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Implementation of biosecurity measures according to legislation in intensive poultry production: An overview across 22 EU and non-EU countries

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A R T I C L E I N F O

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A B S T R A C T

Biosecurity implementation in poultry production is essential for maintaining flock health and preventing diseases. Regulatory frameworks play a key role in standardising biosecurity practices and ensuring compliance among stakeholders. However, there is limited information on how biosecurity measures (BMs) are legally enforced across different European countries. This study aimed to identify which BMs are mandated by legislation and/or other regulatory frameworks in 22 EU and non-EU countries for intensive poultry production. Using a participatory approach involving poultry experts from these 22 countries, data collection and validation were conducted through a questionnaire covering eleven biosecurity categories and comprising 56 BMs. The survey was carried out between December 2022 and December 2023. The number of BMs mandated by legislation for all poultry species varied considerably across countries. Turkey (52), Ukraine (46), and Slovakia (38) had the highest numbers, whereas Denmark, Sweden, and Finland had none. The most regulated BMs included rodent control programs, cleaning and disinfection after each production cycle, and physical or natural farm barriers. Conversely, the least regulated BMs included farm-exclusive personnel and external silo loading, with no regulations concerning keeping other farm animals, poultry species, or pets. Broiler and layer farming were subjected to more compulsory BMs than other poultry species. Additionally, twelve countries reported BMs under other regulatory frameworks, with Serbia (55), Turkey (53), and Poland (49) having the highest numbers, while Sweden (27), Finland (26), and Norway (25) had the lowest. The most regulated BMs included designated clothing and footwear, hygiene locks, and clean house surroundings. The least regulated BMs were related to silo loading, manure collection, and a parking area outside the farm. There was considerable variation in the number and type of BMs mandated by legislation across countries, likely influenced by each country's perceived disease risk. These findings highlight the importance of establishing a harmonized biosecurity framework at the European level to address regulatory heterogeneity and enhance disease prevention in poultry production.

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1. Introduction

The poultry industry is a vital sector of livestock production and one of the fastest-growing sub-sectors worldwide (OECD-FAO, 2023). By 2050, the demand for poultry meat and eggs is projected to increase by 50 % and 40 %, respectively, making poultry an essential source of affordable, high-quality protein (Franzo et al., 2023). Currently, industrial poultry production is predominantly focused on broiler chickens and laying hens, with turkeys, ducks, geese, and other minor poultry species contributing to the sector on a smaller scale (Korver, 2023).

According to the Food and Agriculture Organization (FAO), the European Union (EU) produced approximately 96 billion table eggs in 2021, predominantly from laying hens (FAO, 2023). Similarly, the EU's poultry meat output was estimated at 13 million tonnes in 2022, making it one of the world's largest poultry meat producers (FAO, 2023). However, this output has declined in recent years due to recurring outbreaks of Highly Pathogenic Avian Influenza (HPAI) (Lambert et al., 2022; European Food Safety Authority (EFSA) et al., 2023). These outbreaks highlight the significant impact of infectious disease on the poultry industry and the urgent need to implement measures to prevent the introduction and spread of infectious agents.

Implementing biosecurity measures (BMs) is a key strategy for preventing the introduction and spread of infectious diseases within and between farms (Van Limbergen et al., 2018; Delpont et al., 2023; Saegerman et al., 2023). Beyond preserving animal health, effective biosecurity plays a crucial role in public health, as it reduces the risk of poultry products being contaminated by foodborne zoonotic pathogens such as *Salmonella* and *Campylobacter* (Horvat et al., 2022; Zaki et al., 2023). Additionally, by enhancing poultry performance (de Castro Burbarelli et al., 2017), the implementation of and compliance with BMs help to reduce the overuse of antimicrobials, addressing the pressing issue of antimicrobial resistance (Dhaka et al., 2023). Despite the well-established benefits, low compliance with BMs, including inadequate control of personnel and visitor entry, hygiene lock use, and vehicle flow management, continues to be a concern on European poultry farms (Laconi et al., 2023; Souillard et al., 2024). This emphasises the need for targeted efforts to improve biosecurity compliance and ensure a safer, more sustainable poultry production.

The Council of Europe has emphasised the pivotal role of biosecurity in preventing the introduction and spread of animal diseases across the European Union (EU) territories through an integrated approach involving all Member States and fostering cooperation across relevant sectors and actors (European Commission, 2016). While EU regulations exist regarding transmissible animal diseases (EU, 2016/429), they do not include specific rules on biosecurity measures, resulting in flexibility for Member States in how these measures are implemented and enforced. This flexibility, however, may contribute to variation in national approaches and pose challenges to achieving a coherent and consistent application of biosecurity practices across Europe. Previous studies have suggested significant variability among countries, highlighting a lack of standardised measures and regulations at national level (Dewulf and Van Immerseel, 2019; Mallioris et al., 2023). Despite the well-recognised benefits of biosecurity measures, there is still limited information on how these measures are implemented and legally enforced across different European countries, particularly within existing regulatory frameworks.

The objective of this study was to provide an overview of BMs regulated by legislation and other regulatory frameworks in poultry production across 22 EU and non-EU countries. The study was conducted within the COST Action (CA20103) - Biosecurity Enhanced through Training Evaluation and Raising Awareness (BETTER).

2. Materials and methods

2.1. Questionnaire

A questionnaire was developed within COST BETTER to collect information on the implementation of BMs according to legislation and/or other regulatory frameworks, as well as the level of BMs implementation in poultry farms (Table 1). The focus was on intensive poultry farming systems, including broilers, layers, ducks, turkeys, breeders, and other minor poultry species. Out of the 47 countries participating in the COST BETTER (BETTER Newsletter 7), the questionnaire was distributed to 27 countries where a Country Focal Point (CFP)/Poultry expert was available.

