inspectors, and scientists.

4.3 | Prevention measures and willingness

Overall, participants were willing to implement additional preventive measures, although small abattoirs and poultry abattoirs were significantly less eager to do so. Among nonwilling respondents, one poultry abattoir respondent mentioned that the EU should have more uniformity in meat inspection and quality criteria among its member states. Indeed, threshold levels of meat with pathogenic bacteria may differ between countries (EFSA Panel on Biological Hazards (BIOHAZ), 2008; EFSA & ECDC, 2015). More research is needed on incentives of abattoirs to implement preventive measures, taking into account differences between animal species and company size. In this study, the most frequently mentioned incentive was scientific proof (54%), which is similar to the finding of Lupo et al. (2016). Furthermore, Lupo et al. (2016) found that the cost–benefit balance is an incentive. In this study, only 16% of the respondents mentioned the importance of economic incentives.

4.4 | Practical application

The majority of respondents (61%) mentioned that abattoirs or the entire sector should be responsible for the implementation of preventive measures, which is similar to the 62% of FBO's found by Lupo et al. (2016). In contrast to the 75% of respondents who believed that competent authorities should be responsible for risk prevention (Lupo et al., 2016), only 25% of the respondents in this study mentioned governmental bodies. However, poultry abattoirs were significantly more in favor of governmental bodies assuming responsibility.

Only 14% of the respondents mentioned that the responsibility should be assumed by a partnership between either the sector or abattoir and governmental bodies. This differed from the opinions of stakeholders in the United States and Canada, where a study concluded that all stakeholders along the food chain should assume responsibility for the food safety policy (Sargeant et al., 2007). Several participants indicated that they perceive that only meat quality is seen as their responsibility and seem to request a closer collaboration with governmental bodies. This contrasts for example with Hung, Verbeke, and de Kok (2016) who reported that a diverse group of stakeholders involved in meat supply chains and related monitoring and controls referred to safety as the first priority, though this study related specifically to innovating processed meat products (Hung et al., 2016).

5 | CONCLUSION AND RECCOMENDATIONS

This research provides insights into the attitudes and opinions of abattoirs in Belgium and the Netherlands toward microbiological safety of meat and the implementation of preventive measures. Generally, abattoirs seem to be well aware of hazardous pathogens for public health and of their responsibility. However, foodborne pathogens that are not included in official monitoring and food control programs are clearly less known. This underscores the relevance of regulations, legislations, and information provisioning, as well as the need for further education and awareness raising among FBOs. The majority of participants believes that future preventive measures should have a strong scientific evidence base, and not only be implemented on abattoir level, but also involve farmers and even extend to consumers. Nevertheless, significant differences were found among animal species, company size, and countries, which risk managers and policymakers should take into account during evaluations of current meat safety and quality programs as well as during the set-up and implementation of future preventive measures.

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CONFLICT OF INTEREST

None.

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