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Biosecurity practices in Belgian veal calf farming: Level of implementation, attitudes, strengths, weaknesses and constraints

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ABSTRACT

The shift from cure toward prevention in veterinary medicine involves the implementation of biosecurity. In cattle farming, the application of biosecurity measures has been described to a limited degree, yet no data on biosecurity on veal farms is available. A high degree of commingling of veal calves from multiple farms causes frequent disease outbreaks, and thereby high antimicrobial usage and increased risk of antimicrobial resistance. Therefore, this study aimed to describe the current implementation of biosecurity on veal farms in Belgium. To this extent, a list of the most important calf diseases (n = 34) was created, and risk factors and related biosecurity measures for these diseases were determined and included in a questionnaire. Herd visits and face-to-face interviews were conducted on 20 randomly selected veal farms, comprising 8.3% of the target population. A categorical principal component and clustering analysis were performed to determine the influence of the veal companies on the farms' biosecurity level. Awareness of biosecurity was very low among the farmers. All farms used an "all-in, all-out" production system with calves originating from multiple farms without quarantine. On average, farms were filled in 11.4 days (range 2–52). The degree of commingling for these farms was 1.24, meaning that, on average, 124 calves originated from 100 farms. Veterinarians wore farm-specific boots on eight farms (40%) and farm-specific clothes on six farms (30%), while technical advisors wore farm-specific boots on six farms (30%) and farm-specific clothes on four farms (20%). Disinfection footbaths were only used in five farms (25%) despite being present in all farms in the sample. Concerning internal biosecurity, none of the farmers isolated sick animals; only one farmer (5%) had a physically separated hospital pen, and only 11 farmers (55%) both cleaned and disinfected the stables after each production cycle. In most farms, animals were of comparable age. Healthy calves generally remained in the same compartment during the entire production cycle, limiting the risks associated with the movement of animals. No influence of the integrations on the biosecurity level could be determined. It can be concluded that a few biosecurity measures, such as "'all-in, all-out" and compartmentation, are implemented relatively well, while other measures, such as good cleaning and disinfection and proper entrance measures for visitors and personnel can easily be improved. The improvement of measures regarding the introduction of animals of different origins will require more fundamental changes in the veal industry.

1. Introduction

The impact of infectious animal diseases and the measures to control them are of great importance for animal health, public health, food safety, and the economy. In order to implement the European Commission's Animal Health Strategy vision, "prevention is better than cure,' and the European Union Animal Health Law states that biosecurity is one of the key tools in preventing the introduction, development, and spread of transmissible animal diseases to, from, and within an animal population. In the recent past, some studies regarding

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biosecurity in cattle farms have found that the overall application of biosecurity measures was low (Sarrazin et al., 2014; Renault et al., 2018a). As far as we are aware, no studies regarding biosecurity in intensive veal-rearing systems have yet been executed.

Biosecurity is defined as all measures that aim to prevent pathogens from entering or leaving a herd, referred to as external biosecurity, and all measures aiming to reduce the spread of pathogens within a herd, referred to as internal biosecurity (Damiaans et al., 2018). External biosecurity contains measures concerning animal movements, e.g., purchase and transport of live animals. Biosecurity also includes the entrance of visitors, such as the herd veterinarian, and possible contact with other animals of the same or other species. Internal biosecurity contains measures concerning the health management of the animals, compartmentation of different age groups, and cleaning and disinfection.

In Europe and North America, a high number of excess dairy and, to a lesser degree, beef calves are reared in the highly integrated veal industry (Brown and Claxton, 2011). The veal sector is strongly integrated and industrialized and is therefore substantially different from conventional cattle farms (Pardon et al., 2014). Therefore, it cannot be assumed that biosecurity measures and levels of implementation on veal farms are comparable to conventional dairy and beef farms. The veal-rearing system is highly similar throughout the majority of the main veal-producing countries, often with veal companies working across borders (Sans and Fontguyon, 2009). Therefore, biosecurity in Belgian veal farms could, to a certain extent, be considered representative of European veal production.

In Europe, before entering the veal sector, calves from dairy or beef farms are collected by salesmen and transported to a sorting center. The age when leaving the farm of origin differs between countries. In the sorting center, calves are sorted by breed, bodyweight, and conformation, and are thereafter transported to the veal farms (Schoonmaker et al., 2002). White veal calves are slaughtered at a maximum age of 8 months. Most veal calf farms in Belgium are part of a veal company (Pardon et al., 2014). Veal companies organize the veal farming process from the top down, with their own sorting centers, feed factories, and slaughterhouses. The companies generally own the calves, distribute feed to the farms, and impose some management requirements, while the farmer gets paid for each calf he raises on his farm.

The veal sector might benefit from improved biosecurity since several researchers have suggested that improved disease prevention is possible through increased biosecurity on the farm (Roca et al., 2015). Due to the high degree of commingling calves from different farms of origin, infected calves can lead to a rapid spread of disease on the veal calf farm, causing severe health and welfare issues and economic losses. As biosecurity may (partially) prevent these losses, it is considered a cost-effective method of prevention (Van Schaik et al., 2001).

The high level of antimicrobial use in veal-rearing is causing considerable concerns (Pardon et al., 2012) as it facilitates development of antimicrobial resistance (McEwen and Fedorka-Cray, 2002) as has previously been demonstrated (Catry et al., 2016). As shown in other animal species, a possible way to reduce the level of antimicrobial use and its subsequent resistance selection is to improve the level of biosecurity (Postma et al., 2016; Collineau et al., 2017).

Biosecurity practices are often neglected by cattle farmers who assume that the risk of infection in their animals is low (Nöremark et al., 2016). This assumption is likely not the case for veal farmers since the risk of infection is known to be high (Pardon et al., 2011; Knight et al., 2013). Moreover, cattle farmers have indicated a lack of information regarding biosecurity (Damiaans et al., 2018; Higgins et al., 2018). This lack can be presumed to be similar among veal farmers because comparable channels of information are available. Thus, in order to improve biosecurity on veal farms, its strengths, weaknesses, and constraints should first be identified.

Therefore this study aimed to determine the main biosecurity measures in veal production and the application level of these measures in Belgian veal farms as reported or observed during a visit.

2. Material and methods

2.1. Disease selection

First, a list of cattle diseases that are either endemic in Belgium or at risk of (re)emergence was developed according to the methodology previously described by Renault et al. (2018b). An initial list of diseases was based on a literature review after a search of the PubMed database. In the list, both calf diseases and diseases of high importance in cattle, or with zoonotic potential, were included. Diseases not occurring in, or not at risk of emergence in Belgium (never reported in Europe), were removed from the initial list. Second, three different data sources were accessed to select the most important diseases from this list: 1) a combination of recently described prioritization methods applied to the literature search, including all notifiable diseases (ANSES, 2010; Havelaar et al., 2010; Humblet et al., 2012; McIntyre et al., 2014; Ciliberti et al., 2015); 2) data on disease occurrences in the last three years, provided by regional animal health centers; and 3) an online survey among bovine veterinary practitioners (Renault et al., 2018a).