Three sections (Biosecurity legislation, Biosecurity other than law, and Biosecurity implementation; (Supplementary materials) were included in the questionnaire. The first section collected information on BMs mandated by legislations, regulations and legal recommendations enforced at the European, national and/or regional levels within each country. The second section gathered similar data on BMs required by other regulatory frameworks, such as those set by integrated companies or farm protocols. The third section focused on the level of BMs implementation. This study reports only the outcomes related to the first two sections of the questionnaire.

Each question in the first two sections had four response options: “YES (mandatory)”, “YES (recommended)”, “PARTLY”, and “NO”. “YES (mandatory)” referred to BMs mandated by any legislation such as laws, decrees, regulations, directives, or guidelines issued by relevant legal authorities, e.g. European Commission and/or national/regional authorities, or by other regulatory frameworks. “YES (recommended)” indicated that the BMs were recommended by the same authorities. “PARTLY” referred to BMs that were either not applied to all poultry species or only partially enforced. “NO” referred to BMs with no evidence of being legally mandated or recommended by any authority.

If a BM was mandatory across all poultry species, the “ALL” option was selected. If a BM did not apply to all poultry species, the “PARTLY” option was chosen, with additional notes provided for clarification. Before dissemination within the COST BETTER network, the questionnaire was pretested by two poultry biosecurity experts during a validation session, and minor adjustments were made based on their feedback.

2.2. Data collection

One questionnaire per country was sent via email to the CFPs within the COST BETTER network. CFPs were identified on a voluntary basis within the network. They were responsible for completing the questionnaire, either independently or in collaboration with other poultry experts (designated by the CFP) from their country. In cases where the CFP was not a poultry expert, they consulted with or delegated the task to qualified national experts to ensure accurate data reporting. The

Table 1
Overview of the questionnaire structure. The questionnaire was structured into eleven biosecurity categories, investigating a total of 56 biosecurity measures (BMs).

Biosecurity categories	No. of measures in each category
Farm delimitation	5
Entrance of vehicles into the farm	3
Personnel and visitors	6
Entrance of people into the farm	7
Poultry house	9
Equipment and materials	4
Cleaning and disinfection	5
Food and water supply	5
Dead-bird disposal	3
Litter and manure management	7
Pest control	2

professional affiliations of all contributors are provided to support the credibility of the data sources. Prior to dissemination, an online training session was conducted to standardise the data collection process. CFPs were asked to complete the questionnaire between December 2022 and December 2023, and return it to the research team. After submission, individual online meetings were held with each CFP to validate the information and clarify any potential misunderstandings. A participatory approach was adopted to ensure comprehensive and standardised data collection (Fig. 1).

2.3. Data analysis

Data from the validated questionnaires were compiled into a Microsoft Excel® (version 365) spreadsheet. Descriptive statistics was performed to assess the extent to which BMs were regulated by legislation across countries and to identify the most and least regulated BMs. Three datasets were created, covering I) all poultry species, II) broilers, and III) layers. Broilers and layers were analysed separately due to their economic significance in poultry production within the participating countries. Responses from the first section of the questionnaire (i.e., legislation enforced at the national and/or regional level) were converted into ordinal data using a scoring system. The highest score was assigned to BMs fully mandated by legislation, while the lowest score was given to BMs with no regulatory enforcement. For the dataset covering all poultry species, two additional response options were included: I) “PARTIALLY” when the BM was required only for a specific poultry species (e.g., broiler, layer, turkey, etc.); and II) “PARTLY/PARTIALLY” when the BM was only partly present in the legislation and applied to a specific poultry species. The final scoring system was as follows: “YES (mandatory)” = 5, “YES (recommended)” = 4, “PARTIALLY” = 3, “PARTLY” = 2, “PARTLY/PARTIALLY” = 1, “NO” = 0. Empty cells in the broiler and layer datasets were replaced with “NO” as response option. To explore potential associations or differences between countries regarding BMs regulation, heatmaps based on hierarchical clustering and Euclidean distance were generated using the pHeatmap package (version 1.0.12) in R (version 4.3.1) (https://www.r-project.org/). Hierarchical clustering was used to group similar data points by iteratively merging clusters based on their similarity. Euclidian distance was calculated using the “dist” function. The resulting dendrogram was visualized alongside a heatmap to highlight relationships between data points. For BMs required by other regulatory frameworks, a descriptive analysis was conducted using Microsoft Excel® (version 365) to determine which countries provided data, the levels at which the data were collected, and the poultry species covered. Due to the limited data available per country, a formal statistical analysis could not be conducted.

3. Results

Out of the 27 countries to which the questionnaire was initially distributed, no response was received from two countries (i.e., Germany and the Republic of Cyprus), while data from three countries (i.e.,

