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Characterization of biosecurity practices among cattle transport drivers in Spain

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ABSTRACT

Transmission of pathogens between farms via animal transport vehicles is a potential concern; however, the available information on driver routines and biosecurity measures implemented during transport is limited. Given the above, the aim of this study was to describe and characterize the prevailing practices and biosecurity measures adopted by cattle transport drivers in Spain. Eighty-two drivers were surveyed via face-to-face or remotely. The survey included questions on general characteristics of the drivers (type of journeys and vehicles) together with biosecurity practices implemented during cattle transport and vehicle hygiene practices. Results showed that several risky practices are performed quite frequently such as visiting different premises with different levels of risk (e.g., breeder and fattening farms); entering the farm premises to load/unload animals, passing by several farms to load and unload animals, or not always cleaning and disinfecting the vehicle between travels, among others. To explore similarities among the drivers and identify groups sharing specific practices, hierarchical clustering on principal components (HCPC) was computed on the results of multiple correspondence analysis (MCA). The first three MCA dimensions (out of 13) were retained in the agglomerative clustering and four different clusters were identified. Clusters 1 and Cluster 4 accounted for 39.5% and 29.6% of respondents, respectively. The clusters were mainly differentiated by practices in the loading/unloading of cattle, such as the frequency of contact with animals remaining on the farm, and the frequency of the vehicle's disinfection between farms. Cluster 2 and Cluster 3 were of similar size, about 15% of respondents each. Cluster 2 consisted of drivers who mainly made journeys to slaughterhouse, while drivers in Cluster 3 were characterised by the use of working clothes and boots. Based on these findings, it is advisable to increase awareness on the role that animal transport can have in the spread of pathogens between cattle farms and the importance of biosecurity in preventing such transmission. There is also a need to support animal transport professionals in such task, not only through the development of initiatives to increase awareness, but also through the investment in improving cleaning and disinfection facilities and to consider the economic cost associated with some practices to not compromise the economic viability of the sector.

1. Introduction

The transport of live animals is necessary during the production cycle of animals for different reasons such as the purchase of replacements or sending animals to fatten or slaughter. A high number of animals are moved every day and almost all cattle are transported at some moment of their lives. According to the available data, about 4 million cattle are moved every year between different countries within the European Union (Dahl-Pedersen and Herskin, 2023). In the case of other species these number of movements can be even much higher. For example, in 2021 Denmark exported 14.5 million of piglets (Gao et al., 2023b).

Vehicles used for animal transport can play a significant role in the spread of pathogens, either through direct contact when animals from different farms are loaded in the same truck or, by indirect contact, through contaminated vehicles that have not been properly cleaned and disinfected between transports (Dee et al., 2005; Benavides et al., 2020;

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Alarcón et al., 2021; Gao et al., 2023a). Moreover, due to stress during transport, shedding of some pathogens may be exacerbated (Barham et al., 2002). To reduce this risk, several biosecurity practices are recommended, such as limiting the entry of vehicles into the farm premises, avoiding mixing animals from different farms in the same transport, cleaning boots between loading and unloading, wearing exclusive or clean work clothes, and following vehicle cleaning and disinfection protocols, among others (Barrington et al., 2002; Wrathall et al., 2004; Fike and Spire, 2006; Newell et al., 2011; Dewulf and Immerseel, 2019; Alarcón et al., 2021). However, only a few studies described which biosecurity practices are applied during transports and all of them concluded that there is large room for improvement (Greger, 2007; Brennan and Christley, 2012; Schnyder et al., 2019; Nielsen et al., 2022). Indeed, only a few livestock drivers clean and disinfect vehicles, allowing pathogens to persist in vehicles and thus increasing the risk of pathogen spread between farms (Greger, 2007). Moreover, often compliance with biosecurity practices during transport is out of the control of the farmers as frequently transport vehicles are not owned by them (Brennan and Christley, 2012). Therefore, as it is common for farmers to use professional transport companies, these companies should implement appropriate biosecurity measures and drivers should follow hygiene recommendations to minimise the risk contamination on the farm.

Animal transport vehicles have been related to different disease outbreaks. For example, in Germany and Belgium in 1997, vehicles that had not been properly cleaned and disinfected were traced as the most likely source of classical swine fever virus in these countries (Elbers et al., 1999; Mintiens et al., 2001). In Spain, in 2001, contaminated transport vehicles were identified as the likely source of classical swine fever virus for almost 10% of the infected farms (Allepuz et al., 2007). Similarly, animal transport vehicles have also been identified as an important element for the transmission of foot and mouth disease between farms in England (Ellis-Iversen et al., 2011).

The objective of this study was to characterize which biosecurity practices are regularly implemented during the transport of cattle in Spain and to identify profiles of drivers applying similar biosecurity practices in the transport of animals to inform strategically the development of awareness campaigns.