2.2. Building the questionnaire

Based on the final list of diseases (Table 1), a review of the literature on risk factors and biosecurity measures related to each of the diseases was performed. This review was kept as broad as possible to have a complete overview of all factors concerning biosecurity, and then cross-referenced with previous biosecurity questionnaires and a biosecurity reference work (Dewulf and Van Immerseel, 2018). For this reason, a search of the PubMed database was performed with this combination of terms: “name of disease and/or pathogen,” or “cattle,” “risk factors” or “epidemiology” or “prevalence” or “biosecurity measures” or “control measures.” The list of risk factors and biosecurity measures for each disease was integrated into an exhaustive list with all known (published) risk factors and biosecurity measures relevant for veal calves. If possible, a corresponding biosecurity measure was identified for each risk factor. Risk factors that cannot be controlled, or for which no biosecurity measure is available (e.g., birth weight, weather), as well as risk factors related to parturition or shortly thereafter (e.g., hygiene at parturition and provision of colostrum) were discarded. Though this last category is considered important, these risk factors are outside the control of the veal farmer because the animals arrive at two weeks of age. The total list of biosecurity measures is provided in Annex 1. This table also provides the number of risk factors each measure addresses, and the number of diseases for which it was cited in the literature. In Table 2, an overview of the 12 most important biosecurity measures, and their relation to the 34 most important calf diseases is provided.

Based on the list of biosecurity measures and complemented with content and experience from previous questionnaires concerning biosecurity in pig and broiler production (www.biocheck.ugent.be), a questionnaire assessing the implementation of biosecurity on veal farms was created. In addition to questions about the implementation of biosecurity, questions about motivators or hurdles when implementing biosecurity measures were also asked, as well as general attitudes and knowledge regarding disease prevention and biosecurity. A draft questionnaire was tested on two veal farms. The final questionnaire consisted of 40 open-ended questions and a maximum of 114 multiple choice questions (Annex 2) and is available upon request by readers. Part of the multiple choice questions, 57 in total, were arranged into 3 tables to facilitate data collection.

2.3. Visiting farms

A random sample of 60 farms from all Belgian veal farms (241 farms in 2016) was obtained from the Flemish Animal Health Service

Table 1
List of the 34 most important calf diseases with their respective transmission routes.

Disease	Transmission Pathways							Selection Criteria		
	Direct contact	Transplacental	Venereal	Indirect/ fomite	Ingestion	Inhalation	Vector	Prioritization exercises	Labresults	Veterinary survey
Bovine respiratory diseases (including Pasteurella spp., Mannheimia haemolytica, bovine adenovirus, …)	1			1	1	1		1	1	1
Bovine viral diarrhea	1	1	1	1	1	1		1	1	1
Infectious Bovine Rhinotracheitis(IBR)	1			1		1		1	1	1
Mycoplasma bovis	1			1	1	1		1	1	1
Salmonellosis	1			1	1	1		1	1	1
Anaplasmosis		1		1			1	1		1
Babesiosis							1	1		1
Botulism	1			1	1	1		1		1
BRSV	1			1		1			1	1
Campylobacteriosis	1			1	1			1	1	
Coccidiosis	1			1	1				1	1
Cryptosporidiosis	1			1	1			1		1
Diarrhea/enteritis, neonatal (Rotavirus, coronavirus, E. coli, adenovirus, …)	1			1	1				1	1
Leptospirosis	1		1	1	1	1		1	1	
Lice and ectoparasites	1			1					1	1
Q Fever/Coxiellosis	1			1	1	1	1	1		1
Schmallenberg disease		1					1	1	1	
Anthrax	1			1	1	1		1		
Aujeszky's Disease	1			1	1	1		1		
Bluetongue	1	1		1			1	1		
Bovine Spongiform Encephalopathy		1			1			1		
Brucellosis	1	1	1	1	1			1		
Dermatophytosis/-mycosis	1			1			1			1
E. Coli verotoxic	1			1	1			1		
Enterotoxemia (*Clostridium* spp)	1			1	1					1
Enzootic bovine leucosis		1		1			1		1	
Foot and Mouth Disease	1			1	1	1		1		
Giardiasis	1			1	1				1	
Infectious Bovine Keratoconjunctivitis	1			1			1[a]			1
Listeriosis	1			1	1			1		
Necrobacillosis (laryngitis)	1			1						1
Rabies	1			1	1	1		1		
Scabies	1			1						1
Tuberculosis (bovine)					1	1		1		

[a] Only mechanical vector.

(Diergezondheidszorg Vlaanderen). A computer-generated random number (Excel®, Microsoft) was assigned to each of the 60 farms, and the numbers were sorted from low to high. Selected farmers were contacted, starting with the farm assigned to number 1, and were asked to collaborate until 20 farmers willing to cooperate were selected. The sample size was limited to 20 farms due to limited time and resources, as it was part of a research project to study and quantify biosecurity on different types of cattle farms. A total of 28 farmers were contacted to obtain a sample from 20 veal farms. Of the 8 farmers not willing to participate, 1 was no longer active, 3 cited a lack of time, 3 wished to receive no visitors to keep a closed farm, and 1 farmer did not give a reason. The study farms were visited between November 2016 and February 2017, and face-to-face interviews were conducted by the first author in Dutch, the native tongue of both farmers and interviewer. The visit consisted of a tour of the farm and the interview itself. Participants were informed beforehand of the procedure. Written informed consent was obtained from the participating farmers.

2.4. Data processing

After the survey, all data was entered into a Limesurvey-form and exported to the statistical package IBM® SPSS® Statistics 25.0. The results were analyzed using basic descriptive analysis. The frequency of each answer and, when possible, the mean, median, standard deviation (SD), quartiles, minimum, and maximum were calculated.