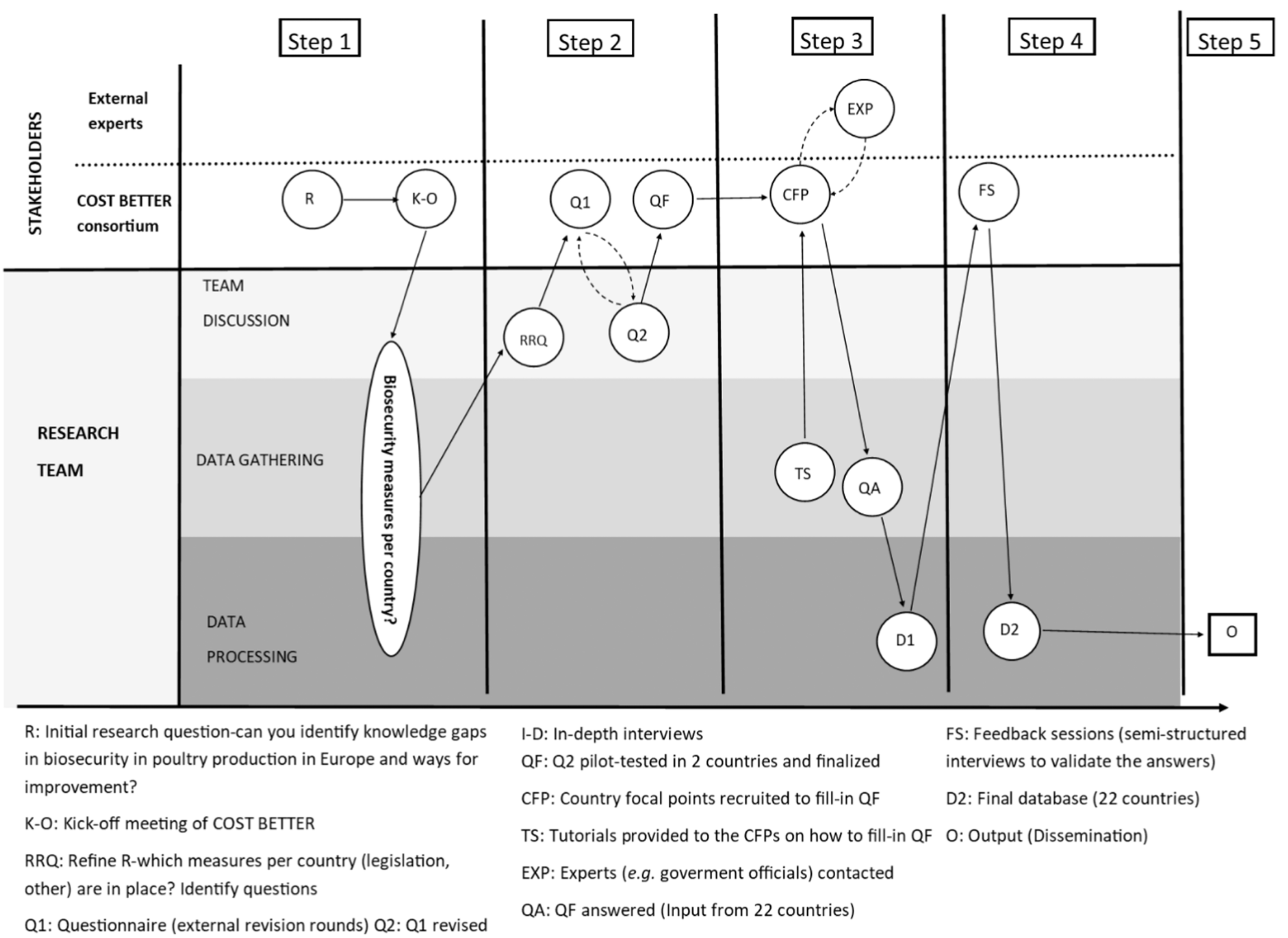

Fig. 1. Stepwise process of data collection. The schematic diagram illustrates the multi-step participatory approach adopted in this study, involving collaboration between the research team and stakeholders, including external experts and the COST BETTER consortium. The process encompassed several key steps: identifying knowledge gaps, designing and refining the questionnaire, and collecting data through Country Focal Points (CFPs)/Poultry experts.

Romania, Montenegro, and Portugal) were received but not validated. Consequently, data from 22 countries, including fourteen EU Member States (i.e., Belgium, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, the Netherlands, Poland, Slovakia, Spain, and Sweden), five EU candidate countries (i.e., Turkey, Serbia, Kosovo, North Macedonia, and Ukraine), one European Economic Area (EEA) member state (i.e., Norway), and two EU Near Neighbourhood or COST Member Countries (i.e., Israel and Tunisia) were validated and analysed. All countries provided information regarding BMs implemented at the national level, with none indicating any specific rules at the regional level. Fig. 2 summarises the countries' response to the questionnaire.

3.1. BMs mandated by legislation

The number of BMs mandated by legislation varied considerably across countries. Turkey (n = 52/56, 92.8 %), Ukraine (n = 46/56, 82.1 %), Slovakia (n = 38/56, 67.9 %), and Kosovo (n = 37/56, 66.1 %) reported the highest number of mandatory BMs, while Denmark, Sweden, and Finland stated that no mandatory BMs were legally mandated for all species (Fig. 3).

Hierarchical clustering of ordinal data from the 56 BMs across all poultry species revealed a large cluster of countries where BMs were mostly unregulated or only partially regulated by legislation (Fig. 4). Additionally, two smaller clusters emerged: one consisting of major European poultry producers (e.g., Italy and France) and another comprising primarily EU Candidate Countries (i.e., Kosovo, Serbia, Turkey, and Ukraine) and EU Near Neighbour or COST Member Countries (i.e., Israel and Tunisia). These two clusters exhibited a higher number of BMs regulated by legislation. The clustering analysis further revealed that countries with higher poultry production densities, such as Italy, France, and Spain, tended to have more comprehensive and stringent biosecurity regulations. In contrast, a larger group of countries showed limited or partial legislative regulation of BMs, particularly those with smaller or less intensive poultry sectors. This pattern suggests that production intensity may influence the extent to which biosecurity is formally regulated, possibly reflecting both risk perception and national priorities in animal health governance.