2. Material and methods

2.1. Sampling design and sample selection

To estimate the proportion of drivers implementing the different biosecurity practices, we used the sample size formula to estimate a proportion (Dohoo et al., 2003). Using a worst-case assumption, we assumed that 50% of the drivers would apply each measure and the desired precision for the estimate was set to 10% with a level of confidence of 95%. With this starting hypothesis, 97 drivers were expected to be surveyed. In Spain, live animal transport is regulated by law (European Union, 2005). Drivers and vehicles must be authorized to perform animal transport. In the case of the vehicles and their characteristics, this authorization may be for journeys of less than 8 h, more than 8 h, or up to 12 h. All authorized drivers and/or companies are registered in a national system named SIRENTRA (Anonymous, 2016). As this register is not publicly accessible, it was not possible to have access to a complete sampling frame to do a random sampling. Therefore, a convenience sampling was followed by the snowball sampling. In our study, snowball sampling consisted of surveying the first drivers contacted and then asking them to recommend other drivers, who might be willing to particulate in the study.

Different channels were used to contact the first drivers: a) through personal networks from the authors of this article, b) the agri-food cooperatives in Spain disseminated information about the project among their members and asked for volunteers to participate (https://www.agro-alimentarias.coop/), c) visiting the cleaning and disinfection centres of several cattle slaughterhouses from Catalonia (Northeast of Spain) and asking the drivers to participate before or after the cleaning and disinfection of their vehicles, and d) every time that a driver was interviewed, we asked about the possibility of performing a similar interview with a colleague.

2.2. Survey

The survey covered the following aspects:

i) Characteristics of the drivers and the type of vehicle they usually used: years of experience, self-employed or employees in a company, number of animals that were allowed to be transported or maximum time allowed to travel with their vehicle (Anonymous, 2022).
ii) Characteristics of their journeys: national/international movements, production systems visited (i.e., dairy and/or beef), the purpose of animals transported (e.g., for replacement, for fattening or for slaughter) and for each purpose, number of journeys per day, the number of farms from which the cattle where loaded/unloaded, and the time spent on the journeys.
iii) Biosecurity practices during loading and unloading of cattle: whether they had to enter the farm premises and/or the stables where animals are located, and their practices related to the use of boots and clothes.
iv) Cleaning and disinfection practices of the vehicle: time spent cleaning and disinfecting each vehicle, frequency of cleaning and disinfecting, and routines during the process.

The survey was piloted with four drivers using a face-to-face interview to test it for clarity and adequacy of the questions. Modifications and amendments were included in the survey where needed. The original survey, in Spanish, can be found in the supplementary material Annex 1 (Fig. 1. S1).

2.3. Definitions used in this study

2.3.1. Journey

A journey was defined as the itinerary between the loading of cattle onto a vehicle at one point and the moment when the last animal was unloaded, regardless of the number of stops within that journey and whether new animals were loaded. Therefore, a journey began when the first animal was loaded in the vehicle and ended when the last animal was unloaded from the vehicle. A graphical depiction of the definition of a journey, including the different possible loading/unloading points, is shown in Fig. 1.

2.3.2. Categories of transported animals

Seven types of journey were identified according to their destination or the category of animal being transported: i) rearing: weaned calves to be raised in another farm as future breeders; ii) replacement: heifers to be used as part of the reproductive stock; iii) fattening: rearing of calves for meat production; iv) slaughterhouse: the slaughter of fattened calves; v) culling: movement to the slaughterhouse because the animal is no more productive or because other reasons (e.g., has some injury from which cannot be recovered); vi) pastures: movement to a seasonal pasture and vii) bulls: males to be used in breeding.

2.3.3. Shared journey

If during one journey, the driver made a stop to load or unload animals from other farms, this was considered a shared movement.

2.4. Data analysis

The surveys responses were coded and tabulated using MS Excel. The R software version 4.2.2 (R Core Team, 2023) was used for data

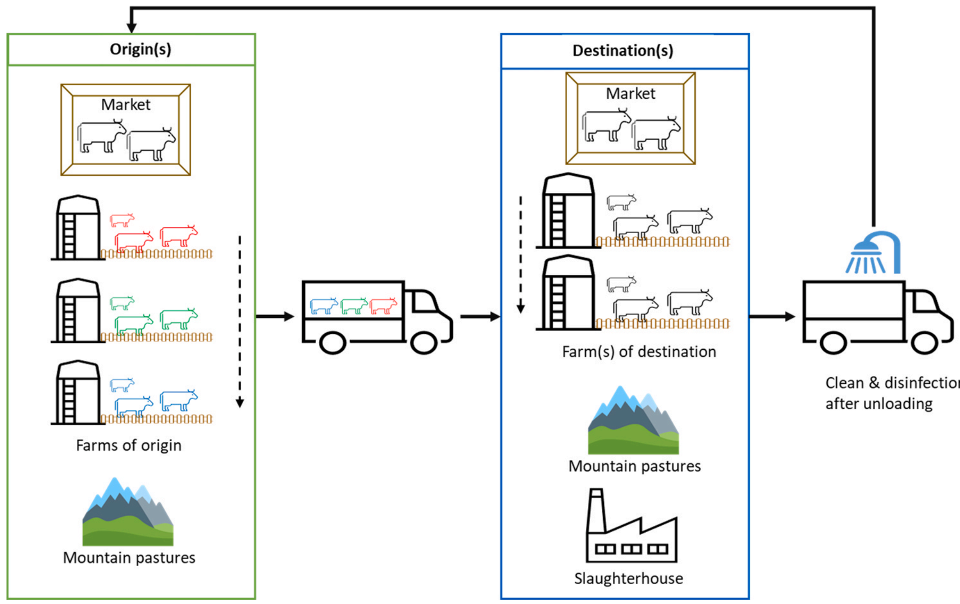

Fig. 1. Representation of journey. According to the definition in this study, one journey would begin and end with the vehicle empty, regardless of the number of loading and unloading points during the journey. The dotted arrow represents the optional stops between farms for loading or unloading and the solid arrow represents the mandatory flow of events.

processing and descriptive analysis.

