



Behavioural drivers of on-farm biosecurity implementation in livestock: A literature overview with insights for research

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ABSTRACT

Global livestock intensification heightens disease risks, making effective biosecurity crucial. However, the inconsistent adoption of biosecurity measures and the behavioural drivers behind this variability are not fully understood. This review assessed the current state of knowledge and identified evidence gaps regarding drivers influencing stakeholders' decision-making and the implementation of biosecurity practices, to clarify why well-established measures are not consistently applied and to guide research addressing the factors shaping biosecurity implementation.

Following PRISMA 2020 guidelines, a systematic search up to October 2023 was conducted across PubMed, Web of Science, and Scopus. Using a literature overview methodology, we retrieved relevant review articles on biosecurity decision-making (first phase), from which we identified relevant original research cited within them (second phase). Thematic analysis used the Capability, Opportunity and Motivation Behaviour (COM-B) model, with the Theoretical Domains Framework (TDF) guiding the coding procedure.

Of 811 reviews initially retrieved, 37 were included. From these, 205 original research articles were identified, of which 78 were included. Most original studies originated from Europe and Central Asia ($n = 38$), highlighting geographical biases. Research mainly targeted farmers ($n = 78$), with few studies targeting veterinarians ($n = 6$). While 45 articles addressed all three COM-B components, beyond half ($n = 46$) reported four or fewer TDF domains, suggesting important knowledge gaps in the literature.

Future studies should target understudied regions, TDF domains (e.g. Skills, Goals and Reinforcement) and stakeholders (e.g. farmers) to effectively implement biosecurity measures. This will help the livestock sector adopt evidence-based biosecurity and adhering to it, improving animal health and resilience worldwide.

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1. Introduction

The intensification of livestock production systems, driven by the growth of the global human population (UN-WPP, 2024) and the rising demand for animal-derived products, has increased the vulnerability of animal populations to infectious disease outbreaks (Thornton, 2010; Jones et al., 2013; Gilbert et al., 2021; OECD, FAO, 2024). These outbreaks entail considerable economic and social costs, affecting not only the livestock sector, either directly or indirectly, but also related industries and even public health (Scott et al., 2004; Dehove et al., 2012; FAO, 2016; Soliman et al., 2023). This underscores the urgent need for robust preventive strategies, among which biosecurity measures play a critical role.

Biosecurity is defined as “a set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases, infections or infestations to, from and within an animal population” (WOAH, 2024). Biosecurity is not only a key component of preventive veterinary medicine, but also a pillar of animal welfare (Saegerman et al., 2012; Cross et al., 2019; Youssef et al., 2021). However, numerous studies have identified a wide range of barriers to the successful implementation of biosecurity measures, ranging from global market pressures to personal discomfort (Buchan et al., 2023).

Implementing biosecurity measures is often fraught with multifactorial challenges encompassing social, psychological, and economic factors (Niemi et al., 2016; Rimi et al., 2016; Hidano et al., 2019; Pao et al., 2022; Buchan et al., 2023; Farrell et al., 2023).

Studies show that implementing biosecurity measures can lead to enhanced productivity and clear financial benefits (Fasina et al., 2012; Kompuu et al., 2020). Still, farmers often perceive limited economic benefit in implementing biosecurity measures (Fasina et al., 2012; Siekkinen et al., 2012); and therefore increasing farmers' awareness of the financial feasibility of implementing biosecurity measures is likely to encourage adoption. Nevertheless, the average cost of biosecurity may vary depending on the specific livestock system, as e.g. broiler production tends to be less costly than layer farms (Siekkinen et al., 2012).

However, economic considerations alone do not fully explain uptake. Social and cultural factors—such as prevailing norms—also play a significant role. In some studies exploring economic concerns, the influence of social norms tends to be neglected (Cialdini et al., 1991).

The existing literature has predominantly focused on factors that primarily operate at the individual level, such as knowledge, attitudes and practices, and focused only on some of the stakeholders involved in animal farming (mainly farmers and veterinary practitioners) (Higgins et al., 2018; Maye and Chan, 2020; Huston and Wenzel, 2024). On the other hand, contextual elements or factors operating at the situational level, which may also significantly influence behaviour, are often overlooked (Cialdini et al., 1991; Pao et al., 2022). Psychological dynamics, such as tensions between veterinarians and farmers, also shape biosecurity practices. While veterinarians often rely on persuasion, farmers may resist or disengage (Shortall et al., 2016). However, collaborative approaches like coaching and structured planning can improve compliance (Amalraj et al., 2024). Among sociological factors, the uptake of biosecurity measures may be influenced by social cues or the behaviour of peers (Trinity et al., 2020). At times, biosecurity measures may also emerge in areas where institutional gaps exist, involving protocols that do not necessarily align with core biosecurity principles, thereby further complicating implementation (Enticott and Franklin, 2009).

These examples illustrate that research on the behavioural drivers of biosecurity remains fragmented and often lacks a cohesive theoretical foundation, which is necessary to ensure a holistic understanding of the complexities of behavioural influences. It is therefore essential to understand the full range of factors that influence implementation, so that effective and efficient interventions aimed at enhancing biosecurity practices could be designed and applied for all relevant stakeholders; thereby reducing the risk of introduction and spread of infectious

diseases within livestock populations (Higgins et al., 2018; Huston and Wenzel, 2024).

To understand the complexity of human behaviour, along with the decision-making, particularly in health-related contexts, a range of theories and models from the social sciences have been developed. Some aim to identify behavioural determinants, such as the traditional Theory of Reasoned Action (TRA), the Health Belief Model (HBM), and the Theory of Planned Behaviour (TPB) (Fishbein and Ajzen, 1975; Becker et al., 1977; Ajzen, 1991), as well as more recent models like Triandis's Theory of Interpersonal Behaviour (TIB) and the Transtheoretical Model of Change (Triandis, 1980; Prochaska and Velicer, 1997). Others aim to provide a theory-driven ontology of behaviours, by aiming to classify and organise factors that may influence behaviour, such as the Capability-Opportunity-Motivation Behaviour model (COM-B; (Michie et al., 2011)) and the Theoretical Domains Framework (TDF; (Atkins et al., 2017)). Among these, the COM-B model can serve as a theoretical framework, while the TDF can be used as a methodological tool. According to COM-B (Michie et al., 2011), a specific behaviour will occur only when the individual has the capability (psychological or physical) and the opportunity (physical and social environment) to perform it and is motivated (through reflective and automatic mechanisms) to enact that behaviour. The TDF, for its part, enables the identification of 14 domains related to cognitive, emotional, environmental, and social influences on specific behaviours (Atkins et al., 2017), within the three main components of COM-B.

