Original Full Paper

Assessment of pulmonary lesions associated with Porcine Respiratory Disease Complex in Colombian swine herds using slaughterhouse lung scoring systems

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Abstract

Porcine Respiratory Disease Complex (PRDC) causes substantial economic losses in swine production due to decreased efficiency and increased reliance on pharmaceuticals for disease control. Diagnosis of PRDC can be achieved by evaluating lung lesions at slaughterhouses, which enables assessment of herd health status and the formulation of targeted control strategies. In this study, the MADEC and SPES scoring systems were employed to characterize lung lesions associated with PRDC in pigs slaughtered in Colombia. A total of 16,223 red viscera (lungs, heart, and liver) from 15 commercially advanced farms were examined, utilizing the MADEC system for cranioventral consolidations and the SPES system for dorsocaudal pleuritis. Additionally, histopathological analyses and multiplex PCR tests were performed on randomly selected samples to identify microscopic lesions and respiratory pathogens. Approximately 70% of diaphragmatic lobes on both sides exhibited mild lesions (MADEC1), while severe lesions (MADEC3–4) were predominantly observed in the cardiac and accessory lobes. The prevalence of pleuritis was 17.7%, with SPES types 1 and 2 being most common. *Glaserella parasuis* was the only pathogen detected in the analyzed samples. Furthermore, concurrent use of up to five antimicrobial groups was documented across the farms. In conclusion, the observed respiratory lesions likely reflect the widespread circulation of PRDC agents, underscoring the need to enhance biosecurity, vaccination programs, and epidemiological surveillance in Colombian swine production. The adoption of standardized systems, such as MADEC and SPES, facilitates effective monitoring and control of respiratory diseases throughout the production chain.

Keywords: Porcine Respiratory Disease complex, lung pathology, abattoirs, antimicrobial use, epidemiological surveillance.

Introduction

One of the most critical aspects of analyzing animal health plans in animal production systems is determining lesion findings in slaughterhouses, which can assess the suitability of carcasses for human consumption and provide feedback for epidemiological investigations of infectious agents present on the farm, as well as the quality of animal health plans. In swine production systems, it is essential to evaluate lesions associated with Porcine Respiratory Disease Complex (PRDC), a multifactorial disease that primarily affects swine farms worldwide. PRDC causes significant economic losses for the industry by adversely affecting production parameters. Additionally, it increases the cost due to the use of antimicrobial drugs for controlling bacterial infections, as well as vaccines and other biosecurity measures. Only a small number of pigs raised under commercial conditions are slaughtered without pulmonary lesions (11, 17, 28).

To assess pulmonary lesions and other organs, as well as their association with various pathogens, including viral and bacterial infections, in pigs at the slaughterhouse, various approaches have been developed. These approaches are known as systems for evaluating and monitoring pulmonary lesions, some of which were proposed by various authors (10, 12, 13, 15, 33, 35). These systems help to determine the incidence and severity of injuries caused by respiratory diseases in pigs, such as enzootic pneumonia, atrophic rhinitis, pleurisy, and pleuropneumonia (27).

The most commonly used classification systems are MADEC and SPES. The Slaughterhouse Pleurisy Evaluation System (SPES) assigns a score for dorsocaudal pleurisy based on the extension and localization of pleural adherences associated primarily with *Actinobacillus pleuropneumoniae* infections (7). Otherwise, the MADEC system scores the lesion as cranioventral consolidation, characterized by gray-to-purple coloration and associated with *Mycoplasma hyopneumoniae* infection (20). One of the most common lesions observed in the analysis of meat carcasses in slaughterhouses is pneumonia and pleurisy, with prevalences oscillating between 19% and 79% and between 3.8% and 62%, respectively, according to the country and the system used (25).

Although these systems are valuable, it is essential to consider their limitations, as they may overlook subclinical lesions or localized lesions in deep organs. Additionally, the sensitivity to punctuation can vary among veterinary professionals, depending on their level of expertise. However, the early detection and characterization of lesions in the slaughterhouse contribute to a better understanding of the epidemiology of PRDC, enabling the implementation of more effective control measures, reducing economic losses, and improving animal welfare (17, 20).

In Colombia, there are no prior studies analyzing pulmonary lesions associated with PRDC in pig slaughterhouses from commercial pig farms. Therefore, the objective of this study was to evaluate pulmonary lesions in pigs at slaughter in Colombia using the MADEC and SPES scoring systems.

Material and Methods

Farms' characteristics and inspection of viscera at the slaughterhouse

A total of 16,223 red viscera (lungs, heart, and liver) were inspected over a six-month period (January to July 2019) in a private slaughterhouse in Bogotá, Colombia. The animals originated from 15 farrow-to-finish farms located in the "central region" of the country, comprising the departments of Boyacá, Cundinamarca, Meta, and Tolima. All farms used antimicrobials and vaccination programs against bacterial pathogens, including *Mycoplasma hyopneumoniae, Actinobacillus pleuropneumoniae*, and *Glaserella parasuis*, as well as viral agents such as Porcine Circovirus Type 2 (PCV2) and Porcine Parvovirus Type 1 (PPV1). Data on antimicrobial use were collected from the participating farms through structured records provided by farm managers. Information included the types of antimicrobial groups used to control respiratory diseases during the production cycle. Antibiotics were classified into pharmacological groups for subsequent descriptive and co-occurrence analyses. Post-mortem inspection was conducted along the slaughter line in the processing area using standard procedures, including visual examination as an initial screening step to identify gross pathological alterations, an approach associated with a reduced risk of carcass contamination (11).

Macroscopic inspection

The lungs inspected were evaluated using the MADEC system for cranioventral consolidation (used for Enzootic Pneumonia), which estimated the proportion (%) of lung parenchyma affected and its extension. The classification was MADEC1: <25%, MADEC2: >26-50%, MADEC3: 51-75% and MADEC4:>75% (10). The SPES system, as described by Dottori et al. (7), involves assigning a score to each lung based on the presence, extent, and location of adhesions (33). Lesions can be observed in the diaphragmatic lobes and require at least three months to resolve; therefore, their disappearance before arrival at the slaughterhouse is doubtful (8). This classification system includes five different scores, determined as follows: 0, absence of chronic pleuritis; 1, cranioventral lesion—pleural adhesion between lobes or on the ventral edge of the medial and diaphragmatic lobes; 2, focal unilateral dorsocaudal lesion; 3, bilateral lesion or extensive unilateral lesion affecting at least one-third of a diaphragmatic lobe; and 4, severely extensive bilateral lesion affecting more than one-third of both diaphragmatic lobes (20). Pleuritis observed at the slaughterhouse with scores between 2 and 4 is a lesion indicative of infections associated with *Actinobacillus pleuropneumoniae* (21).

Microscopic evaluation

For histopathological analysis, eleven samples were selected based on the presence and severity of macroscopic lesions observed during slaughterhouse inspection, aiming to include representative cases of different lesion patterns. The number of samples analyzed was influenced by logistical and budgetary constraints associated with laboratory processing. Fragments of tissue of 2 cm^3, with both healthy and injured tissue present, were fixed in 10% buffered formalin and sent to the SERVIPAT® pathology laboratory in Bogotá, D.C., Colombia, where they were processed using routine protocols, with sections of 4 µm that were stained with Hematoxylin and Eosin (HE) and analyzed microscopically according to the method described by Karabasil et al. (14).