A biosecurity scoring system was created with binary variables, where 1 indicated the presence of a biosecurity measure and 0 indicated the absence. These scores were added up to generate a score on a scale of 0 to 10 for each biosecurity category, with a total of seven categories describing measures concerning animal movements, visitors, contact with other animals, disease management, compartmentation, cleaning and disinfection, and calf management. Next, a categorical principal components analysis (CATPCA; SPSS 25.0) and clustering analysis, as previously described by Van Steenwinkel et al. (2011) and Sarrazin et al. (2014), were performed to combine the information originating from multiple variables. Based on this information, the researchers assessed whether the veal companies influenced biosecurity levels. To this end, the categories were given an ordinal measurement scale in the CATPCA analysis. The veal companies were included as a supplementary nominal measurement to explore their relationship with the biosecurity levels. For the analysis, 3 major and a group of minor veal companies, as described in Pardon et al. (2014), were randomly assigned a number from 1 to 4. The object scores, following the CATPCA analysis, were included in a k-means cluster analysis (KMCA; SPSS 25.0) to compare the clusters to the veal companies.

3. Results

3.1. Literature research

After selection, as described in the Material & Methods section, the final list contained the 34 most important calf diseases (Table 1). A total

Table 2
Twelve biosecurity measures considered most important, and their presence in literature for the 34 most important calf diseases.

Disease	Biosecurity Measures												References
	Ensure free source of origin on purchase	Prevention of transmission by visitors	Prevention of direct and indirect contact with animals of neighboring farms	Prevention of (in)direct contact with wildlife, pets, rodents, birds and insects	Proper carcass disposal	Prevention of feed and water contamination	Separation of infected animals	Elimination of permanently infected animals	Working organization and compartmentation	All in/all out system of separate stables	Cleaning and disinfection of stables and equipment	Sanitary vacancy after cleaning	
Anaplasmosis	2	0	2	0	0	0	0	2	0	0	0	0	1–4
Anthrax	0	0	0	0	2	0	0	0	0	0	0	0	5,6
Aujeszky's Disease	2	2	2	0	0	1	0	0	0	2	0	0	4,7
Babesiosis	0	0	2	0	0	0	0	2	0	0	0	0	4
Bluetongue	2	0	0	0	0	0	0	2	0	2	0	0	4,7,8
Botulism	0	0	0	0	2	2	0	0	0	0	0	0	9–19
Bovine respiratory diseases	2	2	1	2	0	2	2	2	2	2	2	2	20–92
Bovine respiratory syncytial virus	1	2	2	2	0	0	1	0	1	1	0	0	21, 29, 32, 40, 58–62, 93–105
Bovine Spongiform Encephalopathy	1	0	0	0	0	2	0	2	0	0	0	0	4,7,106,107
Bovine viral diarrhea	2	2	2	2	0	0	2	2	2	2	2	2	43,58,108–119
Brucellosis	2	1	2	2	2	2	2	2	1	2	1	0	4,7,120–126
Campylobacteriosis	0	0	0	0	0	0	0	2	0	0	1	1	4,8
Coccidiosis	1	1	1	1	0	0	1	0	2	2	2	1	127-142
Cryptosporidiosis	2	2	1	1	0	0	2	2	1	1	2	2	130,132,143–158
Dermatophytosis/ -mycosis	0	0	0	0	0	0	1	0	2	0	2	2	4,159
Diarrhea/enteritis	2	2	1	2	0	0	2	2	2	2	2	1	51, 54, 59, 60, 143, 147, 149, 152, 158, 160–179
E. Coli (verotoxic)	2	2	2	1	0	1	2	0	1	1	2	1	180–190
Enterotoxemia (Clostridium spp)	0	0	0	0	0	0	0	0	2	0	0	0	191–201
Enzootic bovine leucosis	2	0	0	0	0	0	2	2	0	0	0	0	202–205
Foot and Mouth Disease	2	2	2	0	2	0	1	2	1	2	2	2	4, 206–212
Giardiasis	2	2	1	1	0	0	2	2	1	1	2	2	150,155,213
Infectious Bovine Keratoconjunctivitis	1	0	1	0	1	0	0	2	0	1	0	0	214–224
Infectious Bovine Rhinotracheitis(IBR)	2	2	2	1	0	0	2	2	2	2	2	2	43, 58, 61, 89, 225–248
Leptospirosis	1	0	2	2	0	2	0	2	0	0	1	1	4,249
Lice and ectoparasites	2	2	2	0	0	0	0	0	0	2	2	2	250–265
Listeriosis	0	1	2	2	0	2	1	0	2	0	2	2	266–290
Mycoplasma bovis	2	2	2	0	0	1	2	2	2	2	2	2	21, 26, 29, 32, 63, 66, 95, 291–308
Necrobacillosis (laryngitis)	0	0	0	0	0	0	0	0	1	0	0	0	309–327
Q Fever/Coxiellosis	2	2	0	0	0	0	1	2	2	2	2	2	4,328–330
Rabies	2	0	2	2	0	0	0	0	0	0	0	0	331–346
Salmonellosis	2	2	1	1	0	2	1	2	1	2	2	1	143,347–363
Scabies	1	1	1	0	0	0	0	0	0	1	1	1	364–378
Schmallenberg disease	0	0	0	0	0	0	0	0	0	0	0	0	8,379–383
Tuberculosis	2	1	2	2	0	0	1	2	2	1	1	0	4,384,385

"2" means the measure was mentioned as such in literature for the disease, "1" means the relevance of the measure could be deduced from context, while "0" means that the risk factor was not found in literature for that disease.
The numbered references in the last column are provided in Annex 3.

of 385 articles related to these diseases were reviewed to list all risk factors and biosecurity measures as input for the questionnaire.

The full list of biosecurity measures can be found in Annex 1. One of the most frequently mentioned risk factors was animal movement. Animal movement includes the purchase of animals and all associated biosecurity measures, such as ensuring that the farm of origin is free from infection, limiting the number of source farms, and collecting information on animal and farm of origin as well as testing the animals after purchase and quarantining new animals. These measures were described as risk factors for multiple diseases and were considered important for the questionnaire, especially since the veal sector has its own system for purchase.

Another frequently mentioned group of measures is related to visitors. The use of farm-specific clothing and footwear before entering the stables is often mentioned as well as the use of a disinfection footbath and hand-washing facilities before and between the animals' lodgings. Measures concerning management of diseased animals, such as quick recognition, good assessment and correct treatment of disease, and elimination of disease carriers were also frequently cited. Finally, all measures related to cleaning and disinfection of housing and equipment after each use were considered important, according to the literature.

3.2. Farm characteristics and attitude toward biosecurity

The majority of the participating farms (Fig. 1) were located in the province Antwerp (n = 13), which corresponds to the area with the highest density of veal farms in Belgium. The other participants were located in West-Flanders (n = 4), Limburg (n = 2) and East-Flanders (n = 1). The maximum number of calves present on the farm ranged from 212 to 1700 calves. Other farm characteristics can be found in Annex 4.

Sixteen farms were part of three veal companies coordinating the highest number of Belgian veal farms (veal company 1: 6 farms; veal company 2: 6 farms; veal company 3: 4 farms), and four farms belonged to three smaller veal companies.