This review employs the COM-B model and the TDF framework to identify gaps in knowledge concerning the social, psychological, and economic factors that influence biosecurity-related behaviours in livestock systems. By identifying knowledge gaps in the literature, this study aims to contribute to a stronger theoretical understanding of the behavioural drivers of biosecurity in livestock contexts, to support the development of effective and efficient biosecurity interventions.

This work was conceptualised and developed within the scope of Work Group 2 (WG2) of the Biosecurity Enhanced Through Training Evaluation and Raising Awareness (BETTER) COST action (CA20103) [<https://better-biosecurity.eu/>], funded by the European Union. This Action seeks to evaluate how biosecurity is currently used in the livestock sector and to understand facilitators and barriers for biosecurity implementation. This initiative is particularly relevant, as effective training and communication strategies for stakeholders must be grounded in evidence about behavioural drivers.

2. Materials and methods

We employed an overview methodology (Grant and Booth, 2009) to consolidate evidence on the determinants influencing biosecurity decision-making in livestock systems. This approach was selected to synthesise evidence across a diverse body of literature, including indirect sources not indexed under common biosecurity terminology. We first conducted a systematic search to retrieve reviews addressing the question, ‘What are the social, psychological, and economic factors influencing the implementation of biosecurity measures by various stakeholders in livestock farming?’ (Phase 1). Within these reviews, we identified original articles also relevant to the topic (Phase 2).

2.1. Phase 1: review of reviews

The systematic search for reviews was conducted originally in August 2022 and updated in October 2023. It was run across PubMed®, Web of Science Core Collection (WOSCC), and Scopus based on title, abstract, and keywords. Only peer-reviewed reviews published in English between 2000 and 2023 were included. The start date of 2000 was chosen to be comprehensive and capture the foundational literature on this topic while remaining manageable. The end date of October 2023 corresponds to the date when our systematic search was finalized.

The workflow followed the principles of the PRISMA 2020 guidelines

for reporting systematic reviews (Page et al., 2021).

This search focused on reviews addressing the Population, Intervention, Context and Outcome (PICO) framework (Stern et al., 2014). Table 1 presents the PICO framework applied in this search.

We built search strings using Boolean operators to combine relevant keywords ('OR' to differentiate keywords within each PICO category and 'AND' to combine keywords across PICO categories). The search strategy, including search terms, were agreed upon by all authors. All search strings used are available as supplementary material (Appendix A).

Review articles retrieved during the search were screened twice using the same inclusion criteria (Table 2). The initial title and abstract screening were performed in Microsoft Office Excel (Microsoft, 2022) by 24 researchers participating in BETTER's WG2 (Scaling-up the knowledge and experience of stakeholders and of the general public). All screeners received a standardised protocol to ensure consistent application of inclusion criteria. Once completed, selected reviews were extracted, if available, and screened in full, independently, by two authors. Reviews for which the full texts could not be retrieved or found across the institutional libraries consulted were excluded from further analysis.

Retained reviews were further analysed to extract and analyse data; and to identify cited original research relevant to this topic.

Notion (Notion, 2024), a flexible, all-in-one workspace that can be tailored for systematic reviews—was used to support full-text screening, original article identification, and data extraction from both reviews and original articles retained after all screenings. Its hierarchical file organisation, version control, and collaborative features enabled team-based screening, concurrent discussions across articles, and clear documentation of eligibility rationale.

To extract data from the reviews retained, the COM-B model and the TDF were used to classify the determinants of biosecurity decision-making. These models were used to analyse and categorise the identified determinants into 14 domains, allowing for granular thematic analysis. Extracted data were synthesised into a database in Notion.

The hierarchical relationship between the COM-B components and the TDF domains (Cane et al., 2012) enabled a scalable dual-phase data analysis. The COM-B's broad behavioural components were aligned with TDF's granular domains, which made it possible to strategically match methodological rigor to practical constraints (Table 3).

Concurrently, all original research citations pertaining to biosecurity decision-making determinants were extracted from the reviews to populate a second database that served as the foundation for the second phase of the study.

2.2. Phase 2: original research articles

The second phase of the study involved screening and analysing original research articles identified in the reviews retained in phase one. First, duplicated original articles (those cited in more than one review) were removed. Like the screening of the reviews, all original articles

Table 1

Population, intervention, context and outcome (PICO) search terms used to structure Boolean operators search in a systematic review.

Population	Not specified
Intervention	Not specified
Context-topic	Biosecurity
Context-field	Livestock, Farm animal, Bovine, Cattle, Dairy, Beef, Veal, Cow, Herd, Pig, Swine, Porcine, Boar, Sow, Poultry, Chicken, Broiler, Layer, Turkey
Outcome	Psychological, Social, Economic, Knowledge, Experience, Perception, Attitude, Practice, Behav*, Belie*, Intention, Motivation, Decision, Driver, Barrier, Chang*, Personal*, Identif*
Filters applied	[Review Articles - Systematic Review - Similar], 2000–2023, English

Table 2

Inclusion criteria applied to title and abstract, and full text screening, including descriptions used to filter articles.

Selection Criteria	Description
Review / Original research	- First phase: Articles that were reviews, such as systematic review, narrative review, scoping review, and meta-ethnography, including meta-analyses. - Second phase: Articles that included original research.
Biosecurity-	- Articles that dealt with biosecurity, intended as management practices and/or physical measures designed to prevent and control infectious diseases on farms (i.e., reduce the risk of introduction and spread of livestock diseases to, from, and within an animal population). - It can refer either to a set of measures/practices or to a specific one. - Articles related to working conditions, management of waste and residues, or laboratory practices should be excluded. - It needs to be about biosecurity, it cannot just "mention" biosecurity.
Farming / Livestock sector	- Articles that addressed on-farm biosecurity in livestock production systems, excluding species considered livestock in only a limited number of countries, such as horses, rabbits and camelids, or mini-livestock (i.e., bush rodents, guinea pigs, frogs, giant snails, manure worms, insects) and aquatic livestock (i.e., fish, crustaceans, and molluscs) or other domestic animals.
Behavioural determinants	- Articles that addressed determinants that affect the behaviours and/or practices of stakeholders (i.e., farmers, veterinarians, and traders) in the implementation of biosecurity measures.

Table 3

Alignment of COM-B Components and TDF Domains.

COM-B component	TDF Domain
Capability	- Knowledge - Skills - Memory, Attention and Decision Processes - Behavioural Regulation
Opportunity	- Social Influences - Environmental Context and Resources
Motivation	- Social/Professional Role & Identity - Beliefs about Capabilities - Optimism - Beliefs about Consequences - Intentions - Goals - Reinforcement - Emotion

Adapted from (Cane et al., 2012)

were screened twice (title and abstract screening, followed by full-text screening), using the inclusion criteria shown in Table 2, except publication type.

