



## Research Article

# What are desirable biosecurity trainings for veterinary practitioners and farmers?



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## ABSTRACT

Effective biosecurity training is essential for disease prevention in livestock systems; however, substantial gaps persist. We combined an online survey (74 fully completed questionnaires; 267 views) with two World Café workshops (~60 participants) to map the current provision, competence levels, and training needs across Europe. Key findings: (i) self-rated biosecurity knowledge differed markedly between stakeholder groups and veterinarians and other stakeholders reported median scores close to 80/100; (ii) more than three-quarters of cattle (77%) and 70% of swine veterinarians perceived a major gap in their ability to demonstrate the economic benefits of biosecurity to clients; (iii) 39–44% of cattle and small-ruminant veterinarians reported inadequate mixed (theory + practice) training formats, and up to 50% of poultry veterinarians identified deficits in communication and behavior-change skills; (iv) across all discussions, participants favored modular, blended delivery that couples concise e-learning with on-farm coaching, supported by externally audited certification and greater farmer co-design. Therefore, recommendations focus on developing species-specific, flexible modules that embed communication and cost-benefit elements, provide micro-learning units for time-constrained farmers, and operate within a tiered certification framework linked to continuing professional development. Implementing these measures will narrow competence gaps, strengthen veterinarian–farmer engagement, and enhance disease preparedness throughout European livestock production.

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## 1. Introduction

Effective interdisciplinary biosecurity training is essential for preventing and mitigating the spread of infectious diseases in livestock establishments and operations. In the current context, “training” can be defined as a structured process aimed at enhancing the knowledge, skills, and attitudes of individuals involved in the effective implementation of biosecurity measures. The motivation to focus on biosecurity training stems from the recognition that livestock diseases can have devastating effects on animal health and welfare, food safety and security, and farmers’ livelihoods and mental health. Inadequate biosecurity practices can lead to substantial losses owing to the economic impact of infectious diseases. Several studies have highlighted the correlation between biosecurity adherence and disease incidence in livestock populations.<sup>1–4</sup> For instance, despite the widespread acknowledgment of the importance of biosecurity in Sweden, many farmers do not consistently follow the recommended practices because of insufficient training and poor communication regarding the significance of these measures in preventing disease transmission.<sup>5</sup> Furthermore, the global nature of livestock trade and the potential of zoonotic diseases to affect human health underline the urgent need to implement effective biosecurity measures.<sup>6–8</sup>

Effective biosecurity training encompasses several key components, including the provision of clear and context-specific guidelines, practical application of biosecurity measures, and ongoing assessment of practices. Training should be tailored to the specific challenges faced by different farming establishments and operations, particularly small-scale farms, which often lack the resources to implement comprehensive biosecurity protocols.<sup>9,10</sup> This is especially relevant for backyard farms with subsistence purposes, where access to veterinary services is limited and the farm diversity is high.<sup>11</sup> These households often rely on multiple income sources and actively participate in social and cultural activities, which can increase the risk of disease introduction. In such contexts, one-size-fits-all approaches are inadequate; instead, training should equip veterinarians with the skills to communicate effectively, develop tailored solutions, and engage with farmers while recognizing their socio-economic and cultural backgrounds. Moreover, participatory approaches that foster community-level engagement, treating the village as an epidemiological unit, can enhance biosecurity uptake and create local ownership of disease prevention strategies.<sup>12</sup> Effective training must also address the psychological and behavioral aspects of farmers and livestock operators, fostering a culture of biosecurity that encourages proactive disease prevention rather than reactive measures.<sup>13</sup> This involves not only instructing farmers and allied professionals about the risks associated with infectious diseases but also demonstrating the economic benefits of investing in biosecurity practices.<sup>4,14</sup>

Current biosecurity training programs in Europe seem to vary widely in terms of content, delivery methods, and overall effectiveness. Many programs lack standardization, leading to confusion among farmers regarding the best practices.<sup>15,16</sup> For instance, while some training initiatives focus on theoretical knowledge, others emphasize practical applications, and a few successfully integrate both aspects in a way that resonates with farmers’ daily work.<sup>17,18</sup> Additionally, the effectiveness of these programs is often compromised by poor communication between veterinarians and farmers, as differing perceptions of biosecurity can hinder collaborative efforts to implement effective measures.<sup>19,20</sup> This inconsistency in training approaches highlights the need for a consistent framework that can be adapted to different farming contexts while ensuring that all stakeholders are on the same page regarding biosecurity practices.<sup>21</sup>

Veterinarians and farmers have different but overlapping needs and expectations for biosecurity training. Veterinarians often seek comprehensive training to embrace leadership, equipping them with the theoretical knowledge and practical skills necessary for developing biosecurity plans and effectively communicating with farmers and allied professionals.<sup>22</sup> However, farmers typically prefer training that is concise, practical, and aligned with the species they farm, their husbandry methods, seasonal workloads, real-life examples, and the financial implications of biosecurity measures.<sup>23,24</sup> Bridging the gap between these two perspectives is crucial for enhancing the overall effectiveness of biosecurity training programs, as both parties play vital roles in disease prevention and control in livestock operations.<sup>25</sup>

This study aimed to identify the current state of biosecurity training at the European level, evaluate the gaps, needs, and expectations of veterinarians and farmers, and provide recommendations for improving biosecurity training programs. This study aims to contribute to the development of recommendations for more effective and standardized biosecurity training for stakeholders.

## 2. Materials and methods

This study was conducted under the framework of the COST Action CA20103 Biosecurity Enhanced Through Training, Evaluation and Raising Awareness (BETTER) (<https://www.cost.eu/actions/CA20103/>; <https://better-biosecurity.eu/>). The COST Action BETTER aims to improve biosecurity in livestock production by identifying knowledge gaps and barriers, motivators, and developing practical tools to enhance training, evaluation, and awareness across stakeholder groups. This study was conducted in two steps. First, preliminary data on existing training were collected using an online survey and Internet resources. Second, the characteristics of effective biosecurity training were identified using the World Café method.

### 2.1. Online survey

The online survey format was chosen because of its efficiency in data collection and its ability to reach a wide audience.

#### 2.1.1. Design

The initial concept of the survey was developed during a two-day meeting of the Working Group 4 (WG4) members in Lisbon, Portugal (June 8–9, 2022), and training gaps were identified during the World Café activity in Ghent, Belgium (February 7–8, 2023).<sup>13</sup> A prototype version was tested among the WG4 members. The detailed responses collected through this survey served as a foundation for discussions during the World Café meeting in Padova, Italy (February 6–7, 2024), where further refinement of biosecurity training needs and recommendations was achieved.

An online survey was designed to gather comprehensive information on existing biosecurity training programs and the experiences of stakeholders involved in biosecurity and herd health management. Responses to herd health management were analyzed and published separately.<sup>26</sup> The survey targeted veterinarians, farmers, students, and other stakeholders<sup>2</sup> in Europe. It was structured to cover various aspects of biosecurity training, including participants’ backgrounds, knowledge and experience of biosecurity, and perspectives on existing training programs. The final version of the online survey is provided in the Supplementary Material (S1).<sup>27</sup>

<sup>2</sup> Options available were: a) Consumers, b) Transporters, c) Wildlife managers / Game keepers / Hunters, d) Trainers and e) Producers / Advisors / Managers / Policy makers / Veterinary statutory bodies. Multiple choice was possible.

To increase the number of potential respondents, the survey was translated into Albanian, German, Italian, Portuguese, Spanish, and Turkish.

Participants were asked to indicate their profession (e.g., veterinarian, farmer, student, or other stakeholder) and primary focus, such as the animal species with which they work most frequently (e.g., cattle, poultry, swine, small ruminants, or others). A full survey with translations and results is available in the Supplementary Materials (S1 and S2).<sup>27,28</sup>

The participants were asked to rate their knowledge of biosecurity and to self-assess their knowledge on a scale from 0 to 100. This method allowed respondents to express differences in their perceived understanding, offering a more subjective, yet informative, measure of their experiences. Self-assessment tools like this have been shown to encourage reflection and self-awareness, helping identify areas for improvement that can ultimately enhance learning outcomes.<sup>29</sup> Such assessments can reveal critical knowledge gaps.<sup>30</sup> Additionally, it can provide information on the design of targeted educational interventions aimed at strengthening biosecurity measures.<sup>31</sup> This self-assessment was designed to measure participants' confidence in understanding the topic. For subsequent analysis, respondents were stratified by self-reported professional role (veterinarian, farmer, other stakeholder, student), with duplicates resolved to a single primary role, and group distributions (median, IQR) were compared descriptively and visualized with violin plots.

The participants were asked to identify the biosecurity training they were aware of and to assess their current status of biosecurity training. All responses that included biosecurity training or training, including biosecurity as a subsection, were included in the analyzed dataset (inclusion criteria for “training”). The additional inclusion criteria and categorization of the responses are presented in the Supplementary Material (S3).<sup>32</sup>

The survey continued with questions to determine whether the respondents were aware of any ongoing or recent biosecurity-related projects/initiatives. The respondents were asked to identify these projects and provide details such as the project title, acronym, and funding sources (national or international). If participants were aware of projects/initiatives not listed in the survey, they were encouraged to provide additional information to help expand the database of relevant projects.