Molecular Detection of Infectious Agents

From 11 samples, three samples of 10 grams from three randomly selected samples with severe MADEC lesions (MADEC4) were selected for molecular analysis using quadruplex PCR to assess the presence of selected bacterial pathogens associated with PRDC (*Actinobacillus* *pleuropneumoniae, Actinobacillus suis, Glaserella parasuis, Streptococcus suis*). The limited number of samples processed was determined by logistical and budgetary constraints. Samples were packed in a sterilized vacuum bag and frozen at -80°C until they were sent at 4°C in a cooler to the Molecular Biology Laboratory from the Diagnostic Unit of the Faculty of Agricultural Sciences at the University of Antioquia. A commercial kit, BIONEER AccuPower Porcine Respiratory 4-Plex PCR ®, was used. A total of 4 µL of DNA was added to the PCR mix and submitted to the following protocol: initial denaturation at 95°C for 5 minutes(min), followed by a second denaturation at 95°C for 30 seconds, annealing at 65°C for 1 min, and extension at 72°C for 5 min, for 35 cycles. Finally, three µL of the amplified product were loaded onto a 2% TBE agarose gel (4).

Statistical analysis

Descriptive statistics were used to present the absolute and relative frequencies of lesions and their distribution across sides and lobes within each system. Correlational analyses were also conducted for the MADEC system to assess whether the distribution of lesion categories (MADEC1–MADEC4) was independent of side (Left vs. Right). A 2×4 contingency table (side × MADEC category) was created, and Pearson's chi-squared test of independence was applied. Similarly, for each side, a contingency table (Lobe × MADEC category) was generated (3 × 4 for the Left; 4 × 4 for the Right), and Pearson's chi-squared test was applied using Fisher's Monte Carlo method.

To identify differences between pairs of lobes, paired post-hoc comparisons with Bonferroni correction and Monte Carlo simulation were conducted. By grouping the flank and lobe into a single variable, "Complete Lobe" (7 levels), its independence from the MADEC category was assessed using Pearson's chi-squared test, again employing Monte Carlo simulation for low cell counts. To further explore which lobes differed significantly in the distribution of MADEC categories, paired post-hoc comparisons between lobes (2×4 tables) with Bonferroni correction were performed. To estimate the probability of each MADEC category according to anatomical location (flank and lobe), a multinomial logistic regression model was fitted, which is appropriate for response variables with more than two categories and no strict numerical order. This regression estimates the probabilities of belonging to each MADEC category relative to the base category (MADEC1).

Results

A total of 16,223 red viscera (comprising lungs, heart, and liver) were inspected over six months in 2019. The primary lesions found were bronchopneumonia (9,381), pulmonary pleurisy (2,781), pulmonary abscess (207), and interstitial pneumonia (133). Otherwise, 554 red viscera had polyserositis (pleurisy, pericarditis, and hepatic adherences); additionally, 787 hearts had pericarditis, and 146 livers had adherence, and 2,234 inspected viscera had no apparent pathological changes.

Due to the severity of the lesions, and in accordance with sanitary normativity (22, 23), a total of 1,326 red viscera were condemned by national sanitary authorities during the study. The most common causes of condemnation were pulmonary pleurisy, pericarditis, and hepatic adhesions, and they originated from Cundinamarca, Tolima, and Boyacá.

MADEC System

The MADEC system was employed across 15,727 pulmonary lobes, and the overall results are presented in Table 1. The most common distribution pattern was <25% (MADEC 1) in 70% of pulmonary lobes bilaterally, followed by MADEC 2 (22.5% in the right lung and 21.1% in the left lung). More serious scores (MADEC3 and MADEC4) are present at low proportions (MADEC3: Right 5.1%, Left 8.0%; MADEC4: Right 2.4%, Left 0.8%). Figure 1 shows the percentage distribution of pulmonary lesions by the flank and lobe evaluated. MADEC1 lesions show a higher prevalence, primarily in the right (95.1%) and left (98.7%) diaphragmatic lobes. Additionally, MADEC2 showed similar prevalence across cardiac lobes bilaterally (27.1% on the right and 25.5% on the left).

This predominance indicates significant heterogeneity in the distribution of severity scores between lobes for each flank. There were statistically significant differences between the lobes on the same side (p = 0.0099 for the left side and p = 0.0216 for the right side). For the left lung, the severity of lesions evaluated is as follows: Apical/Cardiac, p = 0.00423; Apical/Diaphragmatic, p = 0.003; and Cardiac/Diaphragmatic, p = 0.003. For its part, on the right side, the results were as follows: Accessory/Apical: p = 0.00104, Accessory/Cardiac: p = 0.00259, Accessory/Diaphragmatic: p = 0.00905, Apical/Cardiac: p = 0.00135, Apical/Diaphragmatic: p = 0.00980, and Cardiac/Diaphragmatic: p = 0.00198.

The Heatmap (Fig. 2) indicates that MADEC1 lesions were most probably in all lobes, especially in the left (96.5%) and right (96.3%) diaphragmatic lobes. MADEC2 and MADEC3 were most likely in the right accessory lobe (32.6% and 4.5%, respectively) and the left cardiac (25.3% and 10.9%. MADEC4 was most likely in the right apical lobe (9.3%). Multiplex PCR analysis was performed on three lung samples with severe MADEC lesions (MADEC4); among these samples, *Glaserella parasuis* was detected, whereas the other targeted pathogens in the assay were not identified. This pattern suggests that diaphragmatic lobes are more likely to experience mild injuries, whereas the right accessory and left cardiac lobes have a greater likelihood of severe injuries. These findings align with the observed anatomical distribution and previous statistical analyses.

SPES System

In contrast, the SPES system enabled analysis of the distribution of pleuritis types, which are typically associated with infections caused by *Actinobacillus pleuropneumoniae* infection (Fig. 3). Type 2 pleuritis was the most prevalent, affecting 35% of cases (978 out of 2.781 lungs), followed by types 1, 3, and 4.

Antibiotic therapy

Antibiotic use patterns for the control of respiratory diseases on farms are summarized in Figures 4 and 5. Overall, usage frequencies were similar across most groups, with Fluoroquinolones/Quinolones used on 11 out of 15 farms. Beta-lactams/Aminopenicillins and Pleuromutilins were each used on seven farms, while Phenicols and Macrolides were each used on six farms. The least commonly used antibiotics were Tetracyclines (4/15), Miscellaneous antibiotics (2/15), and combined Sulfonamides (1/15) (Fig. 4). Usage patterns per farm, which indicate the simultaneous use of the eight antimicrobial groups, are shown in Figure 4. Only two farms relied on a single pharmacological group for respiratory disease control, while the remaining farms use between two and five different antimicrobials concurrently. Based on these results, a co-occurrence analysis was conducted to identify common drug combinations across all farms (Fig. 5). Notably, the most frequent combinations involved Fluoroquinolones/Quinolones, particularly their use with Macrolides, as well as combinations with Tetracyclines, Phenicols, Pleuromutilins, and Beta-lactams/Aminopenicillins (four farms). Three farms combined Fluoroquinolones/Quinolones with Sulfonamides and miscellaneous antimicrobials (Fig. 5).