During screening, key metadata, including publication year, study area, target species, and stakeholder groups, were documented within the second Notion database to support subsequent thematic and temporal analyses. Original articles for which the full texts could not be retrieved or found across the institutional libraries consulted were not further analysed.

Following the screening, and also similar to the reviews, retained original articles were subsequently analysed using the COM-B model (Michie et al., 2011) and the TDF (Atkins et al., 2017).

Representative descriptions of each TDF domain were extracted when available to construct a comprehensive table of domain-specific facilitators and barriers. To enhance coding consistency and objectivity, the first two authors (MD, HCCF) conducted iterative calibration exercises under the supervision of the last author, involving multiple synchronous in-person and virtual sessions to resolve discrepancies. Fifty papers were screened independently (25 % of 195 from the second

phase of screening), but in parallel, and Cohen’s kappa (κ) was used to quantify inter-rater agreement. The alpha level for statistical significance was set at 0.05.

3. Results

Phase 1 of the study began with an extensive literature search focused on review articles, that yielded 811 review articles (with this being the starting point of the process, as shown in Fig. 1). After a rigorous screening process (as shown in Fig. 1), 37 review articles were retained for subsequent analysis. In phase 2, 205 articles were screened, with this number representing the original research articles cited in the 37 review articles identified in Phase 1, resulting in a final dataset of 78 original research articles retained for the subsequent content analysis (see Fig. 2).

3.1. Descriptive characteristics of articles included

3.1.1. Publication trends

While reviews retained in Phase 1 were published between 2005 and 2023, the 78 original research articles in Phase 2 spanned a period of more than 25 years. Fig. 3 shows the number of these articles published each year from 1998, the year of the earliest article retained, to 2023, the year of the most recent.

3.1.2. Geographical distribution and targeted species

In the included reviews, information on the geographical distribution was not always collected or specifically targeted, with most reviews (25 out of 37 reviews) addressing the global challenges of biosecurity, rather than specific regions. Still, some reviews (12 of the 37 reviews) focused on a specific region(s) or country: with 6 reviews focused on Europe (in general), 1 on Norway, 1 on Ireland; 1 in Southeast Asia, 2 on Bangladesh, and 1 on Malaysia.

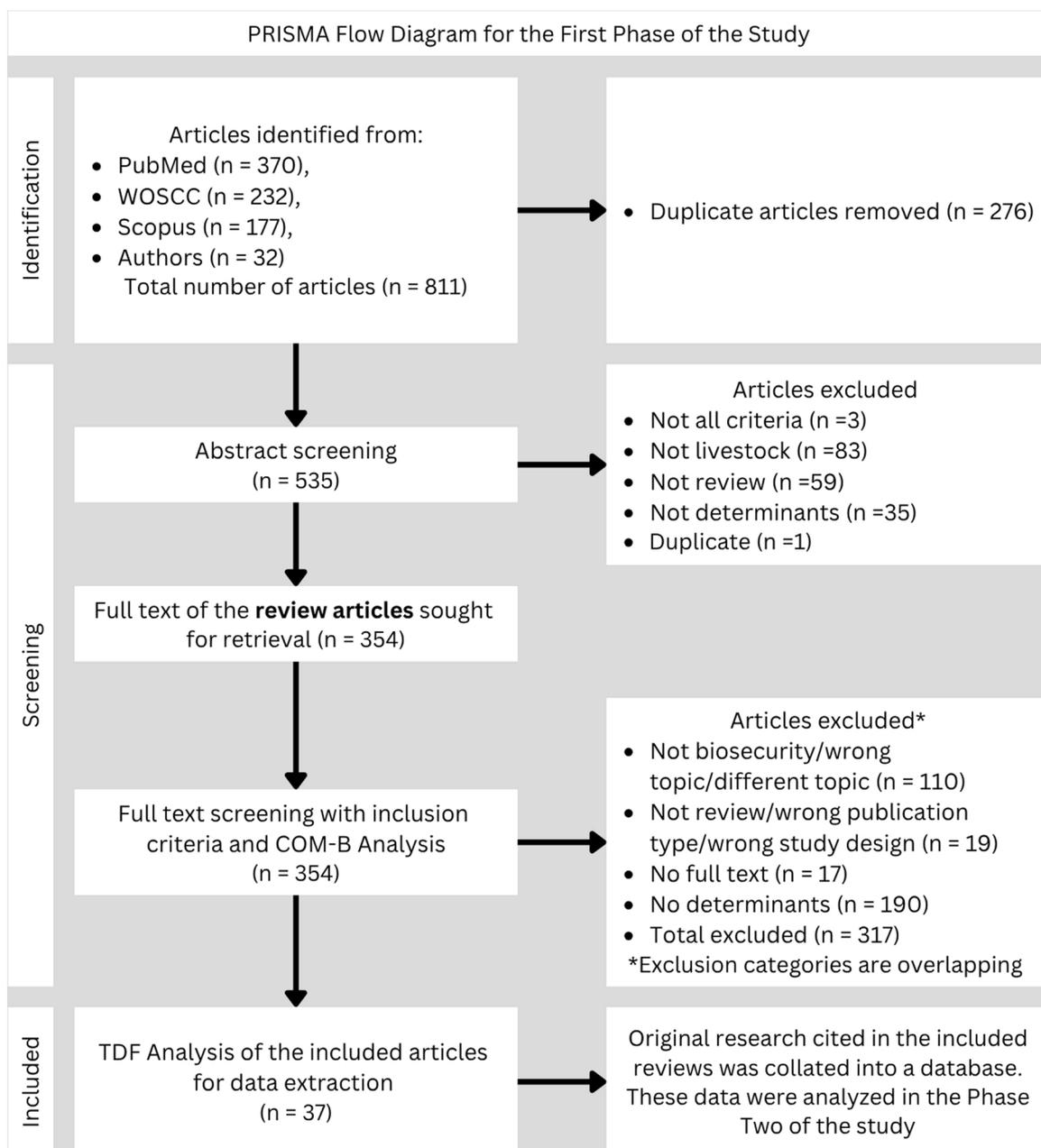


Fig. 1. PRISMA flow diagram of first phase of the analysis for identification of review articles.

