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Benchmarking of anatomopathological lesions assessed at slaughter and their association with tail lesions and carcass traits in heavy pigs

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ABSTRACT

Recording lesions at the abattoir provides information for benchmarking pig health and welfare conditions. The study involved 79 batches of Italian heavy pigs, mainly tail-docked. The aim of the study was to identify the prevalence of anatomopathological lesions and to identify relationships with carcass traits. The scoring of enzootic pneumonia-like lesions (EP), chronic pleuritis (CP), dorso-caudal pleuritis, white spots on the liver and tail lesions (TLs) was carried out. Relationships among the lesions, the season of slaughter, slaughtering age and carcass traits were tested using logistic regression. Enzootic pneumonia-like lesions were observed on 30.20% (± 14.94) of the lungs with an average score of 0.91 (± 0.77). The prevalence of CP was 38.07% (± 15.86) with an average score of 0.83 (± 0.34) and an *A. pleuropneumoniae* index (APPI) of 0.71 (± 0.39). The prevalence of pericarditis and peritonitis was 5.5% (± 3.73) and 1.09% (± 0.64), respectively. White spots on the liver showed a prevalence of 12.94% (± 23.60) and an average score of 0.02 (± 0.04). The prevalence of TLs was 34.08% (± 11.21); 29.64% (± 11.21) showed moderate damage, and 4.44% (± 5.02) severe damage, not associated with pulmonary lesions or carcass traits. Dorso-caudal pleuritis, suggestive of previous *Actinobacillus pleuropneumoniae* infection, remained similar and was strongly associated with a higher lean meat percentage. Additional studies are necessary to better understand this association. The results showed that preventive measures against *Actinobacillus pleuropneumoniae* are deemed necessary to reduce dorso-caudal pleuritis and to improve pig health and carcass value.

HIGHLIGHTS

- Cardiopulmonary lesions and tail lesions are indicative of poor welfare and loss of profit in the pork chain and could share common risk factors;
- Dorso-caudal pleuritis, suggestive of previous *Actinobacillus pneumoniae* infection, was associated with carcass traits;
- Tail lesions were not associated with lung lesions or carcass traits. Both lesions can share similar risk factors but have different aetiologies.

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Pulmonary lesions; pleuritis and pericarditis; tail lesion; carcass traits; animal health and welfare


Introduction

Abattoir meat inspection has the primary role of safeguarding meat safety (Van Staaveren et al. 2016). In addition, the recording of data at the abattoir has provided substantial information for benchmarking health status and for judging the standard of animal housing and management during the production period and/or pre-slaughter (Stärk et al. 2014; Teixeira et al. 2016; Nannoni et al. 2017), enhancing surveillance on health and welfare indicators (EFSA. 2011).

Respiratory diseases are one of the major factors threatening swine health, and they can be responsible for extensive economic losses (Meriardi et al. 2012). Respiratory diseases can result from the interaction of infectious agents, farm conditions and host physiology (Stärk 2000). Of respiratory diseases, the development of ventrocranial bronchopulmonary lesions is suggestive of enzootic pneumonia (EP-like lesions); *Mycoplasma hyopneumoniae* infection and other bacteria can cause EP-like lesions (Madec and Derrien 1981; Mousing et al. 1990). Chronic pleuritis (CP) is

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 Supplemental data for this article can be accessed [here](#).

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also frequently observed in pigs' lungs at the abattoir, and it can be ventro-cranial or dorso-caudal (Merialdi et al. 2012). Ventro-cranial pleuritis is considered to be a complication of enzootic pneumonia (Christensen and Enoe 1999) while chronic dorso-caudal pleuritis is suggestive of previous *Actinobacillus pleuropneumoniae* infections (Enoe et al. 2002; Meyns et al. 2011; Merialdi et al. 2012). Some studies have reported the effect of several risk factors on the development of respiratory diseases, such as biosecurity level, air quality, the season in which the growing cycle started (Maes et al. 2001; Ostanello et al. 2007), and the general health and immune status of the pig (Stärk 2000). Other lesions can be observed at the abattoir on the pericardium, peritoneum and liver. Pericarditis can arise from the haematogenous dissemination of bacteria or the lymphatic extension of inflammation from adjacent tissues, such as the lungs or pleura. Peritonitis is common in growing pigs and is associated with systemic bacterial infections in which *Glaesserella parasuis* (originally known as *Haemophilus parasuis*) is the most common. The subsequent development of fibrinous intra-abdominal adhesion, can impair normal gut functions and cause discomfort, reduce feed intake and, for the most part, affect the production parameters in pigs (Zimmerman et al. 2012). White spots on the liver are chronic lesions due to *Ascaris suum* larvae migration which can cause hepatic fibrosis and therefore affect productive parameters (Zimmerman et al. 2012).

The presence of abscesses in the carcass has been found to be one of the main causes of carcass trimming since pyaemia can occur after an ascendant infection mainly caused by skin injuries and tail lesions (Valros et al. 2004; Gillman et al. 2008; Teixeira et al. 2016).