The analysis of the broiler (Supplementary Material, Figure S1) and layer (Supplementary Material, Figure S2) datasets showed similar results. This pattern may be explained by the economic and strategic importance of broiler and layer production systems within the poultry sector, which typically operate at larger scales and higher animal densities than other poultry types. These intensive production systems are associated with increased risks of disease spread, including notifiable diseases such as avian influenza and zoonotic infections like *Salmonella spp.* Consequently, they are more frequently prioritized in national legislation and biosecurity frameworks to mitigate economic losses, safeguard animal health, and protect public health (EFSA Panel on Animal Health and Welfare (AHAW), 2023; FAO, 2021; European Commission, Directorate-General for Health and Food Safety, 2020). In detail, four main clusters were identified in both heatmaps, representing: I) countries where almost all BMs were mandatory (or recommended) by legislation (i.e., Serbia, Turkey, Ukraine, Kosovo, and Slovakia); II) countries where more than half of the BMs were mandatory or recommended (i.e., Hungary, Italy, and Spain); III) countries where less than half of the BMs were regulated by legislation (i.e., Israel, Tunisia, France, Greece, Poland, Denmark, and Norway); and IV) countries where only few BMs were regulated by legislation (i.e., North

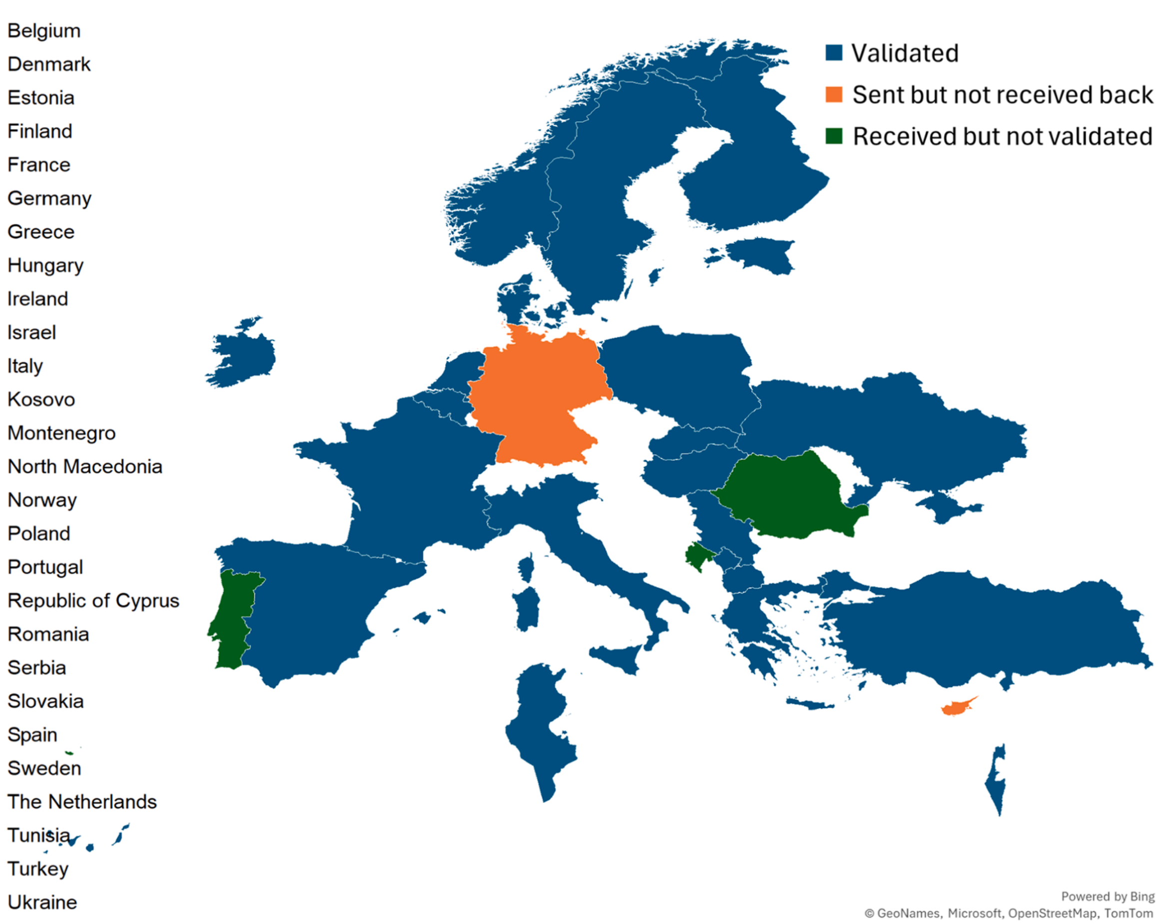

Fig. 2. Response status to the questionnaire by participating countries. The map displays the response status across 27 participating countries. Countries are colour-coded based on their response.