Finally, respondents were asked to provide feedback on their biosecurity training, including pre-identified training gaps per livestock species, depending on the format (e.g., online, face-to-face, or hybrid), quality of the content, and presence of certification or quality control mechanisms. The survey also sought to understand the participants' preferences for future training, such as the preferred delivery method, duration, and focus area.

### 2.1.2. Sampling & dissemination

The survey was distributed, and data were collected from July 11 to September 12, 2023, using the QuestionPro Survey Software (QuestionPro, Inc., USA; <https://www.questionpro.com/>) software. The survey was distributed to potential respondents through COST action members (who were kindly asked to disseminate it), the Federation of Veterinarians of Europe (FVE) mailing list, newsletters, and their social media channels, as well as the social media platform LinkedIn™.

### 2.1.3. Privacy and data protection statement

The survey was reviewed and approved by the Data Protection Officer of the Estonian University of Life Sciences on July 10, 2023, prior to data collection. No personal information was collected through the online survey. Data collection was compliant with the European General Data Protection Regulation (GDPR). Consent

to participate in the study was obtained from (potential) participants before the start of the survey.

### 2.1.4. Data cleaning & descriptive statistics

The responses were analyzed to identify key trends and measure gaps in biosecurity training worldwide, as well as in livestock species and professional groups. The descriptive analysis focused on categorizing the types of training available, participant satisfaction levels, and identifying areas of training that require improvement.

From the initial survey data, all answers that did not provide information regarding biosecurity training programs or projects were removed. The referenced data (check S2) include information such as the training title, duration, and type (face-to-face, remote, or hybrid) of the training, organizer, livestock species group involved, training methods (e.g., lectures), target audience (e.g., farmers, veterinarians), learning level, tuition fees, certification provided, granting of the European Credit Transfer and Accumulation System (ECTS), frequency of application submissions, and evaluation of training. To validate and complete the information gathered from the survey, the Google™ search engine was used, and the title of the corresponding training, as provided in the responses, was entered. Biosecurity training was defined as training explicitly labeled as such, as well as any training that included biosecurity content (training, websites with videos, articles, podcasts related to biosecurity, and so on). As many answers to the survey did not meet the above-mentioned criteria, the responses were regrouped into five (sub-)categories: epidemiology training, projects, congresses or workshops, colleges, and organizations (full list provided in S3).<sup>32</sup>

An online survey flowchart was created using the web application Draw.io (draw.io AG, Zürich, Switzerland, <https://www.draw.io.com/>), data management was performed using Microsoft Excel 2019 (Microsoft Corporation, Redmond, USA, <https://office.microsoft.com/excel>), and data analysis and charts were created using RStudio version 2024.12.0 Build 467: Integrated Development Environment for R (Posit Software, PBC, Boston, USA <https://www.posit.co/>). Plots were created using the R-package ggplot2: Elegant Graphics for Data Analysis (Springer-Verlag, New York, NY, USA; <https://ggplot2.tidyverse.org>).

## 2.2. World Café

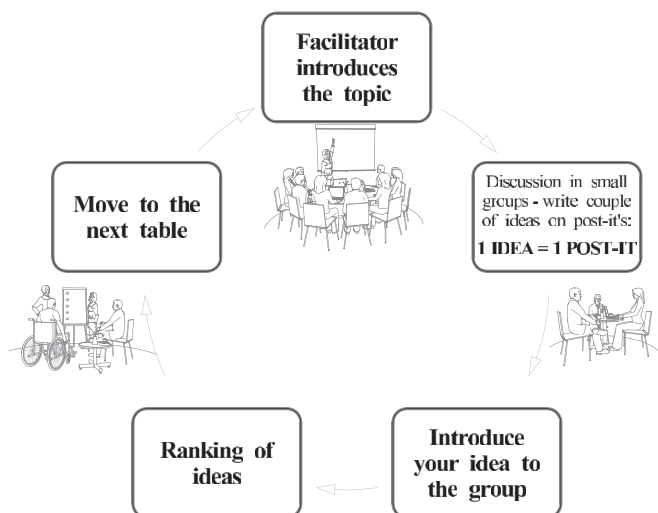
### 2.2.1. Overview & design

The World Café methodology was structured to facilitate interaction and exchange of ideas among participants.<sup>33</sup> This method was selected for its proven effectiveness in engaging diverse stakeholders and addressing complex issues, such as biosecurity training needs for veterinarians and farmers.<sup>9,13</sup> This approach fosters collaborative dialogue and knowledge sharing in an informal café-style setting, where participants rotate between tables to discuss predetermined questions.<sup>34</sup> To ensure that the discussions were based on real-world experiences and the specific needs of stakeholders, a brief presentation of the survey results was presented during the face-to-face meeting of BETTER on February 6, 2024, in Padova, Italy, prior to the World Café event.<sup>35,36</sup> The survey data collection process followed qualitative research methodologies, enhancing the relevance of the discussions regarding the practical biosecurity needs of veterinarians and farmers.<sup>1</sup>

The key components of the event design are as follows:

#### Group Structure

The participants were divided into four groups, each led by a facilitator and a reporter (Fig. 1). This structure allowed for focused discussions on specific aspects of biosecurity training, enabling an



**Fig. 1. World Café Methodology for Thematic Analysis.** The illustration outlines the structured process of the World Café methodology used to gather insights and ideas from the participants. The steps began with the facilitator introducing the topic, followed by small-group discussions in which participants wrote their ideas on post-it notes (1 idea = 1 post-it). Each group member introduced their ideas to the group before moving to the next table to ensure exposure to a range of perspectives. The process concludes with a ranking of ideas that allows for the prioritization of key themes. This iterative process combined with thematic analysis enabled the identification of critical priorities and recommendations for improving biosecurity training programs. The use of structured rotation and trained facilitators enhanced the validity and depth of discussions, contributing to reliable and actionable findings. Illustrations were created by Ahmet Mehmeti.

in-depth exploration of key topics while ensuring diverse perspectives.<sup>37</sup> Facilitators played a crucial role in ensuring that the discussions remained focused on the guiding questions, whereas the iterative nature of the World Café allowed participants to rotate between groups, enriching the dialogue with fresh insights and perspectives.<sup>38</sup>

One table focused on the topic of developing biosecurity training for veterinary practitioners, and another on developing biosecurity training for farmers. The participants were asked to focus on the learning objectives, content and type of training, duration of training, content and species covered, and target audience (farmers and veterinary practitioners). The remaining two groups focused on biosecurity web pages (data not shown).

### Welcoming Atmosphere

A welcoming environment was created to encourage participation and ensure that all voices were heard. Each facilitator had a designated space to allow for a smoother workflow without interference. Establishing this environment is vital for fostering open dialogue among veterinarians, farmers, and other stakeholders, enabling productive discussions on biosecurity training needs to be held. This approach aligns with the core principles of the World Café, which emphasizes inclusivity and respect for diverse perspectives.<sup>39</sup>

### Guiding Questions

A series of questions derived from the survey were created to stimulate discussions on biosecurity training for veterinary practitioners and farmers. These questions were designed to provoke thought and allow participants to explore the topic from multiple angles, including the training content, delivery methods, and learning objectives.<sup>40</sup> By grounding these questions in real-world survey data, the dialogue became more relevant and impactful.

### Iterative Discussions

The iterative process of group rotation ensured that each group could build on the discussions of previous groups, creating a rich dialogue and synthesizing ideas. This method allows for a dynamic exchange of perspectives and continuous refinement of ideas.<sup>41,42</sup> Previous research has supported the effectiveness of the World Café methodology in fostering meaningful conversations and generating actionable insights.<sup>13</sup>

#### 2.2.2. Data collection and thematic analysis

Data collection during the World Café was qualitative, involving the documentation of discussions through notes taken by both participants and facilitators, and the identification of the most important topics at the end of each discussion. This approach ensured that a wide range of insights were captured, which could inform future biosecurity training programs.<sup>43</sup> To ensure the comprehensiveness of the collected data, the discussions were guided by the seven integrated principles of the World Café: setting the context, creating a hospitable space, exploring questions, encouraging everyone to contribute, connecting diverse perspectives, listening together for patterns, and sharing collective discoveries.<sup>44</sup>

The notes collected during the World Café were examined using thematic analysis, a systematic approach that allows for the identification of common themes and insights. The most important themes identified in each group were as follows. Veterinary practitioners need effective communication strategies with farmers, particularly on how to encourage them to adopt biosecurity measures. It is important to strengthen their basic knowledge of biosecurity and learn how to develop, adapt, and implement biosecurity plans tailored to specific farm systems. For farmers, the focus should be on understanding the principles and benefits of biosecurity, supported by practical tools, self-assessments, and species-specific guidelines. Additionally, there is a need for personalized and cost-effective, real-life examples. This method significantly contributes to the validity of the findings by providing a structured framework for the interpretation of qualitative data.<sup>45</sup> Thematic analysis has enabled the identification of priorities and recommendations that can guide the development of more effective biosecurity training programs for the industry.<sup>46</sup>

#### 2.2.3. Internal validation of the World Café methodology

Several steps were taken to ensure the internal validity of the World Café methodology employed in this study:

**Pre-event survey:** Online survey results provided a basic level of understanding of the current biosecurity training landscape, ensuring that the World Café discussions were grounded in real-world experiences and stakeholder needs.<sup>35</sup>

**Facilitator training:** The facilitators were instructed to guide discussions effectively, ensuring that all participants contributed meaningfully and that the discussions remained focused on the research objectives.

