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Veterinary perspectives on biosecurity measures in small-scale farming systems across European countries: Results from a cross-national survey

F. Duarte [a], J. Prodanov-Radulović [b], B. Mehmedi [c], A. Piccirillo [d], M. Stukelj [e], E. Kldiashvili [f], V. Nedosekov [g], B. Milovanovic [h], N.D. Ayaz [i], R. Yildiz [j], S. Meling [k], I. Toftaker [l], A. Sirbu [m], A. Dodovski [n], A. Allepuz [a,*], A. Zbikowski [o], Xh. Koleci [p], C. Berger [q], J. Starič [e], M.E. Filippitzi [r], L. Moskalenko [s], L. Gresakova [t], I. Chantziaras [u], K. Berggren [v], M. De Nardi [w], G. Graziosi [w], I.M.G.A. Santman-Berends [x]

[a] Departament de Sanitat i Anatomia Animals, Universitat Autònoma de Barcelona, Cerdanyola del Vallès, Barcelona 08193, Spain
[b] Scientific Veterinary Institute "Novi Sad", Rumenacki put 20, Novi Sad 21000, Serbia
[c] Department of Veterinary Medicine, Faculty of Agriculture and Veterinary, University of Prishtina, Republic of Kosovo
[d] Department of Comparative Biomedicine and Food Science, University of Padova, Legnaro, Italy
[e] Veterinary faculty, Clinic for ruminants and pigs, University of Ljubljana, Slovenia
[f] Petre Shotadze Tbilisi Medical Academy, Ketevan Tsamebuli avenue 51/2, 0144 Tbilisi, Georgia
[g] Department of Veterinary Epidemiology and Animal Health, National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony St, 15, Kyiv 03041, Ukraine
[h] Scientific Institute of Veterinary Medicine of Serbia, Janisa Janulisa 14, Belgrade 11000, Serbia
[i] Department of Food Hygiene and Technology, Faculty of Veterinary Medicine, Kırıkkale University, Türkiye
[j] Department of Internal Medicine, Faculty of Veterinary Medicine, Burdur Mehmet Akif Ersoy University, Burdur, Türkiye
[k] Norwegian Veterinary Institute, 1433 Ås, Norway
[l] Departement of Production Animal Clinical Sciences, Norwegian University of Life Sciences, 1433 Ås, Norway
[m] FMMAE Ramnicu Valcea, Constantin Brancoveanu University of Pitesti, Romania
[n] Department of Avian Diseases, Faculty of Veterinary Medicine – Skopje, Ss. Cyril and Methodius University in Skopje, Lazar Pop Trajkov 5-7, 1000 Skopje, Macedonia
[o] Department of Pathology and Veterinary Diagnostics, Institute of Veterinary Medicine at WULS (SGGW) Warsaw, Poland
[p] Faculty of Veterinary Medicine, Agricultural University of Tirana, Albania
[q] Independent consultant, Switzerland
[r] Laboratory of Animal Production Economics, School of Veterinary Medicine, Aristotle University of Thessaloniki, Greece
[s] Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Science, F.R. Kreutzwaldi, Tartu 51014, Estonia
[t] Institute of Animal Physiology, Centre of Biosciences of the Slovak Academy of Sciences, Soltesovej 4-6, 040 01 Kosice, Slovak Republic
[u] Faculty of Veterinary Medicine, Ghent University, Salisburylaan 133, Merelbeke 9820, Belgium
[v] Department of Clinical Sciences, Swedish University of Agricultural Sciences, PO Box 7054, SE-750 07 Uppsala, Sweden
[w] Department of Veterinary Medical Sciences, University of Bologna, Via Tolara di Sopra 50, 40064 Ozzano dell'Emilia, BO, Italy
[x] Department of research and development, Royal GD, Deventer, the Netherlands

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ABSTRACT

Maintaining sufficient levels of biosecurity at the farm level is crucial to prevent the introduction and spread of pathogens. However, data on biosecurity awareness and implementation in small-scale or backyard (hereafter referred to as small-scale) holdings across Europe are lacking. While the risk posed by these farms is generally regarded as limited, they represent a diverse group of farmers and do play a role in disease introduction and spread. The aim of this study was to explore veterinarians' perspectives on small-scale farming in Europe, including the frequency of farm visits, the definition of small-scale farming, the current status of biosecurity, and the most important measures to prevent pathogen introduction and spread. A multidisciplinary team developed a comprehensive survey to collect veterinarians' perspectives on biosecurity in small-scale farms. The survey was translated into 16 languages, digitalised, and distributed online between July and December 2024 by participants of COST Action BETTER. Data were analysed descriptively, and clusters of veterinarians were distinguished using multiple correspondence analysis. In total, 346 veterinarians from 23 countries participated in the survey. There is no standard definition of small-scale farming throughout Europe. According to the participating veterinarians,

* Corresponding author.
E-mail address: Alberto.Allepuz@uab.cat (A. Allepuz).

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a small-scale farm was defined as having a median number of fewer than 20 cattle, 30 small ruminants, 13 pigs, or 99 heads of poultry. Three clusters of veterinarians were identified based on geographical location, field experience, biosecurity training, and perceived biosecurity awareness within the small-scale farming community. Biosecurity measures already applied in small-scale farming included fencing, carcass management, and biosecurity measures related to purchasing and feeding practices. According to the participating veterinarians, the most important biosecurity measures for small-scale farms to prevent pathogen introduction and spread included factors related to the introduction of animals, such as quarantine facilities, testing for health status, and purchasing animals from farms with a high health status. Besides factors related to the introduction of animals, hygiene measures and fencing were also frequently indicated as the most important biosecurity measures. Nevertheless, significant differences were found between the clusters regarding the importance of specific biosecurity measures. This study provides valuable insights into the perceived awareness, implementation, and desired biosecurity measures in European small-scale farming and underscores the importance of integrating small farms into "One Health" strategies, given their potential role in the spread of infectious diseases.