Patterns of biosecurity and hygiene practices implemented by the drivers during cattle transport (i.e., the respondents' profiles) were identified by performing a hierarchical clustering on principal components (HCPC) on the results of a multiple correspondence analysis (MCA) (Husson et al., 2010) using the "FactoMineR" (Lê et al., 2008) and "factoextra" (Kassambara and Mundt, 2020) packages in R Statistical Software.

Responses for which less than 50% of the questions were answered were excluded from the analysis. Only the questions related to practices and biosecurity were included for analysis using multiple correspondence analysis (MCA). Variables were coded with the letter "q", where "q" means question, and a sequential number to simplify illustration. As a previous step of the MCA, a comparison between pairs of variables was carried out. Only variables with a correlation coefficient between -0.4 and 0.4 (95% confidence level, $P < 0.05$) were retained. In addition, categories of active variables with less than 10% (at least eight drivers selecting the category) were also not considered for the analysis. Missing values were imputed using the regularised iterative algorithm from the "missMDA" package (Josse and Husson, 2016).

MCA was performed on the indicator matrix, and the number of dimensions to retain was determined by examining the eigenvalues (a measure of inertia, or variance, accounted for by a dimension). Assuming randomness in the data, those dimensions with eigenvalues $> 1/ [(\text{No. active variables}) - 1)]$ were considered in the results (Bendixen, 1995).

HCPC was then performed on the selected MCA dimensions to cluster individuals based on similar patterns in survey responses, thus identify groups of drivers that share specific biosecurity and hygiene practices. Ward's method with the Euclidean distance metric was used to aggregate individuals into homogeneous groups and build the HCPC tree (Kassambara and Mundt, 2020). The number of clusters was defined using the automatic cut-off point of the "FactoMineR" package (i.e., based on the inertia of the partitions).

3. Results

3.1. Descriptive analysis

Between November 2021 and November 2022, 82 drivers transporting cattle were interviewed: 26 face-to-face and 56 by phone call. Drivers from different regions of Spain were included in the study, despite most of them worked in Catalonia (north-eastern Spain), followed by Andalusia and Extremadura (south and south-central Spain, respectively). Further details on the home location of the driver can be found in supplementary material Annex 2 (Table 1. S2).

In Table 1, the characteristics of the drivers and the type of vehicle

Table 1
Characteristics of the 82 surveyed drivers.

Variable	N[a]	%
Affiliation of the drivers	**82**	
Self-employed	40	48.8%
Transport company	34	41.5%
Production company or cooperative	8	9.8%
Professional experience (years)	**82**	
≤ 10	21	25.6%
> 10 - ≤ 20	28	34.1%
> 20	33	40.2%
Number of vehicles regularly used	**82**	
One	64	78.0%
Two or more	18	22.0%
Type of vehicle regularly used	**82**	
Truck	38	46.3%
Semi-trailer	21	25.6%
Full trailer	23	28.0%
Transport authorization	**81**	
Less than 8 h	48	59.3%
Until 12 h	12	14.8%
More than 8 h	21	25.9%
Type of farm visited	82	
Mixed	43	52.4%
Single type[b]	39	47.6%
International routes	82	
Yes	19	23.2%
No	63	76.8%

[a] Not all the variables sum 82, as response rate was not 100% for all questions.
[b] Only two drivers worked only with dairy farms.

they usually used are described. Forty-eight percent (40/82) were self-employed and 74.3% of the drivers had more than 10 years of experience transporting live animals. The most common practice was to use one and the same vehicle on a regular basis. Most of the drivers used trucks (i.e., the smallest type of vehicle) and journeys were done mainly by vehicles authorized to transport for less than 8 h a day. Fifty-two percent of the drivers (i.e., 43 out of 82) reported visiting both dairy and beef farms, while the rest exclusively visited one type of production system. From this last group, two drivers reported visiting only dairy farms and the other 37, only beef farms. International journeys were done by just 23% of the drivers (19/82).

According to the definition of a journey, most of the drivers reported that in their daily work they made, on average, one journey per day, with a maximum of two journeys in a day. However, some drivers reported that on some days with a high demand of work, they could make a maximum of three, and even one of them reported to make up to four journeys in one single day (Sup. Mat. Annex 2 (Table 2. S2)).

The number of different types of journeys made by each driver is described in Table 2. The most common were movements to the slaughterhouse, followed by fattening farms, and the least frequent were journeys with bulls and to seasonal pastures. Only 13 drivers indicated that they exclusively made one type of journey, which was mostly to the slaughterhouse, while two drivers only moved animals for replacement and the remaining driver, only for culling.

The most common was to combine two different types of journeys in their working routines. As a matter of fact, a total of 35 drivers combined movements to the slaughterhouse with the transport of breeders (i.e., rearing, replacement, bulls, and pastures). In addition, one driver reported that he routinely made five different types (Table 3).