Histopathologic results

Of the 11 tissue samples submitted for histopathologic examination, three results are shown. Macroscopic and microscopic (histopathologic) images from SPES4 (Fig. 6A), SPES2 (Fig. 7A), and MADEC2 (Fig. 8A) lung samples collected during the study are shown. Histologic sections stained with Hematoxylin & Eosin reveal bronchiolar epithelium exfoliation (SPES4, 40×) (Fig. 6B), and pulmonary edema (SPES4, 100×) (Fig. 6C), moderate activation of BALT (SPES2, 40×) (Fig. 7B), and mild pulmonary congestion (MADEC2, 40×) (Fig. 8B). These findings are consistent with nonspecific inflammatory and circulatory alterations and are not pathognomonic of specific etiological agents such as *Mycoplasma hyopneumoniae* or *Actinobacillus pleuropneumoniae*. Among the remaining samples, three exhibited severe, multifocal suppurative bronchointerstitial pleuropneumonia, accompanied by marked activation of bronchus-associated lymphoid tissue

(BALT). Four samples showed incipient or mild multifocal mixed bronchopneumonia with moderate BALT activation, while one sample presented chronic polyserositis. Overall, these findings are consistent with inflammatory processes affecting the respiratory system; however, they are not pathognomonic and do not allow definitive attribution to specific etiological agents.

Discussion

Studies investigating lung lesions in slaughtered pigs are diverse, underscoring the value of such analyses for evaluating the effectiveness of health programs on pig farms. To the authors' knowledge, this is the first study of its kind conducted in Colombia. While global research has documented the prevalence of MADEC-type lesions in slaughtered pigs, no studies have characterized the anatomical distribution of these lesions within individual lobes or assessed whether specific lobes are more closely associated with certain degrees of injury. Our study, therefore, provides the first such patterns described in Colombia and is among the earliest worldwide. Predicted probabilities for MADEC1 and MADEC2 lesions were similar in the apical and cardiac lobes on both sides. For more severe lesions (MADEC 3 and 4), this pattern persisted bilaterally in the cardiac lobes and in the accessory lobe. These findings confirm that lung involvement is not uniform across lobes and suggest an increased susceptibility to severe lesions in certain lobes, possibly due to host factors (anatomical or physiological) or pathogen factors (including pathogenicity, virulence, and mechanisms of transmission).

Although molecular analysis was limited in this study, the observed cranioventral pattern of lung lesions is consistent with those commonly associated with airborne transmission of *M. hyopneumoniae* (32). However, this interpretation should be made with caution, as direct etiological confirmation was not established. Among the small number of samples analyzed by PCR, *Glaserella parasuis* was detected; this finding is exploratory and cannot be used to infer the absence of other PRDC-associated pathogens, but may suggest an opportunistic infection pattern, as previously described by Zhang et al. (36). It is important to note, however, that the inability to detect certain microorganisms (as occurred in this study) may reflect the multifactorial nature of these lesions, influenced by a combination of biological, immunological, environmental, and management factors that affect pathogen epidemiology, pathogenesis, virulence, and ultimately, their detectability. Also, it may be due to sampling limitations or to potential nucleic acid degradation in slaughterhouse-derived tissues, rather than to their true absence in the evaluated farms (1, 5). Therefore, further investigation is required to better understand the role of coinfections and pathogen interactions in lesion development. In some instances, pigs may recover from acute disease but retain anatomical lesions detectable at slaughter, even in the absence of identifiable microbial agents (20).

De Conti et al. (6), using the MADEC methodology in Brazil, found that the central pulmonary lesion is cranioventral consolidation, with an average MADEC score ranging from 1.58 to 2.83 (mild to moderate lesions), like the results obtained in this study; however, *Pasteurella multocida* was identified as the predominant causative agent of lesions, in coinfection with Influenza A virus and *M. hyopneumoniae.* Globally, studies such as Pallarés et al. (24) have found that the predominant pulmonary lesions in Portugal and Spain, in descending order, were bronchointerstitial pneumonia, suppurative bronchopneumonia, fibrinous bronchopneumonia, interstitial pneumonia, and pleuritis, findings consistent with those of the present study. Similarly, Przyborowska-Zhalniarovich et al. (29) reported bronchopneumonia as the most common lesion (57.8%), with an average MADEC score of 1.74, which aligns with the results observed in this study.

Despite these similarities, notable differences exist. In this study, all lungs examined exhibited some degree of MADEC-type lesion, with mild lesions (MADEC1: 70%) being the most common. Conversely, Przyborowska-Zhalniarovich et al. (30) found that only 45.1% of pig lungs in Poland showed lesions, with the majority being severe (MADEC 2, 3, and 4), collectively accounting for 94.57%. Kuberka et al. (16) also noted that lung lesions at slaughter were common (73.5% with mild to moderate lesions) and primarily due to multifactorial microbial causes. Differences between studies may stem from varying management practices, environmental factors, and seasonality. Notably, the fact that all evaluated pulmonary lobes showed some degree of lesion highlights systemic challenges in Colombian pig production. This widespread occurrence may reflect deficiencies in farm management, biosecurity, and disease prevention, increasing the risk of PRDC. These findings underscore the need for targeted research to identify local risk factors and implement effective preventive strategies. Expanding research on this topic within Colombia is crucial for understanding the dynamics of respiratory disease in national production systems and for developing effective prevention and control strategies for PRDC. Additionally, it is important to acknowledge that lesion assessment at slaughterhouses involve a degree of subjectivity, which may introduce observer-related variability, particularly in the classification of mild lesions; this should be considered in future studies.

Otherwise, the overall occurrence of pleuritis-type lesions, as assessed using the SPES system, was 17.68%, with SPES types 1 and 2 lesions being the most prevalent. This prevalence exceeds that reported in studies from Brazil—Arruda et al. (2) 11.3%, Galdeano et al. (9) 13.1%, Baraldi et al. (3) 9%, and Petri et al. (26) 12.3%—and Poland, where Kuberka et al. (16) observed an overall prevalence of 12.1% and an average score of 1.96. Regarding the SPES system's utility for lesion analysis and clinical correlation, Sipos et al. (34) found that pulmonary scores may not accurately reflect field clinical situations in porcine pleuropneumonia. Their research indicated that SPES results were higher during the subacute/chronic phases than during the acute/peracute phases. This finding also underscores the importance of effective vaccination protocols for reducing lung lesions at the herd level.