**Structured rotation:** The iterative group rotation process exposes participants to diverse perspectives, reducing the risk of bias and enriching the data collected.<sup>37,47</sup>

**Thematic analysis:** This provides a systematic approach to identify key themes and enhance the reliability and validity of the findings.<sup>48</sup> This process ensured that the insights gathered during the World Café were translated into actionable recommendations for improving biosecurity training programs.

### 2.3. Qualitative matching of online survey and World Café findings

A qualitative matching exercise was conducted to compare the biosecurity training programs reported in the online survey with the training gaps identified during the World Café discussions.

We checked whether the training program's focus areas or objectives were highlighted in the World Café sessions. When the same emphasis emerged in both sources, it was recorded as a “✓” (match). Conversely, any focus identified in the World Café that did not appear in the survey-reported training programs was classified as a “✗” (mismatch) to evaluate the alignment between the surveyed training programs and the consensus reached at the World Café.

### 3. Results

#### 3.1. Online survey

A total of 267 individuals viewed the survey, of which 141 initiated the survey and 74 completed it (Fig. 2 shows the survey logic flow). While some participants dropped out during the survey, 111 respondents provided insights into biosecurity training programs.

Regarding profession(s), 93 marked “veterinarian” and five marked “farmer.” Other options were “undergraduate student” ( $n = 1$ ) or “other stakeholder” ( $n = 24$ ); it was possible to choose multiple professions (Table 1). Of the 86 veterinarians, 65 completed the first question in the designated section, with two dropouts after that. The average completion time was six minutes.

Respondents self-assessed their biosecurity knowledge on a scale of 0–100, with distinct trends observed across stakeholder groups (Fig. 3). Veterinarians ( $n = 93$ ) and other stakeholders ( $n = 24$ ) reported higher levels of biosecurity knowledge (median values near 80), whereas farmers ( $n = 5$ ) displayed wider variability in their responses, with a lower median (approximately 50), reflecting a more diverse understanding of biosecurity knowledge.

Participants were asked to indicate their experience with biosecurity as a topic. The majority (34.7 %,  $n = 41$ ) of the respondents reported more than 10 years of experience in biosecurity. In contrast, 8.5 % ( $n = 10$ ) of the respondents had less than one year of experience or no experience, highlighting the diverse range of expertise among the survey participants (Fig. 4).

The veterinarians were asked to identify the main species groups with which they worked on. Most veterinarians worked with cattle ( $n = 32/70$ , 45.7 %). Other common specializations were poultry ( $n = 10$ ) and swine ( $n = 10$ ), each representing 14.3 % of the sample, while small ruminants ( $n = 9$ ) and “other” species each represented 12.8 % ( $n = 9$ ) of the veterinarians' responses.

##### 3.1.1. Online survey: Training gaps

Figs. 5–8 highlight the key gaps and challenges in biosecurity training for veterinarians specializing in different animal species.

Fig. 5 reveals remarkable gaps in biosecurity training that used a mixed approach, particularly among veterinarians specializing in cattle and small ruminants, with 39 % ( $n = 12$ ) of cattle specialists and 44 % ( $n = 4$ ) of small ruminant specialists reporting somewhat big “somewhat big” or “very big” gaps. Fig. 6 shows the perceived gaps in communicating biosecurity benefits to stakeholders, with the largest gap observed among veterinarians specializing in cattle (77 %,  $n = 24$ ) and swine (70 %,  $n = 7$ ). Fig. 7 shows the deficits in soft skills training for biosecurity implementation, with the largest gaps reported by small ruminant (44 %,  $n = 4$ ) and poultry specialists (50 %,  $n = 5$ ). Fig. 8 indicates that the recognition of biosecurity-trained professionals is lacking, particularly among veterinarians specializing in cattle (73 %,  $n = 22$ ) and small ruminants (67 %,  $n = 6$ ).

##### 3.1.2. Online survey: Biosecurity trainings

A total of 59 valid responses were obtained from a survey on biosecurity training, projects, and websites. As many responses

did not fully match our predefined criteria,<sup>3</sup> we consolidated them into new categories (e.g., epidemiology training, congresses, and colleges/organizations). The most frequently mentioned categories were biosecurity training and projects, with 15 responses each, followed by herd health management training (seven responses) and colleges/organizations (four responses). A few respondents provided only non-specific or N/A responses (Table 2).

Fifteen training programs qualified as “Biosecurity training,” 11 of which focused exclusively on biosecurity and four of which covered broader topics (including biosecurity modules). Table 3 summarizes the key characteristics of these programs, including the delivery type, audience, certification, and quality control.

In addition to the general scope and structure of the 15 biosecurity training programs, species coverage was examined as well. Most focused on poultry (four programs) or swine (two programs), while several addressed multiple species or broader topics such as general biosecurity/food safety. Table 4 summarizes the species and thematic focus of each training program based on freely available website descriptions.

The three epidemiological training sessions were face-to-face. The language of the webpages of the training course was English; however, no information regarding the language of the training was provided. The duration of training ranged from four weeks to two years, and the level of training was either intermediate or advanced. All training programs were addressed to frontline veterinarians, and a certificate or master's degree was awarded.

#### 3.2. World Café results

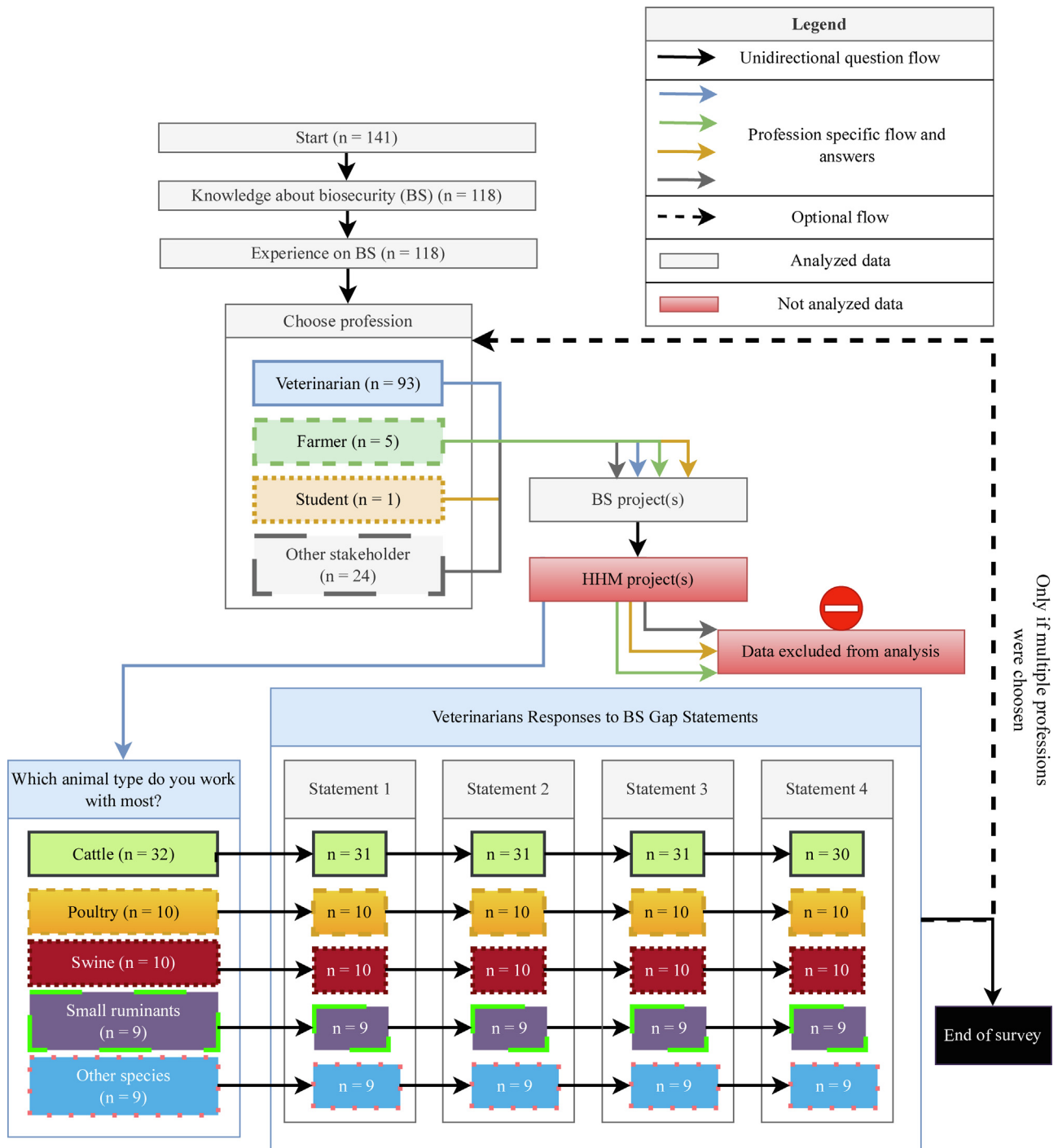
The World Café discussion was attended by 67 participants, mostly from academic and veterinary backgrounds, from 25 countries, including European Union Member States, the United Kingdom, Western Balkan countries, and Norway. The participants were divided into four equal groups, focusing on identifying the key needs and expectations of biosecurity training tailored to veterinary professionals (Table 5) and to farmers (Table 6). The discussion was guided by three main questions: (a) What should the learning objectives be? (b) What content or topics should be covered? (c) What type of training methods should be prioritized (e.g., practical vs. theoretical, online, or face-to-face)?