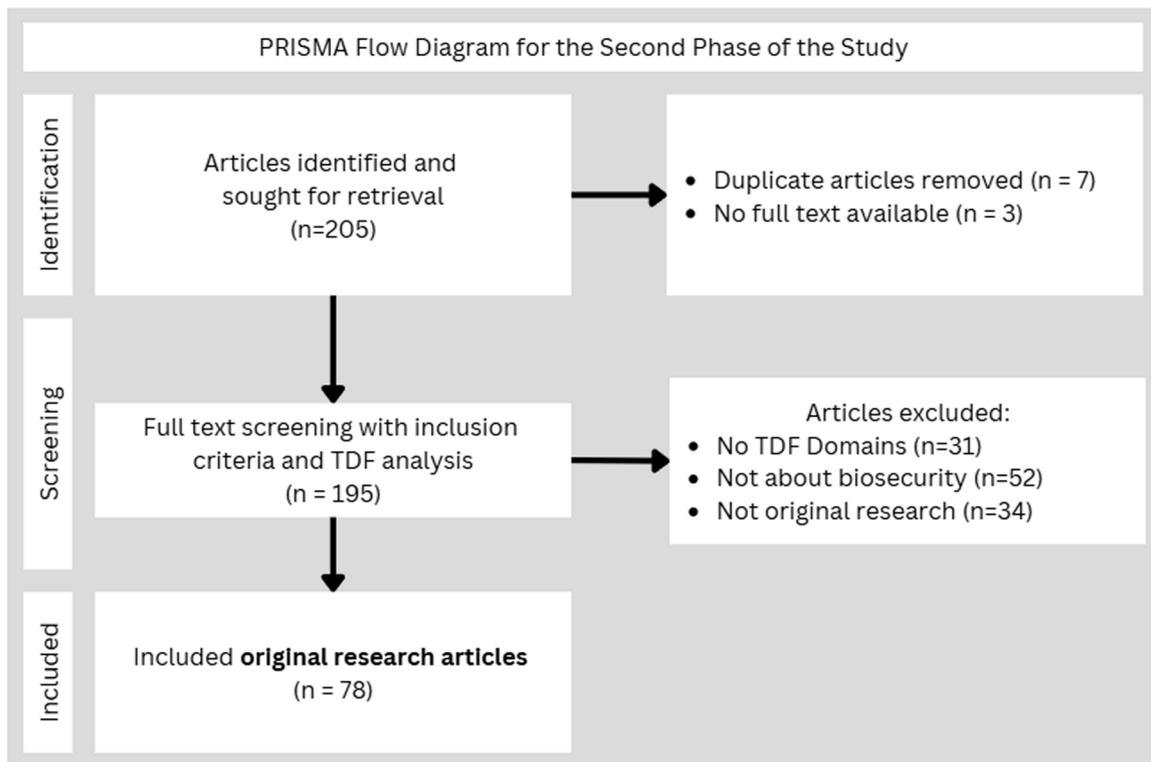


Fig. 2. PRISMA flow diagram of second phase of the analysis (identification of original research articles).

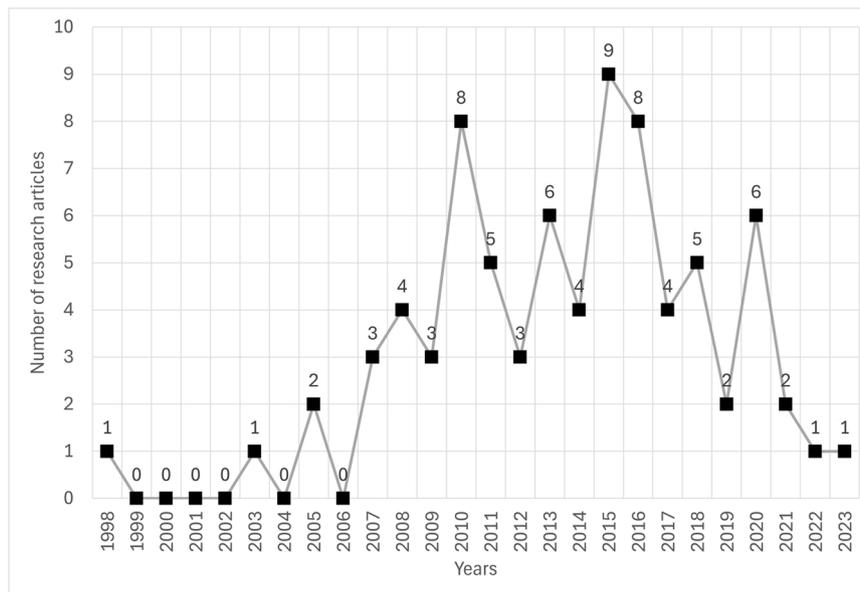


Fig. 3. Number of original research papers by year of publication.

All original research articles included in this analysis explicitly specified one or more countries or geographic regions as sources of their data, with some studies focusing on individual countries and others encompassing multiple countries. A total of 27 countries were represented in the dataset. These countries, along with the number of studies conducted in each, were categorised by region according to the FAO classification (FAO, 2024) and further grouped by the species investigated (Appendix E). Most studies (n = 38) were conducted in Europe and Central Asia. Some regions such as South America, Eastern Europe, and large parts of Asia and Africa were underrepresented in this dataset.

Furthermore, studies from specific countries tend to focus on certain livestock species: e.g. publications from the United States have predominantly focused on cattle production, whereas studies from Bangladesh (Asia and the Pacific region) have emphasised poultry production.

3.1.3. Targeted stakeholders

The included reviews did not consistently report the stakeholders studied, so this information was directly collected from the original studies cited.

All original studies included (n = 78) farmers as their primary audience, while a smaller subset (n = 6) included both farmers and veterinarians.

3.2. Thematic findings

The results of the (review and original) article categorisation according to the COM-B model and the TDF framework are shown in Table 4. Example quotes for each TDF domain extracted from original papers were summarised on Appendix B. Further details on the full categorisation of the different TDF domains per article can be seen on Appendix C1 (original articles) and C2 (reviews).

3.3. COM-B and TDF results

3.3.1. Reviews

The COM-B analysis of the 37 review articles identified a significant overlap: 18 articles addressed all three components simultaneously, while others exhibited partial overlaps. Seven articles combined motivation and capability, two articles linked opportunity and motivation, and one article integrated capability and opportunity.

The TDF analysis of the 37 review articles revealed a heterogeneous distribution across the domains. Environmental Context and Resources (n = 24), Knowledge (n = 20), and Social Influences (n = 17) were the most frequently represented domains. In contrast, Optimism (n = 1) and Reinforcement (n = 1), were the least common, followed by Memory Attention and Decision Processes and Skills (n = 3).

3.3.2. Original articles

The COM-B analysis of the original research articles in Phase 2 showed a balanced distribution among all three components. However, following a similar trend to the reviews, the TDF analysis of these original research articles also revealed a heterogeneous distribution of TDF domains.

Most original articles had all three COM-B components, while more

Table 4
Number of original research (N = 78) and review articles (N = 37) with each COM-B component and TDF Domain.