Alawneh et al. (1) found that, according to the SPES system, the overall prevalence of pleuritis in pigs in the Philippines was 22%, a result slightly higher than that reported in this study. They also identified associated risk factors, including the lack of swine cholera vaccination programs, pigs originating from commercial farms rather than small-scale farms, and the presence of another pig farm within 500 meters. All of this highlights the need to establish longitudinal epidemiological studies on pig farms across different departments to determine risk factors, disease presentation dynamics, and their direct impact on national productivity, and to combine these with analyses at the slaughterhouse level. Economic analyses of the effect of pleuritis indices in pigs at slaughter revealed that pigs with a higher degree of lesion incurred an additional cost of USD 1.29 per kilogram, compared to USD 1.32 for milder cases. Furthermore, total revenue decreased by 1.36%, and the return on investment dropped from 5.33% to 3.90%, primarily due to reductions in average daily weight gain (18).

Finally, regarding antibiotic use during the finishing stage on the surveyed pig farms, up to five different drugs were used within the production systems, a trend that appears to be common globally. Mallioris et al. (19) reported that the primary reasons for antimicrobial use varied according to production stage, with musculoskeletal/neurological diseases (62.9% of farms) and respiratory diseases (52.3%) being the main drivers. The most frequently used pharmacological groups were tetracyclines, macrolides, lincosamides, and trimethoprim-sulfonamides, consistent with the findings of this study. Patterns of use among different subpopulations are crucial for understanding these dynamics. Additionally, the frequent use of these drugs may reflect the need for more frequent treatment, longer treatment durations, or higher doses (19).

In conclusion, lung lesions in pigs at slaughter were persistent. Most lobes showed some degree of involvement according to the MADEC scale, with mild lesions predominating (MADEC1: 70%). Pleuritis (SPES) had a significant prevalence (17.7%), with SPES categories 1 and 2 being the most common. A cranioventral pattern was identified for mild/moderate lesions, and a concentration of severe lesions (MADEC3–4) in the cardiac and accessory lobes. The predominant detection of *Glaserella parasuis* in the submitted samples suggests its possible involvement in severe lesions, although the small number of molecular samples limits etiological conclusions. The frequent and concomitant use of several antimicrobials on the evaluated farms poses risks to therapeutic efficacy and the selection of resistance. Longitudinal studies are recommended.

Data Availability

All the original contributions presented in this study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author Contributions

Paula Andrea Heredia Beltrán: Investigation, Data curation, Formal analysis, Writing original draft. **Miguel Andrés Soler Uribe**: Conceptualization, Methodology, Formal analysis, Writing – original draft preparation. **Victor Manuel Acero Plazas**: Conceptualization, Formal analysis, Supervision, Writing – review and editing. **Luis Edgar Tarazona Manrique:** Formal analysis, Visualization, Writing – review and editing. All authors have read and approved the final version of the manuscript.

Conflict of Interest

The authors declare no competing interests.

Generative AI Use Statement

The authors did not use generative artificial intelligence tools or technologies in creating or editing any part of this manuscript.

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References

1. Alawneh JI, Parke CR, Lapuz EJ, David JE, Basinang VG, Baluyut AS, et al. Prevalence and risk factors associated with gross pulmonary lesions in slaughtered pigs in smallholder and commercial farms in two provinces in the Philippines. Front Vet Sci. 2018;5:7. doi: 10.3389/fvets.2018.00007
2. Arruda LP, Malcher C, Petri FAM, da Silva DG, Storino GY, Almeida HMS, Sonalio K, Toledo LT, de Oliveira LG. Pathological analysis and etiological assessment of pulmonary lesions and its association with pleurisy in slaughtered pigs. Vet Microbiol. 2024;292:110039. doi: 10.1016/j.vetmic.2024.110039
3. Baraldi TG, Cruz NRN, Pereira DA, Galdeano JVB, Gatto IRH, Silva AFD, et al. Antibodies against *Actinobacillus pleuropneumoniae*, *Mycoplasma hyopneumoniae* and influenza virus and their relationships with risk factors, clinical signs and lung lesions in pig farms with one-site production systems in Brazil. Prev Vet Med. 2019;171:104748. doi: 10.1016/j.prevetmed.2019.104748
4. Bioneer. AccuPower® Porcine Respiratory 4-Plex PCR Kit. 2020. https://eng.bioneer.com/20-mpr-1115.html
5. Cid D, Fernandez-Garayzabal JF, Pinto C, Dominguez L, Vela AI. Antimicrobial susceptibility of *Pasteurella multocida* isolated from sheep and pigs in Spain – short communication. Acta Vet Hung. 2019;67:489–98. doi: 10.1556/004.2019.048
6. De Conti ER, Takeuti KL, Schwertz CI, Bianchi RM, Driemeier D, Barcellos DESN. Agents of pneumonia in slaughtered pigs in southern Brazil. Pesq Vet Bras. 2021;41:e06669. doi: 10.1590/1678-5150-PVB-6669
7. Dottori M, Nigrelli AD, Bonilauri P, Merialdi G, Gozio S, Cominotti F. Proposta per un nuovo sistema di punteggiatura delle pleuriti suine in sede di macellazione: la griglia SPES (Slaughterhouse Pleurisy Evaluation System). Large Anim Rev. 2007;13:161–5.
8. Espigares D. Un sistema práctico para valoración de lesiones pulmonares en matadero. Programa CLP. Anaporc. 2017;14(136):16-19.

9. Galdeano JVB, Baraldi TG, Ferraz MES, Almeida HMS, Mechler-Dreibi ML, Costa WMT, et al. Cross-sectional study of seropositivity, lung lesions and associated risk factors of the main pathogens of porcine respiratory diseases complex (PRDC) in Goiás, Brazil. Porc Health Manag. 2019;5:23. doi: 10.1186/s40813-019-0130-0

10. Garcia-Morante, B., Segalés, J., Fraile, L., Pérez de Rozas, A., Maiti, H., Coll, T., & Sibila, M. Assessment of *Mycoplasma hyopneumoniae*-induced Pneumonia using Different Lung Lesion Scoring Systems: a Comparative Review. J Comp Pathol. 2016;154(2-3): 125–134. doi: 10.1016/j.jcpa.2015.11.003

11. Ghidini S, De Luca S, Rinaldi E, Zanardi E, Ianieri A, Guadagno F, Alborali GL, Meemken D, Conter M, Varrà MO. Comparing Visual-Only and Visual-Palpation Post-Mortem Lung Scoring Systems in Slaughtering Pigs. Animals. 2023; 13(15):2419. doi: 10.3390/ani13152419

12. Goodwin RF, Hodgson RG, Whittlestone P, Woodhams RL. Some experiments relating to artificial immunity in enzootic pneumonia of pigs. The Journal of Hygiene. 1969; 67(3):465–476. doi: 10.1017/s0022172400041887

13. Hannan PC, Bhogal BS, Fish JP. Tylosin tartrate and tiamutilin effects on experimental piglet pneumonia induced with pneumonic pig lung homogenate containing mycoplasmas, bacteria and viruses. Res Vet Sci. 1982; 33(1):76–88. doi: 10.1016/S0034-5288(18)32364-6

14. Karabasil N, Čobanović N, Vučićević I, Stajković S, Becskei Z, Forgách P, Aleksić-Kovačević S. Association of the severity of lung lesions with carcass and meat quality in slaughter pigs. Acta Vet Hung. 2017;65(3):354–65. doi: 10.1556/004.2017.034

15. Madec F., Kobisch M. Bilan lésionnel des poumons de porcs charcutiers à l'abattoir. Journ. Rech. Porc. 1982;14:405–412.