Table 4 shows the number of journeys per week made by the drivers. Shared journeys were reported within all the different types of movements, except for movements to seasonal pastures. In these shared journeys, it was common to load or unload animals in between one and six other farms (see details in Table 5).

In Table 6, practices during the loading and unloading of animals are described. Even though most of the drivers (65.8%) reported frequent use of a loading dock, access into the perimeter of the farm (62.0%) or the cattle stables (60.8%) were frequent practices. In addition, having contact with animals remaining in the farm (e.g., for sorting animals that will be loaded with a batch) was a frequent practice for 55.7% of drivers.

Regarding work clothes, most of the drivers used their own boots, which were commonly cleaned with cold water between different farms. Only one driver reported cleaning and disinfecting the boots between different farms. Also, a non-negligible proportion of drivers (19.8%) cleaned the boots only at the end of the day (not between farms) and four drivers did not routinely clean their boots. Several drivers (48/79) mentioned to have a compartment in their vehicle specifically designed for separating clean and dirty clothes. Finally, a high proportion of drivers (45.5%) reported entering the truck cabin with their working clothes.

Table 7 shows the practices for cleaning and disinfection of the vehicles. Most of the drivers reported washing and disinfecting their vehicle between journeys, and 56.8% of them used detergent and disinfectant. Notably, 32.1% of them used only disinfectant without prior use of detergent. Moreover, 46.9% of the drivers stated that they had to drive more than 30 km to reach a cleaning and disinfection centre. Additionally, drivers mentioned that farmers rarely request a certificate of cleaning and disinfection of the vehicle (43.2%).

Table 3
Frequency of combinations of different types of journeys made by those drivers that combine more than one type of movement in their daily practice (N = 68).

Type of journey	N	%
Slaughterhouse and fattening	28	41.2%
Slaughterhouse and "breeders"[a]	19	27.9%
Slaughterhouse, fattening and "breeders"[a]	11	16.2%
Slaughterhouse, fattening and culling	5	7.4%
Slaughterhouse, fattening, culling and "breeders"[a]	3	4.4%
Culling and "breeders"[a]	2	2.9%

[a] "Breeders" include rearing, replacement, bulls, and movements to/from pastures.

Table 4
Number of journeys per week and proportion of drivers loading/unloading animals at multiple farms during a single journey.

Type of journey	Number of journeys per week				Journey-sharing drivers[b]	
	N	Min	Median	Max	N	% of drivers
Rearing	17	0.25	1	4	7	41.2%
Replacement	13	0.25	1	4	4	30.8%
Fattening	47	0.2	2	6	29	61.7%
Slaughterhouse	76	0.25	4	20	52	68.4%
Culling	14	1	2	8	12	85.7%
Pastures[a]	10	0.25	1.5	5	0	0.0%
Bulls	2	3	3.5	4	1	50.0%

[a] During the corresponding period.
[b] Number of drivers that shared journeys divided by the total number of drivers performing each type of journey.

3.2. Multiple correspondence analysis

Data from 81 surveys were included in the multiple correspondence analysis (MCA) which was performed using 10 active variables and five supplementary categorical variables. The complete list of variables and their categories analysed can be found in supplementary material Annex 3 (Table 1. S3). The ten active variables contained 23 active categories in total. The categories of variables were also abbreviated and linked to their corresponded code of variable.

For the MCA interpretation, three dimensions were chosen from the 13 generated (i.e., 23 active categories - 10 active variables), accounting for 39.8% of the cumulative variance (see Sup. Mat. Annex 3 (Fig. 1. S3). The correlogram with the most contributing variables for each retained dimension and a table with detailed MCA results can be found in Sup. Mat. Annex 3 Fig. 2. S3 and Table 2. S3, respectively. Briefly, the first dimension was characterized by the practices of the drivers regarding the loading and unloading of animals (Fig. 2), including: making shared journeys (q21), mixing cattle of different age within a journey (q114),

Table 2
Number of different types of journeys made by the specific type of journey.

Type of journey	Total	1 type (N = 13)		2 types (N = 45)		3 types (N = 21)		4 types (N = 2)		5 types (N = 1)	
	No. of drivers	No. of drivers	%	No. of drivers	%	No. of drivers	%	No. of drivers	%	No. of drivers	%
Rearing	17	0	0%	9	53%	7	41%	0	0%	1	6%
Replacement	13	2	15%	3	23%	5	38%	2	15%	1	8%
Fattening	47	0	0%	28	60%	16	34%	2	4%	1	2%
Slaughterhouse	76	10	13%	42	55%	21	28%	2	3%	1	1%
Culling	14	1	7%	2	14%	8	57%	2	14%	1	7%
Pastures	10	0	0%	5	50%	5	50%	0	0%	0	0%
Bulls	2	0	0%	1	50%	1	50%	0	0%	0	0%

Table 5
Number of farms where animals are loaded/unloaded in shared journeys by farm type.

Type of journey	No. of farms from where animals are loaded in shared journeys				No. of farms where animals are unloaded			
	N	Min	Median	Max	N	Min	Median	Max
Rearing	7	2	2	3	1	2	2	2
Replacement	4	2	2	3	5	2	3	4
Fattening	29	2	3	6	3	2	2	2
Slaughterhouse	52	2	2	5	n/a			
Culling	12	2	3	5	n/a			
Pastures	0				0			
Bulls	1	2	2	2	0			

Table 6
Activities carried out during the loading of animals.