COM-B Components			TDF Domains		
Components	No. of original research articles	No. of review papers	Domains	No. of original research articles	No. of review papers
Capability	63	30	Knowledge	53	20
			Skills	3	3
			Memory	14	3
			Attention and Decision Processes		
			Behavioural Regulation	14	4
Opportunity	63	24	Social Influences	25	17
			Environmental Context and Resources	60	24
Motivation	67	29	Social/ Professional Role and Identity	29	10
			Beliefs about capabilities	39	5
			Optimism	12	1
			Beliefs about consequences	46	13
			Reinforcement	10	1
			Intentions	16	0
			Goals	6	8
			Emotion	15	3

than half of these articles had four or fewer TDF Domains. Fig. 4 shows a summary of the number of different COM-B Components or TDF domains found across the reviews and original articles analysed. Article codes and the TDF domains identified can be found on Appendix C1 for original research and appendix C2 for review papers.

The TDF analysis of the 78 original research articles revealed a heterogeneous distribution across the domains. Environmental Context and Resources (n = 60), Knowledge (n = 53), Beliefs about consequences (n = 46), and Beliefs about capabilities (n = 39) were the most frequently represented domains. In contrast, Skills (n = 3), Goals (n = 6), Reinforcement (n = 10) and Optimism (n = 12) were the least common.

The full list of original articles per domain is presented on Table 5 (article codes can be found on Appendix C1). Representative quotes illustrating descriptions of each TDF domain were extracted from the original research articles by the first two authors and confirmed by the supervisor of the analysis. These quotes were used to identify barrier and facilitator themes for each TDF Domain (Table 5).

No quotes were extracted from the reviews as these did not refer to original findings.

3.3.3. Inter-rater reliability of TDF analysis

Inter-rater agreement results for overall and domain-specific agreement presented are presented in Appendix D. The agreement levels ranged between 92 % and 100 %, with all values being statistically significant (p < 0.001). Cohen's kappa values for all domains are available in Appendix D.

4. Discussion

This review employs the COM-B model and the TDF framework to identify gaps in knowledge about biosecurity-related behaviours in livestock systems. By identifying knowledge gaps in the literature attempting to contribute to a stronger theoretical understanding of the behavioural drivers of biosecurity in livestock contexts, to support the development of effective and efficient biosecurity interventions.

To the best of the authors' knowledge, this is the largest review of reviews on the drivers influencing the biosecurity behaviour of stakeholders to date.

4.1. Descriptive results

The publication trends observed for review articles showed a steady rise in the number of reviews after 2013, with most being published on year 2021, indicating an increased scientific interest in the field of biosecurity. Regarding the original articles, the trend showed about 1–2 articles published per year to more than three per year after 2007. This likely reflects the same trends observed in the reviews, since these articles were derived from review references.

The results of the geographic metadata of original research highlighted disparities in the country distribution of biosecurity research. While countries like the United Kingdom, the United States of America, Uganda, and the Netherlands were well represented, there are notable gaps in research from many parts of the world, particularly in South America, Eastern Europe, and large parts of Asia and Africa, in our final dataset. This stresses regional disparities in research prioritisation and infrastructural capacity to study biosecurity behaviour, highlighting that research within the scope of our review, should be increased in these regions. For example, this could be done through the establishment of formal and informal partnerships and scientific networks between underrepresented regions and overrepresented regions, to enhance knowledge, resources and tools in this regard (e.g. using new technological tools for biosecurity improvement – see e.g. Mon et al. 2024; Tun et al. 2024 and researching farms acceptance and use of such technologies). Moreover, the disparity between countries is particularly evident at the species level, certain countries focused on certain the

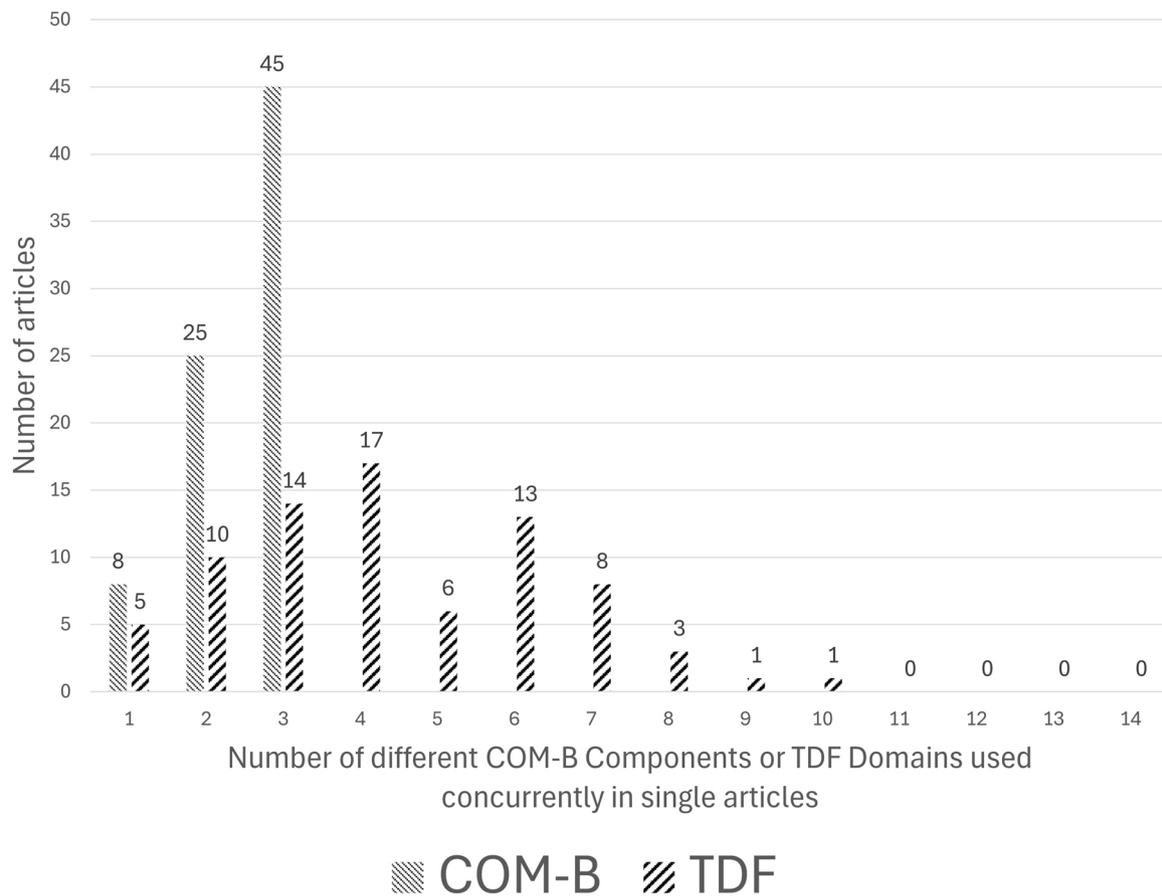


Fig. 4. Distribution of original articles by the Number of COM-B Components and TDF Domains Present.

livestock species, likely in connection to their socioeconomic impact in those regions, i.e. cattle was often the subject of research in the United States and studies from Asia and the Pacific focused mostly on poultry. A similar uneven geographical distribution can be observed in general biosecurity research (Mutua et al., 2022) or research on biosecurity economics (Heikkilä, 2011).