1. Introduction

Maintaining sufficient levels of biosecurity at the farm level is crucial to prevent the introduction and spread of pathogens, thereby significantly contributing to the health and welfare of farmed animals. Biosecurity, as defined by the World Organisation for Animal Health (WOAH), is a set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases to, from, and within an animal population (World Organisation for Animal Health, 2024). Healthier animals lead to better animal welfare, improved sustainability of animal production systems, reduced antimicrobial use, and the production of safer foods. Although the costs and additional labour involved in maintaining good biosecurity can be perceived by farmers (Moya et al., 2020), the benefits are not as clear because losses that may have been prevented by sufficient biosecurity remain unseen and are often based on assumptions rather than actual field observations (Bester et al., 2024; Ellis-Iversen et al., 2010). The combination of the direct costs and additional labour associated with biosecurity, and the prevented losses that remain unseen, hinders the implementation of biosecurity measures, particularly in settings with limited resources. Moreover, in small-scale farming, it is even more challenging for farmers to be incentivised to invest in biosecurity (Conan et al., 2012). For them, the reasons for keeping animals often go beyond financial gain (such as cultural heritage or hobby), highlighting how different types of farming (e.g. commercial, backyard) can lead to different uptakes of biosecurity (Short et al., 2021; Enticott, 2008).

In recent years, several studies have described the biosecurity levels applied on livestock farms and shown that standards are highest for poultry and swine but lower for other farming species (Nöremark et al., 2010). However, these studies were primarily conducted on commercial farms. There are limited European studies evaluating biosecurity in small-scale or backyard farming, hereafter referred to as small-scale, and most focus on either poultry or swine (Di Francesco et al., 2025; Plut et al., 2023). This lack of studies has also been reported outside Europe (Morris et al., 2023b). In some cases, small-scale farmers are included as a subgroup in larger studies, which often conclude that small-scale farmers adopt fewer biosecurity measures compared to commercial farmers (Correia-Gomes et al., 2021; Paquette et al., 2020; Nöremark et al., 2010). Nevertheless, a substantial part of the approximately 9.1 million farms in the European Union are classified as small holdings with less than five hectares of land. While detailed statistics on livestock type and herd size are limited at the EU level, available data suggest that small-scale livestock farming plays an essential role in the agricultural landscape, particularly in regions characterised by traditional farming practices.

Biosecurity measures in livestock production vary considerably depending on factors such as farm size, type of disease threat, national regulations, and available resources. Large-scale commercial farms generally adopt a more systematic and disciplined approach to implementing biosecurity protocols compared to small-scale or backyard holdings (Kuster et al., 2015). However, in such small-scale systems, the level of biosecurity knowledge and the extent of implementation remain insufficiently explored. This gap is critical across research and policy development. Although the role played by these farms in the dynamics of infectious diseases at national level is generally regarded as limited, due to mostly only having local or regional farm contacts (Souvestre et al., 2021; Bavinck et al., 2009), they can play a role in disease introduction and spread (Plut et al., 2023; Holloway, 2019; Smith and Dunipace, 2011). Furthermore, the diversity of small-scale farms varies significantly across different regions of Europe (Guarín et al., 2020), and there is no standard definition of small-scale farming. In Western Europe, small-scale farms are often seen as a residual group that keeps a few animals for personal consumption or companionship, while according to experts, in Eastern Europe, small-scale farming is the predominant farming system in many countries. Insight into biosecurity awareness and implementation levels is important because previous research has shown that sufficient awareness of biosecurity measures positively influences their adoption (Loeillot et al., 2025; Paquette et al., 2020). Thus, understanding the current status is the first step towards actions to enhance biosecurity levels.

The aim of this study was to: describe the frequency of veterinary visits to small-scale farms by animal species; assess veterinarians' opinions on the definition of small-scale farming; describe the current status of biosecurity in small-scale farming; and evaluate veterinarians' opinions on the most important biosecurity measures for preventing pathogen introduction and spread. Additionally, this study defines awareness as farmers' comprehension and understanding of technical concepts related to biosecurity.

This work is part of the COST Action "BETTER" (Biosecurity Enhanced Through Training, Evaluation and Raising awareness). In this initiative, a multidisciplinary group of over 400 researchers from 46 countries collaborates to evaluate biosecurity measures and understand the motivating factors and barriers to biosecurity implementation (www.better-biosecurity.eu).

2. Material and methods

2.1. Study design, population and survey development

A face-to-face workshop on biosecurity measures that could be implemented in extensive livestock systems was organised at the University of Belgrade – Faculty of Agriculture, Belgrade-Zemun, on 25 and 26 September 2023, with a small group of 25 researchers participating in the COST Action, originating from ten countries across Europe. During this workshop, the study design was agreed upon, and a first draft of the survey was developed. The target population for this study was defined as veterinarians, preferably those working in the field, with awareness of small-scale farming in their country of work. Veterinarians were chosen as the target audience based on the assumption that they could objectively assess the awareness and implementation of biosecurity measures among small-scale farmers in their country. The target sample size was set at a minimum of 300 veterinarians from at least ten

European countries. With a sample size of 300, a percentage can be estimated with a precision of 6% at a 95% confidence level, assuming no prior knowledge of the prevalence (i.e., assuming an estimated prevalence of 50%) (Stata® version 17). The requirement to include at least ten countries to enable multicountry conclusions was agreed upon with the country representatives involved. This sample size allows the estimation of key proportions with acceptable precision and supports exploratory comparisons across regions and species, providing a comprehensive overview of biosecurity awareness and implementation among small-scale holders.

The survey included questions on the frequency of veterinarians' visits to small-scale farms by species (cattle, small ruminants, pigs, and poultry). Based on their responses, participants were presented only with questions relevant to the animal species they reported visiting at least once per year. The full survey and the corresponding results related to visit frequency are provided in the Supplementary Materials (Figs. S1.1 and S1.2, respectively).

To ensure veterinarians had a consistent understanding of what constitutes a small-scale farm, definitions were agreed upon by experts and included in the survey to clarify what was meant by "small-scale". A small-scale holder was defined as having fewer than five cows or fattening calves, fewer than 20 heads of sheep or goats, fewer than five sows or ten fattening pigs, or fewer than 50 birds. Survey respondents were also given the opportunity to add the definition of small-scale farming used in their own country.