### 4. Discussion

The survey revealed perceived gaps in biosecurity training among veterinarians, with notable variations across animal species they mostly worked with. Veterinarians working with cattle and small ruminants reported large to moderate gaps, while those working with other species, including aquatic and companion animals, were more likely to perceive smaller training gaps. Additionally, the need to demonstrate the benefits of biosecurity to stakeholders and improve soft skills in communication and behavioral change was emphasized, particularly among veterinarians working with swine and other species. A notable proportion of respondents also indicated a need for better recognition and labeling of biosecurity-trained practices, especially in the cattle and small ruminant categories (Figs. 5–8).

Based on this survey, a selection of biosecurity training programs was identified and reviewed in this study. Categorization of the survey responses revealed that most respondents reported a training program exclusively in biosecurity and projects, followed by projects/training in herd health management (Table 2). This aligns with the training needs emphasized by the World

<sup>3</sup> Descriptions of predefined criteria can be found in Supplementary Material 3.



**Fig. 2. Survey Structure and Flow for Assessing Biosecurity Knowledge, Experience, and Training Gaps.** This diagram presents the structure and flow of an online survey designed to assess knowledge, experience, and perceived training gaps in biosecurity (BS) and herd health management (HHM) across various professional groups. The survey began by asking participants to rate their knowledge and experience of BS, followed by their selection of profession: veterinarian, farmer, student, or other stakeholder. Profession-specific pathways guided the participants to identify ongoing BS and HHM projects relevant to their roles. Veterinarians were further categorized based on the livestock species with which they primarily worked, including Cattle, Poultry, Poultry, Swine, Small Ruminants, or Other Species. Subsequently, the participants responded to four key statements assessing the gaps in BS training. These statements covered the use of a mixed theoretical and practical approach (**Statement 1**), the need to demonstrate the benefits of biosecurity (**Statement 2**), the importance of communication and behavioral change skills (**Statement 3**), and the need for the recognition or certification of veterinarians trained in biosecurity (**Statement 4**).

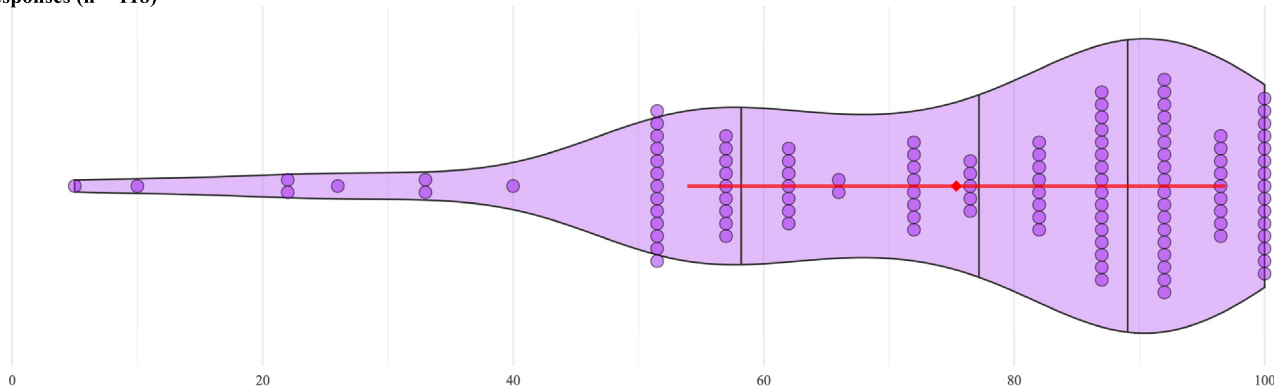
Café experts. Studies have indicated that veterinarians prefer on-site practical sessions and direct lectures as training methods.<sup>49</sup> While farmers recognized opportunities to enhance biosecurity practices on their farms, they underscored the importance of receiving practical guidance and financial support to facilitate these improvements.<sup>50</sup> Another study analyzing the impact of

participatory training of smallholding pig farmers found that the training was effective in improving farmers' knowledge of biosecurity; however, there was limited adoption of biosecurity practices and only modest changes in attitudes towards their implementation.<sup>51</sup> In our survey, only three out of 15 trainings were organized face-to-face, while nine were online courses. Online courses were

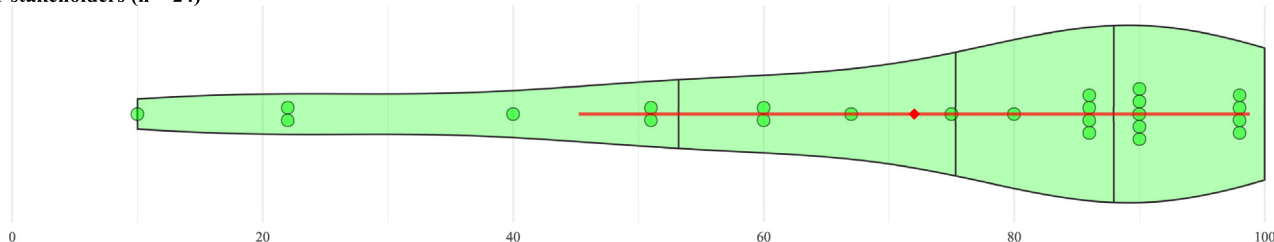
**Table 1**  
**Cross-Tabulation of Participants by Profession.** Participants had the option of selecting multiple professions, resulting in an overlap across categories. The table reflects the total number of participants identified as veterinarians, farmers, students, and other stakeholders as well as the combinations of these professions.

Profession	Veterinarian	Farmer	Student	Other Stakeholder	Total
<b>Veterinarian</b>	93	3	0	3	99
<b>Farmer</b>	3	5	0	2	10
<b>Student</b>	0	0	1	0	1
<b>Other stakeholder</b>	3	2	0	24	29
Total	99	10	1	29	139

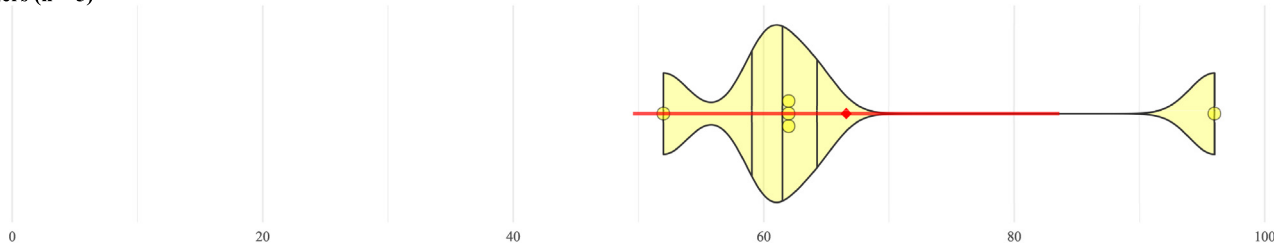
All responses (n = 118)



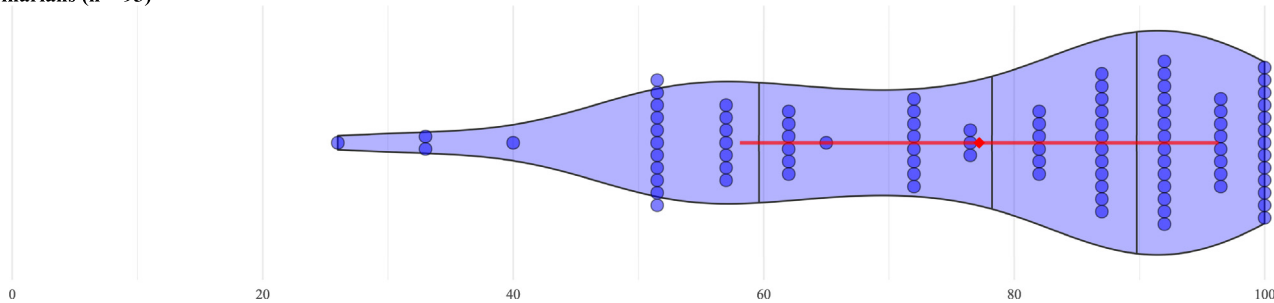
Other stakeholders (n = 24)



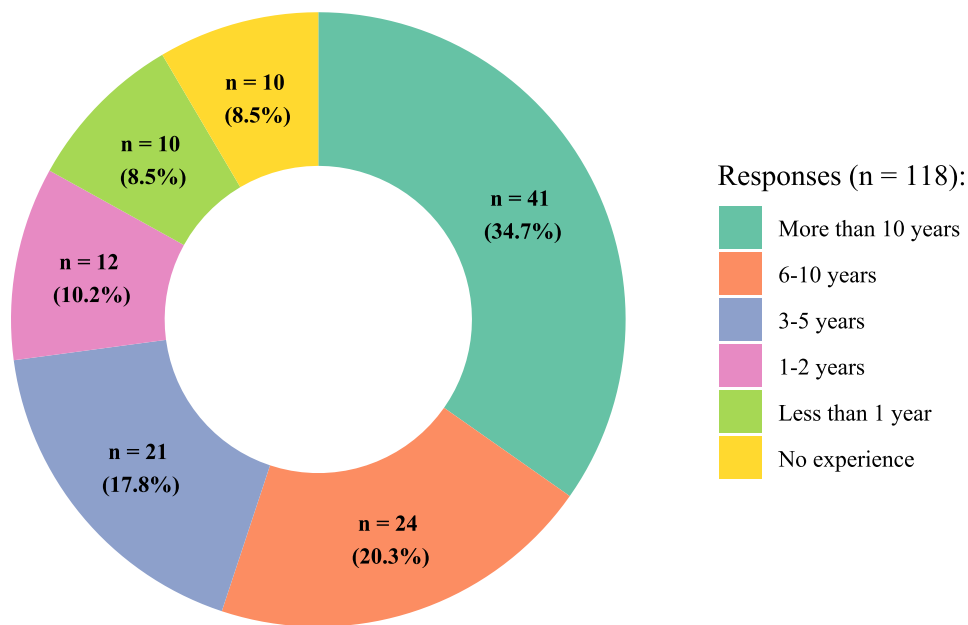
Farmers (n = 5)



