DOI: 10.31073/onehealthjournal2025-II-03
UDC 636.939

ASSESSMENT OF BIOSECURITY PRACTICES AND ADAPTATION OF THE EVALUATION SYSTEM AT MINK FARMS USING ITEM RESPONSE THEORY

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Abstract. *The paper presents the results of a study on the implementation of biosecurity practices at mink farms in the Kyiv region, utilizing the Item Response Theory (IRT) methodology, which was adapted to assess the level of biosecurity and identify key aspects requiring improvement. The primary focus is on segregation, sanitation, and management practices, which are critical for minimizing the risk of infectious disease spread. The analysis revealed significant differences between the two studied farms. The first farm demonstrated substantial gaps in the implementation of measures, whereas the second farm exhibited a more stable level of biosecurity, though some aspects remain insufficiently implemented. The study's findings provide valuable insights for developing recommendations to enhance biosecurity standards and improve farm management efficiency.*

Keywords: biosecurity, mink farms, segregation, sanitation, Item Response Theory, IRT, veterinary practices.

Biosecurity is a fundamental component ensuring the sustainable functioning of mink farms (Robertson et al., 2020). Modern management practices include a set of preventive measures aimed at reducing the risk of infectious diseases, such as Aleutian disease, mastitis, and other pathologies that can lead to significant economic losses (Panicz et al., 2021). Aleutian mink disease remains one of the most serious threats in the industry, being widespread globally and causing substantial damage by reducing animal productivity, increasing veterinary costs, and deteriorating the quality of final products (Prieto et al., 2017).

High morbidity rates negatively impact animal productivity, increase veterinary costs, and lower the quality of end products (Peacock et al., 2023). Furthermore, inadequate biosecurity levels contribute to high mortality and farm losses (Compo et al., 2017). To assess animal welfare on mink farms, the WelFur system was developed, based on four key principles (adequate nutrition, housing, health, and behavior) and 12 criteria of assessment (Møller et al., 2012). However, this system does not cover biosecurity aspects, emphasizing the need for separate measurement and analysis methods.

Particular attention is given to the integration of innovative technologies in biosecurity. Automated disinfection systems, digital tools for health monitoring, and regular staff training are essential components of successful management (Gregers-Jensen et al., 2017). These measures have already demonstrated effectiveness in reducing disease incidence and improving farm profitability worldwide (Peacock et al., 2023).

In Ukraine, particularly in the Kyiv region, mink farms have significant economic potential. However, the level of implementation of modern biosecurity practices remains largely undefined, requiring detailed analysis.

This study aims not only to examine the current state of biosecurity on farms but also to develop assessment tools. The use of Item Response Theory (IRT) provides a structured approach to analyzing the effectiveness of implemented practices, allowing for the identification of the most critical aspects for improvement (Silva et al., 2019).

Among the possible biosecurity assessment methods, risk management and mathematical modeling were considered (Lewerin et al., 2015; Korotkov et al., 2021). However,

the IRT method was selected for this study as it offers a structured approach to evaluating the effectiveness of implemented measures. This method enables the identification of the most critical biosecurity aspects requiring improvement and is highly adaptable to the specific needs of farm enterprises.

Thus, this research contributes to the development of biosecurity science and the formulation of recommendations for enhancing the efficiency of mink farm management in the face of modern challenges.

The aim of study was to assess the level of biosecurity at two farms using the Item Response Theory (IRT) method.

Materials and methods. Fourteen key biosecurity practices were selected as the most crucial for preventing the spread of pathogens. Data were collected through farm audits and surveys of responsible personnel. Two parameters were determined for each practice: a ("discrimination") – an indicator of how significantly the practice influences biosecurity assessment; b ("importance") – a threshold that defines the criticality of the given practice.

Key Values for Calculations. For each of the 14 biosecurity practices, the following parameters were assigned: Discrimination ("a"). The discrimination value (a) typically ranges from 1.0 to 3.0: a = 1.0: The practice has low significance in distinguishing biosecurity levels; a = 2.0: The practice has moderate significance; a = 3.0: The practice is critically important for determining biosecurity levels. Importance ("b"). The importance value (b) typically ranges from 0.0 to 1.0: b = 0.0: The practice is almost unnecessary; b = 0.5: The practice is important but not critical; b = 1.0: The practice is essential.

