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Survey on swine biosecurity measures in Hungary

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Abstract

Biosecurity is a broad term used to describe defence strategies or management procedures used to combat pathogens that spread disease in animal population. Biosecurity practices and implementation is essential to prevent the spread of disease and safeguard animal health and public health. The aim of this study is to evaluate the effectiveness of biosecurity practices specifically pertaining to internal and external biosecurity practises in the Hungarian swine industry. The current study used a free online survey called Biocheck.Ugent Pig® (Biocheck) to evaluate biosecurity practices across 33 farms in Hungary. The current study found average biosecurity scores across 33 farms were 85.5%, 75.3% and 80.8% for external biosecurity, internal biosecurity and overall biosecurity respectively. The results of the current study reveal that Hungary's average biosecurity scores are higher compared to previously reported studies in different European countries. Hungary’s average biosecurity scores are consistently above the world average, reflecting strong national biosecurity protocols.

Összefoglaló

A biobiztonság kifejezés alatt az állatállományokban betegségeket terjesztő kórokozók elleni védekezési stratégiákat, ill. állomány-egészségügyi intézkedéseket értjük. A biobiztonsági intézkedések és azok helyes gyakorlati megvalósítása elengedhetetlen a fertőző betegségek terjedésének megelőzéséhez, valamint a kedvező állat- és közegészségi állapot fenntartásához. Jelen kutatás célja a nagylétszámú magyar sertéstelepeken alkalmazott belső és külső biobiztonsági intézkedések hatékonyságának értékelése. Kutatásunk során 2024 januárja és márciusa között 33 magyarországi nagylétszámú sertéstelepen mértük fel és értékeltük a biobiztonsági gyakorlatot az online elérhető Biocheck.Ugent Pig® (Biocheck) kérdőív segítségével. A felmért sertéstelepek esetében az átlagos értékek 85,5%, 75,3% és 80,8% voltak a külső, a belső és az összesített biobiztonság terén. Az eredményeink azt mutatják, hogy az átlagos biobiztonsági értékek a magyarországi intenzív sertéstelepek esetében jellemzően magasabbak, mint más európai országok esetében, továbbá meghaladják a világátlagot is, ami hatékony nemzeti biobiztonsági protokollokat tükröz.

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Table of Abbreviations

AMU	Antimicrobial usage
ASFV	African Swine Fever Virus
Biocheck	Biocheck.Ugent Pig®
E. coli	*Escherichia coli*
Max	Maximum
Min	Minimum
PEDv	Porcine Epidemic Diarrhea Virus
PRRS	porcine reproductive and respiratory syndrome
SD	Standard deviation
SPF	Specific pathogen free
U.S.	United States
WOAH	World Organization for Animal Health

1. Introduction

Biosecurity is a broad term used to describe defence strategies or management procedures used to combat pathogens that spread disease in animal populations. These strategies may include; cleaning and disinfection measures, movement restriction of animals and goods stramping out protocols, surveillance zones, vaccination programs, quarantine etc. Biosecurity protocols aim to provide security defences against diseases that threaten animal welfare, agricultural productivity, and food security. Biosecurity is considered as part of the "One Health" approach to safeguard human and animal health as well as economic security and animal biodiversity [1, 2].

With the growing world population predicted to be at 9.7 billion people in 2050, more pressure is interposed on food production. To feed the world population more efficiently agricultural practises are required to meet the growing protein demand. It is therefore required from farm producers and the farming sector to increase number of animals on smaller geographical space [3, 4]. Higher animal density on smaller land areas will create an ideal environment to propagate and spread pathogens in animal and human populations.

Biosecurity can aid in disease prevention and the spread of sickness among animals. The One Health Concept a multidisciplinary approach that helps to understand the shortfall between agriculture and public health [5] is of specific value. As part of the one health concept, animal health and food security will have to review its current system to take the food chain into account. It will require a more holistic approach, which takes a wider range of sectors into consideration. If one focuses solely on the impact of biosecurity on animal health, it will be considered insufficient [6]. Biosecurity is a pivotal bridge between agriculture practises and public health. Furthermore, biosecurity is essential to link the health of people and health of animals together [1, 6, 7].

The aim of this study is to evaluate the effectiveness of internal and external biosecurity practices in the Hungarian, large-scale, intensive swine farms by using the Biocheck.Ugent Pig® (Biocheck) [8] scientific scoring tool and database for biosecurity measures.

2. Literature Review

2.1. General Biosecurity Measures

The fundamental base of biosecurity is to protect from serious infectious agents through preventative measures and managerial practises [9–11]. It is important to first have a basic understanding of the general principles of biosecurity. There are five major principles to consider when planning biosecurity protocols and measures [9, 12]. These principles provide the foundation of understanding biosecurity, which includes 1) bio-exclusion or segregation; 2) low infection pressure; 3) prioritising high risk of transmissions; 4) biosecurity awareness and lastly 5) higher population density results in higher risk to infection.

2.1.1. Bio-exclusion or segregating

Disease or infectious agents are transmitted between individuals through direct contact with infected individuals or other sources of infection [9, 12]. Thus, it is important to focus on directly and indirectly excluding these factors or associated infectious sources. To avoid the transmission of disease we must isolate production stock from these sources to ensure no direct or indirect contact to the pathogens or factors are possible [11, 13]. Further steps can be taken to decrease disease transmission, by segregating high risk animals (immune-compromised, sick, new stock) from low risk animals (healthy or resistant) to the greatest extent possible [4, 9]. In some incidences it is unavoidable and low-risk animals get into contact (directly or indirectly) with high-risk animals. In those circumstances, additional precautions must be taken to ensure biosecurity measure are followed regularly and without exemption [9, 13].

2.1.2. Reducing infection pressure

As already mentioned above it is not always possible to keep production stock completely free from disease. It is not always feasible to keep animals in a complete sterile environment because this sterility can just as easily be broken [13–15]. The goal is to reduce the infection pressure on the population. High infection pressure means there is a high pathogen load present and which can easily infect the population, especially if the individuals are highly susceptible. Pathogen infectivity can further be increased when a population is highly susceptible due to being immune-compromised. The objective is to reduce infection pressure to a point where the population's natural immunity can effectively combat or resist the pathogens [9, 12].