Following the initial workshop, a draft of the survey was created and discussed with BETTER participants during multiple online meetings, resulting in a near-final version. This version included questions regarding the profile of the veterinary respondent, the definition of small-scale farming, the current status of biosecurity in small-scale farming, and the most important biosecurity measures for preventing pathogen introduction and spread (Table 1).

The near-final version of the survey was digitalised using EUSurvey (https://ec.europa.eu/eusurvey), an online survey tool hosted by the European Commission. Through BETTER, a call was made to identify volunteer focal points from the participating countries to take part in this work. Once these country focal points (CFPs) expressed their interest, they were included in all communication and meetings to finalise the survey. The digital survey was translated from English into multiple additional languages to facilitate pilot testing with three veterinarians per country in the Netherlands, Serbia, Slovenia, Italy and Spain. Based on feedback from these veterinarians, a final version of the survey was drafted and translated into sixteen different languages (Fig. 1). This study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The final version of the survey was reviewed and approved by the Ethics Committee of the Autonomous University of Barcelona, Spain – approval number CEEAH 7134. The final survey was published in the last week of July 2024 and remained open for five months, until 31 December 2024. The complete timeline from the initial discussion to the publication of the survey is depicted schematically in Fig. 1.

Table 1
Overview of the topics and corresponding questions included in the survey on biosecurity in small-scale farms across Europe.

Topic	Questions
Profile of the respondent	Country of employment, working area (e.g., field, business, research, or official veterinarian (policy)), years of experience, frequency of small-scale farm visits per species.
Definitions	Per species of interest: what is the veterinarians' definition of small-scale.
Current status of biosecurity in small-scale farms	Biosecurity awareness, risk behaviours in small-scale farming, and the top five applied biosecurity measures in small-scale farming.
Most important biosecurity for small-scale	Name the top three most important biosecurity measures per species of interest.

2.2. Analysis

Each CFP used their optimal approach to recruit respondents in their country. The survey was advertised in newsletters, mailings were sent to groups of veterinarians, veterinarians were contacted in person during veterinary events, and they were informed about the survey in meetings. Active participation of the CFPs was encouraged by sending regular updates on the number of respondents and by organising monthly online meetings to discuss the process. Additionally, interim descriptive analyses were performed in September 2024.

Stata, version 17®, was used for data cleaning, validation, map creation, and descriptive analyses. Chi^2 tests in Stata were used to evaluate differences in the definition of small-scale farming by geolocation of the respondents. In agreement with the COST Action participants, the countries that participated in the survey were grouped into five different geolocations:

1. Balkan: Albania, Croatia, Greece, Kosovo, Montenegro, North Macedonia, Serbia, Slovenia
2. Central Europe: Hungary, Poland, Slovakia, Ukraine
3. Türkiye: Turkey
4. Northern Europe: Denmark, Estonia, Finland, Netherlands, Norway, Sweden
5. Southern Europe: France, Italy, Portugal, Spain

As an exploratory approach, using the responses received, a hierarchical clustering on principal components (HCPC) was conducted based on the results of multiple correspondence analysis (MCA) (Husson et al., 2010). This analysis was performed using R software version 4.2.2 (R Core Team, 2023). Questions related to the veterinarian ($n = 5$), risk behaviour of small-scale holders ($n = 11$), and perceived biosecurity awareness by small-scale holders ($n = 1$) were included for analysis using MCA.

As a preliminary step prior to the MCA, variables with a Spearman correlation coefficient of ±0.4 or higher (at a 95% confidence level, $p < 0.05$) were considered for exclusion from the dataset. Additionally, variables with response rates below 10% were either grouped with similar categories or excluded from the analysis. MCA was performed using the indicator matrix method. The optimal number of dimensions to retain was determined by the lowest mean square error of prediction (MSEP). Ward's method with the Euclidean distance metric was used to aggregate individuals into homogeneous groups and build the HCPC tree. All other MCA and HCPC settings were kept at their default values from the "factoextra" and "FactoMineR" packages (Kassambara and Mundt, 2020; Husson et al., 2010).

For each of the identified clusters, in-depth descriptive results, including Chi^2 statistics to evaluate differences between groups, were presented regarding the most commonly implemented biosecurity measures according to veterinarians and the biosecurity measures perceived as most important for this specific group of farmers.

3. Results

3.1. Respondents

Between August and December 2024, a total of 346 veterinarians from 23 countries responded to the survey (Fig. 2). The number of surveys completed per country ranged from one (Sweden, France, and Croatia) to 61 (Ukraine). On average, 15 veterinarians per country participated in the survey, with a median of 13. A detailed table showing the number of surveys by country is provided in Supplementary Material Table 1.S1.

Of the 346 veterinarians, 266 indicated that they regularly visit small-scale cattle farms, 234 regularly visit small-scale small-ruminant

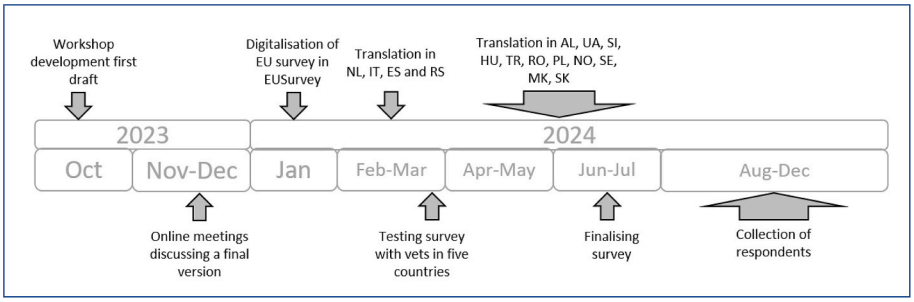

Fig. 1. Schematic overview of the timeline from the initial workshop to the final publication of the survey evaluating biosecurity in small-scale farms across Europe.