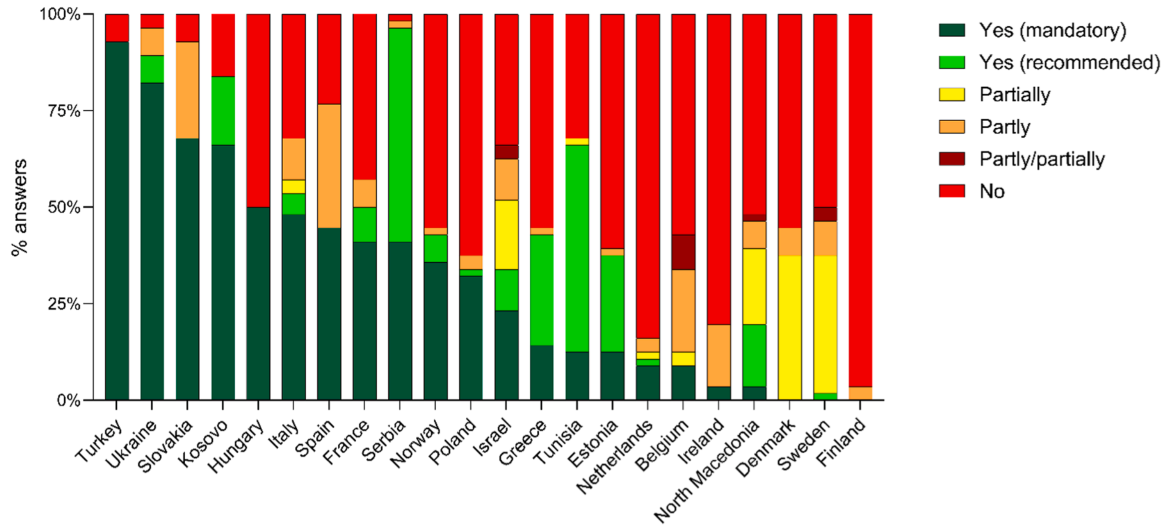

Fig. 3. Number of BMs regulated by legislation in each country. The legend shows different response options: "YES (mandatory)" refers to BMs mandatory by legislation. "YES (recommended)" indicates BMs recommended by legislation. "PARTIALLY" refers to BMs that were mandatory only for a specific poultry species. "PARTLY" refers to BMs that were either not applied to all poultry species or only partially fulfilled. "PARTLY/PARTIALLY" refers to BMs that were only partly present in the legislation and valid for a specific poultry species. NO" refers to BMs with no evidence of being legally mandated or recommended by any authority.

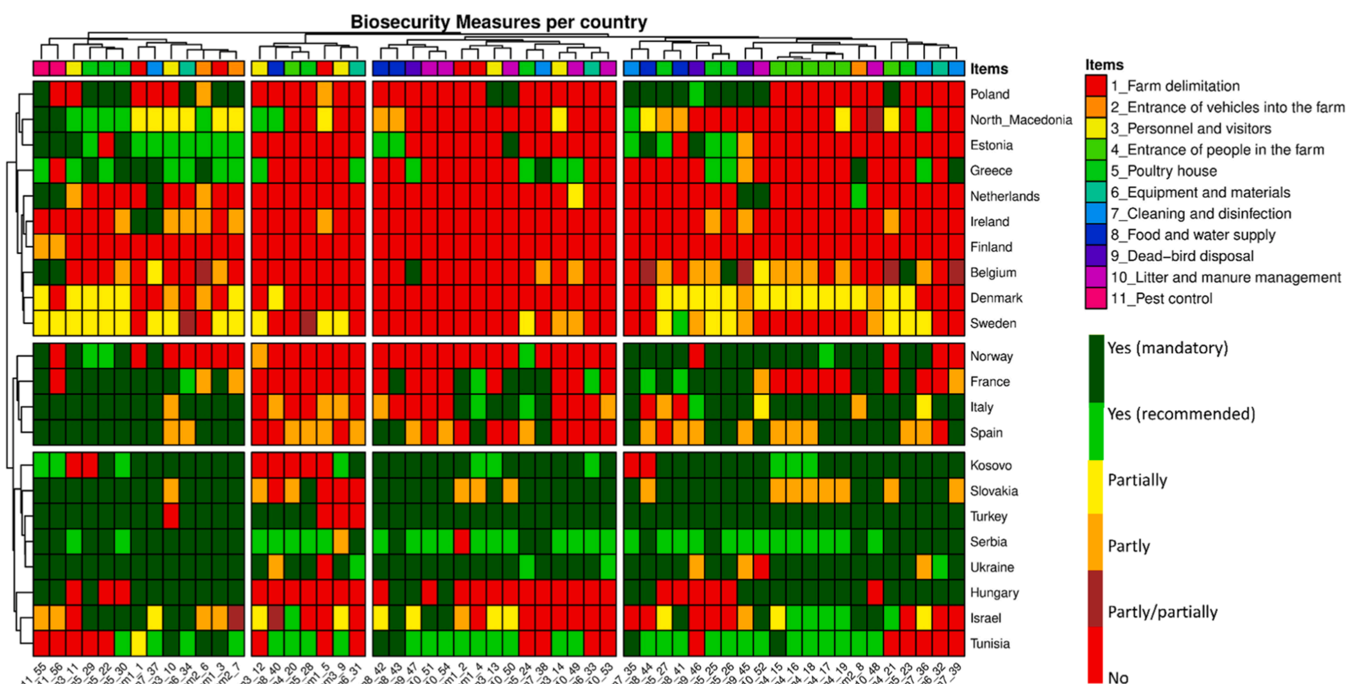

Fig. 4. Heatmap showing hierarchical clustering of countries and BMs. The heatmap illustrates the clustering of countries and BMs according to their regulation, based on ordinal data including all poultry species. The colour-coding represents the degree of implementation: green for "YES (mandatory)", light green for "YES (recommended)", yellow for "PARTIALLY", orange for "PARTLY", brown for "PARTLY/PARTIALLY", and red for "NO." The hierarchical clustering at the top groups the BMs, while the clustering on the left groups the countries, highlighting patterns and similarities in biosecurity practices across the different participating countries.

Macedonia, Estonia, Ireland, Sweden, Finland, the Netherlands, and Belgium).

When considering individual BMs, nine were found to be legally mandatory for all poultry species in at least half of the countries. These included measures related to farm delimitation, entrance of vehicles into the farm, poultry house, cleaning and disinfection, and pest control Conversely, six BMs from different categories (i.e., farm delimitation, personnel and visitors, entrance of people into the farm, poultry house, equipment and materials, and food and water supply) were legally mandated in fewer than 10 % of participating countries. The most regulated BMs were rodent control programs (n = 14/22, 63.3 %), cleaning and disinfection of the poultry house after each production cycle (n = 13/22, 59.1 %), and the presence of physical (e.g., fences) or natural (e.g., trees) barriers surrounding the farm area (n = 12/22, 54.5 %). Among the least regulated BMs, there were personnel working exclusively on one farm (n = 1/22, 4.5 %), and the loading of silo outside the farms (n = 1/22, 4.5 %). No country regulated the presence of other farm animals, poultry species, or pets on the farms, through legislation.