2.1.3. Prioritising high risk transmission routes

Not all routes of infection transmission are of equal importance. It is important to consider the efficiency the of transmission routes and to be able classify specific routes as either high or low risk. The risk of disease transmission is much higher and more effective through direct contact with infected animals than through feed [9, 16].

When considering the routes of transmission, one must keep in mind the specific disease or pathogens one is trying to avoid. For example, African Swine Fever's (ASF), route of transmission is through direct contact with wild-animals and infected commercial swine has a much higher risk of disease transfer, than the route of vectors like ticks [4, 17, 18]. The probability and frequency of wild animals being diseased with ASF is much higher and therefore classified as a higher risk route of transmission. Ticks, the carrier of African Swine Fever Virus (ASFV) in wild swine, has a lower probability to infect commercial pigs kept indoors as the frequency of ticks found on these animals are lower [9, 12, 19].

The importance of a disease transmission route depends on the specific disease being targeted. A transmission route may be irrelevant for one disease but highly significant for another. For instance, Swine influenza's main route of transmission is via air, whereas *Escherichia coli* (*E. coli*) infects its host through direct or indirect contact of body fluids. *E. coli*'s route of transmission puts emphasis on diseased animals rather than airborne infection [18, 20–22].

To implement effective biosecurity measures, it is essential to identify and understand the routes of disease transmission. The main routes of disease transmission of a pathogen into and inside of a production system are illustrated by **Figure 1** [3, 12, 23].

Figure 1. Illustration of the main routes of transmission of disease [15,17, 32].

The main transmission pathways for pathogens entering a farm system can be either direct or indirect [23, 25]. Direct transmission routes refer to disease spreading from individual-to-individual animal. This means the disease is transmitted from infected individuals to healthy individuals [9]. This direct contact between pigs allows the transferring of a pathogen (bacterial or viral) from one host to another [25, 26].

Indirect routes refer to spread of pathogens from infected pigs to other non-infected pigs through contaminated fomites and vectors. Fomites carry a high risk of pathogen transmission are contamination via personnel through their clothes, vehicles or food [23, 24]. The most common vectors in piggeries capable of transmitting viral pathogens originate from either mammals or arthropods. Mammalian species of note are wild-boar, bush pig, warthog, birds and other rodent vermin. Insects that are of importance for disease spread to pigs are ticks, hog louse (*Haematopinus suis*), mosquitoes, and biting flies [12, 18].

2.1.4. Biosecurity awareness and risk assessment

The frequency of occurrence of a pathogen in the population contributes to disease transmission. The frequency that a pathogen is present in a population can be due to repeated practices within the production system [9, 15]. For example, an animal caregiver who routinely handles animals without proper precautionary measures, such as washing hands regularly or between batches or groups, can markedly increase the risk of disease transmission [9, 13, 16]. Routes initially considered low risk can escalate to significant risk when the frequency of exposure increases, and precautionary measures are not implemented. An example of this is when authorised personnel entering housing units, the probability of transmitting disease through footwear is low if proper age flow (younger to older) to units is implemented [9, 12, 13]. The risk increases significantly when personnel frequently move between housing units without regular foot-bath dipping or adherence to proper pig flow. In this case, the likelihood of disease transmission through footwear shifts from low to high, as no precautionary measures are being taken by the staff [9, 12, 13]. According to animal health Ireland, the concept well and states that "it is important to focus on action that are repeated frequently even if they are considered of low risk" [12].

2.1.5. Higher population density

Larger population size will have an increased risk of obtaining an infection or disease [27, 28]. More animals means that there is a higher number of animals that can become infected and consequently maintain the pathogen or infection cycle [9, 27]. This also increases the infection pressure level to a point that is over the limit that the population cannot manage [12, 29]. It is also important to consider that high productive and high producing herd can be more vulnerable to disease introduction. High health herds, nucleus herds and specific pathogen free (SPF) disease herds are considered more susceptible to the introduction of specific diseases. When considering large herds, the number of animals and type of herd is important when assessing risk of disease introduction in larger population herds [12].

Biosecurity at a primary production level (farm) can be subdivided into two broader concepts: internal and external biosecurity measures [1, 9]. Internal biosecurity measures, aim to reduce or prevent the spread of a pathogen between animals in the system [1, 11, 12]. **Table 1** outlines some of the basic internal biosecurity measure and management procedure that could be implemented [12, 30].

Table 1. General internal biosecurity practices

Regular cleaning and disinfection practises	Encourage frequent hand washing and disinfection between houses and farm sectors.
	Have many hand/boot washing and disinfection stations throughout the farm and between farm sections.
	Require foot baths to disinfect boots at each separate housing unit and between farm sections.
	Routine washing, cleaning and disinfection of houses (including feeding/ water troughs) with appropriate step by step guide.
	Disinfect waterline as well during routine housing cleaning and disinfecting practises.
	Allow adequate drying time/down time after each housing cleaning before new group of animals are introduced.
Protective clothing and work uniform	Having mandatory work uniform/ protective clothing and footwear worn by all employees.
	Marking clothing, footwear and equipment per farm section (ex. Colour to easily defined and identifiable from other farms sectors to limit cross-contamination).
Appropriate stocking density	Provide enough adequate space for animals to thrive and express normal behaviour.
Personnel management	Separate personnel groups dedicated to a specific housing unit or farm section. (ex. never allowing personnel from a growing unit section to enter the farrowing unit).
	Have separate break rooms or cafeteria dedicated for employees to take lunch breaks and not allow any food or beverages to exit said area into the piggery unit or farm sectors.
Closed herd practises	Quarantine newly bought-in animal from other farms.
	Allow for adequate adaption time between quarantine and herd introduction.
Standard pest control program	Have standard control protocol for insects and vermin (rodent, birds, etc.), that is implemented routinely on a monthly or weekly basis.
Herd health	Separate sick or injured animals immediately from big groups.
	Dispose of dead animals and carcass upon initial finding according to production system waste disposal guidelines.
	Check on healthy animals first before moving to sick animals, moving from least diseased to diseased animals.
	Have separate equipment for each farm section or housing units for vaccinations and treatment of animals.
	During routine vaccination or sick/injured animal treatment, use single-use needles and injectors, OR restrict multiple-use needle and injectors to one litter/ animal group/ pen.
	Disinfect any equipment used during routine vaccination or treatment of sick or injured animals (ex. Thermoregulators, multi-use injectors, stethoscope, etc.).
Waste management	Implement a clear outlined waste disposal plan that ensures effective removal of dead animal carcass and other biological waste matter.
	Have separate waste disposal protocols for animal waste and equipment waste (ex. different waste bins or drain system for discarding liquids).
	Dispose of disinfectant foot bath contents on a daily or twice daily basis.
	Discard bio-contaminated and medical waste and single use equipment safely.
	Have separate areas to preform post-mortem on carcasses of interest and dispose correctly of carcasses after use
Pig group flow practises	Reduce and limit mixing of animal groups and litters.
	Limit cross fostering to only the first 24 hours.
	All-in and all-in system: never mix pigs of different age groups and operating houses. Excluding moving grouped house sows to farrowing & farrowing to heat detection & servicing stations, etc.