Veterinarians (n = 93)



**Fig. 3. Violin Plots of Distribution of Knowledge Scores in Biosafety.** Distribution of self-assessed knowledge scores (0–100) for biosafety among all respondents, other stakeholders, and veterinarians. Violin plots display the density of scores with individual data points. Red diamonds indicate the mean and red lines indicate the standard deviation. The 25th to 75th percentiles are represented by the black vertical lines on the violin plots. Everybody who picked multiple professions were excluded and counted only once, more specifically, Veterinarian (n = 6), Farmers (n = 5), Other Stakeholders (n = 5), and Students (n = 1).



**Fig. 4. Participants' experiences with biosecurity as a topic.** Chart illustrates the survey responses to the question: "How long experience do you have on biosecurity as topics?" Participants selected one answer that best described their experience on a timescale ranging from no experience to > 10 years.

found to be highly effective training methods for enhancing inter-professional communication skills, particularly among the younger generation of veterinarians, including veterinary students and apprentices training to become veterinary assistants.<sup>52</sup> Another study, set within a two-year biosecurity project, found that veterinary practitioners became progressively more comfortable, capable, and consistent in providing biosecurity advice, while noting improved uptake by farmers, thereby illustrating a progression along the conscious-competence learning model and highlighting the need to enhance biosecurity education for future veterinarians, particularly by strengthening veterinarian–farmer relationships.<sup>53</sup>

The highest number of veterinarians responding to the survey were mostly working with cattle (31 out of 65 respondents), and their preferred approach to implementing biosecurity was the mixed approach (that biosecurity implementation should combine theoretical "basic principles" and practical, farm-specific measures), with nearly 43 % of the responses (Fig. 5). Veterinarians have emphasized the importance of training that goes beyond basic principles to include practical exercises, such as the development of farm-specific biosecurity plans (e.g., hands-on workshops for farms with similar challenges) and conducting follow-up evaluations.<sup>54</sup>

#### 4.1. Discussion group focusing in veterinary practitioners needs

##### 1. Mixed Approach to Training

**Key Insight:** The need for a mixed approach in biosecurity training, combining theoretical knowledge and practical applications supplemented with visual aids and case studies, was strongly emphasized. Veterinarians expressed the importance of training that goes beyond basic principles to include hands-on exercises, such as creating farm-specific biosecurity plans (e.g., hands-on workshops for farms with similar challenges) and conducting follow-up evaluations.

##### 2. Importance of Communication Skills

**Key Insight:** Much of the discussion focused on the need for better communication skills training. Veterinarians struggle to

effectively communicate the importance of biosecurity measures to farmers, particularly in terms of their economic benefits and long-term impacts.<sup>5</sup>

##### 3. Recognition and Certification

**Key Insight:** There was a consensus on the importance of formal recognition for veterinarians who undergo biosecurity training. The participants supported the idea of a certification system that would provide veterinarians with credentials signifying their biosecurity expertise.

##### 4. Economic Considerations in Biosecurity

**Key Insight:** This discussion also highlighted the need to incorporate economic evaluation into biosecurity training. Veterinarians emphasize that understanding the cost-benefit analysis of biosecurity measures is crucial for making informed decisions and convincing farmers of the value of these practices.<sup>55</sup>

#### 4.2. Discussion group focusing in farmers' needs

##### 1. Practicality and Accessibility of Training

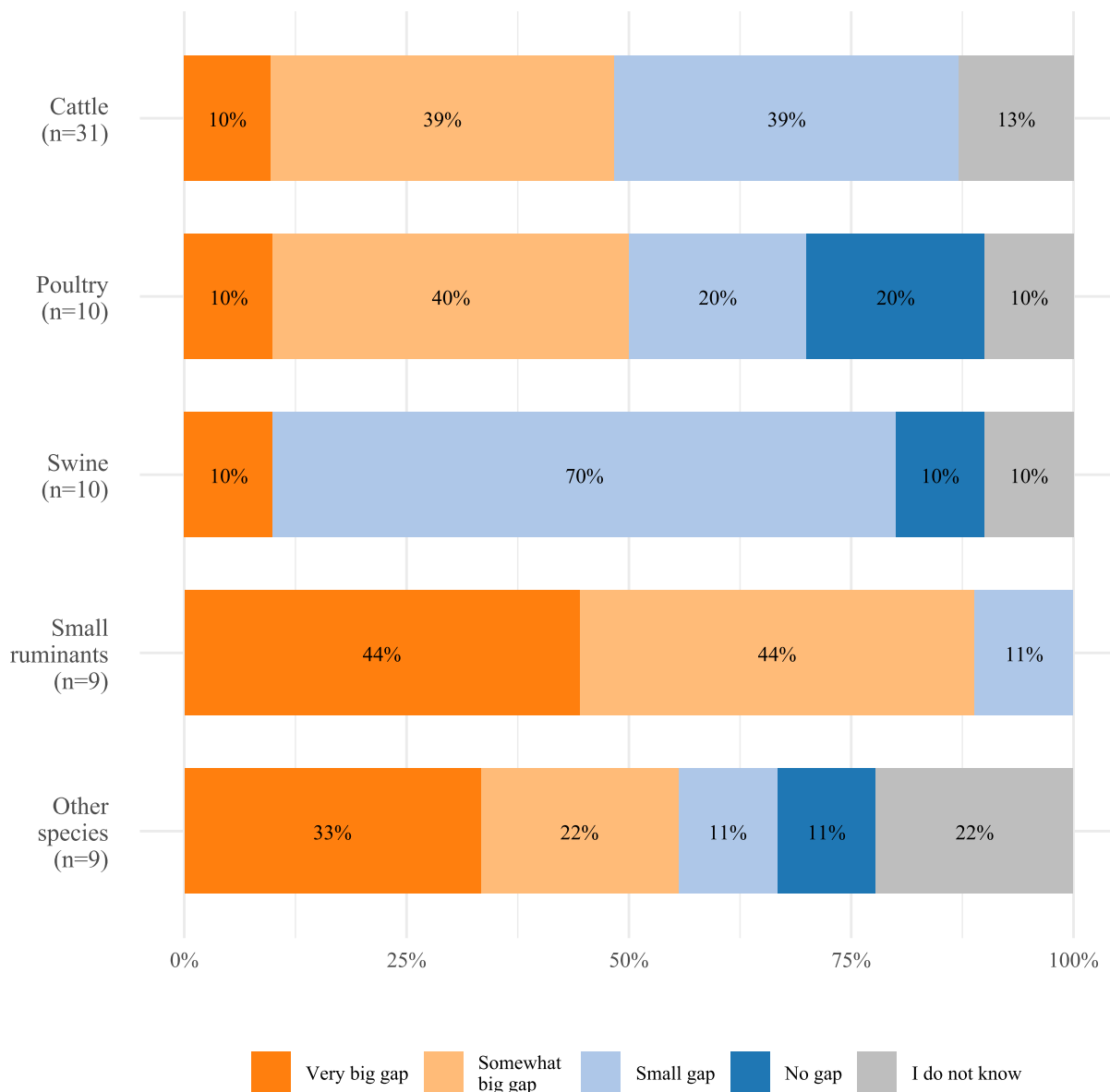
**Key Insight:** The discussion groups stressed the importance of practical and accessible biosecurity training for the industry. They suggested short, focused training sessions that could easily fit into farmers' busy schedules.

##### 2. Peer Learning and Community Engagement

**Key Insight:** Peer learning was a significant theme in the discussion groups. Farmers have indicated that the most effective learning occurs through peer-to-peer interactions in which experiences and practical advice are shared.<sup>56</sup>

##### 3. Content Simplicity and Relevance

**Key Insight:** The discussion groups called for training content that was straightforward and directly relevant to the daily



**Fig. 5. Veterinarians’ Perceived Gap in Training for a Mixed (Theory + Practical) Biosecurity Approach.** Respondents were asked how strongly they agreed (on a scale from “Very big gap” to “No gap”) that biosecurity implementation should combine theoretical “basic principles” and practical, farm-specific measures. The stacked bars show the percentage of responses within each species with which the veterinarian works the most (Cattle, Poultry, etc.). Among the nine veterinarians who selected “other species” as their main focus, 44.4 % (n = 4) worked with companion animals, 33.3 % (n = 3) with aquatic animals, and 22.2 % (n = 2) with multiple species.

operations of the farmers. This emphasizes the need for practical examples and case studies to illustrate the real-world impacts of biosecurity measures.<sup>55</sup>

#### 4. The Role of Veterinarians in Training

**Key Insight:** Although veterinarians were seen as essential in supporting farmers in implementing biosecurity measures, the discussion groups stressed a greater focus on developing their skills in communication and farmer engagement.