Furthermore, although most of the review articles included addressed biosecurity from a worldwide perspective, 12 of these articles focused on a few specific countries and/or regions. One such example were the six reviews focusing on Europe (from the total of 37), as this is likely to create some biases in the data presented about the original articles geographic metadata. The higher number of reviews focusing Europe may reflect the relative higher access to literature databases in this geographical area.

Another possible reason for the lack of research in particular geographical areas might be related to the requirement to conduct such research. Using social science tools in veterinary science settings requires a multidisciplinary approach. Multidisciplinary teams enable researchers to collaborate and provide learning opportunities, while economic constraints, national policy differences, or cultural differences, create barriers to this kind of collaboration effort (Luo and Luebcke, 2009).

Variation in research focus across livestock species suggest that importance given to biosecurity decision-making research varies across species. Although this can be partially explained by population density differences of livestock species across different regions (FAO, 1997), it still does not fully explain this observation as only two countries had research on biosecurity decision-making in sheep farms, from the 35 countries with more than 10 million sheep population.

Past epidemics can also be a driving factor in research. Initial spread of the highly pathogenic H5N1 strain of avian influenza in Asia coincides

with a higher proportion of research on poultry in the region (Kilpatrick et al., 2006). The massive economic cost of avian influenza in affected countries (Fasina et al., 2008) with global consequences (Djunaidi and Djunaidi, 2007) likely exacerbated the need for research or sparked more interest into it in Asian countries.

Factors which influence farmers' compliance with biosecurity measures are an important research topic. Reviewed articles show that the main target of biosecurity behaviour research are the farmers, while veterinarians are seldom studied along with farmers. This result accompanies the devolving responsibility of biosecurity to individual farmers (Higgins et al., 2018). While research on farmers' biosecurity behaviour is necessary to increase their adoption and adherence to biosecurity practices (Renault et al., 2021), the role of veterinarians in biosecurity implementation as information sources for farmers is also important (Renault et al., 2018). However, their role goes beyond informing farmers and their ability to design and implement effective biosecurity programmes is crucial (England, 2002). To be effective in motivating farmers, communication skills play an important role (Moya et al., 2020). Therefore, the TDF domains of knowledge, professional role and identity, intentions, and behavioural regulation are closely related to the relationship between farmers and veterinarians and should be prioritised for future research.

4.2. Theoretical integration and gaps

Based on the literature reviewed, two main results emerged. First, the literature concerning predictors of biosecurity behaviour implementation is "scattered" and lacks a theoretical basis that provides a clear understanding and broad view of potential influences on behaviour. To fill such gaps, we applied the COM-B model as the theoretical basis for understanding broad components of determinants.

Table 5

Facilitator and barrier themes for each TDF domain derived from representative quotes extracted from original articles. Article codes refer to article numbers on appendix C1.

TDF Domain	Barriers theme	Facilitators theme	Articles (coded on Appendix C1) referencing TDF domain
1 Knowledge (An awareness of the existence of something)	<ul style="list-style-type: none"> Stakeholder lacks knowledge of good biosecurity practices 	<ul style="list-style-type: none"> Educating stakeholder results improved biosecurity decision making High knowledge score correlated with better biosecurity compliance 	1, 3, 4, 6, 7, 8, 10, 11, 12, 13, 18, 19, 20, 22, 23, 25, 26, 27, 28, 29, 31, 34, 36, 38, 40, 42, 46, 48, 49, 50, 51, 53, 54, 55, 56, 58, 59, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 72, 73, 74, 75, 76, 78
2 Skills (An ability or proficiency acquired through practice)	<ul style="list-style-type: none"> Stakeholder lacks ability to implement their biosecurity knowledge 	<ul style="list-style-type: none"> Stakeholder's professional experience effects their biosecurity decision making 	3, 22, 61
3 Social/professional role and identity (A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting)	<ul style="list-style-type: none"> Farmer's cultural identity prevents positive decision-making regarding biosecurity practices Gender discrimination regarding access to knowledge 	<ul style="list-style-type: none"> Farmers accepting veterinarians' role for their farm's biosecurity Participation to a program regarding disease control motivated farmers for positive decision-making regarding biosecurity practices Accepting taking biosecurity measures as a part of being a good farmer motivated farmers' decision-making regarding biosecurity practices 	3, 11, 12, 13, 18, 19, 20, 24, 25, 27, 33, 34, 36, 44, 45, 47, 50, 53, 54, 55, 56, 61, 63, 67, 69, 71, 75, 76, 78
4 Beliefs about capabilities (Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use)	<ul style="list-style-type: none"> Farmer believes to their inability to control disease Farmers believe that they can control disease spread and this belief prevents seeking help 	<ul style="list-style-type: none"> Stakeholders are aware of their ability to take appropriate biosecurity measures. 	3, 4, 6, 8, 10, 11, 12, 15, 17, 18, 24, 25, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 44, 51, 52, 53, 54, 55, 56, 58, 60, 63, 67, 69, 70, 71, 72, 73, 77
5 Optimism (The confidence that things will happen for the best or that desired goals will be attained)	<ul style="list-style-type: none"> Stakeholders are pessimistic about their ability to apply measures or efficacy of those measures 	<ul style="list-style-type: none"> Stakeholder's optimism motivates their positive biosecurity decision-making 	10, 24, 31, 36, 37, 39, 41, 42, 44, 52, 54, 60
6 Beliefs about Consequences (Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation)	<ul style="list-style-type: none"> Belief about inefficacy of biosecurity measures negatively affected farmers' decision-making regarding biosecurity practices Belief about inefficacy of biosecurity measures in the scenario of non-compliance of other farmers negatively affects farmer's compliance 	<ul style="list-style-type: none"> Believing that biosecurity measures will positively affect their animals' yield motivates farmers' positive decision-making regarding biosecurity practices 	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 15, 17, 24, 25, 26, 28, 29, 32, 34, 36, 37, 38, 40, 41, 42, 43, 44, 47, 51, 54, 55, 57, 58, 60, 63, 64, 65, 66, 67, 69, 70, 73, 74, 75, 76, 77
7 Reinforcement (Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)	<ul style="list-style-type: none"> Lack of financial support for on-farm changes prevents farmers from taking action 	<ul style="list-style-type: none"> Expected financial gain from biosecurity compliance motivates farmers to make on-farm changes 	25, 28, 32, 35, 38, 42, 51, 54, 68, 69
8 Intentions (A conscious decision to perform a behaviour or a resolve to act in a certain way)	<ul style="list-style-type: none"> Farmers are not motivated to apply biosecurity measures without an obvious reason 	<ul style="list-style-type: none"> Clear intentions to maintain animal health and prevent disease led to higher adherence to biosecurity practices 	4, 12, 25, 33, 35, 39, 41, 42, 54, 55, 56, 63, 66, 69, 76, 77
9 Goals (Mental representations of outcomes or end states that an individual wants to achieve)	<ul style="list-style-type: none"> Lack of specific goals related to biosecurity 	<ul style="list-style-type: none"> Stakeholder wants to improve their farm's profitability Stakeholder wants to achieve disease-free status 	18, 32, 45, 51, 69, 70
10 Memory, attention and decision processes (The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)	<ul style="list-style-type: none"> Inability to retain biosecurity information 	<ul style="list-style-type: none"> Farmer retains information from a previous education material which results in positive biosecurity compliance 	2, 3, 10, 17, 30, 37, 39, 41, 60, 66, 71, 73, 74, 76
11 Environmental context and resources (Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour)	<ul style="list-style-type: none"> Lack of financial means negatively affects stakeholder decision-making regarding biosecurity practices 	<ul style="list-style-type: none"> Supportive environmental factors, including infrastructure and available resources, make it easier to comply with biosecurity protocols 	1, 3, 4, 5, 7, 8, 9, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 36, 37, 38, 39, 41, 43, 44, 47, 48, 50, 51, 52, 53, 55, 57, 58, 59, 61, 63, 64, 65, 66, 67, 68, 69, 72, 73, 74, 75, 76, 78
12. Social influences (Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)	<ul style="list-style-type: none"> Farmers' fear of being rebuked or ridiculed by their peers for their biosecurity compliance 	<ul style="list-style-type: none"> Social pressure for making on-farm changes motivates positive decision-making regarding biosecurity measures 	3, 4, 6, 7, 11, 12, 18, 19, 24, 27, 29, 32, 34, 38, 39, 41, 44, 47, 54, 55, 65, 67, 69, 74, 77
13 Emotion (A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event)	<ul style="list-style-type: none"> Having emotional attachment to a sick and possibly disease spreading cow prevents farmer to take action regarding to biosecurity 	<ul style="list-style-type: none"> Having pride for being a good farmer motivates farmers to adopt biosecurity measures Farmers feel better when they comply with biosecurity measures to avoid blame attributed to spreading disease 	3, 7, 24, 25, 30, 34, 44, 51, 55, 56, 65, 66, 69, 70, 74
14 Behavioural regulation (Anything aimed at managing or changing objectively observed or measured actions)	<ul style="list-style-type: none"> If a measure doesn't work farmer is very quick to change 	<ul style="list-style-type: none"> Veterinarian's advice to a farmer to improve biosecurity in their farm 	6, 7, 13, 14, 18, 21, 39, 40, 42, 46, 59, 70, 71, 73