3.2. BMs mandated by other regulatory frameworks

Regarding BMs mandated by other regulatory frameworks (e.g., integrated poultry industry or farm protocols), twelve out of 22 participating countries reported data (Fig. 5). Among the countries with the highest number of BMs regulated by non-legislative frameworks across the different poultry species, Serbia led with 55 out of a total of 56 BMs, followed by Turkey (n = 53/56), and Poland (n = 49/56). In contrast, Sweden (n = 27/56), Finland (n = 26/56) and Norway (n = 25/56) reported the lowest number of BMs (Fig. 6) mandated by other regulatory frameworks. Ten countries (i.e., Estonia, France, Israel, Italy, Kosovo, North Macedonia, Slovakia, Spain, Tunisia, and Ukraine) did not report any data on BMs mandated by non-legislative frameworks. Poland provided data at the regional level, while Serbia reported at both national and regional levels. All other countries reported only at the national level.

Regarding poultry species, Belgium and Denmark reported compulsory BMs beyond legal requirements for broilers, layers, and breeders, while Finland reported compulsory BMs for broilers, layers, breeders, and turkeys. Greece, Hungary, Ireland, Norway and North Macedonia did not provide species-specific data. The Netherlands reported BMs for layers, while Poland covered broilers and breeders. Serbia, Sweden, and Turkey reported BMs for all poultry species, with minor poultry species reported by Serbia.

4. Discussion

At the European level, BMs for the poultry sector are governed by various regulations and directives established by the EU Commission. For example, Regulation (EU) 2016/429, known as the Animal Health Law (AHL), has been in force since 2021 and represents a significant step toward managing transmissible animal diseases within the EU. In addition to the AHL, other regulations govern the movement of poultry and hatching eggs within the EU (EU, 2005, 2016, 2019, 2020a, 2020b). While these regulations play a pivotal role in protecting animal and public health, they often do not specifically address biosecurity in animal production. In routine on-farm practices, there is limited actionable guidance from these regulations. To better support farmers, veterinarians, and other stakeholders, more specific guidelines on biosecurity appear to be needed both at the European and national levels. The findings of the present study suggest that a more clear and comprehensive biosecurity act at the European level should be in place. European countries could then adapt and regulate the implementation of BMs according to their national circumstances and epidemiological situation.

Using a participatory approach for data collection offered several advantages. By involving stakeholders such as CFPs and external poultry experts, we ensured that the data captured the diverse biosecurity scenarios across participating countries, considering their unique disease contexts, national regulatory frameworks, and farming practices. The iterative refinement of the questionnaire, from the initial identification of knowledge gaps to pilot testing and revision, allowed us to continuously improve its relevance and accuracy. This iterative enhancement was crucial in ensuring that the data gathered were comprehensive and representative of diverse regulatory environments. Additionally, providing tutorials on completing the finalized questionnaire ensured consistency and clarity in responses, reducing variability and misunderstandings in data reporting. Subsequent validation through expert consultations and feedback sessions further improved data reliability.

While this approach enhanced data quality, several limitations must be acknowledged. This study relied on self-reported data provided by Country Focal Points (CFPs), which may have introduced bias due to varying levels of expertise consulted and differences in the availability and interpretation of national data across countries. Furthermore, the questionnaire was not always completed exclusively by the CFPs; in some cases, it was filled out collaboratively with national poultry experts or solely by experts designated by the CFPs. Although this flexibility was necessary to accommodate national contexts, identifying and engaging the most knowledgeable individuals to provide accurate and representative information proved challenging and was time-consuming. Additionally, the results presented in this study reflect the period during which data were collected in each country. It is possible that some countries have since introduced new legislation that is missing in this study.

Our findings indicate that certain biosecurity categories such as "Poultry House" (88 regulations across participating countries) and "Equipment and Materials" (71 regulations) were the most commonly reported as mandated by legislation, reflecting their fundamental role in ensuring poultry health. This trend highlights the prioritization of physical structures and critical resources in maintaining biosecurity standards. In contrast, categories like "Pest Control" (21 regulations) and

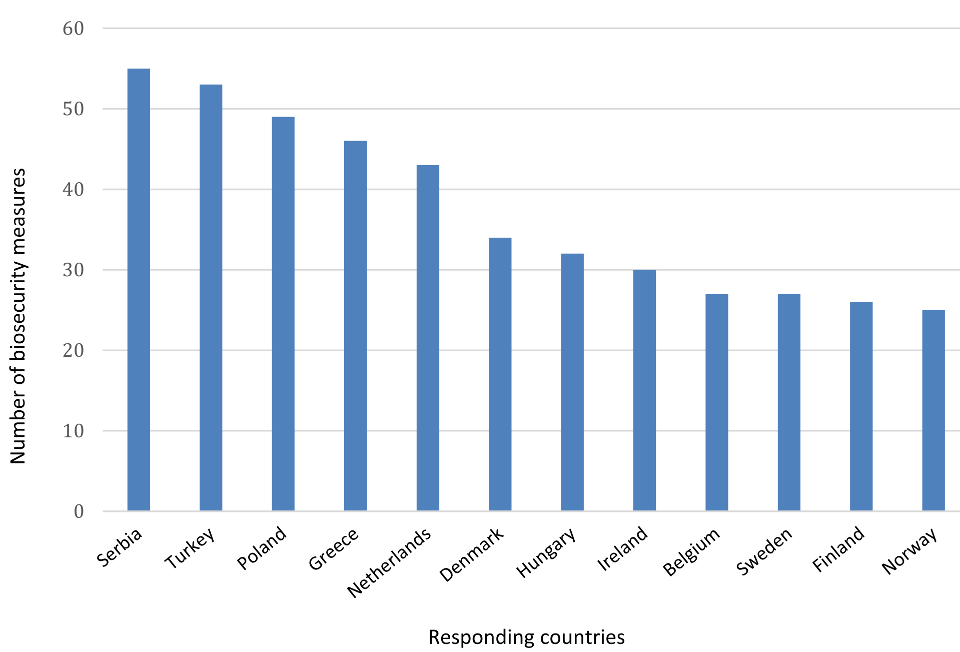

Fig. 5. Number of biosecurity measures (BMs) regulated by other regulatory frameworks in each country.