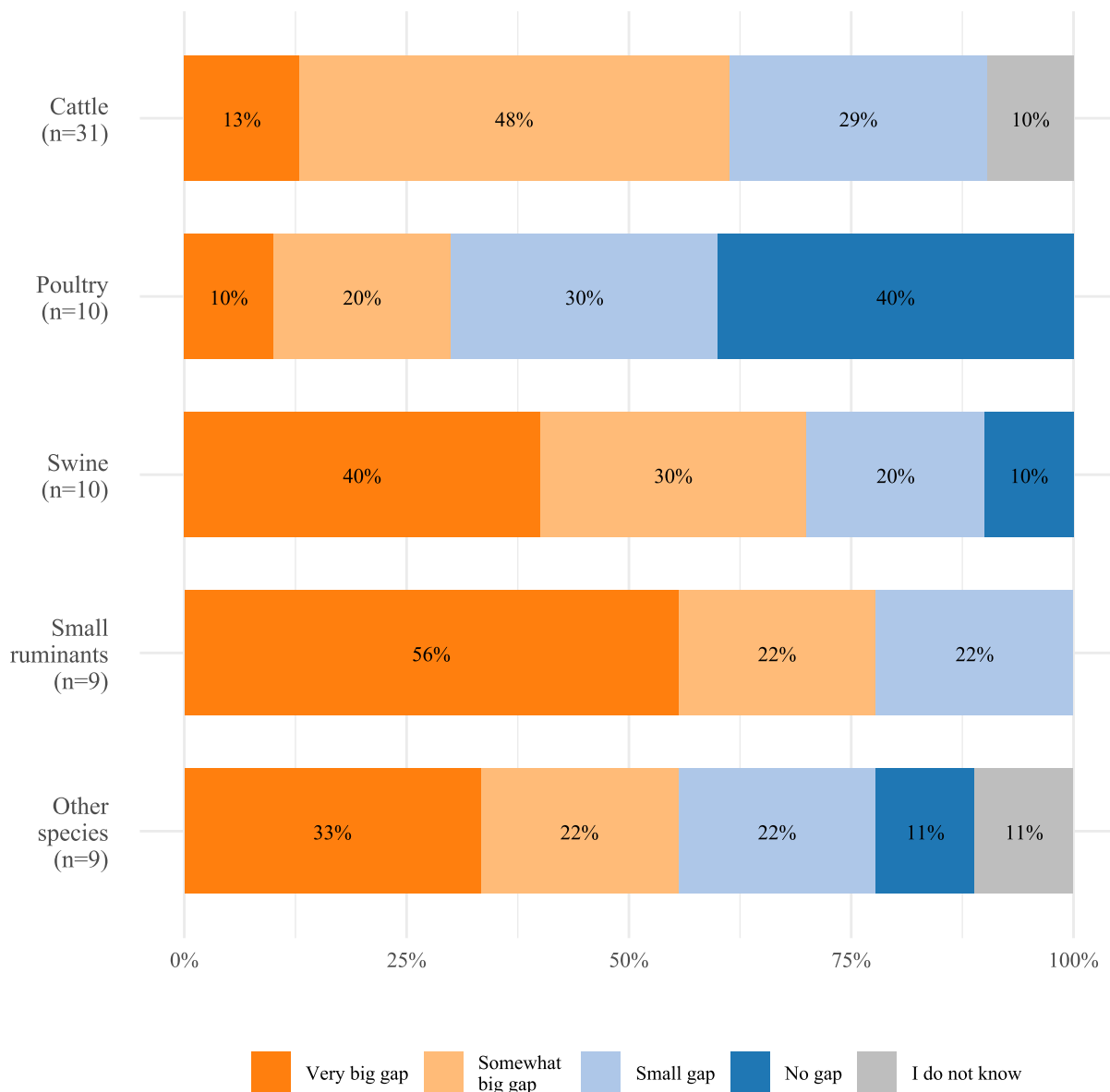
#### 4.3. Limitations

Online survey participation was voluntary, and no financial incentives were provided to the respondents. The lack of responses from farmers might stem from them being inundated with requests from industry bodies and feed companies, which may blur

the lines between legitimate surveys and spam messages.<sup>57</sup> Additionally, Farmers’ associations and student bodies were not specifically contacted for the dissemination of the online survey, which could have significantly limited the reach.

Additionally, World Café participants were mainly veterinarians representing academic organizations, although some participants also represented other types of organizations, including industry organizations and professions. This may have influenced their views on the setup of the biosecurity training. Participants’ perceptions may deviate from those of veterinary practitioners or farmers. Moreover, the World Café participants did not have to consider budgetary constraints. Thus, proposed solutions, such as face-to-face training, may not fully account for training affordability. Nevertheless, these results provide useful insights for future biosecurity training programs.

Finally, because knowledge of biosecurity was assessed using a self-reported 0–100 visual-analog scale, the scores reflect



**Fig. 6. Veterinarians' perception of whether there is a training gap in Demonstrating Biosecurity Benefits.** Respondents were asked how strongly they agreed (on a scale from “Very big gap” to “No gap”) that veterinarians needed to show stakeholders the economic or other benefits of biosecurity. The stacked bars show the percentage of responses within each species with which the veterinarian works the most (Cattle, Poultry, etc.). Among the nine veterinarians who selected “other species” as their main focus, 44.4 % (n = 4) worked with companion animals, 33.3 % (n = 3) with aquatic animals, and 22.2 % (n = 2) with multiple species.

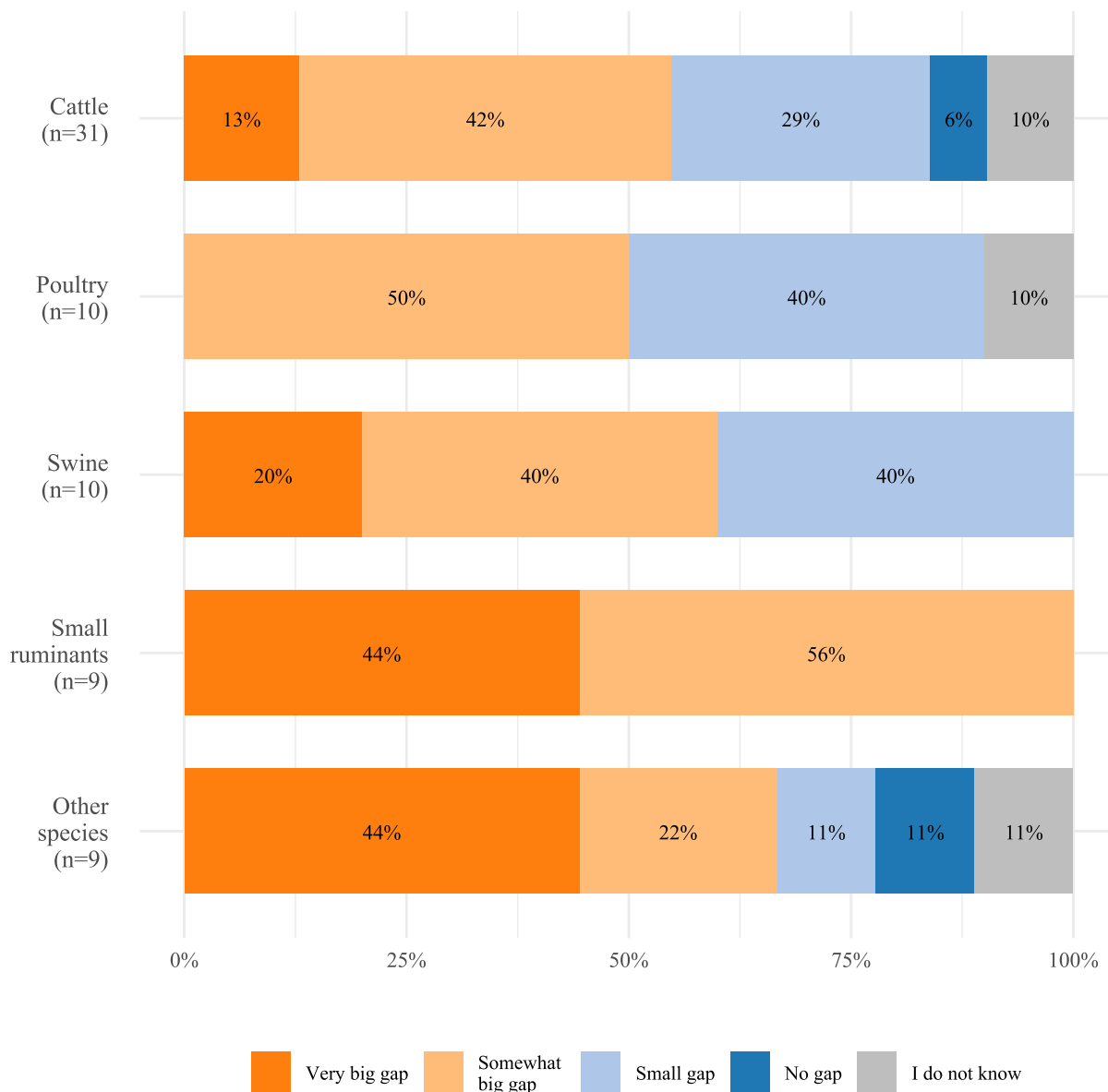
perceived rather than objectively measured competence; therefore, they should be interpreted cautiously and triangulated with observed performance in future studies.