16. Kuberka Z, Mee JF, Walaszek-Kayaoglu A, Klimowicz-Bodys MD, Dors A, Rząsa A. Relationships between pig farm management and facilities and lung lesion scores, and between lung lesion scores and carcass characteristics. BMC Vet Res. 2024;20(1):124. doi: 10.1186/s12917-024-03968-2

17. Maes D, Sibila M, Pieters M, Haesebrouck F, Segalés J, de Oliveira LG. Review on the methodology to assess respiratory tract lesions in pigs and their production impact. Vet Res. 2023; 54(1):8. doi: 10.1186/s13567-023-01136-2

18. Malcher CS, Petri FAM, Arruda LP, Aguiar GA, Storino GY, Sonalio K, et al. Health-economic impact attributable to occurrence of pleurisy and pneumonia lesions in finishing pigs. Vet Sci. 2024;11(12):668. doi: 10.3390/vetsci11120668

19. Mallioris P, Stefanopoulou M, Luiken REC, Wagenaar JA, Stegeman A, Mughini-Gras L. Diseases associated with antimicrobial use in pig farms and risk factors thereof: A cross-sectional study in the Netherlands. Prev Vet Med. 2025; 240:106535. doi: 10.1016/j.prevetmed.2025.106535

20. Merialdi G, Dottori M, Bonilauri P, Luppi A, Gozio S, Pozzi P, et al. Survey of pleuritis and pulmonary lesions in pigs at abattoir with a focus on the extent of the condition and herd risk factors. Vet J. 2012;193(1):234–9. doi:10.1016/j.tvjl.2011.11.009

21. Meyns T, Van Steelant J, Rolly E, Dewulf J, Haesebrouck F, Maes D. A cross-sectional study of risk factors associated with pulmonary lesions in pigs at slaughter. Vet J. 2011;187(3):388-92. doi:10.1016/j.tvjl.2009.12.027

22. Ministerio de la Protección Social. (2007). Por el cual se establece el reglamento técnico a través del cual se crea el Sistema Oficial de Inspección, Vigilancia y Control de la Carne, Productos Cárnicos Comestibles y Derivados Cárnicos Destinados para el Consumo Humano y los requisitos sanitarios y de inocuidad que se deben cumplir en su producción primaria, beneficio, desposte, desprese, procesamiento, almacenamiento, transporte, comercialización, expendio, importación o exportación. Colombia.

23. Ministerio de Salud y Protección Social. (2013). Por la cual se establecen los requisitos sanitarios para el funcionamiento de las plantas de beneficio animal de las especies bovina, bufalina y porcina, planta de desposte y almacenamiento, comercialización, expendio, transporte, importación o exportación de carne y productos cárnicos comestibles. Colombia.

24. Pallarés F, Añón J, Rodríguez-Gómez I, Gómez-Laguna J, Fabré R, Sánchez-Carvajal JM, et al. Prevalence of mycoplasma-like lung lesions in pigs from commercial farms from Spain and Portugal. Porc Health Manag. 2021;7:26. doi:10.1186/s40813-021-00204-3

25. Paz-Sánchez Y, Herráez P, Quesada-Canales Ó, Poveda CG, Díaz-Delgado J, Quintana-Montesdeoca MdP, Plamenova Stefanova E, Andrada M. Assessment of Lung Disease in Finishing Pigs at Slaughter: Pulmonary Lesions and Implications on Productivity Parameters. Animals. 2021; 11(12):3604. doi:10.3390/ani11123604

26. Petri FAM, Ferreira GC, Arruda LP, Malcher CS, Storino GY, Almeida HMS, et al. Associations between pleurisy and the main bacterial pathogens of the porcine respiratory diseases complex (PRDC). Animals. 2023;13(9):1493. doi:10.3390/ani13091493

27. Prieto, C; Martínez, F; Segalés, J; Carvajal, A. Enfermedades infecciosas del ganado porcino. España: SERVET. 2017. p. 264

28. Prodanov-Radulović J, Vučićević I, Polaček V, Aleksić-Kovačević S. Current swine respiratory diseases morphology in intensive swine production in Serbia. Acta Vet (Beogr). 2020; 70(1):1–36. doi: 10.2478/acve-2020-0001

29. Przyborowska-Zhalniarovich P, Zhalniarovich Y, Wasowicz K. Estimation of the prevalence of respiratory diseases in pigs in north-eastern Poland: survey of pulmonary lesions in pigs at a slaughterhouse. Vet Med (Praha). 2021;66(6):242–7. doi:10.17221/188/2020-VETMED

30. Przyborowska-Zhalniarovich P, Maes D, Otrocka-Domagała I, Paździor-Czapula K, Wiszniewska-Łaszczych A, Sołtysiuk M. Association between enzootic pneumonia-like lung lesions and carcass quality and meat pH value in slaughter pigs. Animals. 2023;13(13):2210. doi:10.3390/ani13132210

31. Ruggeri J, Salogni C, Giovannini S, Vitale N, Boniotti MB, Corradi A, et al. Association between infectious agents and lesions in post-weaned piglets and fattening heavy pigs with porcine respiratory disease complex (PRDC). Front Vet Sci. 2020;7:636. doi:10.3389/fvets.2020.00636

32. Sarli G, D'Annunzio G, Gobbo F, Benazzi C, Ostanello F. The role of pathology in the diagnosis of swine respiratory disease. Vet Sci. 2021;8(11):256. doi:10.3390/vetsci8110256

33. Sibila M, Aragón V, Fraile L, Segalés J. Comparison of four lung scoring systems for the assessment of the pathological outcomes derived from Actinobacillus pleuropneumoniae experimental infections. BMC Vet Res. 2014;10:165. doi: 10.1186/1746-6148-10-165

34. Sipos W, Cvjetković V, Dobrokes B, Sipos S. Evaluation of the efficacy of a vaccination program against Actinobacillus pleuropneumoniae based on lung scoring at slaughter. Animals. 2021;11:2778. doi:10.3390/ani11102778

35. Straw BE, Backstrom L, Leman A. Examination of swine slaughter. Part II. Findings at slaughter and their significance. Compend. Contin. Educ. Vet. Pract.1986;8:106–110.

36. Zhang NZ, Zhou DH, Huang SY, Wang M, Shi XC, Ciren D, Zhu XQ. Seroprevalence and risk factors associated with *Haemophilus parasuis* infection in Tibetan pigs in Tibet. Acta Trop. 2014;132:94–7. doi:10.1016/j.actatropica.2013.12.021

Tables

Table 1. Macroscopic lesions distribution during inspection in a slaughterhouse using the MADEC system.