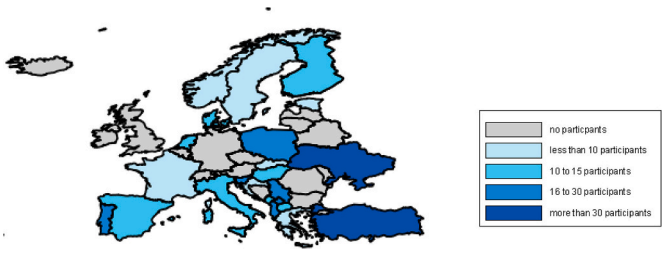

Fig. 2. Spatial distribution of the 346 respondents (veterinarians) who participated in a survey on biosecurity in small-scale farms across Europe.

holdings, 183 regularly visit small-scale pig farms, and 167 regularly visit small-scale poultry farms (Table 2). Most of the participating veterinarians were working in the Balkan region ($n = 114$), followed by Central Europe ($n = 101$). About half of the participating veterinarians worked as field veterinarians (either full-time or part-time), while the remainder worked as industry veterinarians, researchers, or official veterinarians (Table 2).

Twenty-three out of the 346 responding veterinarians (7%) reported visiting small-scale farms less than once per year and were therefore excluded from the detailed analysis of biosecurity measures in such farms. Additionally, 79 (23%) veterinarians specialised in one species (29 cattle, 12 small ruminants, 14 pigs, and 24 poultry). Forty-seven veterinarians specialised in ruminants indicated that they regularly visit both cattle and small ruminant small-scale farms, and 197 veterinarians regularly visited small-scale farms with multiple animal species.

3.2. Definitions of small-scale

The pre-defined expert definitions of small-scale farming from BETTER were compared to those provided by surveyed veterinarians. For all four species, the veterinarians' definitions of small-scale generally included higher maximum numbers of animals (Table 3). Additionally, 23% to 29% of the veterinarians did not specify a maximum number of animals for a small-scale holding. Instead, they described small-scale farmers in qualitative terms, offering a wide range of descriptions such as “keeping animals as pets”, “keeping animals only for their own consumption”, “keeping animals for non-commercial purposes”, and “having animals in numbers too low to generate a sustainable income”. The common theme in all descriptions was that small-scale farming was associated with non-commercial activities.

Geolocation appeared significantly associated with the definition of a small-scale farm across the different species (Chi^2 $P < 0.001$, Fig. 3). For cattle, most veterinarians in the Balkans and Southern Europe indicated that a small-scale farm had a maximum of five head of cattle. In Central and Northern Europe, the most commonly indicated category for the maximum number of head was between six and fifteen, while in Türkiye, veterinarians most often indicated a maximum of 16 to 30 cattle in a small-scale farm (Fig. 3). Similar differences in maximum farm sizes were observed for the other three species. The most notable differences were found in the definition of small-scale poultry farms, with higher acceptable numbers of poultry in Türkiye and Southern Europe (Fig. 3).

3.3. Results of the exploratory clustering

A hierarchical clustering on principal components (HCPC) was performed using the outcomes of a multiple correspondence analysis (MCA). The MCA incorporated 17 active variables, yielding 41 active variable categories, related to veterinarian characteristics, risk behaviour of small-scale holders, and perceived biosecurity awareness by small-scale holders. A total of 346 responses were analysed. Three dimensions were retained, accounting for 22.02% of the total cumulative variance (Fig. 4). Three clusters were identified, comprising 166, 53, and 127 veterinarians in clusters 1, 2, and 3, respectively.

Cluster 1 was characterised by veterinarians from the Balkan region and Northern Europe, primarily general practitioners (i.e. treating multiple animal species), working in the field, and having some training in biosecurity. They consider that small-scale farmers have very limited awareness of biosecurity concepts. Additionally, they identify the highest-risk activities for disease introduction as introducing new animals into the herd without quarantine, purchasing animals with unknown health status, mixing animals of different species, and allowing visitors free access to the farm.

Cluster 2 consists mainly of veterinarians from Türkiye who have no biosecurity training beyond their veterinary education, up to 20 years of

Table 2
Demographic information of the surveyed veterinarians, including species-specific information based on survey responses.

Species	No. vets	Geolocation					Type of veterinarian*		
		Balkan	Central Europe	Türkiye	Northern Europe	Southern Europe	Field	Mixed role practitioner	Not field
		($n = 114$)	($n = 101$)	($n = 37$)	($n = 49$)	($n = 45$)	($n = 106$)	($n = 52$)	($n = 188$)
Cattle	266	99	59	34	41	33	87	41	138
Pigs	183	80	55	1	20	27	61	32	90
Poultry	167	58	60	13	15	21	40	26	101
Small ruminants	234	89	42	28	42	33	77	39	118

* Field = veterinarian solely working as a field vet. Not field = veterinarian working as company vet, researcher or official ministry vet. Mixed role practitioner: vet working part-time as field vet and part-time in a different role.

Table 3
Predefined expert definitions of small-scale farming and the corresponding definitions provided by 346 responding veterinarians across Europe.

Species	Definitions according to experts	Mean (median) maximum small-scale farm size according to veterinarians	25th and 75th percentile	% veterinarians that did not include a number
Cattle	<5 cows/ fattening calves	<42 (<20)	<7 - <99	25% (n = 65)
Small ruminants	<20 sheep/ goats	<55 (<30)	<20 - <99	23% (n = 58)
Pigs	<5 sows/<10 fattening pigs	<53 (<13)	<5 - <99	29% (n = 65)
Poultry	<50 birds	<218 (<99)	<45- < 150	23% (n = 63)