Activities during the loading	N[a]	%
q132. Access to the farm premises[b]	**79**	
Frequently	49	62.0%
Occasionally	25	31.6%
Rarely	5	6.3%
q135. Use of loading dock[b]	**79**	
Frequently	52	65.8%
Occasionally	26	32.9%
Rarely	1	1.3%
q137. Access to the stables where animals are kept[b]	**79**	
Frequently	48	60.8%
Occasionally	25	31.6%
Rarely	6	7.6%
q139. Have contact with animals that remain on the farm[b]	**79**	
Frequently	44	55.7%
Occasionally	29	36.7%
Rarely	6	7.6%
q142. Boots used by the driver	**81**	
Property of the driver	68	84.0%
Property of the farm	2	2.5%
Use the farm's or the driver's boots depending on the destination	11	13.6%
q148. Enter the truck cab with boots and overall[b]	**79**	
Frequently	14	17.7%
Occasionally	22	27.8%
Rarely	43	54.4%
q150. Frequency of boot cleaning	**81**	
Between farms	61	75.3%
Every day	16	19.8%
Rarely	4	4.9%
q156. Practices during boot cleaning	**81**	
Cleaning and disinfection	1	1.2%
Only disinfection without cleaning	9	11.1%
Only cleaning with cold water	71	87.7%

[a] Not all the variables sum 82, as response rate was not 100% for all questions.
[b] Frequently = more than 60% of the journeys; Occasionally = between 20 - 60% of journeys; Rarely = less than 20% of journeys.

Table 7
Practices during cleaning and disinfection of vehicles.

Activities and measures	N[a]	%
q162. Cleaning and disinfection (C&D) after a journey of vehicles between farms[b]	**79**	
Frequently C&D	70	88.6%
Occasionally C&D	5	6.3%
Frequently cleaning and occasionally disinfection	3	3.8%
Occasionally cleaning and no disinfection	1	1.3%
q166. Average distance between farms and C&D centre	**81**	
≤ 30 km	43	53.1%
> 30 km - ≤ 60 km	28	34.6%
> 60 km	10	12.3%
q178. Practices during C&D of trucks	**81**	
Use of detergent and disinfectant	46	56.8%
Only use detergent	5	6.2%
Only use disinfectant	26	32.1%
Only use cold water	4	4.9%
q182. Clothes used during C&D of trucks	**81**	
Overall and raincoat	45	55.6%
Only overall	30	37.0%
Only raincoat	3	3.7%
No work clothes	3	3.7%
q187. Separation between clean and soiled work clothes	**79**	
Use of clothes drawer without separation	17	21.5%
Use of clothes drawer and separation	48	60.8%
Without clothes drawer	14	17.7%
q190. Requirement of C&D certificate by farms[b]	**81**	
Frequently	24	29.6%
Occasionally	22	27.2%
Rarely	35	43.2%

[a] Not all the variables sum 82, as response rate was not 100% for all questions.
[b] Frequently = more than 60% of the journeys; Occasionally = between 20 - 60% of journeys; Rarely = less than 20% of journeys.

and the frequency of contact with animals not being loaded (q139). The second dimension was linked to the hygiene measures adopted by the drivers (Fig. 2 and Fig. 3), mainly the frequency of disinfecting the vehicle between farms (q162), the use of working clothes entering the vehicle's cab (q148), and the frequency of cleaning the boots (q150). The third dimension (Fig. 3) mainly separated drivers who had their own boots from those who used the farm's boots depending on the occasion (q142).

3.3. Hierarchical clustering on principal components

The outcomes of the MCA were used to perform a Hierarchical Clustering on Principal Components (HCPC). The analysis resulted in the identification of four distinct clusters (see Sup. Mat. Annex 3, Fig. 3. S3). The size of each cluster was 32, 12, 13, and 24 drivers, respectively. More details on the characteristics of each cluster can be found in Table 8 and Table 9.

Cluster 1 and Cluster 4 showed the greatest differentiation concerning biosecurity practices (Table 9) and encompassed 56 drivers (69.1%) across these two clusters. In Cluster 1, all drivers went to the slaughterhouse at least once per week and loaded cattle at several farms during the same journey. Most of them mixed animals of different ages in the same load. They had occasionally contact with animals that were not loaded into the vehicle (i.e., remained on the farm). These drivers mainly used their personal boots, and they frequently disinfected their vehicles after each journey between breeder farms. In contrast to the previous cluster, the drivers grouped in Cluster 4 mainly transported "rearing" and "replacements animals" (i.e., breeder farms). During the animal loading procedures, they frequently had contact with animals that remained on the farm, although they did not usually mix animals of different ages in the same load. They reported cleaning the vehicle only occasionally between journeys (most often with hot water), entering in the cabin of the vehicle wearing work clothes, and washing their boots after each journey, but only with water. Cluster 2 and Cluster 3 were smaller in size (14.8% and 16.1% respectively) and had fewer distinguishing characteristics than the previous clusters.

Cluster 2 consisted of drivers who almost exclusively drove to slaughterhouses, which influenced the frequency of vehicle disinfection (required by law after each journey to the slaughterhouse) and their hygiene practices regarding the use of detergents and/or disinfectants when cleaning the boots.