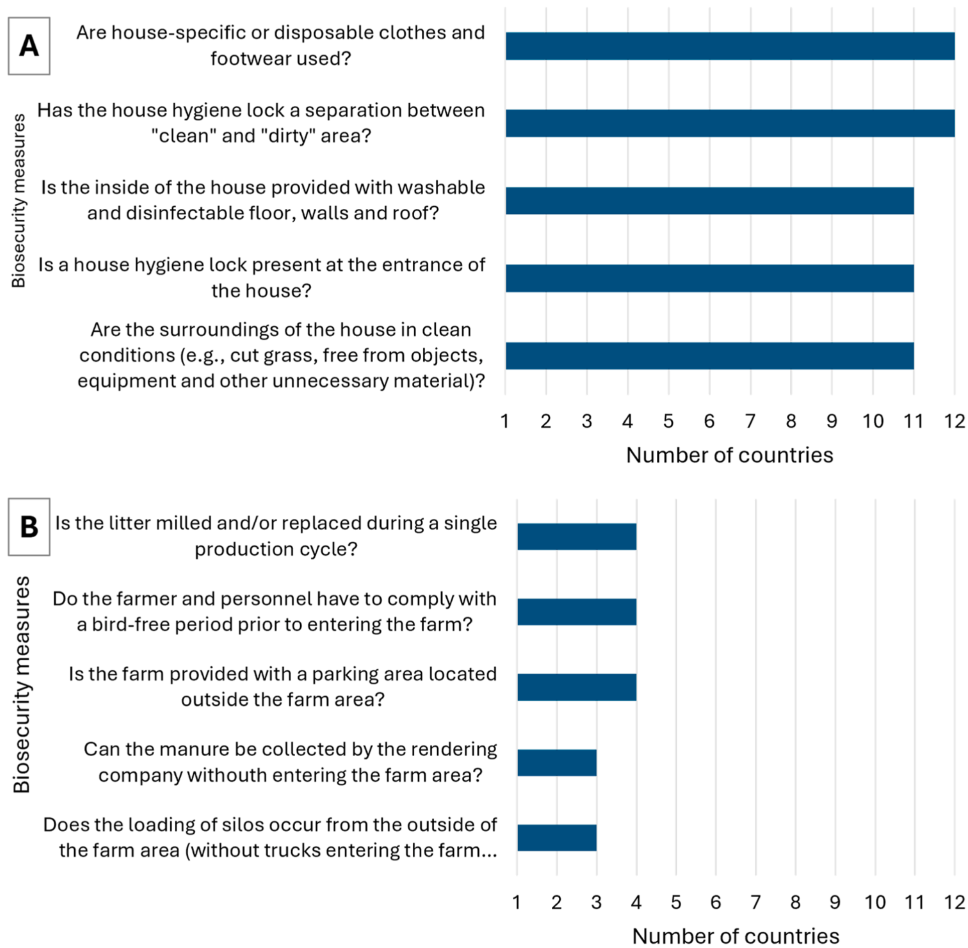

Fig. 6. The most (A) and least (B) regulated BMs by other regulatory frameworks. The frequency indicates the number of countries where these BMs were regulated, out of twelve countries that reported data.

"Entrance of Vehicles" (20 regulations) were less frequently reported as regulated, indicating that while they remain important, they may not be perceived as immediate risks compared to housing, food, and water supply. The most regulated BMs were those with a direct impact on reducing disease transmission and enhancing biosecurity (European Commission, 2019). Previous studies have shown that the regulation and compliance with these measures are crucial in mitigating disease risks, particularly in the EU, where poultry production is mostly executed by integrated companies (Chowdhury et al., 2012; Tilli et al., 2022; Delpont et al., 2023). Moreover, the importance of these biosecurity practices is often emphasised in national biosecurity compliance assessments, which prioritize them due to their proven efficacy (Gelaude et al., 2014). These infrastructure-related measures are frequently considered key indicators of a farm's overall biosecurity status, correlating directly with its ability to prevent disease outbreaks (Van Limbergen et al., 2018; Correia-Gomes and Sparks, 2020). Another potential reason for these BMs being more frequently regulated could be their easiness of checking/enforcement, as they are highly visible.

However, the absence of regulations for some BMs, such as the presence of other farm animals (e.g., swine, cattle, etc.), other poultry species, or pets on farms, as well as practices like personnel working across multiple farms and loading silos outside farms, suggests potential gaps in BMs enforcement. Souillard et al. (2024) also identified the low level of implementation of these BMs in large-scale poultry farms across Europe. Their investigation revealed several factors, including farmers' perception that certain practices, such as preventing the presence of other animals (e.g., swine, cattle, etc.), poultry species, or pets on farms, offered 'no known advantage'. Additionally, practices like silo loading outside the farm were perceived as 'too expensive', while personnel working across multiple farms was seen as a more cost-effective option than employing exclusive farm personnel (Souillard et al., 2024).