Source: based on [11–13, 30–32]

External biosecurity measure aims to prevent or reduce entry of new pathogens into the system [12, 33]. **Table 2** outlines some of the basic external biosecurity measure and management procedure that could be implemented [1, 12, 33]. Both biosecurity measure needs to be analysed and implemented effectively to safeguard animal and public health.

Table 2. General external biosecurity practises

Personnel management	Mandatory showering is needed to enter and exit the facility/ies or farm sections.
	Restrict entry into animal units of private visitors or service personnel that does not have official business or direct service.
	Have registry book to log all personnel/ visitors / service men entering the farm premises.
	Subject all employees to mandatory health screenings and questionaries.
	Do not allow any sick or unauthorised person to enter the facility or farm premises.
	Restrict personnel and visitors from entering premises if they had recent direct contact with pigs.
	Pre-employment screening of personnel. Do not allow staff into holding facility if they own pigs or have been in contact with other swine in the last 12-72 hours.
	Decontaminate and disinfect all personal belongings with UV-light boxes or disinfection spray where possible (ex. prescription glasses, watches etc).
Closed herd practices	Buying animals from disease free and reputable farm.
	Have separate quarantine facility for new incoming pigs section away from primary production site.
	Have separate loading and offloading areas for animals exiting the farm premises and animals entering the farm area, ideally on opposite sides of the farm.
Farm Premises	Fencing of the entire farm premises.
	Fencing must be adequate to prevent any wild animals or unauthorised persons from directly entering animal facilities.
	Farm premises must be geographically isolated from nearby urban residential area.
	Have a perimeter buffer area and implement line separation areas
Feed management	Have designated area that is restricted only for delivery vehicles / feed delivery vehicles.
	Have feed delivery at designated stations where only the first fence barrier is breached. Locating the feeding dispenser/ hob feeders outside the primary and secondary fence barriers.
	Restrict delivery / feed / other vehicles to not enter within a 3-meter radius of barns.
	Require entering vehicles to have tires and undercarriages washed and disinfected before entering the farm premises.
Waste management	Have separate entrance for collection of disposable waste.
	Have separate designated area that allows waste to be handled and disposed off safely and is segregated from the primary production site.

Source: based on [11–13, 30–32]

Having basic infrastructure and protocol in place for biosecurity will not guarantee no risk of diseases from appearing. Only through regular routine implementation of biosecurity measure will it reduces the risk of acquiring disease into primary production sites be reduced [12, 29]. The degree at which the risk of contracting disease is reduced is dependent on how effectively biosecurity measures are followed and executed by personnel [16, 34].

By using biosecurity measures effectively and implementing said strategies on a regular basis a higher economic value can be achieved. A direct link between antimicrobial usage (AMU) and biosecurity has been shown in multiple studies [29, 35–37]. In these studies, it has been concluded that the higher and more effective biosecurity strategies are implemented the less antimicrobials are used in piggeries. Antimicrobial usage has a direct link to public health concerns as higher AMU results in increased risked to pathogen acquired resistance [35, 36, 38]. Antimicrobial acquired resistance is a global public health issue as more resistant pathogens emerges that become life threatening to which modern-day medicine has little to no effective treatment, which the become life threatening.

2.2. Tools to check efficiency and effectivity of biosecurity protocols

In recent years, more focus has been given on defining and measuring biosecurity to recognise if practises put in place give the desired effect. By measuring biosecurity, we can identify any shortfalls or improvements that are required to ensure said measures are achieving the desired results [2, 32, 39]. Implementation of biosecurity measure is of equal importance to planning and setting up biosecurity measure. To evaluate the effectiveness of biosecurity, there are numerous tools, methods or software surveillance systems that can be used [2, 31, 39]. These evaluation systems can be in the form of checklists, questionaries, scoring systems or supporting manuals [32, 33]. By measuring biosecurity, it can help quantify and standardise biosecurity measures. Quantifying biosecurity can be useful in both large and small-scale production facilities to standardise biosecurity measures and supply a baseline to start from [34, 40].

Supporting manuals is a useful tool to educate on biosecurity measures and can also be used as a baseline when setting up biosecurity protocols [27, 39]. Short manuals or descriptive posters can be an impactful tool to educate personnel and farmers on specific biosecurity practises and how to effectively implement them [41]. Manuals are also important for diagnostic test to identify pathogens and give clear guidelines for sampling. This can help to quicker and more accurately identify exciting pathogens in herds [5, 42].

Using checklists and questionaries can simplify biosecurity practices and help to implement biosecurity and management practises on a regular basis [2]. Following a check list is a simplified way to evaluate biosecurity and for which no formal training of staff is required. Checklists further evolved the perception and critical thinking on biosecurity subsets and helped identify which measure are of higher risk of importance [43, 44]. Checklists have been utilized to quantify biosecurity measures by assigning a score to individual herds. This approach offers a comprehensive, objective and quantitative assessment of biosecurity and its levels [2, 39]. This aids farmers to identify potential areas for improvement in their system more readily and easily. Additionally, it allows for the comparison of biosecurity standards across different farms or herds, facilitating benchmarking.

Software surveillance systems are used to quantify and validate biosecurity measures used on farms [39, 40]. These systems are useful to both farmers and veterinarians. With software systems it simplifies biosecurity practises for farmers and improve farm management practises. Software systems not only help improve biosecurity but also help to keep track of biosecurity practises, pin-point weaknesses and validate existing biosecurity practices [2, 40, 45].