Of 20 farmers, only 4 (20%) could give a partial definition of biosecurity, mainly focusing on external biosecurity. Other farmers had no idea (n = 4), defined it vaguely as the reduction of antimicrobial usage (n = 6; 30%), improvement of food safety (n = 3; 15%), or organic production (n = 3; 15%). After explaining the term, 19 farmers (95%) considered biosecurity to be important. All of them considered disease prevention to be cheaper than treatment. Only slightly more than half (11/20; 55%) of the farmers could list five or more biosecurity measures they implemented on their farm, and 19 participants (95%) considered the measures as implemented sufficiently to prevent disease transmission. Seven farmers (35%) preferred that the veterinarian provide them with information on biosecurity or disease prevention. Six farmers (30%) considered professional organizations, such as the animal healthcare association or the veal calf producers association, their preferred source of information. Nine farmers (45%) did not consult any information sources because they believed no such information was available. Two farmers (10%) mentioned the role of the veal company. No farmers seemed to gain information from the internet or from magazines for agricultural professionals.

3.3. Implementation of external biosecurity measures

3.3.1. Measures concerning animal movements

Inherent to the production system in the veal sector, all farms bought calves every 7.5 to 8 months. There was a large difference in the time required to fill the stables for one cycle, ranging from 2 to 52 days. On average, a stable was filled in 11.4 days (SD: 9.6). During the filling of the stable, all farms received animals on three fixed delivery days per week. On three farms, the age difference between calves was larger than two weeks due to a large spread of calves entering the stables. All calves were collected by cattle salesmen at the farm of origin, moved to a sorting center, and delivered by the veal company to the veal calf farms (Table 3).

Six farmers indicated that they paid attention to sanitary status and health management, which refers to the presence of specific diseases on the farm of origin (Table 3). This procedure was based on previous experiences with the farm of origin, in consultation with the veal company. The remaining participants argued that the veal company decides which calves are sent to them, and four farmers emphasized their trust in the company to cover this issue. One farmer believed reviewing the health status of all new calves was unfeasible. A shared opinion was that it is virtually impossible to check all farms of origin, since their number is almost equal to the number of calves. This number is confirmed, since the average degree of commingling for the 20 farms was calculated to be 1.24 (SD = 0.16), meaning that, on average, 124 calves originated from 100 farms. As such, a farm with 500 calves will harbor animals from over 400 different origins.

Upon arrival, calves were divided into high and low risk groups based on visual appraisals by 12 of the 20 farmers (60%). On these farms, weaker calves were housed together and received more attention. Half of the farmers (50%) felt that taking blood samples from all the animals to test for disease is neither feasible nor affordable. Other reasons for not testing upon arrival included that there is no obligation to the government (n = 3; 15%) or to the veal company (n = 3; 15%), or that it would provide little additional information (n = 4; 20%). As the stables are filled in a short period, the farmers mostly felt quarantine was neither feasible nor necessary (n = 19; 95%).

Before animals are transported to slaughter, transport vehicles are generally empty, cleaned and disinfected prior to picking up animals ready for slaughter, according to the majority of the farmers (n = 15; 75%). However, upon delivery of animals to the farm, on 11 farms (55%), not all animals were unloaded, indicating that trucks were not empty and so were not cleaned between farms.

3.3.2. Measures relating to visitors

In 13 farms (65%), access to the stables was controlled by a closed gate and a requirement for visitors to announce themselves before entering. The remaining 7 farmers (35%) believed this was not feasible. The same farmers did not require visitors to register, either because it was not considered important (n = 3; 43%), regularly forgotten (n = 2; 29%), unknown (n = 1; 14%), or not mandatory (n = 1; 14%).

Measures regarding farm-specific clothing and boots were not well implemented by most visitors (Table 4), despite farm-specific clothing and boots being available in a high number of farms (Table 5). Other measures for visitors were rarely implemented. Disinfection footbaths were generally present but were either dirty, empty, or ignored. Footbaths were not used by most farmers and staff, mainly because they believed it was not important on their own farm. Very few participants always washed their hands or wore gloves before entering the stables. Those not washing their hands assumed it was not important. On the few farms where a hygiene lock (a room to change into farm-specific boots and clothing before a visitor can enter the stables) was present, it was consistently used by farm personnel and visitors. For one-third of the farmers (n = 6; 35%) that did not have a hygiene lock, the practice was unknown.

3.3.3. Measures concerning direct or indirect contact with other animals or insects

A standard rodent control program usually consisted of the implementation of rodenticides. Farmers without a rodent control program deemed it not important or only took measures when visibly infested (Table 3). All farmers that implemented measures for insect control (n = 14; 70%) treated the environment, sometimes combined with additional measures (Table 3). These measures were mostly intended to control fly populations during summer.

The use of a well-equipped carcass storage space was often implemented (85%; n = 17), although few (25%; n = 5) regularly cleaned