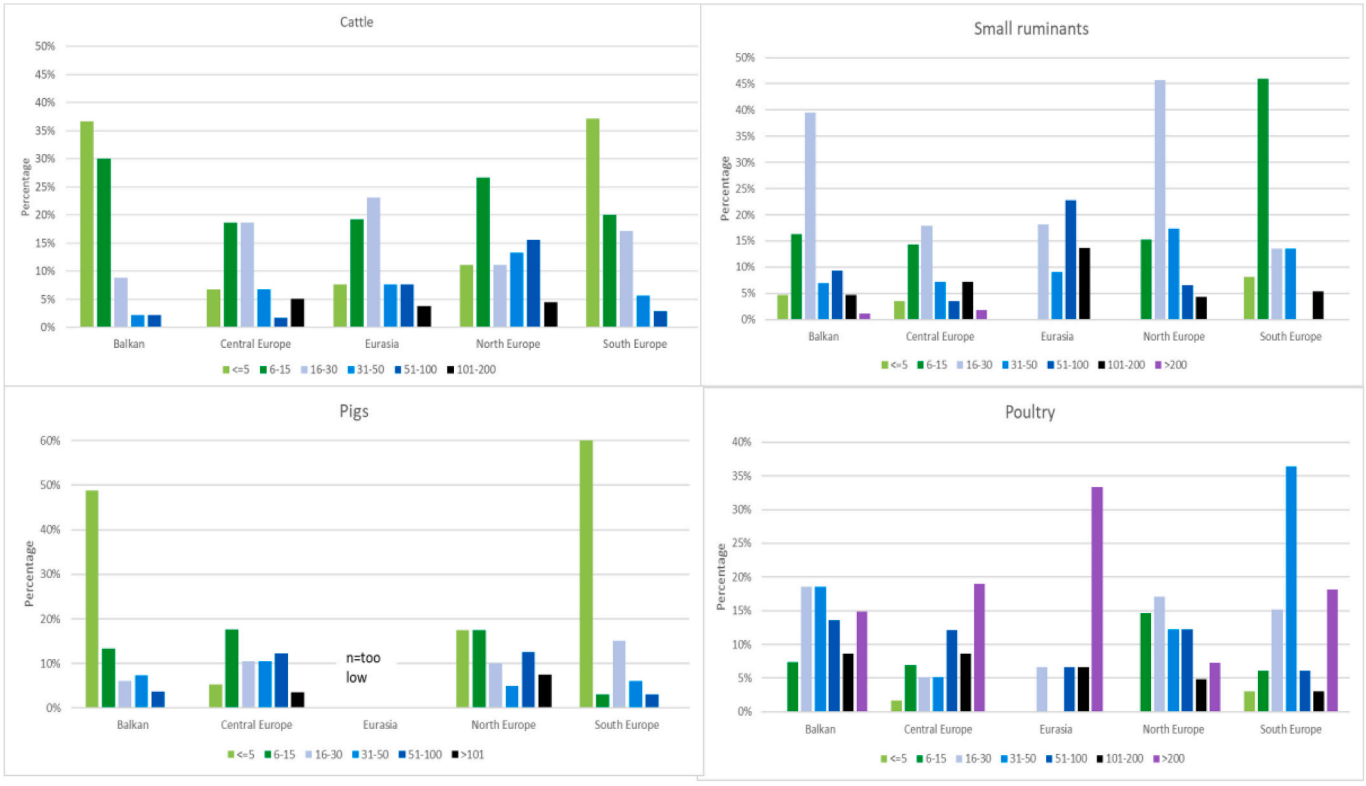

Fig. 3. Distribution of the maximum number of animals in small-scale farms per species across five different regions in Europe. Percentages of veterinarians who provided a qualitative definition of small-scale farming are not included in these graphs.

experience in veterinary practice, and do not work directly in the field (i.e., veterinarians employed by various organizations, companies, veterinary inspectors, researchers, among others). They believe that smallholder farmers have sufficient biosecurity awareness. The primary high-risk activities they associate with smallholder farmers include not regularly cleaning and disinfecting animal housing and introducing new animals into the herd without quarantine.

Cluster 3 is composed of veterinarians from Central and Southern Europe, trained in biosecurity, specialised in a single livestock species, and not working in the field. The risk behaviours they attribute to smallholder farmers include a lack of barriers against wild birds and mammals, failure to use personal protective equipment (e.g. separate clothing and footwear) when entering small-scale farms, outdoor farming, and feeding food waste (including scraps) to animals.

3.4. *Perceptions of biosecurity measures currently implemented by small-scale farmers, according to identified veterinarian clusters*

When asked to name the five biosecurity measures most frequently implemented by small-scale farmers, three measures consistently ranked among the top five for all four animal species (Table 4). According to the veterinarians, the most commonly applied measures were carcass management, perimeter fencing, and biosecurity related to feed purchase. Additionally, for poultry, the most frequently applied biosecurity measure was not sharing equipment and materials with other farmers. This particular measure did not appear among the top five for any other species. There were no differences among the three clusters of veterinarians regarding the five most frequently applied biosecurity measures.

3.5. *Perceptions of the most important biosecurity measures for small-scale farmers, according to each veterinarian cluster*

For all four evaluated species in small-scale farming, biosecurity measures related to the introduction of animals were indicated by veterinarians as the most important for preventing pathogen introduction and spread. From follow-up questions, it was indicated that “presence and use of quarantine facilities” was the underlying factor perceived as most important, followed by “testing animals for their health status before adding them to the herd/flock” and “only purchasing animals from farms with a similar or higher health status”. However, there were significant differences in the perceived importance of animal introduction between the three clusters of veterinarians (Fig. 5). Veterinarians in cluster 3 (Central and Southern Europe) indicated the introduction of animals significantly less often as the most important biosecurity