2.3. Current practises of biosecurity in the swine sector

2.3.1. Biosecurity measures in American swine farms

Biosecurity protocols in the United States (U.S.) swine industry evolved to address growing concerns about disease prevention and containment. The sector focused on enhancing measures to protect against emerging threats like ASF, Porcine Epidemic Diarrhea Virus (PEDv) and PRRS [33, 46]. The biosecurity measures implemented in the U.S. pork industry between 2020 and 2024 demonstrated significant progress in mitigating these disease risks. More enhanced protocols were encouraged on farms to protect the industry against potential disease outbreaks. The Secure Pork Supply Plan and USDA-led initiatives improved emergency preparedness and continuity of operations [47, 48].

According to the national United States Swine Health Improvement Plan (US SHIP) enrolment survey biosecurity practices where more routinely applied in breeding herds than other commercial sites [46–48]. This study further highlighted shortcoming in biosecurity protocols and management practises in commercial and non-commercial farms [46]. The US SHIP survey was done on a voluntary basis and is pivotal in showing that the US pork industry is capable of collaborating over various sectors and provides a baseline on short coming and challenges in biosecurity measures [46].

The United States swine industry still faces challenges to uniformly implement biosecurity measures [48]. Small holder and non-commercial farmers have limited financial capability to implement certain biosecurity practises as well as facing geographical and logistic challenges. Overall, despite these limitations, the industry's proactive steps to enhanced technologies and educational initiatives did improve the countries preparedness and resilience to outbreaks [22, 33, 48]. It is therefore essential to continue collaborating and educational practises to enhance biosecurity while also focusing on equal resource distribution and financial support to farmers who need it.

2.3.2. Biosecurity measures in European swine farms

Despite a growing recognition that enhanced biosecurity leads to improved efficiency and production parameters [3, 28, 49]. Pig farms in Europe, however, still face significant challenges in fully implementing and regulating biosecurity measures. Biosecurity of indoor pigs across Europe is still poorly executed and left unchecked [3, 16]. Biosecurity practices vary widely across countries and regions, since there are no standardized procedures or regulations in place. Each country typically has its own national guidelines or protocols of practice for biosecurity [6, 16, 44] The responsibility is given to the animal owners to manage animal health and implement farm biosecurity practices in accordance to the European Animal Health Law [43, 44]. Several factors influence the effectiveness of these measures being implemented. These factors include capabilities of managers, farm size, geographical placement, production type, technology available and the current epidemiological situation [3, 45, 50]. Small holder farmers or back-yard pig farmers also face challenges to afford and implement of advance biosecurity measures [28, 49]. Not only the lack of advance infrastructure is a limitation in these systems, but also to regulate these systems effectively [4, 49].

This lack of standardization and variability in implementation of biosecurity in different pig enterprises, leads to some farms having more rigorous biosecurity protocols where others may fail or only implement the basic biosecurity measures [4, 39, 51, 52]. Moreover, there is a lack of comprehensive data on the level of biosecurity implementation, particularly on conventional indoor pig farms, in different European countries [16, 44, 45]. As a result, the overall application of biosecurity measures remains inconsistent, leaving farms vulnerable to disease outbreaks and impacting animal health and production efficiency [3, 21, 53]. For biosecurity to be more effectively implemented across Europe, stronger regulation, better education and improved enforcement are needed, alongside a more unified approach to guidelines and data collection [16, 38, 44].

2.3.3. Biosecurity measures in Hungarian swine farms

The Hungarian government has regulations in place that apply to all livestock farmers, regardless of the size of their operations. These regulations are designed to protect animal health, prevent disease outbreak and spread of disease [19, 54]. In Hungary, the pig industry is a significant contributor to the country's economy. Biosecurity measures on farm holdings may include basic hygiene and sanitation practices as well as disease testing and monitoring for common livestock diseases [54–56].

The implementation of biosecurity was very effective during the eradication program of porcine reproductive and respiratory syndrome (PRRS) from Hungarian pig herds [57, 58]. This eradication program was implemented in 2014 and by 2022 the Hungarian pig population achieved PRRSV-free status [54, 57, 59]. The eradication program largely focused on based on a regional territorial principle and was compulsory for all pig holdings within the regions. Large-scale fattening farms focused on depopulating-repopulating or removal strategies as they have a predominant role in the spread of PRRS [57–59]. As part of the restocking strategy, herd replacements focused on introducing disease-resistant breeds with greater genetic superiority [19, 54].

These measures resulted in the successful eradication of PRRS while at the same time enhancing production efficiency and reducing environmental impacts. The program also further provided a unique opportunity for large herds to plan and rebuild infrastructures and adopting more advance technologies. Large-scale pork producers shifted more towards all-in-all-out systems and adopted more advance feeding and air filtration systems to enhance operational efficiency [54, 58]. This program and industry practises shift have shown the shortcoming in the Hungarian pig industry. These challenges are mainly faced by smaller farms that are encountering constraints to access resources. This has emphasized the need for policy interventions to ensure uniform biosecurity standards across the sector [58, 60].