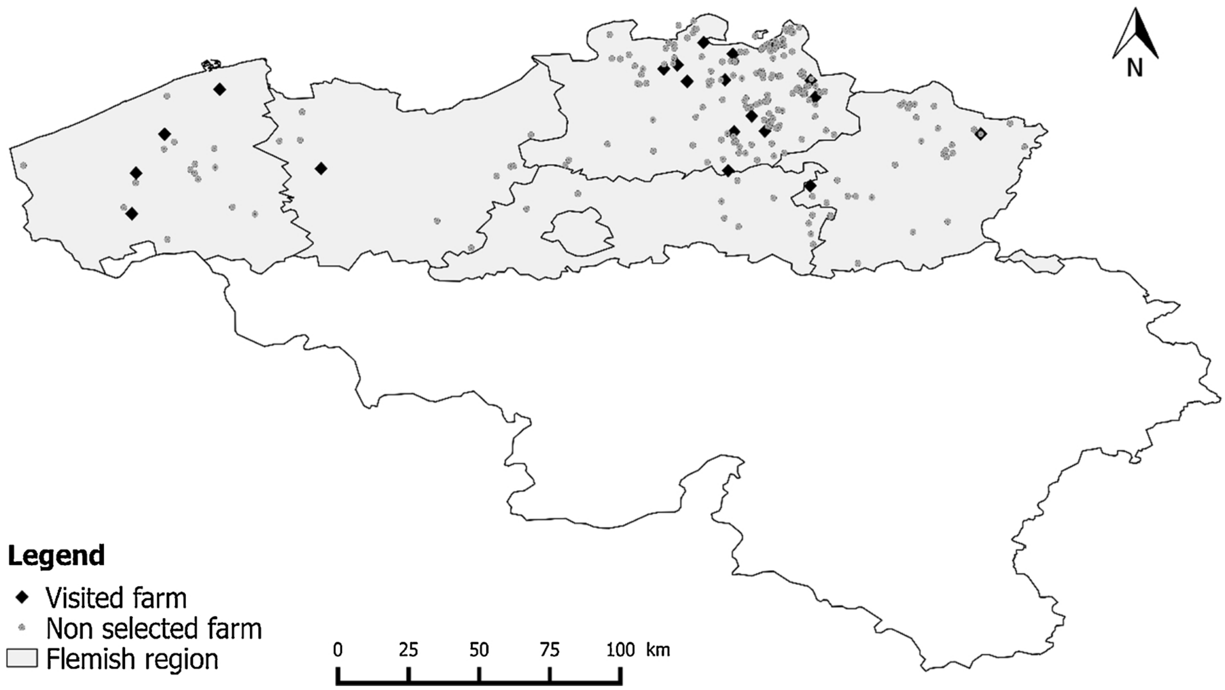

Fig. 1. Map of all Belgian veal farms. Visited farms are marked with a yellow arrow, while non-selected farms are represented by a blue arrow.

and disinfected the carcass storage area. Removal of carcasses by the rendering company without entering the premises was considered very important, although this was only possible on 11 farms (55%).

3.4. Implementation of internal biosecurity measures

3.4.1. Measures concerning disease management

More than half of the farmers (n = 13; 65%) believed vaccination was not important or too expensive because of the short duration of a production cycle and because most vaccines can only be administered at a certain age (Table 5). According to these farmers, most disease outbreaks are observed during the first weeks after introduction, a moment when vaccines are considered not yet effective. Some farmers also mentioned that since the veal companies own the calves, the companies should decide whether to vaccinate. Measures for ectoparasites consisted of preventive treatments, mainly to avoid outbreaks of scabies. Specific treatment for endoparasites was administered only curatively.

Seven of twenty (35%) farmers thought it was not feasible to isolate sick animals and five (25%) farmers applied partial isolation, where the animals were not separated from the other animals (direct contact possible) (Table 5). Although a hospital pen was present on seven farms (35%), only three farmers (43%) indicated that they sometimes isolated sick animals when they were lame or unable to function in the group (e.g., unable to eat, drink, or stand up). Only two out of seven hospital pens were cleaned, disinfected and dried before new animals entered, and an "all-in, all-out" system was used in four hospital pens. Only one farmer implemented all these measures and had a fully, physically separated hospital pen. The farmers that did not take these measures declared them infeasible because their hospital pen was located inside the regular stables, making thorough cleaning unfeasible.

For five participants (25%), elimination or segregation of a carrier of infection depended on the age or clinical status of the animal. An older animal would often go to slaughter while younger animals would be separated.

3.4.2. Measures concerning compartmentation

On the nine farms with multiple age groups, eight farmers performed work from old to young, contrary to established wisdom (Table 5). On 16 farms (80%), equipment, such as wheelbarrows and feeding utensils, were moved between compartments (same age group) without cleaning or disinfection. None of the farms used compartment-specific measures, such as changing clothes and footwear or washing hands between different compartments or age groups. Within the compartment, calves were sorted by drinking speed for economic reasons, since the difference between the animals would impair the growth of slower animals. Between compartments, animals were only moved to segregate carriers of infection.

Only one farm (5%) could not prevent direct contact with another age group due to the structure of the stable. In two farms, the "all-in, all-out" system was not always well applied, i.e., young calves entered the stables while (some) older animals were still present, resulting in possible contact between the age groups. The calf stables were empty after each production cycle on the other 17 farms (85%). The duration of the sanitary vacancy, often also referred to as downtime, a period between production cycles where the stable is not used, was on average 9.8 days (SD = 4.1; range 3–15 days).

3.4.3. Measures concerning cleaning and disinfection

All farmers who always applied a sanitary vacancy (n = 17; 85%), also cleaned their stables during the vacancy. However, only 11 out of 17 farmers also disinfected them. Pipelines used for milk were cleaned once or twice a week. Water and feed troughs were rinsed with water on a daily (n = 5; 25%), weekly (n = 4; 20%), or monthly (n = 1; 5%) basis, or once per production cycle (n = 8; 40%). Two farmers (10%) never cleaned the feed troughs. All farmers used reusable needles to inject the animals.

3.4.4. Measures concerning calf management

In general, calves were housed in individual boxes with both visual and physical contact during the first six weeks. Calves were then sorted by drinking speed within the compartment. Poorly growing calves were isolated in one compartment with a different diet. As one compartment only contained animals of the same age group, air flow within the compartment was considered irrelevant concerning disease spread from younger to older animals (Table 5).

Table 3

Implementation of external biosecurity measures. Column one contains the biosecurity measure, the second column contains the maximum number of farms that can adhere to the measure, while the third to fifth columns contain the adherence to the measure.

Biosecurity measure concerning animal movements	N	Yes	Sometimes	No
Purchasing animals from the same source	20	0		20
Possible contact with other calves before arrival	20	20		0
Check of sanitary status and health management of farms of origin	20	4	2	14
Separation of calves in high/low risk groups based on risk classification	20	12		8
Testing for specific diseases when purchasing	20	0		20
Calves leaving and re-entering the farm	20	0		20
Applying quarantine	20	0		20
Access of transport vehicle to calves' residence prohibited	20	20		0
Transport empty before entering the farm (for loading animals)	20	15		5
Transport clean and disinfected before entering the farm (if empty)	15	14		1
Only the calves on the transport that are supposed to be delivered	20	9		11

Biosecurity measure concerning animal contact	N	Yes	Sometimes	No
Rodent control program	20	13		7
Use of insect repellants on the animals	20	1		19
Use of insect repellants in the environment	20	14		6
Use of insect traps/nets	20	3		17
Handling of manure to limit insects	20	1		19
No contact possible between calves and other cattle	20	19		1
No contact possible between calves and wild ruminants or boar	20	20		0
No access to the stable by cats	20	9		11
No access to the stable by dogs	20	16		4
No access to the stable by birds	20	12		8
No access to the stable by rodents	20	0		20
No (frequent) contact of employees with animals from other farms	20	14		6
Carcass storage space with solid, easy to clean floors	20	17		3
Carcass storage space protected from pets and vermin	17	14		3
Carcass storage space cleaned after use	17	10		7
Carcass storage cleaned and disinfected after use	17	5		12
Carcass removal possible without entering the farm	20	9		11
Carcass manipulation with gloves (or hands cleaned and disinfected afterwards)	20	20		0
No manure from other farms spread within 500 m of the farm	20	5		15
No access to the food storage by cats	20	8		12
No access to the food storage by dogs	20	15		5
No access to the food storage by birds	20	13		7
No access to the food storage by rodents	20	3		17
Feeding utensils cleaned after use	20	8		12
Feeding utensils cleaned and disinfected after use	20	2		18
No use of feeding utensils for manure	20	17		3
Testing of microbial quality of animals' drinking water at least once a year	20	16		4
No sharing of equipment with other farms	20	20		0

Table 4
Implemented biosecurity measures by different visitors before entering the stables. Column one contains the biosecurity measure, the second column contains the maximum number of farms that can adhere to the measure, while the third to fifth columns contain the number of visitors complying to the biosecurity measure.