Lobe	Side	Number of samples	Number of simples according to the MADEC system result			
			1 **<25%**	**2** **26-50%**	**3** **51%-75%**	**4** **>75%**
Apical	Left	1,548	1,308	214	17	9
Cardiac	Left	4,606	2,875	1,176	510	45
Diaphragmatic	Left	448	442	3	2	1
Apical	Right	2,541	2,099	385	38	19
Cardiac	Right	4,319	2,727	1,169	356	67
Diaphragmatic	Right	843	802	35	4	2
Accessory	Right	1,423	763	464	64	132
Total (n) **(%)**		15,728	11,016 (70%)	3,446 (22%)	991 (6%)	275 (2%)

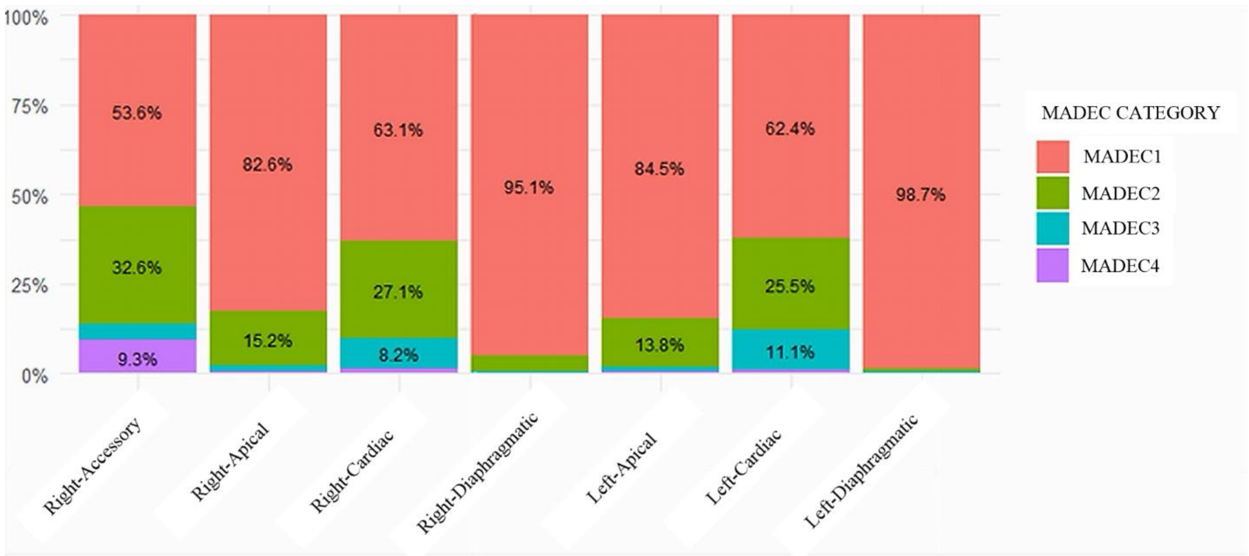

Figure 1. Percentage distribution of MADEC lesions for each pulmonary lobe according to the side

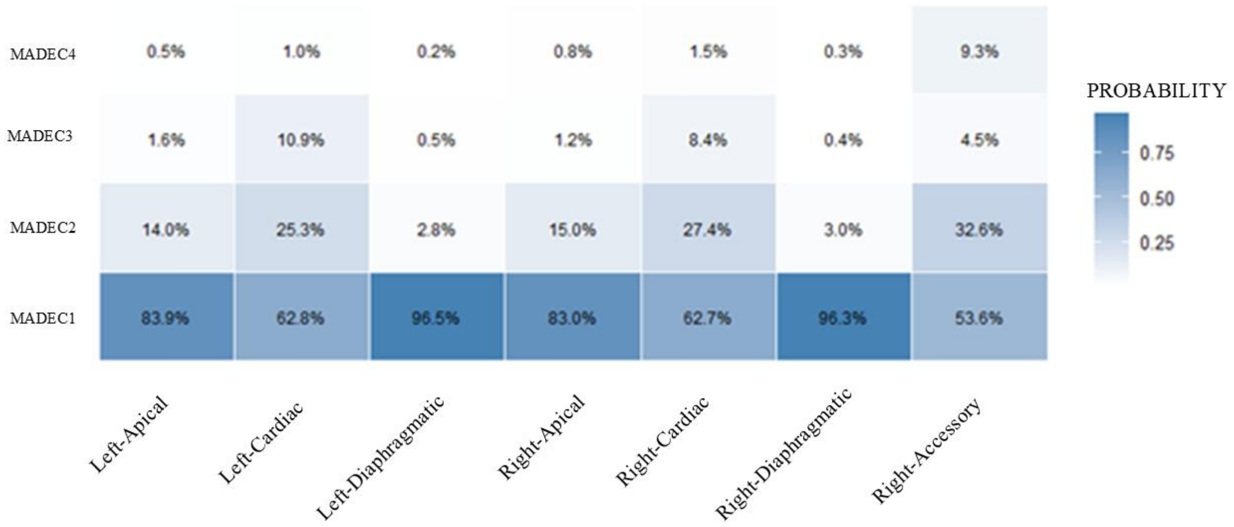

Figure 2. Probability distribution for the presence of MADEC lesions for each lobe evaluated.