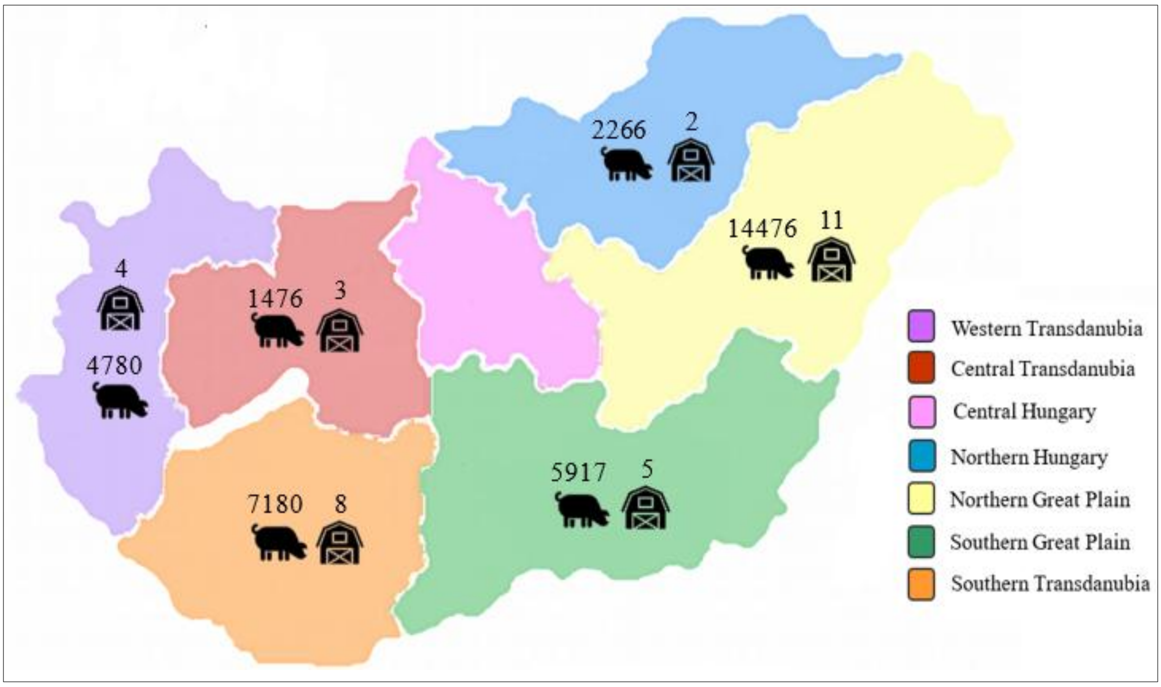
3. Materials and Methods

Biosecurity is only as good as its implementation and attitude towards biosecurity concept. This study will aim to survey the effectiveness of internal and external biosecurity practices in the Hungarian swine industry. This survey will focus how effective these biosecurity practices are implemented in large-scale, intensive, commercial piggeries across Hungary. This survey will be conducted by analysing data gathered via the software scoring based tool Biocheck.Ugent Pig® (Biocheck) [8].

3.1. Farm selection

A total of 33 farms took part in the survey across Hungary, from all the seven official regions of the country. The survey was conducted over a three-month period in the year 2024 from January to March. Farms participating in this survey were all commercial indoor piggery systems. Of the 33-farms, 26-farms are farrow-to-finish productions systems, and seven farms are farrow-to-wean production systems. Farm size varied greatly and ranged between a minimum of 224 to maximum of 2850 sows and their progeny. The number of farms and animal units across all seven official regions of Hungary are illustrated in **Figure 2**.

Figure 2. Map surveyed farms with their animal units in each region across Hungary



Source: based on survey data and drawn in Microsoft® Office 365 Paint by Sunika Süllwald

3.2. Biosecurity survey

The biosecurity survey was conducted using Biocheck, a free online platform that uses an independent scoring system that allows users to see the level and quality of on-farm biosecurity. This scoring system is a scientific risk-based scoring method that is easily accessible and user-friendly. The survey features 131 questions that are categorised into three subcategories. Category one is based on farm-and-herd characteristics which consist out of ten questions in total. Category two consists out of 109 questions based on managerial practises to assess risk of disease introduction. The final category consists of 12 questions that is sub-divided into internal and external biosecurity questions. The 12 questions are biosecurity indicators where each indicator is given a percentile score. Biocheck automatically calculates overall direct and indirect biosecurity percentile scores for three categories namely: the farm of interest, world average and the countries average. A score of 0 indicates "absence of biosecurity measures" and a score of 100 indicates "biosecurity measures without fault. The biosecurity survey questionnaire answers and scores were computed automatically from the Biocheck.Ugent Pig® database and was received in an Microsoft Office Excel® CSV (Comma delimited) format.

3.3. Statistical analysis

For statistical analysis basic descriptive statistics were computed in a Microsoft Office Excel® workbook using the software Microsoft® Excel® for Microsoft 365 MSO (Version 2410 Build 16.0.18129.20158) 64-bit [61]. In addition to the internal and external biosecurity percentile scores, a third score was calculated to represent the overall biosecurity percentile. The overall biosecurity score was calculated using the Microsoft Office Excel® workbook. Tables and figures where further drawn based on the descriptive statistics by using Microsoft Office Excel®.

4. Results and Discussion

Table 3 summarizes the descriptive statistics across all 33 swine farms for external and internal biosecurity scores as well as the overall biosecurity score. It further summarises the 12 internal and external biosecurity indicators across the surveyed farms.

Table 3. Biosecurity scores for internal and external biosecurity indicators over 33 Hungarian swine farms

	Mean	Median	SD	Max	Min
External Biosecurity score	85.8	85	6.0	97	71
Purchase policy of animals and semen	93.0	96	10.5	100	66
Transport of animals, removal of waste & carcass	85.7	88	11.0	100	48
Feed, water and equipment supply	79.6	80	14.9	100	50
Visitors and farmworkers	96.9	100	5.4	100	82
Vermin and bird control	65.8	70	17.4	100	40
Farm location	78.8	90	22.7	100	20
Internal Biosecurity score	75.3	76	11.5	94	39
Disease management	87.9	100	21.4	100	20
Farrowing and suckling period	56.0	50	16.5	100	21
Nursery unit	78.6	86	20.3	100	36
Finishing unit	81.6	86	19.2	100	29
Measures between compartments & equipment use	71.1	71	21.2	100	18
Cleaning and disinfection	82.4	88	19.7	100	30
Overall Biosecurity score	80.8	80	7.6	94	61

4.1. External Biosecurity and Indicators

The average external biosecurity average (85.8) and median (85) are high and consistent over the 33 swine farms as evidenced by the small standard deviation (SD). This indicates that across 33 units the external biosecurity measures are typically well-implemented with minor shortfalls. For external biosecurity indicator of visitors and farmworkers have the strongest performance, with an average of 96.9, median of 100 and small variation between farms (standard deviation is equal to 5.4). This is indicating that control of human-related biosecurity risks is strongly controlled and regularly implemented. The weakest preforming external biosecurity indicators are, vermin and bird control as well as farm location. Vermin and bird control average of 65.8, median (70), minimum (40) and a high variability between farms (standard deviation is equal to 17.4). Vermin and bird control could be better implemented, the data is indicating that pest management and protocols are insufficient or lacking. Farm location is a difficult measure to improve on and is mostly fixed. Farms could face challenges regarding finances or availability of suitable sites to be able to relocate piggery operations to new better suited and secure sites. Farm location had a standard deviation of 22.7 across all 33 farms and had the highest variability between farms and further suggests the complexity of improving this biosecurity measure.