Biosecurity measure related to visitors	N	Farmer/Employees	Veterinarian	Advisor
Restricted access to the stables	20	/	14	14
Wearing farm specific clothes before entrance	20	16	6	4
Wearing farm specific boots before entrance	20	17	8	6
Using a hygiene lock	20	3	3	2
Washing and disinfecting hands before entrance	20	2	4	4
Wearing gloves before entrance	20	1	3	1
Using disinfection footbath before entrance	20	4	5	5

Table 5
Implementation of internal biosecurity measures. Column one contains the biosecurity measure, the second column contains the maximum number of farms that can adhere to the measure, while the third to fifth columns contain the adherence to the measure.

Biosecurity measure concerning disease management	N	Yes	Sometimes	No
Protocols for vaccination	20	1		19
Preventive measures for endoparasites	20	14	2	6
Preventive measures for ectoparasites	20	20		0
Isolation of sick calves	20	0	3	17
Hospital pen placed physically separated from the other calves	3	1		2
Specific equipment available for the hospital pen	3	3		0
Specific equipment for the hospital pen cleaned after use	3	1		2
Feed and water troughs cleaned after use	3	1		2
Handling sick animals in hospital pen last	3	1		2
Registration of animal health data	20	8		12
Elimination of carriers of infection	20	7	5	8
Segregation of carriers of infection (if no elimination)	13	5	5	3
Biosecurity measure concerning compartmentation	**N**	**Yes**	**Sometimes**	**No**
Multiple age groups present on farm	20	9		11
Separation of age groups	9	9		0
No contact possible between age groups	9	8		1
Working from young to old	9	8		1
Specific equipment available for each age group/stable	20	4		16
Specific equipment per age group/stable cleaned after use	4	0		4
Specific equipment recognizable per age group/stable	4	0		4
Farm specific clothing available before entering the farm	20	14		6
Farm specific boots available before entering the farm	20	17		3
Hygiene lock before entering the farm	20	3		17
Hygiene lock only entrance to the stable	3	0		3
Clean and dirty area of the hygiene lock designated and physically separated	3	0		3
Gloves available before entering the farm	20	1		19
Disinfection footbath available and ready for use before entering the farm	20	5		15
Hand washing facilities available and ready for use before entering the farm	20	3		17
Biosecurity measure concerning cleaning and disinfection	**N**	**Yes**	**Sometimes**	**No**
Sanitary vacancy of the calf stables after removal of animals	20	17	2	1
Calf stables cleaned after removal of animals	17	17		0
Calf stables cleaned and disinfected after removal of animals	17	11		6
Calf stables dry before next use	17	13		4
All-in, all-out system in the calf stables	17	15		2
Hospital pen available on farm	20	7		13
No direct contact possible in the hospital pen	7	3		4
No indirect contact possible in the hospital pen	7	1		6
Sanitary vacancy of the hospital pen after removal of animals	7	1		6
Hospital pen cleaned after removal of animals	7	2		5
Hospital pen cleaned and disinfected after removal of animals	7	2		5
Hospital pen dry before next use	7	2		5
All-in, all-out system in the hospital pen	7	4		3
Biosecurity measure concerning calf management	**N**	**Yes**	**Sometimes**	**No**
Age groups < 2 weeks age difference	20	17		3
Draught-free hutches	20	17		3
Slatted floors	20	20		0
Regular cleaning of floors during production rounds	20	0		20
Clean and dry bedding	20	8		12
Always the same bucket (for milk) for a calf	20	20		0
Buckets for milk cleaned after each use	20	3		17
Automated climate control system (temperature, humidity)	20	14		6
Air flow in the stable from young to old	20	20		0

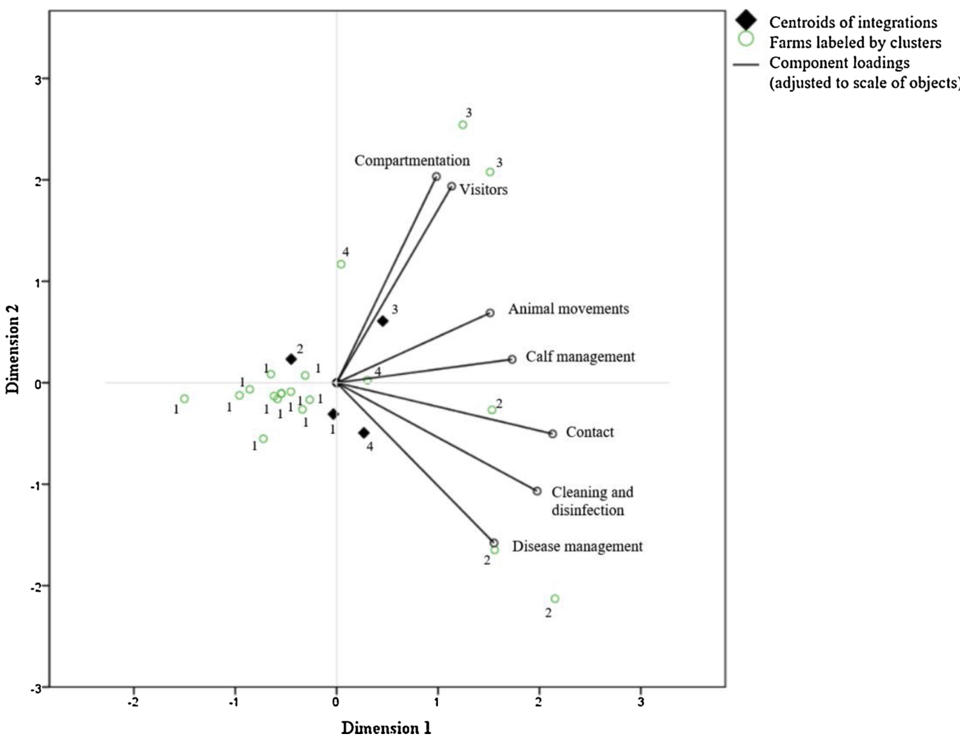

Fig. 2. Triplot of component loadings (the position of the original variables in the two-dimensional space, represented by vectors), multiple nominal category points (veal companies) and objects (individual farms) labeled by the clusters, resulting from the categorical principal component analysis and K-means clustering analysis. The vector of a variable points in the direction of the highest category of the variable, indicating in this case a higher level in biosecurity. The veal companies are located close to the center of the plot, meaning no distinction can be made between the veal companies. The first and second dimension distinguish between the different clusters. The green circles with number 1–4 represent the individual farms part of cluster 1–4. The first cluster has on average the lowest biosecurity, while the second and third cluster tend to have the highest scores. The fourth cluster is located in the center. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.5. CATPCA and KMCA