#### 4.4. Recommendations

The following recommendations are based on the online survey findings and World Café discussions, mainly reflecting the perspectives of experts from academic and veterinary backgrounds, with no direct input from farmers. This limitation may affect the generalizability of the results to broader farming communities, highlighting the need for the future involvement of farmers in co-tailoring (an outline of an Ideal biosecurity-training programme provided in Supplementary material 4).<sup>58</sup>

#### 4.4.1. Tailored training content

Implementation of modular programs that reflect the unique needs of veterinarians and farmers. Specifically, for veterinarians, advanced modules on economic and cost-benefit assessments and detailed farm-specific biosecurity plan creation should be included. To enhance practical relevance, each module will include species-specific case studies and real-world scenarios from participants' farms, allowing for the immediate application of concepts learned. Training for farmers must be hands-on and designed to accommodate their daily tasks. Develop micro-learning units that focus on one biosecurity action per session, making it easier to fit into busy farm schedules. This dual approach ensures that the training is practical and has immediate applicability, ultimately strengthening on-farm biosecurity.



**Fig. 7. Veterinarians' perception of whether there is a training gap in Soft Skills in Biosecurity Implementation.** Respondents were asked how strongly they agree (on a scale from “Very big gap” to “No gap”) that veterinarians require communication and behavior-change skills to encourage stakeholders to adopt biosecurity. The stacked bars show the percentage of responses within each species with which the veterinarian works the most (Cattle, Poultry, etc.). Among the nine veterinarians who selected “other species” as their main focus, 44.4 % (n = 4) worked with companion animals, 33.3 % (n = 3) with aquatic animals, and 22.2 % (n = 2) with multiple species.

**Challenges and requirements for implementation**

Interdisciplinary collaboration: Developing economic modules will require close cooperation with agricultural economists to design cost-benefit tools that reflect diverse farm sizes and species-specific needs.

**4.4.2. Accessible and flexible training formats**

Offer biosecurity training in multiple formats: online for theoretical foundations, hybrid for interactive discussions, and in-person for practical skills and farm visits. To enhance accessibility based on feedback, all online modules were made downloadable for offline use. Communication training should be central, equipping veterinarians with the skills to address farmers' specific questions and motivations.

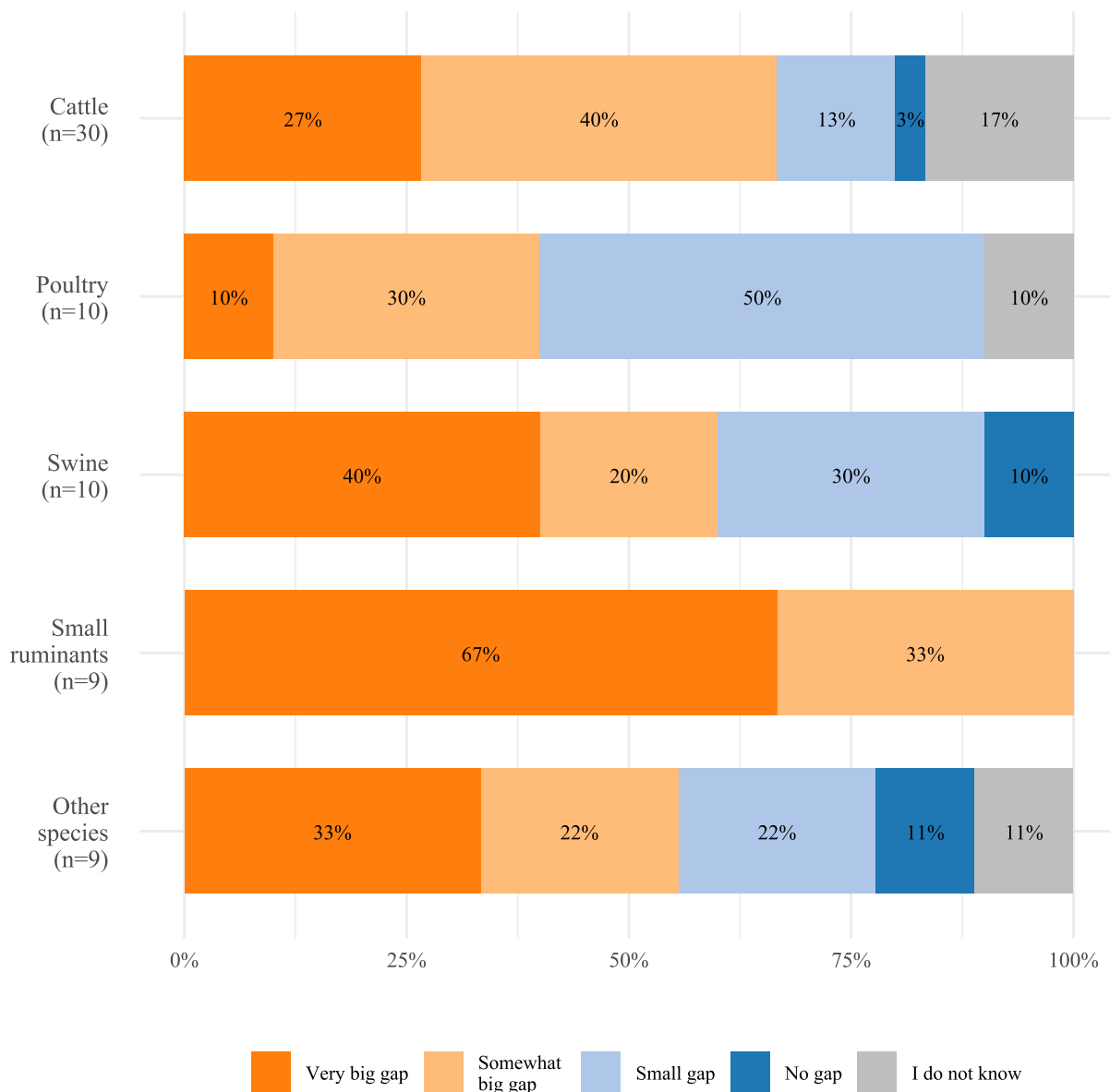
**4.4.2.1. Challenges and requirements for implementation.** Quality assurance across formats: Ensuring consistency in the achievement of learning objectives both online and in-person will require web

designers/IT specialists to collaborate on standardized learning management systems with built-in tracking of progress and engagement.

**4.4.3. Focus on communication skills**

Integration of communication skills throughout biosecurity training. Effective strategies for engaging farmers in the practical and economic benefits of biosecurity should be emphasized. Establish a continuing professional development (CPD) system to assess knowledge retention and ensure that veterinarians stay up to date with best practices.

*Challenges and requirements for implementation.* Capacity gaps in soft skills: Many veterinarians lack soft skills to address this gap; collaboration with social and behavioral scientists is needed to design modules on active listening and address resistance to change.



**Fig. 8. Veterinarians' perceptions of recognition of biosecurity training.** Respondents were asked how strongly they agree (on a scale from “Very big gap” to “No gap”) that practices or veterinarians trained in biosecurity are readily identifiable (via specific labeling or certification). The stacked bars show the percentage of responses within each species with which the veterinarian works the most (Cattle, Poultry, etc.). Of the nine respondents who selected “other species” as their main focus, 44.4 % (n = 4) worked with companion animals, 33.3 % (n = 3) with aquatic animals, and 22.2 % (n = 2) with multiple species.

**Table 2**  
**Categories of Biosecurity-Related Information.** The survey responses (n = 59) were grouped into categories. The classification was based on freely available information and expert reviews to improve clarity and comparability.

Category	Number of responses (n = 59)
Biosecurity training(s)	15
Epidemiology training(s)	3
Projects/trainings on Herd Health management	7
Congresses/Workshops	2
Colleges/Organizations	4
Projects	15
Responses without biosecurity information	4
N/A	9

4.4.4. Certification and quality control

Implement a certification system with clear quality control measures recognized by professional bodies and linked to CPD.

To meet the request for formal recognition certificates, ECTS will be required. By including case studies and financial assessment tools, veterinarians can convincingly present the economic value of biosecurity to farmers.

*Challenges and requirements for implementation.* Accreditation processes: Obtaining ECTS accreditation involves curriculum review, academic representatives, and quality assurance that must align course outcomes with ECTS standards.

Maintaining standards: Ongoing quality control requires content updates based on emerging situations and learner feedback.

4.4.5. Consideration of farmer perspectives

Farmers should be actively involved in designing and validating biosecurity training programs. Follow-up surveys, focus groups, and targeted World Café sessions were used to capture their needs. Experts anticipate that farmers will prefer online materials

**Table 3**  
Overview of Biosecurity Training Programs reported in the online survey (n = 15).

Characteristic	Details
Focus	11 exclusive to biosecurity; 4 broader scope (includes biosecurity modules)
Delivery type	9 online; 2 hybrid; 3 face-to-face; 1 not specified
Educational tools	6 based on lectures; 1 using virtual classrooms/training/face-to-face; 4 combining lectures + workshops; 4 using videos/postcards/etc.
Audience	8 open-access; 1 veterinarian-only; 3 for organization members; 3 for farmers
Certification	7 offered certificates; 4 did not; 1 led to a master's degree; 3 no information
ECTS	1 awarded 25 ECTS (website no longer accessible for confirmation)
Fee	8 free; 4 with a participation fee; 3 not specified
Curriculum information	11 with a curriculum or training outline; 4 no details
Program active*	11 confirmed active; 4 no updates provided
Evaluation	3 required exam/test/project; 9 no evaluation; 3 not specified
Quality control	10 under university/official organizations; 5 unspecified

\* Active status was checked in September 2024. ECTS = European Credit Transfer and Accumulation System.