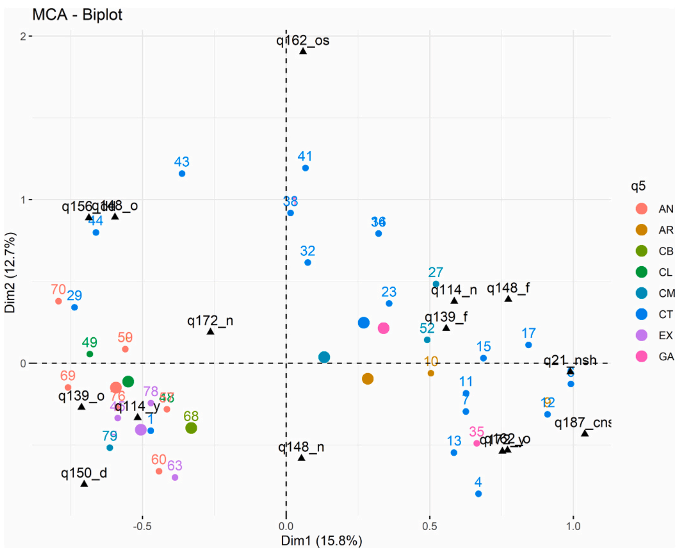

Fig. 2. Graph of the categories of variables and individuals according to dimensions 1 and 2. The categories of variables are shown in black, and the colours represent the Autonomous Community (AN: Andalusia; AR: Aragon; CB: Cantabria; CL: Castile and Leon; CM: Castilla-La Mancha; CT: Catalonia; EX: Extremadura; GA: Galicia) to which the drivers belong (q5). The graph shows the top 15 categories of variables and the top 40 contributing drivers. In supplementary material Annex 3 (Table 1.S3) contains a list of all the variables and their corresponding categories.

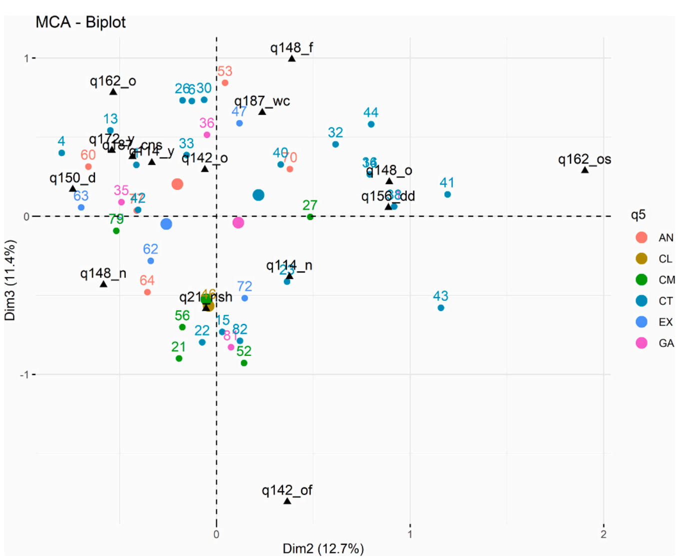

Fig. 3. Graph of the categories of variables and individuals according to dimensions 2 and 3. The categories of variables are shown in black, and the colours represent the Autonomous community (AN: Andalusia; CL: Castile and Leon; CM: Castilla-La Mancha; CT: Catalonia; EX: Extremadura; GA: Galicia) to which the drivers belong (q5). The graph shows the top 15 categories of variables and the top 40 contributing drivers. In supplementary material Annex 3 (Table 1.S3) contains a list of all the variables and their corresponding categories.

Drivers in Cluster 3 travelled to both slaughterhouse and breeder farms. They usually loaded cattle of homogenous ages from only one farm per journey. Moreover, they did not enter in the vehicle's cab wearing work clothes and tended to use the farm's boots if available.

4. Discussion

Results from this study show an inadequate adherence to biosecurity protocols. Risk practices are common such as entering the farm premises to load/unload animals, passing by several farms to load and unload animals, combining journeys with different levels of risk or not always cleaning and disinfecting the vehicle between journeys, among others. Therefore, biosecurity practices related to cattle transport in Spain have a large room for improvement, and the question is how to achieve improvements.

An important barrier might be the number of existing cleaning and disinfection centres and the conditions they offer to the drivers to perform an adequate cleaning and disinfection of their vehicles. According to the results of this study, a high proportion of drivers had to drive more than 30 km to arrive at one of these centres, and several of them had the nearest centre located more than 60 km away. This long distance might hamper an adequate cleaning and disinfection of the vehicles and make it difficult for them to reach the cleaning and disinfection centres. Furthermore, considering the working time regulations, which establish limits for drivers' driving and working time (European Union, 2006), leaving less time for cleaning and disinfection of vehicles.

The efficacy of cleaning and disinfection (C&D) of the vehicles relies on adherence to proper C&D protocols and the conditions offered by the C&D centres. For instance, the effectiveness of these processes can be significantly influenced by the time available to the drivers, the availability of hot water with sufficient pressure and disinfectant, driver training and the correct use of detergent and disinfect products. Indeed, using only one of the products (e.g., solely disinfectant) may decrease the efficiency of the C&D process (Dee et al., 2004). Currently, the existing legislation does not mandate supervision during the C&D process. As a matter of fact, in 2018, a Danish study identified that 42% of the pig transport vehicles were not properly cleaned and disinfected (Gao et al., 2023b). Poorly washed, and empty animal transport vehicles pose a risk to the next load of animals, even after several days, as was evidenced by Gao et al. (2023a) for African Swine Fever in pig live animal transport. Based on their results, without an efficient C&D, the probability of pigs getting infected from the contaminated vehicle remained non-negligible after several days at 10 °C due to a slow decay of virus at that temperature.