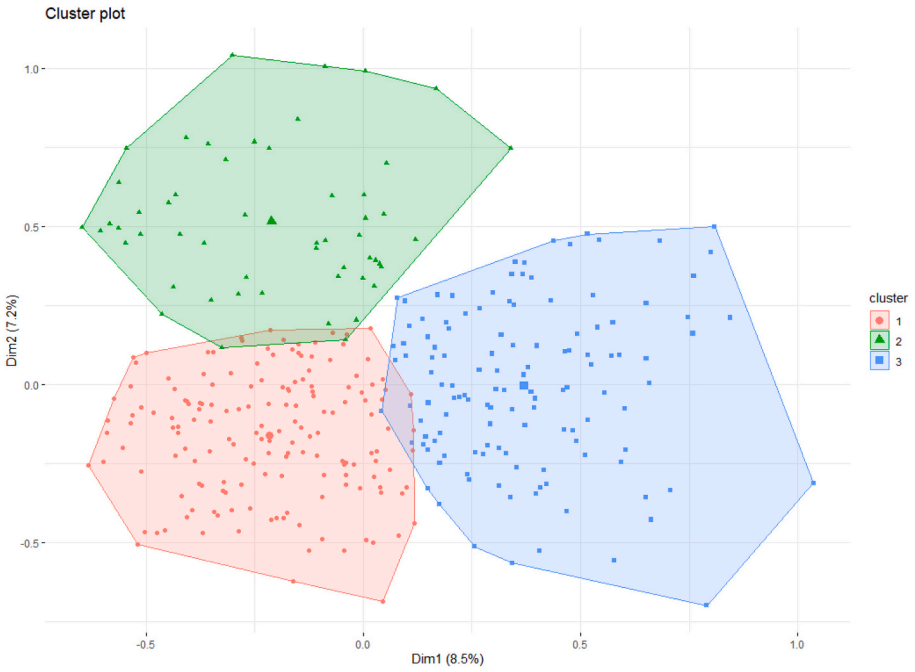

Fig. 4. Visualization of the three clusters resulting from the hierarchical clustering on principal components (HCPC) analysis based on the results of the multiple correspondence analysis (MCA). Clusters were calculated using the first three MCA dimensions (cumulative inertia: 22.02%), but for visualization purposes, the plot displays dimensions 1 and 2. Percentages indicate the proportion of explained inertia for each axis. Points represent characteristics and perceived biosecurity in small-scale farms, as reported by veterinarians across Europe, clustered using Ward's method with the Euclidean distance metric.

Table 4
Ranking of the five biosecurity measures most frequently perceived as implemented in small-scale farms across Europe, by livestock species, according to 346 surveyed veterinarians. Values indicate the rank position assigned by veterinarians to each biosecurity measure within the five most frequently implemented measures for each species (1 = most frequently implemented; 5 = least frequently implemented within the top five).

Biosecurity measures	Poultry	Small ruminants	Cattle	Pigs
Complete fencing around the animal perimeter	2	4	1	2
No shared equipment and materials	1	x	x	x
Separation of different species	x	5	4	x
Washing hands after handling the animals	5	x	x	5
Carcass management	4	1	2	1
Biosecurity related to purchase and feed is implemented	3	2	3	3
No introduction of animals in previous month	x	x	5	x
Separate clothes when contacting animals	x	5	x	4
Separate boots when in contact with different species	x	3	x	x

X indicates that the biosecurity measure was not ranked among the five most frequently implemented measures for the corresponding species.

measure compared to those in cluster 1 (Balkan region and Northern Europe) ($P < 0.05$). Veterinarians in cluster 3 more frequently identified hygiene as the most important biosecurity measure for preventing the introduction and spread of pathogens. The hygiene-related factors specified as most relevant included “presence of disinfection barriers at the barn entrance”, “use of separate boots and/or clothing”, and “manure removal”. Specifically for poultry, “implementation of pest control” and “wild bird control” were also frequently mentioned. Furthermore, veterinarians in cluster 3 more frequently indicated fencing-related measures in pig and poultry small-scale farms as most important for preventing pathogen introduction and spread, compared to veterinarians in cluster 1 ($P < 0.05$). The most important underlying factors included “closed fencing surrounding the entire animal perimeter” for both poultry and pigs, “double fencing” for pigs, and “nets to protect poultry from wild birds” for small-scale poultry farms.

When evaluating the top three measures deemed most important by veterinarians for preventing pathogen introduction and spread, “introduction of animals”, followed by “hygiene” and “fencing” remained the key factors. The cluster difference related to the importance of animal introduction persisted, with veterinarians in cluster 3 (Central and Southern Europe) citing it significantly less often as the most important biosecurity measure compared to those in cluster 1 ($P < 0.05$). However, the difference among the three clusters of veterinarians regarding hygiene were no longer significant. The importance of pig fencing remained significant, with veterinarians in cluster 3 including this measure more frequently in their top three compared to veterinarians in cluster 1. More detailed results related to the top three most important measures for preventing pathogen introduction and spread are provided in Supplementary Material Fig. 3.S1 of this article.

4. Discussion

This study aimed to evaluate farmers' awareness and the implementation levels of biosecurity on small-scale farms across Europe. An overview of biosecurity in this type of farming is relevant, as these farms vary greatly in their structure and purpose. The population of small-scale holders is substantial in every European country, resulting in an impact on local disease dynamics that cannot be ignored.

For this study, veterinarians were surveyed instead of small-scale holders because field veterinarians are believed to be the main point