Additionally, the TDF approach provided the methodological approach or “lens” through which the literature could be reviewed, to understand the state of the art of research in this regard.

Second, due to the lack of theoretical and methodological approaches to the study of human behaviour, there is also a lack of integrative and broad understanding of the variables/factors that may predict biosecurity behaviours due to potential biases in research in this regard. We elaborate on this next.

If we consider the three main components of the COM-B model, results seemingly show that the literature overall, has provided a good understanding of the determinants of on-farm biosecurity behaviours. This is because the number of research papers that focus on Capability, Motivation and Opportunity, have very similar numbers overall (Table 4). This could lead to the conclusion that all factors are adequately covered in the literature. However, when we consider the specific TDF domains within each of the three components, a clearer picture emerges. Indeed, by considering the specific TDF domains, much research focuses on specific variables. As examples are the quotes extracted on knowledge (Alarcon et al., 2014), beliefs and attitudes towards biosecurity measures (Brennan et al., 2016), and perceived barriers (e.g. costs) to implementation (Buchan et al., 2023), as some of the drivers of human behaviour (see Appendix B). However, much of the variance in human behaviour can also be explained by factors associated with the situation in which they occur, and not only individual variables such as knowledge, attitudes, beliefs and overall perceptions, which are examples of the “Capability” category of the COM-B model. This may indicate that this type of research is leaning towards what is known as correspondence bias: “the tendency to draw inferences about a person’s unique and enduring dispositions from behaviours that can be entirely explained by the situations in which they occur” (Gilbert and Malone, 1995). In the context of the studies collected in this review, this was often observed whenever there was a tendency to over-attribute actions to internal dispositions such as knowledge, thus effectively underestimating the influence of external situational factors. Therefore, while the “Capability” component is of much relevance in this research context, by not considering other factors from the “Opportunity” and “Motivation” components implies an incomplete understanding of biosecurity behaviours implementation.

Still, results showed that the “Opportunity” category (i.e. factors associated with the physical and social context surrounding individuals) was also researched in the literature (Table 4). However, when considering specific TDF domains, most of such research has focused on economic drivers of human decision-making (Fasina et al., 2012) or farm (physical) characteristics (Niemi et al., 2016) and much less research has focused on the social environment as a behavioural determinant. Indeed, the social environment may have a positive and/or negative influence on behaviour, as exemplified by Ellis-Iversen and colleagues (2010) who showed that non-supportive social norms function as inhibitors of zoonotic control measures in farms (Ellis-Iversen et al., 2010). Hence, the role of social norms (Schultz et al., 2007) is much understudied in biosecurity behaviour implementation and more research that goes beyond a focus on economic and structural/physical factors is needed in this regard.

Lastly, the results also revealed “Motivation” to be an equally researched category of behavioural influences. Nevertheless, when considering specific TDF domains, much research examples mostly focus on “reflective motivation”, namely the study of beliefs about the individual’s own capabilities for implementing biosecurity measures or beliefs about the consequences of implementing such measures. Much less found are studies concerning specifically “automatic motivation”, i.e. “motivation that involves habitual, instinctive, drive-related, and affective processes (e.g. desires and habits)” (West and Michie, 2020). For example, there were few studies focusing on emotions and even less on behavioural goals, that could be an opportunity to study automatic affective processes and automatic goals activation and operation, in decision-making, although the methodology used often did not use

measures that could allow capturing such automatic processes.

Grounded on the “Behaviour Change Wheel” (Michie et al., 2011) and mapping Behaviour Change Wheel’s COM-B components to the TDF domains (Cane et al., 2012), two conclusions become clear: 1) future research should fill the identified gaps, by studying the understudied specific TDF domains (e.g. Skills; Social influences; Goals; Emotions); 2) in practice, behavioural change interventions could be tested and implemented to focus on such identified gaps. By increasing research on the identified gaps, evidence-based interventions can be implemented in practice. For example, if we identify a need to intervene on Motivation related behaviours which can be about Goals or Beliefs about capabilities, a strategy could be “Enablement” that is “Increasing means/reducing barriers to increase capability or opportunity, beyond education and training”. To intervene on “Opportunity” which could be about Environmental Context and Resources or Social Influences, one could consider “Environmental restructuring” through a change in the physical and social context. Additionally, if we consider the policy level as identified in the “Behaviour Change Wheel”, policy measures could also be implemented to promote motivation for example through “Regulation: and thereby establish rules or principles of behaviour or practice; or promote opportunities/social context changes; or for example through “Environmental/social planning” by designing and/or controlling the physical or social environment (Michie et al., 2011).