The two-dimensional solution of the CATPCA explained 69.7% of the variance of the seven biosecurity categories in the 20 herds (Fig. 2). The percentage accounted for was 41.7% for the first dimension, and 28.0% for the second dimension. The vectorial component loadings represent the contributions of each category to the dimensions, while the different categories of the nominal variable “veal companies” are represented by their centroid coordinates. The vectors appear in the upper and lower right quadrant. The projection of the vector for contact with other animals has the largest contribution to the first dimension (x-axis), followed by the vector for cleaning and disinfection. The vector for compartmentation, which has the lowest contribution for dimension 1, has the largest contribution to the second dimension (y-axis). Veal companies 3 and 4, whose centroids are located in the directions of the vectors, have, on average, the highest biosecurity scores. For veal company 3, this result is mainly related to a higher score for compartmentation and measures for visitors, while these farms score lower on disease management and cleaning and disinfection. In the farms of veal company 4, the opposite applies. On average, the farms of veal company 2 have the lowest biosecurity score. However, the overall differences in biosecurity between veal companies are limited (centroids close to the center).

Based on the KMCA, four clusters were identified (Fig. 2). The first cluster contains the highest number of farms (13) that scored lowest for biosecurity overall. Clusters 2 and 3 scored high for biosecurity. The farms in cluster 2 scored, on average, higher for disease management and cleaning and disinfection, while farms in cluster 3 score higher for compartmentation and visitors. Though this seems similar to the results of veal companies 3 and 4, the clusters consist of farms of multiple veal companies. Overall no clear veal company effect was observed in the clusters.

4. Discussion

To our knowledge, this paper is the first to describe biosecurity on farms with an intensive veal-rearing system. Because of the strong integration and industrialization in the veal sector, it could be theorized that the implementation of biosecurity on veal farms would differ from that of conventional dairy and beef farms. This study was designed to describe the biosecurity level on veal farms as the first step of a larger research project to develop a risk-based biosecurity scoring system for cattle farms. Though no comparison was made with conventional farms, based on the results of this study, a difference in biosecurity level can be expected due to differences in the purchase policy, contact with other animals, compartmentation and cleaning and disinfection (Renault et al., 2018a).

The random sample of 20 veal farms in this study may be considered small, yet it represented about 8.3% of all Belgian veal farms since the sector consists of a limited number of farms. The selected farms were distributed among veal companies corresponding to their market share. Furthermore, the size of the selected farms was representative (average veal farms house 200–1200 veal calves) for the population, and different veterinary practices advised the farmers. Therefore, the selected farms were considered to be representative of the veal calf industry. To a certain extent, selection bias cannot be excluded, due to the possibility that better farms might be more willing to participate.

The face-to-face interviews, in combination with a herd visit, allowed the investigator to observe the majority of the practices and measures, which limited the amount of interview bias due to the socially desired response rather than the true situation (Sarrazin et al., 2014). However, only a single visit to the farm was made, so the actual compliance for some measures could not be determined. Because the herd visits were performed by a single interviewer, investigator variability was avoided. Therefore, it is believed that the presented results provide an accurate image of the biosecurity situation on Belgian veal farms.

Most of the veal farmers considered biosecurity important, though they were not familiar with the term itself and most were not able to list five biosecurity measures, thus indicating that the perceived importance is only sparsely translated into actions. Furthermore, a number of the farmers considered several measures to be unimportant or impossible to implement. This finding confirms previous observations that there is a substantial lack of information on how to improve farm management and how to implement these improvements (Damiaans et al., 2018). The finding also shows that the results of previous studies that suggested measures like risk classification, limitation of the arrival period, and the farms of origin have not been translated into practice (Pardon, 2012). Contrary to, e.g., mortality and antibiotic use on veal farms, biosecurity seems affected by the veal company only in a limited capacity (Bokma et al., 2019). Though biosecurity improvements are partly within the power of the farmers, this limited impact may show the veal companies' lack of policy regarding biosecurity.

Some characteristics inherent to veal production, as it is currently organized, largely hamper the implementation of several biosecurity measures. The most important issue is the huge number of farms of origin. As the purchase of animals is often described as one of the most important risks in disease introduction (Cuttance and Cuttance, 2014; Sarrazin et al., 2017), this procedure is a significant disadvantage for the veal sector. This disadvantage is even aggravated by the induction of stress through the transport and commingling of the calves, resulting in increased susceptibility to new infections (Stokka, 2010). Solving this calf-sourcing risk will require fundamental changes in the organization of the industry. A first step toward limiting the farms of origin could be grouping births in larger dairy farms to increase the number of calves originating from one farm.

Regardless of this fundamental challenge, other measures regarding animal introduction can be taken. For instance, animals with the same disease status could be grouped in the same stable to limit contamination of other calves and the environment. This measure requires more upstream information on the sanitary status of the herds of origin and additional testing, measures that are currently poorly implemented. The national eradication programs for infectious bovine rhinotracheitis (IBR) and bovine viral diarrhea (BVD), currently implemented in Belgium (Royal Decree KB2017-09-18/09, 2017KB-09-18/09, Royal Decree, 2017Royal Decree KB2017-09-18/09, 2017; Royal Decree KB2018-04-27/03, 2018KB-04-27/03, Royal Decree, 2018Royal Decree KB2018-04-27/03, 2018) are expected to decrease the infection pressure caused by these diseases. This decrease is especially important for BVD, as it has been described as one of the major contributors to disease in veal calf-rearing (Pardon et al., 2011). Furthermore, in collaboration with the veal companies, previous experiences with farms of origin could serve as a valuable source of information, provided that this information is recorded and shared (Hobbs, 2004; Pardon, 2012). This type of information could improve the risk classification of animals, which is currently performed only through visual inspection.