Other external biosecurity indicators scored overall high to moderate. Purchase policy of animals and semen scored high across the farms with some variability present between farms (Average = 93.0, SD = 10.5). The high scores suggest strong policies for sourcing animals and genetic material, which contributes minimal disease introduction. The moderate variability could be due to some farms purchasing policies to be less strict and should implement stricter protocols. Transport of animals, waste and carcass handling scored moderately at average of 85.7 and moderate variability (SD = 11) across the farms. This suggest that transportation of animals and management of waste and disposal of carrions are well managed but moderate variability could be due to implementation being irregular or infrequently completed. Lower scoring farms should remove animal carcasses immediately and implement better waste management protocols or design a new waste strategy as this could have detrimental effects on the environment. Feed, water and equipment supply scored moderately and had notable variability (Average = 79.6, SD = 14.9). Units should focus more on this indicator as it has the most room for improvement. There are various protocols, measures or strategies that can be implemented to improve the parameters, which are briefly listed in Tables 2.

4.2. Internal Biosecurity and Indicators

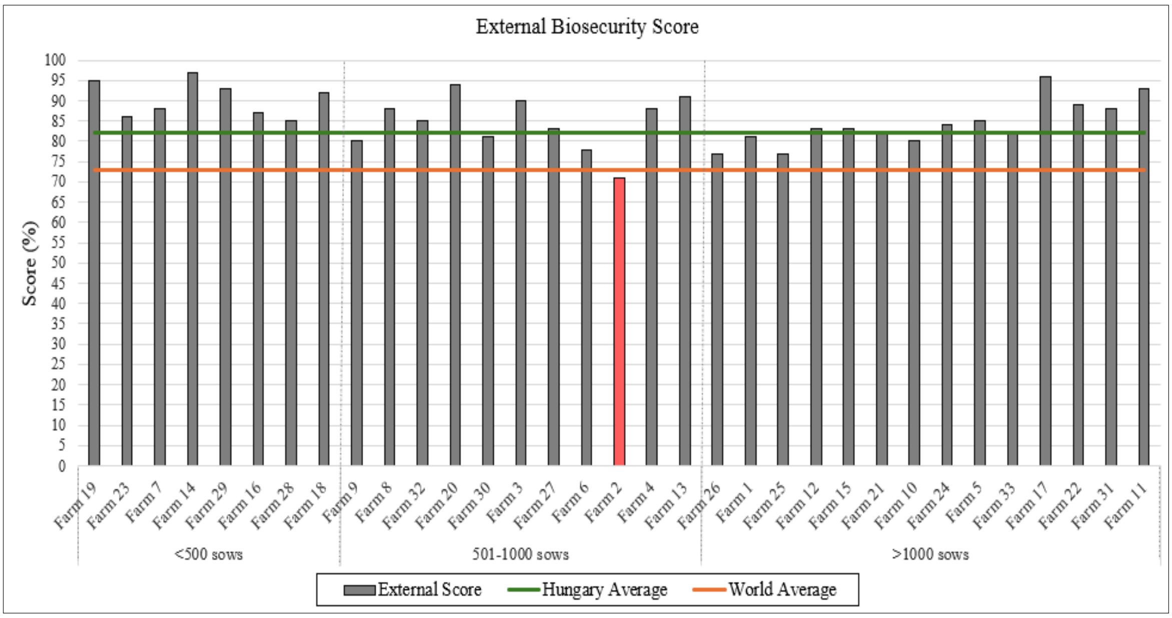
The average internal biosecurity average (75.3) and median (76) are moderately strong but scored lower than external biosecurity across farms. The variable range (94 to 39) between minimum and maximum, respectively, shows insufficient internal security measure of certain facilities. Compared to external biosecurity, internal biosecurity measures scored more moderately and farms scores varied more significantly. The internal biosecurity indicator of disease management scored the highest of the internal indicators (Average = 87.9, SD = 21.4). This indicates that for most facilities this was a high preforming and across farm disease monitoring and treatment is excellent. The high variability (SD = 21.4) and low score (Min=20) however indicates that some farm units have insufficient measures and implementation to prevent or manage disease outbreak is drastically lacking. This internal biosecurity indicator has major implications on public health and epidemiological situation if these parameters are not improved. According to the scores there are two weakest internal biosecurity indicators across 33 swine farms, namely: measures between compartments and equipment use, and farrowing and suckling period. Measures between compartment and equipment scored moderately (Average = 71) and had significant variability (SD = 21.2) among the internal biosecurity indicators. Among all the biosecurity indicators, measures between compartments and equipment scored the lowest minimum value of 18. The low minimum value as well as the variability range of 21.2 indicates that some facilities severely underperform on this measure and there is significant variability between farms. Good management and effective compartmentalization can be an important tactic to combat disease spread and lower infection pressure in the population. Indicator measure of cleaning and disinfection preformed overall well with score of average 82.4 and standard deviation at 19.7. High variability indicates some units are failing to implement proper cleaning protocols consistently. Farrowing and suckling period scored the lowest average among all internal biosecurity measures at 56, but also scored the lowest variability SD at 16.5 across the internal biosecurity indicators as well. This indicates that certain facilities lack consistency and implementation of security measure to safeguard piglet and sow hygiene and health. Low preforming facilities must focus on their managing practises of their farrowing systems to reduce disease risk. Other unit scorings are as follow: for nursery unit (Mean = 78.6, SD = 20.3) and finishing unit (Mean = 81.6, SD = 19.2). Scores are high to moderate with high variability suggesting some facilities lack proper hygiene, movement controls, or compartmentalization.

4.3. Overall Biosecurity Scores

Overall biosecurity score across 33 swine farms where high (Average = 80.8; Median = 80) with lower variability indicating most farms preformed near the mean. The range of maximum and minimum score (94 to 61) is suggesting that lower scoring farms need a more holistic approach to biosecurity. Improvement must then be focused on both internal and external biosecurity measures.

External biosecurity scores for all 33 swine farms are shown in **Figure 3**. The farm units were grouped according to farm size and two reference lines showing the world and country averages for external biosecurity score.

Figure 3. External biosecurity scores across 33 swine farms, categorised according to farm size



The 33 swine farms were categorised into three size groups based on sow number: Category 1) less than 500 sow, consists out of eight farms; Category 2) between 501–1000 sows, consists out of eleven farms; and Category 3) more than 1000 sows, a total of fourteen farms. In Category 1 all units performed well, with their scores comfortably above Hungary's and worlds' averages. All scored above the world and country averages for external biosecurity. These results suggest that smaller units may have better control over biosecurity measures due to their manageable size.