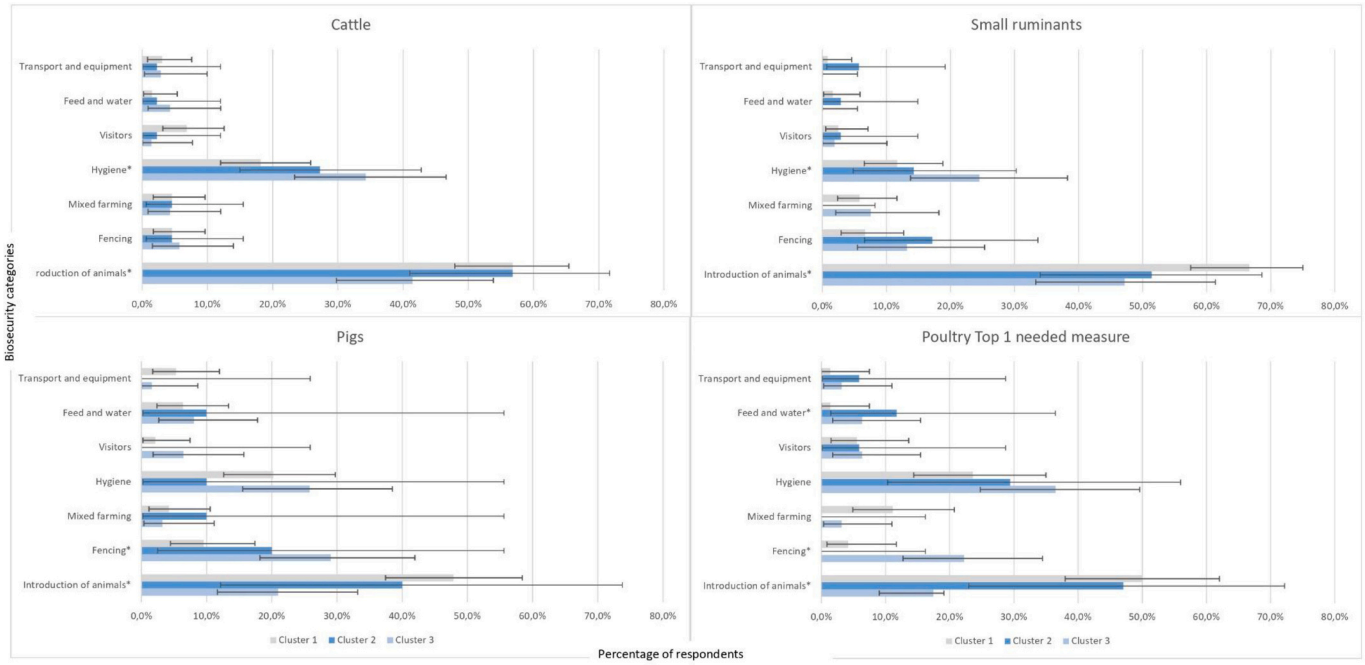

Fig. 5. Most important biosecurity measure(s) to be implemented on small-scale livestock farms to prevent pathogen introduction and spread, as identified by 346 respondents (veterinarians) across Europe. Results are presented by cluster: 166 veterinarians in cluster 1, 53 in cluster 2, and 127 in cluster.

of contact for such farmers regarding health and biosecurity. Therefore, they can provide an unbiased overview of this topic. A key finding was the large variation in how veterinarians define "small-scale" farming. Although the study provided standard thresholds for herd and flock sizes, there was substantial variation in the maximum herd or flock sizes mentioned by veterinarians. These maximum numbers often exceeded the predefined thresholds established by experts. Additionally, approximately a quarter of respondents preferred qualitative definitions, referring to farms as "non-commercial" or "for personal consumption." Given the wide range of definitions, which varied across geographical regions and often included larger herd sizes, it is clear that the operational definition of small-scale farming used in the field is broader than initially assumed. This aligns with previous research suggesting that small-scale farming remains a dominant livelihood strategy in regions such as Eastern and Southern Europe, often blurring the lines between subsistence and professional production (Guarín et al., 2020). Such inconsistencies, combined with differences in legislative frameworks across countries, complicate policy harmonisation and research comparability (Souvestre et al., 2021).

The multiple correspondence analysis (MCA) revealed three clusters of veterinarians, each shaped by regional, professional, and experiential differences. Cluster 1, composed largely of field-based practitioners from the Balkans and Northern Europe, expressed concern about low levels of biosecurity awareness among smallholders. They emphasised risks associated with animal movements, lack of quarantine, and uncontrolled visitor access points that align with documented high-risk behaviours for disease introduction (Alarcón et al., 2021; Benavides et al., 2021; Smith and Dunipace, 2011). In contrast, Cluster 2 primarily included veterinarians from Türkiye, with less field exposure and no formal biosecurity training. They viewed farmers' awareness of biosecurity more positively but identified poor hygiene measures as key vulnerabilities. Cluster 3, which included more specialised veterinarians from Central and Southern Europe, focused heavily on environmental biosecurity, such as pest control and the use of protective clothing, an emphasis often seen in response to zoonotic concerns such as avian influenza (Bavinck et al., 2009).

The perspectives of the veterinarians in the three clusters appear strongly influenced by their contexts. Veterinarians in Cluster 2 seem to be in less frequent contact with small-scale holders than those in Clusters 1 and 3, which may have resulted in a more positive view of biosecurity than that held by field veterinarians drawing on clinical experience and routine interactions with farmers. Conversely, given that A- and B-list diseases such as FMD are endemic and avian influenza occurs regularly in Türkiye, Turkish small-scale holders may have higher disease awareness and therefore higher biosecurity levels. This may also relate to the frequent mention of risk behaviours associated with disease introduction by veterinarians in Cluster 1. In the Balkan region, African swine fever has been associated with high morbidity and mortality in recent years.

Across all clusters, there was agreement on the most commonly implemented biosecurity measures: perimeter fencing, carcass management, and precautions related to feed. However, according to experts from the different countries, the quality of carcass disposal among small-scale farmers varies. During outbreaks of notifiable infectious diseases, carcass disposal is managed and supervised by veterinary authorities and carried out similarly across countries. Nevertheless, outside outbreak periods, animal deaths on small-scale farms occur sporadically, on a weekly or monthly basis. In some participating countries, experts indicated that when an animal dies due to disease, predation, or other causes, the carcass is buried in accordance with national regulations. These burial sites may be located either on the farm perimeter or in a designated communal area used by all farmers in the village. This explains why veterinarians prioritised carcass management. Regardless of whether it is regulated or not, carcass disposal always takes place in some form. The finding that measures such as fencing, carcass management, and feed management are the most frequently applied aligns with earlier studies indicating that visible, tangible, and cost-effective measures are more readily adopted, even in resource-limited settings (Correia-Gomes et al., 2021; Paquette et al., 2020). However, more preventive and systematic measures, particularly those relating to the introduction of new animals, were identified as being less widely adopted but critically important. Interestingly, poultry farms stood out in several respects. Measures such as avoiding shared equipment and controlling access by wild birds were mentioned more frequently. This may reflect heightened public and veterinary awareness of avian influenza risks, which have directly affected backyard flocks during past

outbreaks (Souvestre et al., 2021; Bavinck et al., 2009).

While the hierarchical clustering on principal components (HCPC), based on multiple correspondence analysis (MCA), provided valuable insights into the diversity of veterinary perspectives across Europe, several methodological limitations must be acknowledged. MCA-HCPC is exploratory and identifies associations without providing causal inferences, reflecting co-occurrences rather than independent subgroups. The structure and interpretation of clusters are influenced by the selection and coding of categorical variables, which entails some subjectivity that may affect the stability and generalisability of the clusters (Blasius and Greenacre, 2006). Consequently, the clusters should be interpreted as indicative patterns rather than definitive typologies. Additionally, uneven geographical representation, with countries such as Ukraine and Serbia being highly represented, while others like France, Sweden, and Croatia had only one respondent, may have skewed cluster composition (Gale et al., 2013). Despite these limitations, this study addresses an important gap by offering structured, comparative insights into how veterinary professionals perceive biosecurity challenges in small-scale systems across Europe. These findings can inform regionally adapted strategies for training, policy development, and farm-level interventions.