A two-parameter logistic model (2-PL IRT) was used, where the probability of a farm implementing a given practice was calculated using the following formula:

$$P\left(X_{ij}=1\middle|\theta_j,a_i,b_i\right)=\frac{1}{1+\exp(-a_i\left(\theta_j-b_i\right))}$$

where:

$P\left(X_{ij}=1\middle|\theta_j,a_i,b_i\right)$ — the probability that farm j implements practice i.

θ_j — the biosecurity level of farm “j”.

a_i — discrimination of practice “i”.

b_i — the importance of practice “i”.

The overall biosecurity index θ was calculated as the sum of contributions from all practices using the formula:

$$\theta_j=\sum_{i=1}^{n}a_i\cdot(x_{ij}-b_i)$$

where: x_{ij} – implementation of practice i by farm “j” (0 – not implemented, 1 – implemented).

The calculation results are presented as biosecurity indices for each farm and analyzed in the following sections.

Results of the study. The study examined 14 key biosecurity practices that help prevent the spread of pathogens among animals and ensure the safe operation of the farm. In particular, farm entry control requires both visitors and staff to follow a specific dress code—wearing special clothing provided by the farm. Before entering the farm premises, all individuals must undergo mandatory disinfection. Some farms even have mandatory showers for visitors to eliminate potential pathogens that may remain on clothing or skin.

Newly arrived animals are placed in a quarantine zone for 2–4 weeks to reduce the risk of epidemics. Sick animals are immediately isolated to prevent contact with others. Regarding transport and equipment, after loading or unloading, vehicles are not allowed inside the farm

premises. All transport vehicles undergo thorough cleaning and disinfection before entering the farm.

To ensure sanitary control, enclosures and equipment are regularly disinfected, and waste is placed in designated containers for either recycling or composting. Protection against wild animals is achieved by installing fences and bird-proof nets, preventing the entry of wild birds and other animals.

Farm personnel undergo regular training to ensure they know how to respond effectively in the event of disease outbreaks. Visitors are also provided with clear instructions on farm behavior guidelines. Feed is stored in designated areas away from the main farm premises and is regularly checked for quality, helping to prevent contamination by toxins or pathogens.

These practices form the foundation for maintaining a high level of biosecurity and can be adapted to suit the specific conditions and needs of each farm.

For each practice, two key parameters were determined: discrimination (a), which indicating its ability to influence the overall biosecurity level, and importance (b), which defining its criticality for achieving safe farm conditions.

Below is a table that presents these parameters and the degree of implementation of practices at each of the studied farms.

The overall biosecurity index for each farm was calculated using the following formula:

$$\theta_j = \sum_{i=1}^{n} a_i \cdot (x_{ij} - b_i)$$

де: a_i — discrimination of practice, b_i— importance of practice, x_{ij} — implementation of practice by the farm.

Calculation results: Farm 1: θ_1= -6.0; Farm 2: θ_2= 2.0

Below is an example of the calculation for certain practices:

For the practice "Dress code for visitors and staff":

$$\theta_{1,1} = 2.0 \cdot (1 - 0.5) = 1.0;$$
$$\theta_{2,1} = 2.0 \cdot (1 - 0.5) = 1.0;$$

For the practice "Cleaning and disinfection of transport":

$$\theta_{1,6} = 3.0 \cdot (1 - 1.0) = 0.0;$$
$$\theta_{2,6} = 3.0 \cdot (1 - 1.0) = 0.0;$$

Discussion. The analysis of the obtained data revealed significant differences in the level of biosecurity measures implemented between the two studied farms. Farm 1 had a low biosecurity level (θ_1=−6.0), indicating substantial shortcomings in implementing key measures. In particular, the absence of shower facilities for visitors poses a serious risk for introducing pathogens from external sources, which is consistent with findings in swine farming, where similar measures have been shown to significantly reduce the likelihood of infection transmission (Silva et al., 2019).

There was also non-compliance with disinfection schedules and a lack of regular staff training, which increases the risk of spreading infectious agents. This finding is consistent with studies in cattle and swine farming, where similar deficiencies have been associated with higher disease transmission rates. Farm 2 demonstrated significantly better results (θ_2= =2.0), which can be attributed to the implementation of several biosecurity measures, including the presence of shower facilities for visitors, effectively reducing the risk of pathogen introduction (Silva et al., 2019), as well as proper feed storage organization, which is also a crucial factor in

preventing contamination. However, gaps were still identified, particularly insufficient attention to staff training, a common issue across various livestock sectors.