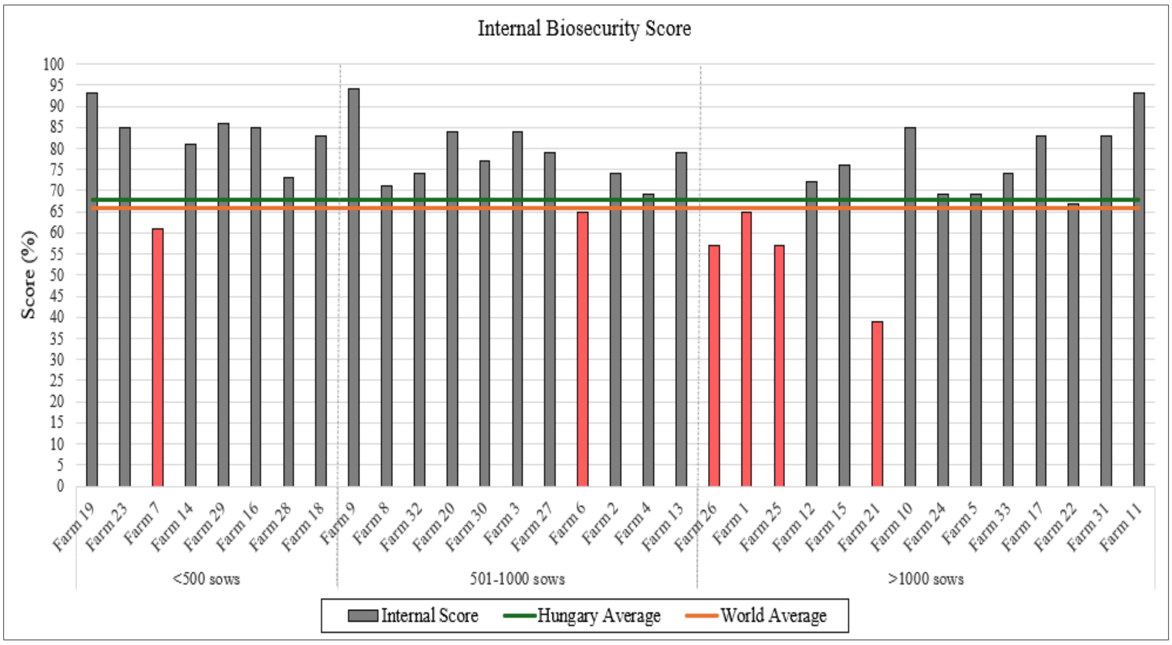
In Category 2, only one farm showed underperformance and four farms scoring below the country's average. This group had the most variability in performance, where the red bar indicates an underperformance. Farm 2 biosecurity score is below both benchmarks. The rest of the units in this group are consistent with national and global standards.

In Category 3 larger units show high consistency, with most units scoring above both Hungary and the worlds' averages. At the same time six farms scoring below the country's average, but above the world average. This suggests that basically these units likely have effective biosecurity systems in place.

Overall Hungary's national average for external biosecurity is higher than the world average, suggesting that Hungary is generally ahead in external biosecurity standards. This suggests that the national biosecurity plan and approach to external biosecurity measures is effective in stopping and managing the spread of disease between pig farms. Combating the introduction of a pathogen into the herds is considered to be effective based on the external biosecurity score.

Figure 4 shows the internal biosecurity scores across 33 swine farms in Hungary, with reference to the Hungary's average (green line) and the world's average (orange line). Internal biosecurity relates to measures within the facility to minimize disease spread, such as hygiene, movement control, and compartmentalization. The commercial swine farms were categorised into three categories according to their size (Category 1: less than 500 sows; Category 2: between 501–1000 sows; and Category 3: more than 1000 sows).

Figure 4. Internal biosecurity scores across 33 swine farms, categorised according to farm size



The 33 swine farms were categorised into three size groups based on sow number: Category 1) less than 500 sow, consists out of eight farms; Category 2) between 501–1000 sows, consists out of eleven farms; and Category 3) more than 1000 sows, a total of fourteen farms. The farms where categorised according to three size groups based on sow number as mentioned above. Category 1, most farms scored above the world and country averages except for one farm underperformed (indicated in red) for internal biosecurity. Category 2, most farms perform at or above benchmark level for national and global averages. Only one farm underperformed on these measures. Category 3 showed the most internal biosecurity performance variability, four farms scored below for both national and world averages, one scored between national and global averages and the rest of the farms scored equally or slightly above the national and global averages.

In Category 1, most of the 8 farms performed above Hungary's and World averages, except for Farm 7 (marked in red), which is considerably below both averages, indicating internal biosecurity deficiencies in this swine unit.

In Category 2, the majority of the 11 farms performed at or above Hungary's and World benchmarks levels, except for Farm 6 (marked in red), which had suboptimal performance.

Category 3 (totally 14 farms) showed the most variability in internal biosecurity measures. Several units, including Farm 21, Farm 25 and Farm 26 (marked in red) severely underperformed and Farm 1 fell just underneath the global average performance. Rest of the farms preformed overall well above the global and national averages, indicating effective internal biosecurity measures.

Figure 5 illustrates the overall biosecurity scores across 33 swine farms, which was calculated as a percentage from the internal and external biosecurity scores.