The costs associated with vehicle washing in Spain can also impact the situation, as prices can vary from being free of charge to several tens of euros, depending on the geographical location. It is evident that given these factors, there may be inconsistencies in the execution and adherence to proper cleaning and disinfection practices. The same holds true for cleaning boots. It was common practice to clean boots either between farm visits or daily. However, the effectiveness of solely using water may be limited (Amass et al., 2000).

Other barriers can be linked to the cost of some biosecurity practices. For example, from the perspective of reducing the probability of spreading pathogens, journeys should not be shared. The ideal would be to not mix animals from different farms in the vehicle and not to unload animals in different farms. However, the cost associated with transport together with the size of the farms, may be associated with the incentive to shared journeys (Villaamil et al., 2020; Muñoz-Ulecia et al., 2021). These circumstances could pose financial challenges for some producers. Additionally, it was noted that there is a lack of specialization among drivers regarding the type of journey or specific productive stages, likely influenced by low demand or seasonality of certain types of journeys (e.g., mountain pastures movements in spring and autumn).

Finally, other barriers might be linked to social aspects. For example, the significant number of drivers entering the farm premises, entering the stables, and directly interacting with animals that would remain on the farm could be attributed to the methods applied on some traditional farms (e.g., animal loading and unloading practices). According to the drivers' responses in the survey, it is customary for the driver to organize the load based on the animals' weight and even assist the farmer in

Table 8
Clusters identified by HCPC. The number of drivers included in each cluster is detailed by geographical location, affiliation, experience, and journey frequencies.

Variables	Cluster 1 (N = 32)		Cluster 2 (N = 12)		Cluster 3 (N = 13)		Cluster 4 (N = 24)	
	N[a]	%	N[a]	%	N[a]	%	N[a]	%
Autonomous community of the driver								
AN: Andalusia	9	28.1%	2	16.7%	2	15.4%	3	12.5%
AR: Aragon	1	3.1%					3	12.5%
CB: Cantabria	2	6.3%						
CL: Castile and Leon	3	9.4%			1	7.7%		
CM: Castile-La Mancha	1	3.1%	1	8.3%	4	30.8%		
CT: Catalonia	8	25.0%	8	66.7%	4	30.8%	15	62.5%
EX: Extremadura	7	21.9%			1	7.7%	1	4.2%
GA: Galicia			1	8.3%	1	7.7%	2	8.3%
MD: Madrid	1	3.1%						
Affiliation of the driver								
Self-employed	16	50.0%	4	33.3%	8	61.5%	11	45.8%
Production company	2	6.3%	3	25.0%			3	12.5%
Transport company	14	43.8%	5	41.7%	5	38.5%	10	41.7%
Year of experience of the driver								
≤ 10 years	8	25.0%	6	50.0%	5	38.5%	2	8.3%
> 10 - ≤ 20 years	11	34.4%	3	25.0%	5	38.5%	8	33.3%
> 20 years	13	40.6%	3	25.0%	3	23.1%	14	58.3%
Frequency of rearing and replacement journeys								
0 journeys	25	78.1%	11	91.7%	9	69.2%	8	33.3%
Up to 1 journey per week	3	9.4%			1	7.7%	5	20.8%
More than 1 journeys per week	4	12.5%	1	8.3%	3	23.1%	11	45.8%
Frequency of journeys to slaughterhouse								
0 journeys					1	7.7%	2	8.3%
Up to 1 journey per week	6	18.8%	1	8.3%	5	38.5%	1	4.2%
Between 2-6 journeys per week	17	53.1%	5	41.7%	7	53.8%	14	58.3%
More than 6 journeys per week	9	28.1%	6	50.0%			7	29.2%

[a] Not all the variables sum the total of the cluster, as some drivers did not answer all questions.

Table 9
Clusters identified by HCPC. Biosecurity-related practices carried out by drivers.