Table 1

Parameters and Degree of Implementation of Practices in each of farms involved in the study

Practice	Discrimination (a)	Importance (b)	Practice execution at Farm «1»	Practice execution at Farm «2»
Dress code for visitors and staff	2.0	0.5	1	1
Shower facilities for visitors	1.0	0.5	0	1
Quarantine zone for new animals	3.0	1.0	1	1
Isolation of sick animals	3.0	1.0	1	1
Restriction of vehicle movement inside the farm	2.0	0.5	0	0
Cleaning and disinfection of transport	3.0	1.0	1	1
Regular disinfection of enclosures and equipment	3.0	1.0	1	1
Waste disposal and composting	1.0	0.0	0	0
Perimeter fencing	3.0	1.0	1	1
Bird-proof nets	1.0	0.5	0	1
Staff training	2.0	1.0	0	1
Visitor guidelines	2.0	1.0	0	1
Feed storage in designated areas	2.0	0.5	0	1
Feed quality control	3.0	1.0	1	1

The use of the IRT method for biosecurity assessment demonstrated its high efficiency in identifying critical management aspects, which is supported by similar studies in swine farming, where IRT helped determine the most discriminative biosecurity indicators (Silva et al., 2019). Among the most highly discriminative practices were the isolation of newly arrived animals and the restriction of vehicle entry onto the farm premises, aligning with findings from biosecurity assessment studies across different livestock sectors.

It is also worth noting that biosecurity assessment can be conducted using other methods, such as risk management (Lewerin, S. S. et al., 2015) and mathematical modeling, as demonstrated in the study by Korotkov et al. (2021), where mathematical approaches were used to assess biosecurity in agriculture. However, the IRT method is easier to adapt and allows for the identification of the most critical biosecurity aspects without the need for developing complex mathematical models.

Overall, the results of this study indicate that the successful implementation of biosecurity requires a comprehensive approach, which includes infrastructure solutions, staff training, and a monitoring system. The obtained findings can serve as a basis for further improvement of biosecurity assessment on mink farms and the adaptation of successful practices from other livestock sectors.

Conclusions. This study demonstrated the effectiveness of applying the Item Response Theory (IRT) model for assessing biosecurity levels on farms. The method not only enabled the determination of the overall biosecurity status but also identified key practices that have the most significant impact on its maintenance. The analysis revealed notable differences between the two farms: Farm 1 had a low biosecurity level (θ_1=−6.0), indicating the need for improved sanitation measures and staff training. In contrast, Farm 2 (θ_2 =2.0) exhibited a more stable biosecurity level due to the control of feed quality and the isolation of newly arrived animals.

The IRT model proved to be an effective tool for analyzing the strengths and weaknesses of biosecurity, enabling the scientifically grounded improvement of safety measures. The obtained results confirm the promising potential of this approach for assessing and optimizing biosecurity on farms of various types.

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ОЦІНКА ПРАКТИК БІОБЕЗПЕКИ ТА АДАПТАЦІЯ СИСТЕМИ ОЦІНЮВАННЯ НА НОРКОВИХ ФЕРМАХ З ВИКОРИСТАННЯМ ТЕОРІЇ ВІДПОВІДІ НА ПИТАННЯ

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***Резюме**. У статті представлено результати дослідження впровадження практик біобезпеки на норкових фермах у Київській області, для чого було використано методику теорії відповіді на питання (IRT) та адаптовано для оцінки рівня біобезпеки та визначення ключових аспектів, що потребують вдосконалення. Основна увага зосереджена на практиках сегрегації, санітарії та управління, які є критично важливими для мінімізації ризиків поширення інфекційних захворювань. Аналіз показав суттєві відмінності між двома досліджуваними фермами. Перша досліджувана ферма виявила значні прогалини у впровадженні заходів, тоді як друга досліджувана ферма демонструє стабільніший рівень біобезпеки, хоча деякі аспекти залишаються недостатньо реалізованими. Результати дослідження надають важливу інформацію для розробки рекомендацій щодо вдосконалення стандартів біобезпеки та підвищення ефективності управління фермерськими господарствами.*

Ключові слова: біобезпека, норкові ферми, сегрегація, санітарія, теорія відповіді на питання, IRT, ветеринарні практики.

DOI: 10.31073/onehealthjournal2025-II-03