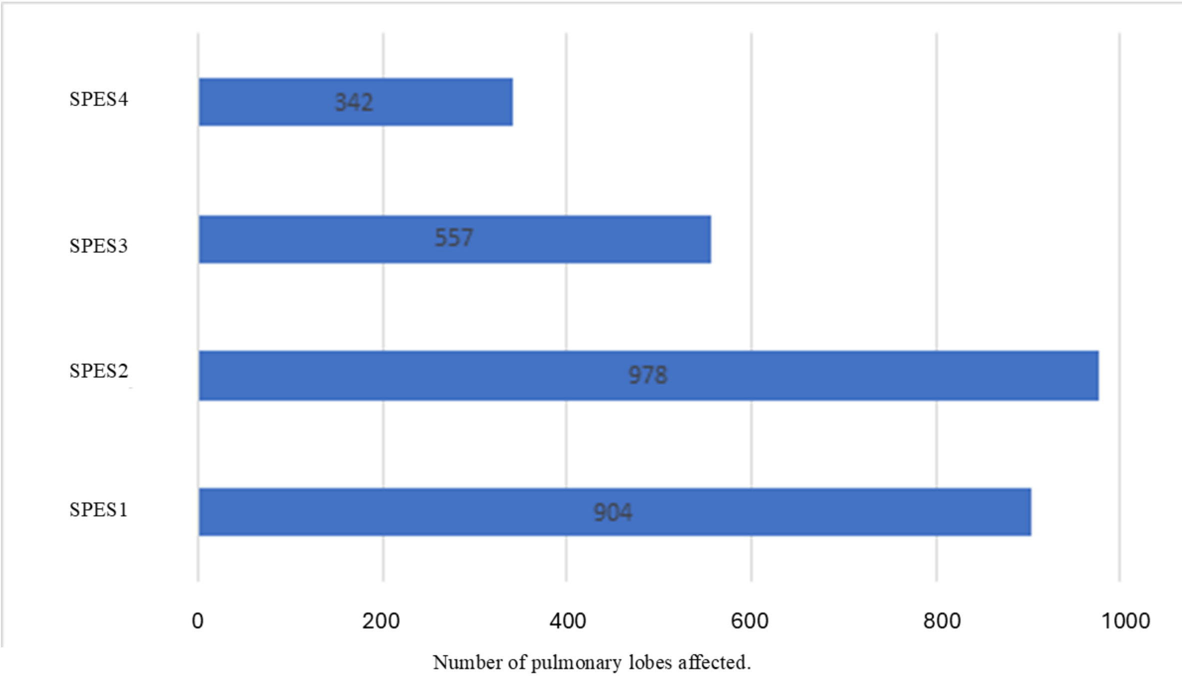

Figure 3. Lesion distribution according to the type of SPES lesion found

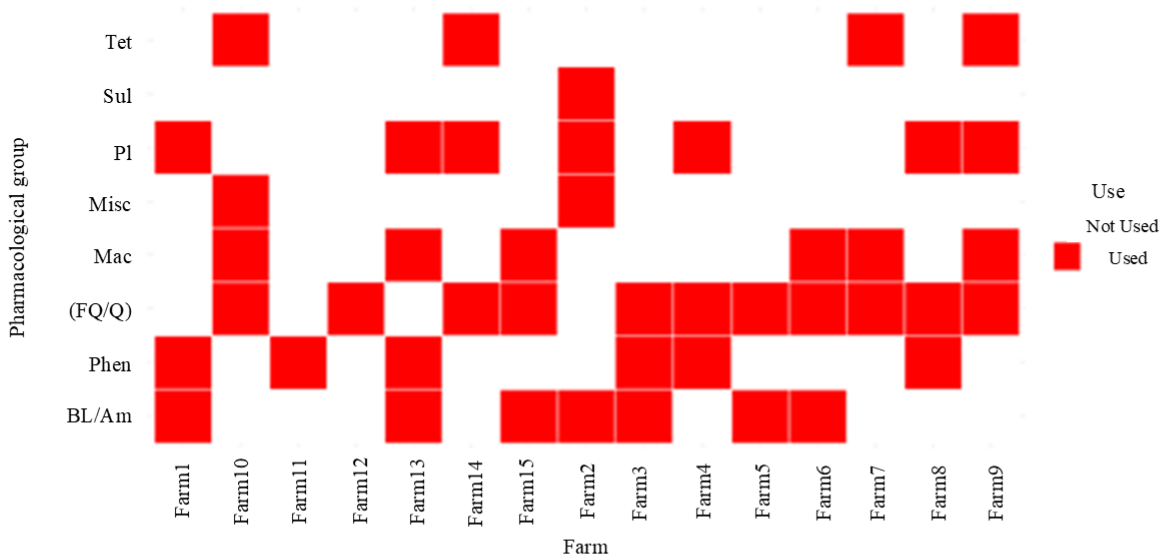

Figure 4. Distribution patterns of antibiotic usage on commercial pig farms included. Note: Fluoroquinolones/Quinolones: (FQ/Q); Beta-lactams/Aminopenicillins: (BL/Am); Tetracyclines (Tet); Miscellaneous (Misc); Sulfonamides (Sul); Macrolides: (Mac); Phenicols: (Phe); Pleuromutilins (Pl).

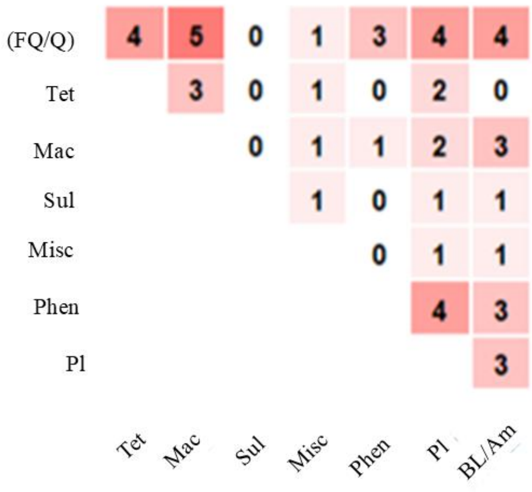

Figure 5. Heatmap for the co-occurrence of pharmacological groups in pig farms. Note: Fluoroquinolones/Quinolones: (FQ/Q); Beta-lactams/Aminopenicillins: (BL/Am); Tetracyclines (Tet); Miscellaneous (Misc); Sulfonamides (Sul); Macrolides: (Mac); Phenicols: (Phe); Pleuromutilins (Pl).