Although the study provides valuable insights, it lacks direct input from smallholders and on-farm audits. Future research should incorporate these perspectives to achieve a deeper understanding of biosecurity practices and the barriers farmers face. Mixed-method studies combining veterinary input with on-farm observations and farmer interviews, as well as longitudinal studies, could offer a more comprehensive view of biosecurity practices and their evolution over time. Nevertheless, veterinarians act as key players, as they are well positioned to serve as trusted advisors, providing technical support and enhancing biosecurity adoption and behavioural change (Duarte et al., 2025; Loeillot et al., 2025). A limitation of our study design was its reliance on local contact points for recruiting veterinarians, as well as the willingness of these veterinarians to participate. This dependency led to notable differences in response rates, which precluded country-level analysis. For instance, countries such as France and Sweden were underrepresented with only one respondent each, whereas Ukraine and Türkiye had more than 30 respondents. These disparities in response rates may be associated with the perceived importance of the topic or broader cultural norms. Specifically, it was significantly more challenging to engage veterinarians from Western European countries compared to those from Eastern and Southeastern Europe. To partially address the imbalanced response rates, we conducted a cluster analysis, which allowed us to combine responses from Northern and Western European countries. Despite this adjustment, the external validity of our findings remains limited for countries with very low participation. Therefore, a follow-up evaluation focusing on Western Europe, where additional knowledge about biosecurity in small-scale farms could be gathered, would be highly advisable. This would help to ensure a more balanced and comprehensive understanding of biosecurity practices across different regions.

The findings from this study highlight the need for more nuanced and inclusive policy frameworks that reflect the diversity and contextual differences of small-scale and backyard farming systems across Europe.

While biosecurity regulations have traditionally focused on commercial operations, small-scale farms can contribute to disease persistence and spread when biosecurity measures are inconsistently applied (Holloway, 2019; Bavinck et al., 2009). Current frameworks tend to overlook specific constraints such as limited resources, lack of infrastructure, and minimal access to veterinary services (Di Francesco et al., 2025; Guarín et al., 2020). To address these gaps, policies should support flexible, context-aware biosecurity standards and harmonise the definition of "small-scale farming" at national and EU levels. In studies conducted in other regions (e.g., the USA), the importance of tailoring interventions to smallholders to improve farm biosecurity and minimise the risk of disease spread has also been highlighted. (Fonseca-Martinez et al., 2025; Lee et al., 2022).

Targeted veterinary outreach and farmer education, tailored to local farming cultures and languages, are critical, especially in regions with lower levels of field involvement or biosecurity training. Biosecurity training programmes should include both farmers and veterinarians, particularly in countries where smallholder systems dominate. Facilitating cross-country collaboration and knowledge exchange through networks such as COST Action BETTER can help adapt policies to practical realities (Moiane, 2025; Morris et al., 2023a). Ultimately, effective biosecurity policy must balance science-driven guidance with field-level feasibility, ensuring that smallholders are equipped, supported, and motivated to contribute to broader animal, environmental, and public health goals.

5. Conclusion

This study provides the first Europe-wide overview of how veterinarians perceive biosecurity awareness and implementation in small-scale and backyard farming systems. The findings underscore the importance of integrating small farms into "One Health" strategies, given their potential role in the transmission of zoonoses and the development of antimicrobial resistance.

Respondents reported substantial variability in biosecurity awareness and adoption among smallholders, influenced by geography, species, and farming context. Notably, the definition of what constitutes a "small-scale" farm varied considerably, reflecting the absence of a standardised classification and highlighting the need for greater policy clarity. Despite often being excluded from mainstream biosecurity frameworks, small-scale farms remain embedded within broader livestock networks and can influence infectious disease dynamics, particularly where preventive measures are inconsistently applied.

Small-scale farming systems, whether subsistence-oriented or semi-commercial, require greater recognition within national and European biosecurity strategies. Supporting both farmers and veterinarians through targeted training, accessible resources, and context-sensitive policies will be essential to improving disease prevention and building more resilient livestock systems across the continent.

CRediT authorship contribution statement

F. Duarte: Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation. **J. Prodanov-Radulović:** Writing – review & editing, Supervision, Formal analysis. **B. Mehmedi:** Writing – review & editing, Validation, Investigation. **A. Piccirillo:** Writing – review & editing, Validation, Investigation, Formal analysis. **M. Stukelj:** Writing – review & editing, Validation, Investigation. **E. Kldiashvili:** Writing – review & editing, Validation, Investigation. **V. Nedosekov:** Writing – review & editing, Validation, Investigation. **B. Milovanovic:** Writing – original draft, Validation, Investigation. **N.D. Ayaz:** Writing – review & editing, Validation, Investigation. **R. Yildiz:** Writing – review & editing, Validation, Investigation. **S. Meling:** Writing – review & editing, Validation, Investigation. **I. Toftaker:** Writing – review & editing, Validation, Investigation. **A. Sirbu:** Writing – review & editing, Validation, Investigation. **A. Dodovski:** Writing – review & editing, Validation, Investigation. **A. Allepuz:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **A. Zbikowski:** Writing – review & editing, Validation, Investigation. **Xh. Koleci:** Writing – review & editing, Validation, Investigation. **C. Berger:** Writing – review & editing, Validation, Investigation. **J. Starič:** Writing – review & editing, Validation, Investigation. **M.E. Filippitzi:** Writing – review & editing, Validation, Investigation. **L. Moskalenko:** Writing – review & editing, Validation, Investigation. **L. Gresakova:** Writing – review & editing, Validation, Investigation. **I. Chantziaras:** Writing – review & editing, Validation, Investigation, Conceptualization. **K. Berggren:** Writing – review & editing, Validation, Investigation. **M. De Nardi:** Writing –

review & editing, Validation, Investigation. **G. Graziosi:** Writing – review & editing, Validation, Investigation. **I.M.G.A. Santman-Berends:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could represent potential competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rvsc.2026.106089.

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