Although critical for disease control, many BMs are not uniformly regulated across countries, possibly due to varying perceptions of risk, enforcement challenges, or lack of awareness of biosecurity benefits (Van Limbergen et al., 2018). In contrast, some countries compensate for the lack of legislation with other regulatory frameworks, such as industry-driven standards. The local epidemiological situation of transmissible diseases may also influence the stringency of BMs. For example, European countries with significant AI outbreaks tend to enforce more rigorous biosecurity protocols to prevent future outbreaks (Delpont et al., 2021; Tilli et al., 2022; Laconi et al., 2023). This approach has been observed in regions heavily impacted by the virus, where stricter measures are implemented in response to past outbreaks to protect the poultry industry (EFSA et al., 2024).

Among the European top poultry-producing countries in our dataset (i.e., Poland, Spain, France, and Italy) (European Commission, 2024), Poland had the fewest number of BMs mandated by law, whereas Italy had the highest number, followed by Spain and France. Other countries, including Sweden, Denmark, Belgium, Finland, Ireland, the Netherlands, Greece, Estonia, North-Macedonia, and Poland, formed a cluster with the lowest number of BMs mandated by law. Meanwhile, Norway, France, Italy and Spain clustered together with a moderate number of regulated BMs. A third cluster included Kosovo, Slovakia, Turkey, Serbia, Ukraine, Hungary, Israel and Tunisia, which had a higher number of BMs mandated by law compared to the previous two clusters. It is important to mention that the number of regulated BMs in a country does not necessarily reflect the actual level of biosecurity implementation. Regulations may instead be tailored to specific risk levels, such as high farm densities or increased exposure to wild birds or to specific characteristics of different poultry production types.

Overall, BMs were more highly regulated in commercial broiler and layer production than in other poultry species (e.g. turkeys, breeders, ducks, minor poultry species). However, this trend may vary among individual countries, especially for breeders, where stricter BMs are recommended (Laconi et al., 2023). This is likely due to the greater economic value of breeders. Nevertheless, broilers and layers remain the primary sources of meat and eggs in the European poultry industry (EU Agricultural Markets, 2024; European Commission, 2024).

Some differences were observed between countries regarding the broiler and layer sectors. Northern European countries, such as Denmark and Norway, clustered with countries that had a higher number of BMs mandated by legislation (e.g., France, Italy, and Spain) in layer farming compared to broiler farming. This trend may be explained by the longer production cycles in this poultry category, which increase the risk of disease spread and require more stringent regulations (Guinat et al., 2019). The greater economic impact of disease outbreaks in layer farms, compared to the shorter lifecycle of broilers, further explains the stricter regulations observed (Scott et al., 2018). Similar trends have been reported across Europe, with countries implementing more rigorous BMs in layer farms to reduce long-term disease risks (Mirwandhono et al., 2023).

The findings of this study highlight the heterogeneity of legislative coverage for BMs across participating countries. This information is highly valuable, enabling countries to adopt BMs tailored to their specific disease risks and prioritize those most relevant to their needs. Differences in biosecurity implementation between countries may be influenced by several factors, including legal requirements, climatic conditions, production density, voluntary disease control programs, industry initiatives, trade patterns, as well as farmers' traditional practices, technical knowledge, infrastructure, attitudes, and financial capacity. Although many countries enforce BMs through legislation, research across multiple animal production systems has shown discrepancies between written standards or guidelines and actual on-farm compliance (Siekkinen et al., 2012). To address this regulatory heterogeneity, the European Commission could consider developing a harmonised biosecurity framework that offers common guidance while allowing for national adaptation. Such an approach would promote greater consistency in biosecurity standards across Europe, while still respecting country-specific contexts and priorities. Farmers are more likely to adopt BMs if they perceive tangible benefits for their farm performance. However, there is a lack of quantitative data linking BMs to production outcomes in poultry (Laanen et al., 2014). Effective biosecurity management relies on collaboration between farmers, veterinarians, and other health professionals, guided by a structured biosecurity plan (Filippitzi et al., 2018). Alonso et al. (2020) has reported that the general public is more aware of animal welfare due to initiatives led by the industry, retailers, and various associations. However, biosecurity has not received the same level of attention. Unlike animal welfare, biosecurity is not yet a priority for the general public (Alonso et al., 2020). One future effort could focus on informing and educating the public about the benefits of poultry raised under proper biosecurity measures.

Facilitating the exchange of information and best practices among European countries can foster mutual learning and help countries align with more advanced biosecurity standards. Addressing current challenges requires a coordinated approach that recognizes the complex interplay of legal, economic, and institutional factors shaping biosecurity regulation within the European poultry sector. Future research should investigate the underlying reasons for limited or inconsistent compliance with certain biosecurity measures and identify context-specific strategies to improve their adoption among poultry farmers. Such research could also explore how policy design, farmer perceptions, and economic incentives influence the implementation of biosecurity regulations across different production systems and regions.

5. Conclusions

The findings of this study provide valuable insights for countries seeking to refine or prioritize biosecurity strategies based on their specific epidemiological contexts. While variations in the number and type of regulated BMs reflect differences in disease situations and associated risks across countries, a harmonized biosecurity framework at the European level could help address this regulatory heterogeneity by providing common guidance and defining specific measures that countries can adapt to their own contexts. This would support the development of tailored, risk-based approaches while promoting greater consistency across national biosecurity strategies. Ultimately, such efforts would enable a more effective response to emerging threats and strengthen biosecurity systems in poultry production across Europe.

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The authors declare no conflict of interest.

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Supplementary materials

Questionnaire, Heatmap on BMs regulated in broilers (Figure S1) and Heatmap on BMs regulated in layers (Figure S2).

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2025.106571.

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