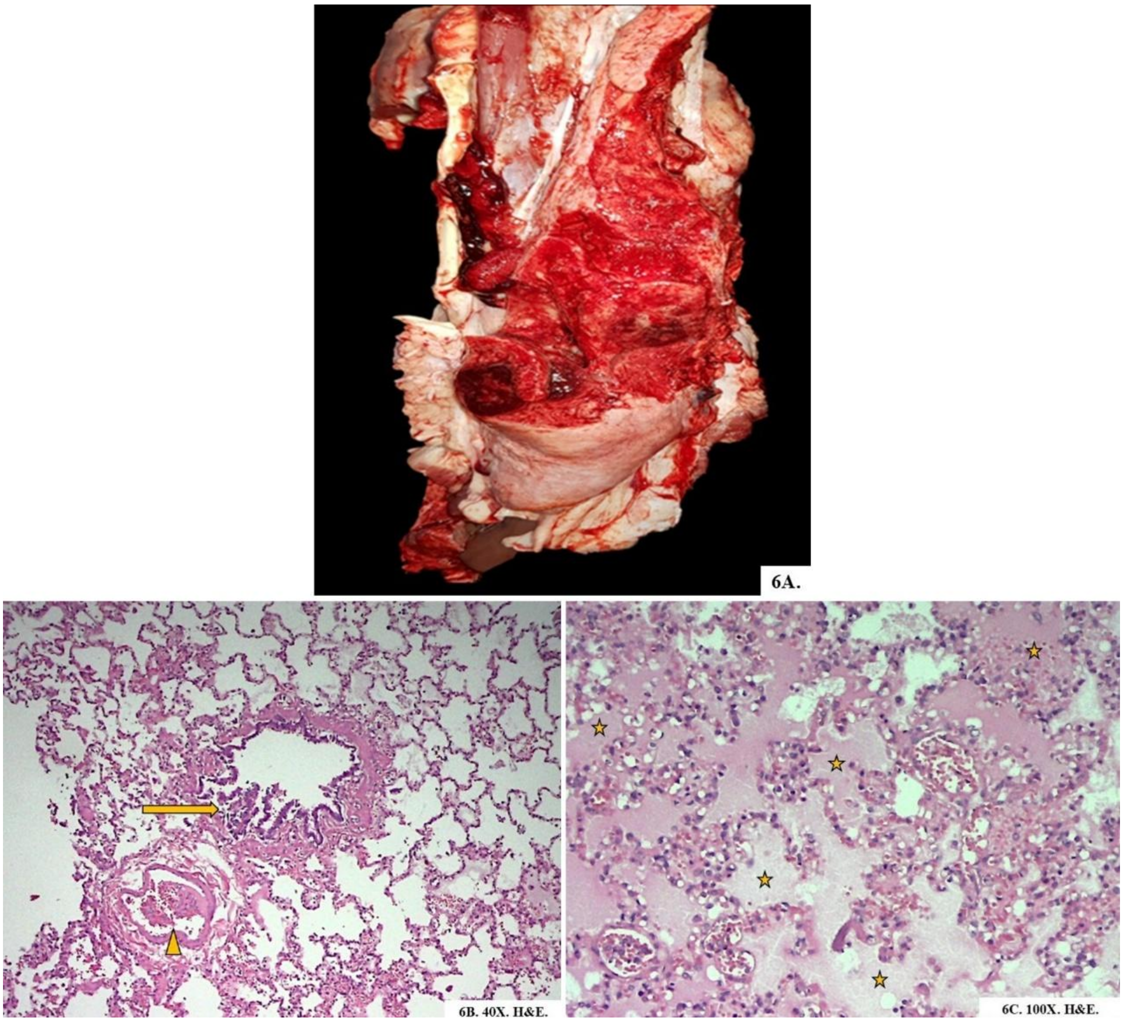

Figure 6. Macroscopic and microscopic (histopathologic) images from a SPES4 sample collected during the study. 6A. Gross image of the lung showing lesions corresponding to a SPES4 score. 6B. Lung tissue section at 40× magnification (Hematoxylin & Eosin stain). The arrow indicates exfoliation of the bronchiolar epithelium, and the arrowhead indicates vascular congestion. 6C. Lung tissue section at 100× magnification (H&E stain). The star indicates pulmonary edema.

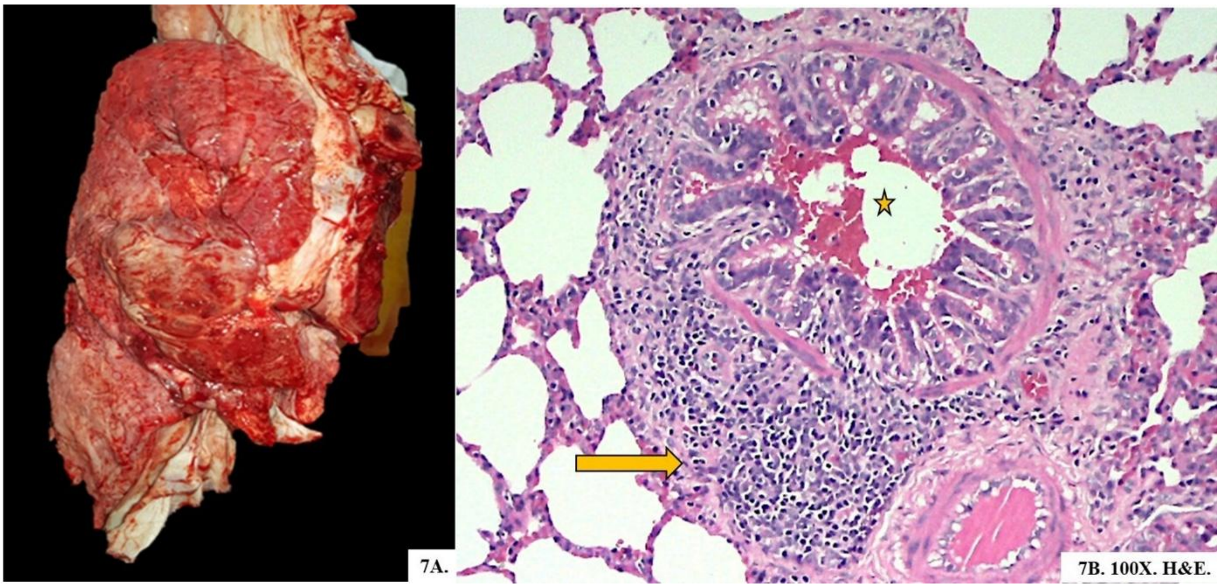

Figure 7. Macroscopic and microscopic (histopathologic) images from a SPES2 sample collected during the study. 7A. Gross image of the lung showing lesions corresponding to a SPES2 score. 7B. Lung tissue section at 40× magnification (H&E stain). The arrow indicates moderate activation of bronchus-associated lymphoid tissue (BALT).

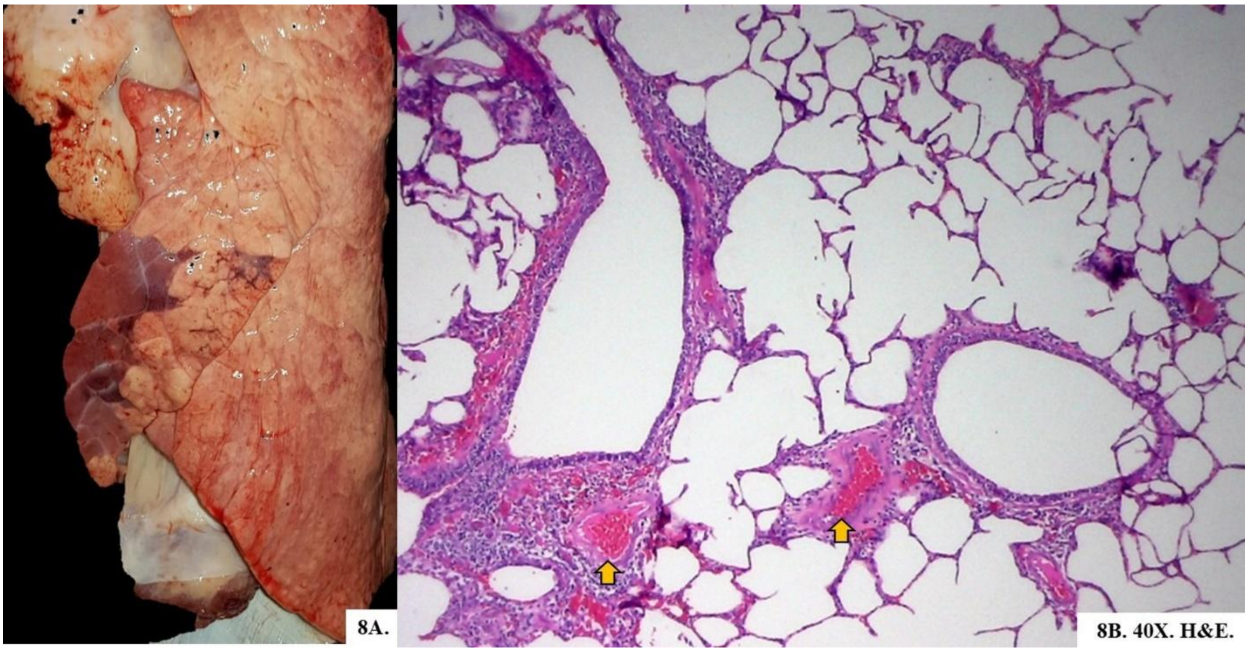

Figure 8. Macroscopic and microscopic (histopathologic) images from an MADEC2 sample collected during the study. 8A. Gross image of the lung showing a MADEC2 score. 8B. Lung tissue section at 40× magnification (H&E stain). The arrows indicate mild pulmonary congestion.