As shown by van Schaik et al. (1998) and Brennan et al. (2008), a higher number of visitors is a risk factor for disease introduction. In veal farms, only two types of visitors visit the farm frequently: the veterinarian and the representative of the veal company. Conventional farms often have more types of visitors, such as salesmen, feed suppliers, hoof trimmers and drivers of milk trucks (Renault et al., 2018a). Nevertheless, the frequency with which some visitors enter influences the risk for introduction of disease. Although only a limited number of visitors enter the farm, the precautionary measures they take upon entrance are insufficient (Table 4). As these professional visitors are, by definition, high-risk visitors since they have frequent contact with animals from different farms, the risk of spreading infection through this route remains high. The implementation of a minimum of preventive measures, such as wearing herd-specific clothing and footwear, by professional visitors is a relatively easy and cheap measure that can be implemented on short notice.

Very few farmers considered themselves or their staff as a risk when entering their own farm, forgetting that they may also transmit disease (Sarrazin et al., 2017). This shows that they do not fully understand disease transmission and the risks associated. This lack of knowledge might reflect in the execution of other biosecurity measures.

Sick animals are rarely physically isolated, even though keeping sick animals in a group has been described as detrimental to the health of other animals (Edwards, 2010). Furthermore, during the first weeks of the rearing period, farmers believe the calves are sufficiently separated. This lack of isolation is likely linked to the observation that during these first weeks, disease outbreaks usually cannot be limited to one or a few animals in the current rearing system. Moreover, most farmers did not consider investing in a hospital pen, even though the benefit in limiting disease transmission by separating the source of infection has been shown repeatedly (Edwards, 2010).

Since the most crucial period for disease prevention is during the first few weeks of the rearing period, farmers consider a number of preventive practices, such as vaccination, unnecessary. However, Lava et al. (2016) concluded that farms where calves were vaccinated had a lower mortality rate. Lava and colleagues also remarked that an ideal vaccination scheme should start at the farm of origin, thus reiterating the importance of information exchange between the origin farms and the veal farm. Admittedly, the calves in the study by Lava et al. (2016) were, on average, one month old upon purchase while, in Belgium, calves are sold at the age of two to four weeks (Pardon et al., 2015). Besides vaccination, maternal immunity is of the utmost importance for the calf's immunity (Delafosse et al., 2015). Measuring serum IgG concentrations of all calves upon arrival, as described by Weaver et al. (2000), could be a measure to ensure the adequate function of the herd's immune system.

Furthermore, a higher serum IgG concentration decreased the risk of mortality, according to Renaud et al. (2018). A concentration of less than 7.5 g/L IgG was shown to decrease average daily gain (Pardon et al., 2015). Moreover, measuring the blood serum values would likely stimulate the farmers of the origin herds to ensure sufficient colostrum administration. Nonetheless, taking blood samples upon arrival is considered infeasible by the majority of the farmers, even though blood samples to check for iron deficiency are taken regularly, and the value of this measure has been described (Maunsell and Donovan, 2009; Maunsell et al., 2011).

Most farmers considered it better not to follow conventional working lines from youngest to oldest, as described by Sarrazin et al. (2014). These farmers prefer to start with the oldest animals, reasoning that a younger group carries and spreads more pathogens from their farm of origin, having only recently arrived. However, the farmers seem to ignore that the older animals have a higher immune status and can be carriers of quickly spreading, high impact diseases, such as *Mycoplasma bovis* and *Salmonella* spp. (Radaelli et al., 2008; Pardon et al., 2011), and therefore can spread disease to the younger animals. By handling the youngest animals first and the sick and quarantined animals last, farmers can reduce the spread of disease within the farm (Sarrazin et al., 2013).

Due to the organization of the veal industry, the application of an "all-in, all-out" system as well as clear compartmentation, which has been described as an adequate biosecurity measure (Maunsell and Donovan, 2009; Maunsell et al., 2011), is easily implementable. Besides the advantages of keeping young, susceptible calves separated from the older cohorts (Sarrazin et al., 2014), each compartment can be cleaned, disinfected, and thoroughly dried during the sanitary vacancy. A clean and disinfected environment is recommended in the literature for multiple diseases, such as *Cryptosporidium parvum*, *Salmonella* spp., and BVD (Daugschies and Najdrowski, 2005; Fossler et al., 2005; Villarroel et al., 2007). Next to the frequency of cleaning and disinfection, a well-designed and adhered-to protocol, including the seven steps described in Van Immerseel et al. (2018), is equally important. These seven steps consist of removal of all organic material, soaking all surfaces, high pressure cleaning, drying, disinfection, drying and testing the efficiency of the procedure. If the stables are not cleaned and disinfected properly, pathogens can survive even after a sufficiently long sanitary vacancy. Research suggests that the length of the sanitary vacancy, which in this study was, on average, ten days, is not as important as a proper cleaning and disinfection procedure (Luyckx et al., 2016). The farmers indicated that they thoroughly cleaned and disinfected their stables more often during recent years due to the distribution of cleaning and disinfection products by the veal company. This example illustrates that the veal company could play a crucial role in the motivation toward the implementation of biosecurity measures. It also illustrates that the farmers are not the sole decision makers and can be influenced regarding their biosecurity policies. Possibly, this understanding explains why several farmers answered that they were not obliged by government or veal company to apply certain measures, but were waiting for guidelines to follow.

In the CATPCA analysis, no clear distinction between the levels of biosecurity in the different veal companies was observed. However, these results do not signify that the veal companies cannot guide and motivate their farmers in improving biosecurity. Instead, the analysis suggests that, at this moment, they do not take the opportunity to address biosecurity, leaving room for improvement.

Most farmers in this study were willing to invest money and time to solve shortcomings on their farm, which is in agreement with previous findings (Damiaans et al., 2018). However, farmers are often hindered by their beliefs that many biosecurity measures are not feasible or important. Farmers often feel they lack information on both the efficacy and feasibility of disease prevention through biosecurity measures (Sarrazin et al., 2014; Damiaans et al., 2018),

The data from this study provides a first indication of the biosecurity level of veal farms, starting with the Belgian situation. Given the fact that the industry is organized in a comparable manner to most European veal-producing countries, often with the same veal companies working in different countries, it can be hypothesized that the obtained results are comparable to production in Europe.

This study provides insights on current biosecurity measures in veal herds and identifies potential priority areas for short, middle, and long term improvements. Several biosecurity measures of high importance, such as "all-in, all-out" and compartmentation, are implemented relatively well whereas other measures, such as cleaning and disinfection, isolation of sick animals, and measures for visitors can easily be improved. The improvement of some measures regarding the introduction of animals from a huge number of different origins with variable infectious and immunity status will require more fundamental changes in the organization of the industry. In the implementation of these improvements, the collaboration between farmers, veal companies, and veterinarians will be crucial.

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Research data

All research data are available with the author.

Transparency declaration

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.prevetmed.2019.104768.

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