The analysis of original research articles revealed a heterogeneous distribution of TDF domains, with Knowledge and Environmental Context and Resources emerging as the most frequently identified domains. This may be attributed to several factors. The ease of identifying and measuring certain domains in research articles may influence their prevalence. Knowledge and Environmental Context are relatively straightforward to assess and often reported in research studies. In contrast, domains like Emotion and Behavioural Regulation may be more complex to operationalise and measure, leading to their underrepresentation. While knowledge is a widely studied topic, research shows that there are more factors affecting biosecurity behaviour (Barenes et al., 2010). While Environmental Context and Resources was another widely studied domain, we see that economic factors alone are not determining behaviour change and there is an intricate network of factors behind it (Garforth, 2015).

Given the above identified research gaps and most researched topics, while the frequently identified domains represent important areas for intervention, it is essential to consider the less frequent domains as well. For instance, exploring the role of skills, goals and reinforcement in shaping biosecurity behaviour could provide valuable insights for intervention development. Future research should delve deeper into these under-explored domains to identify potential intervention strategies that address the full spectrum of behavioural drivers. For example, the Skills domain is seen as a determinant of biosecurity behaviour (Alarcon et al., 2014) and considering skills of the stakeholders would reinforce the success of education themed interventions. Farmers’ goals are a driving factor of their decisions (Jansen et al., 2009) as well as Reinforcement (Noremark et al., 2016) so that these factors would be important in policymaking.

4.3. Limitations of the study

While doing an overview review is a more straightforward and feasible way to deal with a complex topic like biosecurity, it also makes it unlikely to include the most recent studies. Indeed, the distribution of publication years in the original research dataset, a gradual increase until 2015 followed by fluctuations, indicates a handicap in the overview approach. Using reviews to gather research articles makes it harder to reach recent articles, considering the time it takes to publish a review. It is also possible to miss some research articles on the topic, even if they are not that recent. Geographical prevalence of the research can also be affected by the overview approach and by limiting the first dataset in English language.

Analysed papers strengthened the confidence of authors for using an overview approach, as it was revealed that there were studies published about biosecurity behaviour of farmers without using the word biosecurity in title (Aliro et al., 2021), abstract (Ramos et al., 2016), or full text (Alarcon et al., 2014). On the other hand, the biosecurity term was included in the initial search strings to keep the number of resulting articles manageable by the study team. This situation indicates that standardised terminology in biosecurity research is essential. An important point to consider is that the references found originated from review papers themselves, which likely introduced some level of bias, as most original reviews targeted a specific topic, species or geographical region in their scope.

Vaccination was deliberately left out on the working definition of biosecurity. This decision was made to avoid studies using vaccination as a control measure rather than a preventive measure. However, it is possible that studies about vaccination used as a preventive measure might be missed.

The limited geographical distribution of the publications gathered could also be related to the fact that we only looked at those written in English and peer reviewed. Therefore, it is quite likely that many relevant studies are published in languages other than English and on grey-literature (e.g. government reports or industry-led papers).

Another limitation was inter-rater confidence in the COM-B and TDF interpretations. The components used in this framework may be prone to different understandings, despite their clear definitions. To reduce potential subjectivity in the understandings, the research team limited the number of raters following the completion of the abstract screening in the first phase. Only two researchers with veterinary backgrounds screened the full texts in the first phase under the supervision of a behavioural sciences expert. Regarding the TDF evaluation of research papers in the second phase, despite the numerous measures taken to prevent it, rater bias is still a possible reason for the uneven distribution of TDF domains.

Lastly, comparing TDF results with COM-B results showed a stark difference. While distribution in TDF Domains are quite heterogeneous, COM-B components showed, comparatively, an even distribution. This suggests an approach using COM-B may be an important theoretical grounding of studies but not sufficient to extensively assess farmer behaviour, as it may oversimplify the identification of factors that influence behaviours. An approach using COM-B alone as its theoretical template might produce complete-looking results, while missing specific and important aspects of decision making. Hence, it is important to use a theoretical approach – COM-B – combined with an associated theory-driven methodological framework – TDF – to guide the analysis, to provide a better understanding of behavioural determinants of on-farm biosecurity measures implementation in livestock.

5. Conclusion

This review identifies persistent gaps and patterns in biosecurity behaviour research—most notably, the absence of unifying theoretical frameworks to integrate findings across contexts and stakeholder groups. To address this, we advocate for the broader use of behavioural science models, particularly the COM-B model and the TDF framework, as structured tools to classify and analyse behavioural determinants. Integrating these models can guide future research towards more consistent and theory-driven inquiry.

Bridging the observed fragmentation requires multidisciplinary collaboration between veterinary, behavioural, and social sciences. Such integration can help researchers and practitioners design interventions that are not only evidence-based but also tailored to local realities. In particular, the literature underrepresents key behavioural domains such as Skills, Goals, and Reinforcement—factors that are central to habit formation, decision planning, and sustained compliance with biosecurity practices.

The role of veterinarians, though central to biosecurity

implementation, remains insufficiently studied. As trusted intermediaries, veterinarians can influence both motivational and contextual factors, such as shaping farmer confidence (beliefs about capabilities), setting behavioural goals, and reinforcing recommended practices. Future research should better capture these dynamics.

Finally, policy strategies should aim to create environments that foster farmer motivation while reducing structural barriers to biosecurity uptake. In an increasingly interconnected livestock sector, scalable and inclusive interventions must consider not only individual behaviour but also the broader institutional and environmental contexts in which these behaviours occur.

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CRediT authorship contribution statement

Maria Rodrigues Da Costa: Writing – review & editing, Methodology. **Giovanna Ciaravino:** Writing – review & editing, Software, Methodology. **Rui Gaspar:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Helena C. De Carvalho Ferreira:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis. **Mehmet Murat Dogusan:** Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Methodology, Formal analysis, Data curation. **Sebastián Jesús Moya Durán:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Lidiia Moskalenko:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Marnie Louise Brennan:** Writing – review & editing, Methodology, Formal analysis. **Daniele De Meneghi:** Writing – review & editing, Methodology.

Declaration of Competing Interest

The authors declare no conflict of interests.

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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.2025.106768](https://doi.org/10.1016/j.prevetmed.2025.106768).

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