**Table 4**  
**The species Focus of Biosecurity Training Programs (n = 15).** Each program was grouped by the primary species or general biosecurity topic(s) according to publicly available descriptions.

Content	Number of training programs (n = 15)
Poultry	4
Swine	2
General Biosecurity/Food Safety	2
Ruminants <sup>a</sup>	1
Dairy Cattle	1
Swine, Cattle, Poultry	1
Swine, Ruminants, Poultry, Equine	1
Swine, Ruminants, Poultry, Companion Animals	1
Swine, Ruminants, Poultry	1
Swine, Ruminants, Equine	1

<sup>a</sup> Including small ruminants and cattle.

**Table 5**  
**Key Biosecurity Training Needs and Expectations for Veterinary practitioners.** This table highlights the five prioritized areas of focus identified during the World Café discussions.

Main needs and expectations in order of importance:
<p><b>1 How to communicate with farmers?</b></p> <ul style="list-style-type: none"> <li>✓ Veterinarians should be taught effective communication strategies to use when communicating with farmers about biosecurity.</li> <li>✓ How to communicate with farmers in a way that makes a difference?</li> <li>✓ How to teach farmers about biosecurity measures?</li> </ul>
<p><b>2 Learn basic knowledge of biosecurity</b></p> <ul style="list-style-type: none"> <li>⊙ In the beginning of the training have a small self-assessment test for veterinarians to test their current level of understanding about the topic.</li> <li>✓ Basic knowledge, e.g. what are the internal and external biosecurity measures?</li> <li>✓ Understanding the benefits of biosecurity, including the economic benefits.</li> <li>✓ Refresh knowledge of biosecurity for veterinarians who have practiced already for a longer period.</li> <li>✓ Learn about new emerging diseases and important biosecurity measures associated with them.</li> </ul>
<p><b>3 How to make a biosecurity plan.</b></p> <ul style="list-style-type: none"> <li>✓ How to create a biosecurity plan?</li> <li>✓ How to adapt the biosecurity plan to the specific production system and possibly to a specific disease/infectious agent.</li> </ul>
<p><b>4 Implementation of biosecurity</b></p> <ul style="list-style-type: none"> <li>✓ How to evaluate the success of the biosecurity implementation in a farm.</li> <li>✓ Provide training on legislation related to biosecurity.</li> <li>✓ Application of risk assessment and mitigation strategies related to biosecurity.</li> <li>⊙ Demonstrate economic benefits of biosecurity implementation.</li> </ul>
<p><b>5 Mixed type of training (both theory and practice).</b></p> <ul style="list-style-type: none"> <li>✓ Theoretical training should come before practical training.</li> <li>✓ The use of practical examples in training is important. Provide examples of what has worked on one farm but not on another.</li> <li>✓ The use of case studies for example cases.</li> </ul>
<p><b>Other aspects mentioned:</b></p> <ul style="list-style-type: none"> <li>✓ Training should be peer-to-peer (from one professional to another).</li> <li>✓ Critical point Identifying critical control point establishment (similar to HACCP – Hazard analysis and critical control points)</li> <li>⊙ Gamification</li> </ul>

“✓” indicates a training focus or aspect found in both the online survey and the World Café match. “⊙” indicates a focus point or aspect discussed in the World Café but not reported among online survey-listed training programs. Facilitator: TN (Estonian University of Life Sciences); Reporter: EB (Ghent University).

**Table 6****Key Biosecurity Training Needs and Expectations for Farmers.** This table highlights the prioritized areas of focus identified during the World Café discussions.

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Objectives and main needs and expectations in decreasing order of importance:

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**Objectives (in decreasing order of importance)**

- ✓ Biosecurity principles
- ✓ Why is biosecurity important?
- ✓ Meaning of biosecurity
- ✓ Farm self-assessment using questionnaires
- ⊙ Creating biosecurity plan for your farms
- ⊙ Implementation of biosecurity in your farm
- ✓ Key biosecurity measures
- ✓ Educating staff about biosecurity (all people working on the farm)
- ✓ Focus on different animal species.
- ✓ External / Internal farm biosecurity in general.
- ⊙ Prioritize problems or measures according to each farm/ system/ country.

**Content (in decreasing order of importance)**

- ✓ Biosecurity case studies of biosecurity: to show before/ after implementation of biosecurity, to show good/bad examples, to show the results of applying biosecurity in a pandemic outbreak, etc.
- ✓ Basic principles.
- ✓ Creating goals: personalized [goals] for each farmer, benchmarking.
- ✓ Risk factors in each farm/farming system & planning (personalized).

**Specific topics which must be in the training (not in the order of importance)**

- ✓ Specific animal species
- ✓ Specific disease (e.g. African Swine Fever)
- ✓ Specific country
- ✓ Specific production system (e.g. extensive or intensive dairy farming system)
- ✓ Specific issues: animal transport, feed, water, infrastructure, etc.
- ✓ Practical issues (procedures)
- ✓ Cleaning & disinfection
- ✓ Implementation of biosecurity (in a practical way)
- ✓ Benefits of biosecurity
- ⊙ Costs (in regards of cost – benefit side for the farmer)
- ✓ Productivity
- ✓ Health
- ✓ Reduction of Antimicrobial use (AMU)
- ✓ Mandatory and non-mandatory measures

**Type of training recommended**

- ✓ Mixed (theory and practice)
- ✓ Theory (face-to-face or virtual, e.g. recorded webinar)
- ✓ Practical seminars on farm level or virtual visits on farms presenting the best and bad examples of applied biosecurity
- ✓ Short courses (one training session of 2–3 h)
- ⊙ Games or tools that are easy for farmers to use
- ✓ Peer learning with other farmers: discussing the experiences of other farmers together (mentoring, influencing)

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“✓” indicates a training focus or aspect found in both the online survey and the World Café match. “⊙” indicates a focus point or aspect discussed in the World Café but not reported among online survey-listed training programs. Facilitator: AMI (Aristotle University of Thessaloniki); Reporter: CCG (Animal Health Ireland).

## 5. Conclusion

Our findings show that formal biosecurity courses for veterinarians and farmers remain patchy across Europe, and that existing programs rarely address the practical hurdles encountered on real farms. Trainers can close the most critical gaps by adding a hands-on communication module that teaches motivational interviewing and how to frame the economic value of each measure; shifting to a blended “theory-online, practice-on-farm” delivery model that keeps e-learning units under 20 min and makes them downloadable for areas with poor connectivity, reserving scarce face-to-face time for farm walk-throughs and peer discussion; and aligning learning outcomes with the ECTS so that participants earn digital badges or CPD credits and materials are reviewed annually against emerging disease threats. Where budgets are tight, the communication module and ROI examples should take precedence, because they most strongly influence farmer uptake. Throughout the revision process, at least one farmer representative should be consulted to ensure that the language, scheduling, and examples resonate with the day-to-day realities. Implementing these steps will modernize biosecurity training, improve veterinarian–farmer dialogue, and strengthen disease preparedness in diverse livestock systems.

## CRedit authorship contribution statement

**Anna Maria Iatrou:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation. **Blerta Mehmedi Kastrati:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Reze M. Gecaj:** Writing – review & editing, Writing – original draft, Validation, Investigation. **Georgios Batikas:** Investigation, Formal analysis. **Jarkko K. Niemi:** Writing – review & editing, Writing – original draft, Investigation, Data curation, Conceptualization. **Claude Saegerman:** Writing – review & editing, Supervision, Project administration, Investigation, Conceptualization. **Alberto Oscar Allepuz:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Wibke Jansen:** Writing – review & editing, Resources, Methodology, Formal analysis, Conceptualization. **Nancy De Briyne:** Writing – review & editing, Resources, Investigation, Conceptualization. **Daniele De Meneghi:** Writing – review & editing, Validation, Investigation, Conceptualization. **Murat Yilmaz:** Writing – review & editing, Investigation, Data curation. **Evelien Biebaut:** Writing – review & editing, Investigation. **Ramazan Yildiz:** Writing – review & editing. **Marco De Nardi:** Writing – review & editing. **Carla Correia-Gomes:** Writing – review & editing, Writing – orig-

inal draft. **Tarmo Niine:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

### Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Data access statement

Research data supporting this publication are available as supplementary material.

### Supplementary materials

Online survey questions, Mendeley Data, V2, doi: <https://doi.org/10.17632/yfpc6gpmmbm.2>.<sup>27</sup>

Online survey results, Mendeley Data, V1, doi: <https://doi.org/10.17632/gkd29rt3ph.1>.<sup>28</sup>

Webpages database, Mendeley Data, V1, doi: <https://doi.org/10.17632/cybj445fr2.1>.<sup>32</sup>

Mendeley Data, V1, doi: <https://doi.org/10.17632/b3bzk32y4w.1>.<sup>58</sup>

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