Figure 5. Overall biosecurity score across 33 swine farms, categorised according to farm size

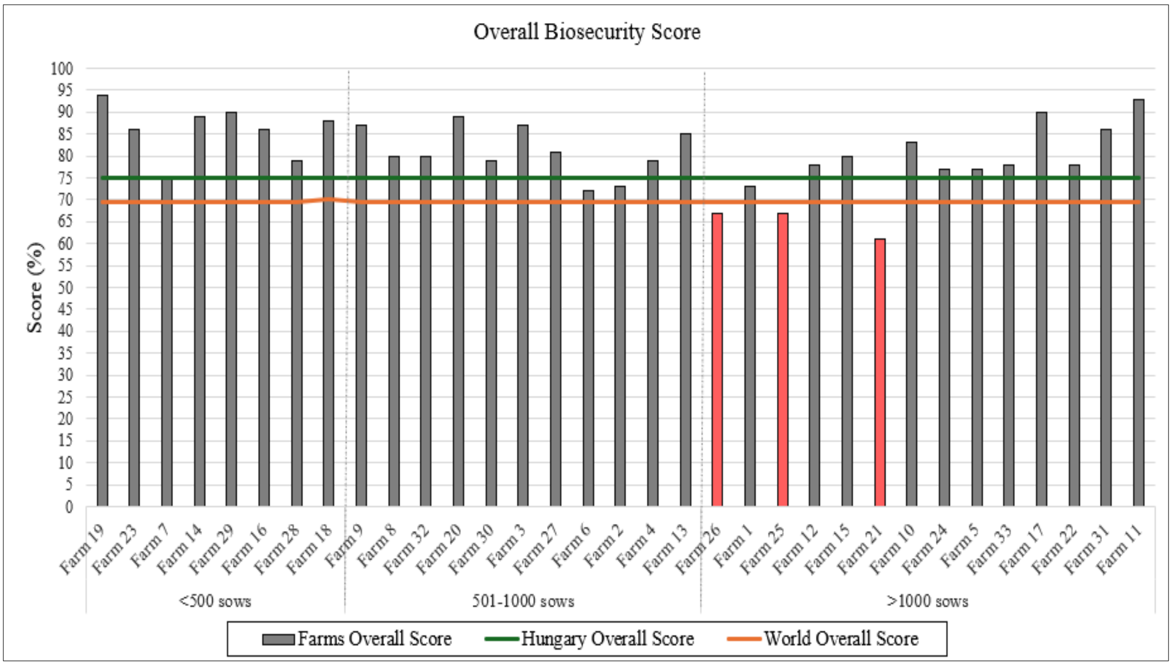


Figure 5 displays the aggregated biosecurity scores of farms across different categories based on farm size (e.g., <500, 501–1000, and >1000 sow-units). It also compares the farms' scores to Hungary's overall score (green line) and the world overall score (orange line). It can be concluded that majority of farms have overall biosecurity scores above the national and global benchmarks, indicating generally good compliance.

Farms with more than 1000 sows tend to show slightly more variability in their scores, with some falling below the global benchmark. In Categories 1 and 2 (less than 500 sows and between 501-100 sows), most farms score comfortably above the national and global average scores. Only three farms in both Category 1 and 2 scored equal or just below the Hungarian benchmark (average) for overall biosecurity.

Outliers for overall biosecurity include Farm 21, Farm 25 and Farm 26 (in red) scored considerably lower than the global and national averages. These farms represent underperformance and are likely contributing disproportionately to variability in the overall biosecurity scores.

5. Conclusions and Suggestions

The current study scored an average score of 85.5% for external biosecurity, 75.3% for internal biosecurity and 80.8% for overall biosecurity. Compared to study conducted by Rodrigues da Costa [40] scores were 78.7%, 57.4% and 68.3% for external, internal and overall biosecurity respectively. A study conducted in Slovenia scored averages of 69.65%; 59.12% and 64.59% for external, internal and overall biosecurity, respectively. Kruse et al. [45], found in their study in Danish sow herds scores for external biosecurity on average 86% and internal biosecurity on average 67%. The results of the current study reveal that Hungary's average biosecurity scores are higher compared to those reported in previous studies conducted in Ireland, Slovenia and Denmark [39, 40, 45].

Most Hungarian swine farms surpass the World Overall Score benchmark, demonstrating strong adherence to biosecurity protocols. Farms achieving close to 100% are likely implementing best practices across both external and internal biosecurity measures.

Low performing (under the benchmark) farms require targeted interventions to address gaps in their biosecurity protocols. These farms are likely struggling with specific biosecurity scoring subcategories. That is why, it is recommended to conduct detailed audits of underperforming farms to identify the specific subcategories driving low scores (e.g., disease management, cleaning protocols, pest control). Our findings show that areas like farrowing and suckling, vermin control, and farm location need improvement across the board. Addressing these weaknesses by providing tailored recommendations could improve their biosecurity protocols and could raise their overall biosecurity scores. Further, the use of high performing farms as benchmarks to develop case studies and training materials for underperforming farms might also be helpful.

Our results show that farm size does not appear to have a consistent correlation with biosecurity scores. However, large farms (>1000 sow-units) exhibit greater variability, indicating that operational complexity might contribute to uneven biosecurity implementation.

Hungary’s average biosecurity scores are consistently above the world average, reflecting strong national biosecurity protocols. The country standard for internal and external biosecurity scores are above global standard and possibly give Hungary a competitive edge in the pig industry.

6. Summary

Biosecurity practices and implementation is essential to prevent the spread of diseases and safeguard animal health and public health. The current study focuses on biosecurity measures in Hungarian large-scale, intensive pig farms, assessing internal and external protocols using Biocheck.Ugent Pig® (Biocheck).

Biocheck is standardized scoring tool that uses a series of questions as indicators and assigns a percentile score to them. This scoring system is a scientific risk-based scoring method that can be used as an indication tool to assess biosecurity performance on a farm. Data from 33 commercial pig farms across Hungary were analysed and were categorized into three size groups according to number of sows: 1) less than 500 sows; 2) between 501–1000 sows and 3) more than 1000 sows.

Our results indicate that Hungary's biosecurity scores surpass global averages, with external biosecurity averaging 85.5%, internal biosecurity at 75.3% and an overall score of 80.8%. These findings reflect Hungary's robust biosecurity protocols and commitment to animal and public health. Key external biosecurity measures, such as visitor management and purchase policies, performed exceptionally well. Internal biosecurity measures, namely vermin control and farm location showed variability. Internal measures such as disease management scored the highest, while the farrowing and suckling period and compartmentalization were weaker areas. This emphasize that better hygiene and movement controls are needed and that there is still room for improvement.

Compared to other European studies, Hungary demonstrated higher biosecurity scores, indicating advanced practices. Nevertheless, smaller and financially constrained farms face challenges, especially in infrastructure and resource access. Larger farms showed more variability due to operational complexity. The study underscores the need for targeted interventions on underperforming farms, emphasizing education, stricter protocols, and benchmarking against high-performing units. Enhanced biosecurity measures can reduce disease risks, improve productivity, and minimize antimicrobial usage, aligning with global health and sustainability goals.

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