Variable	Cluster 1 (N = 32)		Cluster 2 (N = 12)		Cluster 3 (N = 13)		Cluster 4 (N = 24)	
	N[a]	%	N[a]	%	N[a]	%	N[a]	%
Shared journeys with different origins								
No			3	25.0%	6	46.2%	9	37.5%
Yes	32	100.0%	9	75.0%	7	53.8%	15	62.5%
Mixing animals of different ages in the vehicle								
No	4	12.5%	8	66.7%	10	76.9%	16	66.7%
Yes	28	87.5%	4	33.3%	3	23.1%	8	33.3%
Contact with animals that will not be loaded in the vehicle								
Frequently	7	21.9%	9	75.0%	6	54.5%	22	91.7%
Occasional	25	78.1%	3	25.0%	5	45.5%	2	8.3%
Ownership of the boots used during the transport								
Own	32	100.0%	10	90.9%	3	23.1%	23	100.0%
Own and farm			1	9.1%	10	76.9%		
Enter into the cabin with the working clothes								
Frequently	1	3.2%	3	25.0%	1	7.7%	9	39.1%
Occasionally	12	38.7%	8	66.7%			2	8.7%
Rarely	18	58.1%	1	8.3%	12	92.3%	12	52.2%
Disinfection of the vehicle on journeys between different farms								
Frequently	29	93.5%	2	16.7%	11	91.7%	16	69.6%
Occasionally	2	6.5%			1	8.3%	7	30.4%
Only journeys to slaughterhouse (slaughterhouse protocols)			10	83.3%				
Use of hot water to wash the vehicle								
No	27	84.4%	11	91.7%	12	92.3%	10	41.7%
Yes	5	15.6%	1	8.3%	1	7.7%	14	58.3%
Clothes drawer with clean and dirty area								
Clothes drawer and no separation	2	6.5%	2	16.7%	1	7.7%	12	52.2%
Clothes drawer with separation	23	74.2%	7	58.3%	11	84.6%	7	30.4%
Without clothes drawer	6	19.4%	3	25.0%	1	7.7%	4	17.4%

[a] Not all the variables sum the total of the cluster, as some drivers did not answer all questions.

selecting the animals. This practice aims to optimize the carrying capacity of the vehicle. Furthermore, due to the limited availability of farm personnel for loading and unloading animals, drivers often assist in separating the animals from the stables. Most of the surveyed drivers had been involved in animal transportation for 10 years or more. Their experience may lead them to engage in certain longstanding habits or behaviours that could not be aligned with current regulations and may be difficult to change (Moya et al., 2021).

Due to the difficulty in finding drivers, 82 instead of 97 drivers were finally surveyed, resulting in a precision of around 11%, with a proportion of 50%, a confidence level of 95% and an unknown population size. The multiple correspondence analysis (MCA) method is commonly used for exploratory and descriptive analyses. In adherence to the method's recommendations, categories with low frequency and anomalous cases were eliminated (Further details can be found in Sup. Mat. Annex 3). Despite its advantages, this technique is highly sensitive to the dataset used, thus it is recommended to have a sample size with approximately 20 observations for each active category (Di Franco, 2016). In our study, the MCA was conducted with 23 active categories and 81 drivers, being a relatively small sample size (representing only 17.6% of the recommended number). For this reason, the results of these profiles should therefore be approached with caution.

All the drivers who took part in this survey did so voluntarily and without receiving any form of financial compensation or incentives. Consequently, it is plausible that the respondents were more knowledgeable about disease transmission, biosecurity measures, and current regulations, and that they might have provided information that is biased towards the most accurate answer rather than reflecting their actual practices or behaviours. Additionally, due to the snowball sampling, we maximized participation, as participants were already aware that they were going to be contacted for this study, which facilitated their participation. Therefore, interviewed drivers might have recommended individuals from their own work areas or those with similar practices (Sedgwick, 2013; Etikan, 2016).

Although the study has its limitations, and results might not be representative of the situation in Spain, it still can provide a good picture about the present condition of cattle transportation. It has also been able to identify some barriers that could be useful in developing guidelines for future driver training. Furthermore, it highlighted the need to invest in infrastructures to assure an adequate cleaning and disinfection of vehicles. Moreover, identified profiles of drivers could be utilized to strategically enhance awareness campaigns for biosecurity, considering the type of transportation they engage in and the geographical location of the drivers (Beltrán-Alcrudo et al., 2018). In terms of the risk of disease spread between farms and according to our exploratory profiling, Cluster 4 may pose a greater risk than the others. In this cluster, drivers regularly drove both to the slaughterhouse and between farms, coupled with the fact that these drivers often have contact with cattle remaining on farms and do not always clean/disinfect the vehicle between farms. However, the results did not suggest any clear patterns associated with the clusters. None of the four clusters adequately implemented all the recommended biosecurity measures.

It might be desirable to conduct future research on evaluating the effectiveness of implementing specific biosecurity measures and understanding the factors that drive the implementation of these measures. Such studies would be valuable in enhancing understanding on how to reduce the risk associated with the spread of pathogens during transportation. Further efforts to improve cleaning and disinfection facilities for cattle transport vehicles in collaboration between the public and private sectors are desirable.

5. Conclusions

This study showed that biosecurity practices in vehicles used for cattle transport should be reinforced. Results highlighted the need of investment in cleaning and disinfection centres to enable drivers with adequate infrastructures to improve biosecurity without compromising the economic viability of the sector, and the need of further training or awareness campaigns to increase biosecurity in cattle transport.

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Ethics statement

This work has been approved by the Ethics Committee of the Autonomous University of Barcelona – approval number CEEAH 6188.

CRediT authorship contribution statement

Duarte Fernando: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Mateu Enric:** Conceptualization, Investigation, Methodology, Validation, Writing – original draft. **Armengol Ramon:** Conceptualization, Investigation, Validation, Writing – original draft. **Casal Jordi:** Conceptualization, Investigation, Supervision, Validation, Writing – original draft, Writing – review & editing. **Allepuz Alberto:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Ciaravino Giovanna:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Heras Javier:** Conceptualization, Validation, Writing – original draft. **Castellà Joaquim:** Conceptualization, Validation, Writing – original draft.

Declaration of Competing Interest

None.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2024.106138.

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