In addition to visceral lesions, tail lesions can be observed. These lesions could lead to abscesses which spread into the carcass since pyaemia can occur after an ascendant infection, and cause carcass trimming (Harley et al. 2014). Tail lesions are serious injuries derived from tail biting, abnormal behaviour which can originate from multifactorial stress conditions, and is therefore considered to be one of the most reliable indicators of animal welfare in pigs (EFSA 2007). Tail lesions can be the source of chronic and acute pain for the live pig, affecting pig health and causing deterioration of the productive parameters (Schrøder-Petersen and Simonsen 2001). Some studies have found that even slight tail lesions increased pleuritic and pulmonary lesions, and that the risk increases with the severity of tail lesions (Harley et al. 2014)

while other studies did not find any correspondence (Munsterhjelm et al. 2013; Van Staaveren et al. 2016). However, the relationship between respiratory diseases and tail lesions is still uncertain (EFSA 2014) as both issues can have the same predisposing factors (EFSA 2007). For example, poor management and housing conditions (i.e. high airspeed in the ventilation system, season, thermal discomfort, and the presence of gas and dust) have been shown to predispose the occurrence of both tail biting and respiratory disease (EFSA 2007). Tail biting and respiratory disease have also been reported to lead to similar consequences on carcass traits and productive parameters, such as growth reduction, the increasing use of antibiotics, higher carcass condemnation or carcass trimming (Harley et al. 2014 and Martelli et al. 2009). In fact, other studies have reported a correlation between poor health conditions and tail biting outbreaks (Kritas and Morrison 2007; Munsterhjelm et al. 2013), leaving the debate regarding the relationship between respiratory disease and tail lesions open. One factor which can play a major role in the prevalence of tail lesions is tail-docking. Performing tail docking is still one of the methods routinely used by farmers in the many European Union (EU) Member States to reduce tail biting behaviour (Nalon and De Briyne 2019), even though it is banned by Dir. 120/2008 EC as this practice is very invasive and has been proven to affect pig welfare, causing acute and chronic pain in pigs (Sutherland 2015; Viscardi et al. 2017). The last European Commission (EC) report concerning Italy referred to 2017 (European Commission 2018) and reported that almost all the pigs reared for industry were tail docked, and that no measures to avoid this practice had been put into effect. Since then, farmers in Italy have been encouraged to rear pigs undocked, introducing risk assessment tools to avoid tail biting outbreaks and, therefore, the need for tail docking (Alborali & Bertocchi 2021, www.classifyfarm.it). Even if tail docking has been demonstrated not to eliminate tail lesions (Valros and Heinonen 2015), many studies have observed that, overall, tail-docked pigs showed less severe lesions than undocked pigs (Scollo et al. 2016). It is important to report that, even when the rearing conditions provide adequate welfare standards for pigs, tail lesion prevalence may not differ (Vitali et al. 2019).

Tail biting might be a chronic issue as once lesions appear in a group of pigs, the behaviour is difficult to eliminate (Schrøder-Petersen and Simonsen 2001; Taylor et al. 2010).

Chronic lesions can occur at any time on a farm and could impair the health and welfare of pigs, having sudden consequences for productive parameters and carcass traits. In the case of a typical production, such as the product of designated origin (PDO) Parma Ham which requires pigs to have 160 kg of live weight ($\pm 10\%$), at least 9 months of age and less than 55% of lean meat percentage of the carcass (Parma Ham Consortium 2021), retarded growth could increase the time necessary to reach the weight and could impact the composition of the carcass with increasing cost for production and/or determining exclusion from certification (Faucitano 2001).

The present study hypothesised that associations exist among the pluck lesions and tail lesions detected at the abattoir, carcass trimming, carcass traits, season and age at slaughter.

The first aim of the study was to identify the prevalence of pulmonary lesions, pleuritis, pericarditis, peritonitis, carcass trimming or condemnation, and tail lesions, in 79 batches of pigs slaughtered in 2019 in Italy. The second aim was to identify the relationships among the previously mentioned lesions and season, slaughtering age and carcass traits.

Materials and methods

Ethical statement

The observations involved batches of carcass randomly selected at slaughter, and no pigs were sacrificed specifically for the study. Since no tissues or any other samples were collected, there was no need for approval by the Italian Health Ministry in agreement with the EU legislation DL n. 116, 27/01/1992.

Experimental protocol

Data collection was conducted from June to December 2019 by two people in an abattoir located in Italy with a weekly throughput of approximately 12,000 pigs. The speed of the chain was 1 pig every 6 seconds. A.L. scored anatomopathological lesions (EP-like lesions, chronic pleuritis, pericarditis, peritonitis and white spots on the liver). This author is a veterinarian and a member of the Zooprofilactic research institute (Italian public body specialised in epidemiologic and health surveillance, under the control of the Italian Ministry of Health), with more than 10 years of experience regarding these specific assessments. The scoring was carried out using visual inspection and palpation. The observer was placed on the dressing line in proximity to the evisceration. Tail lesions were

assessed by E.S., an animal scientist; this assessor was preliminarily trained by M.V. (expert evaluator) to use the score proposed in the Welfare Quality protocol (Welfare Quality® 2009). The training was performed using visual observation in the same abattoir, and the assessor was considered to be ready when the two scores reached $\geq 85\%$ of concordance. Intra-observer variability was then repeated in the middle and at the end of the experiment. Tail lesion scoring was carried out on each carcass on a raised platform in proximity to the Fat-O-Meter (F-O-M) (OM-SFK, Copenhagen, Denmark) in order to achieve a better view of the tail.

The data regarding carcass trimming were recorded at the dressing line according to the decision of the Veterinary Public Inspector. Slaughter was performed by exsanguination, after head-only electrical stunning. A total of 79 batches were recorded from 43 farms for a total of 10,079 carcass observed. The batches were randomly selected and they were all part of the PDO Parma Ham Consortium. For each batch, the season of slaughter was assigned according to the following categories: summer (S) = from June to September and autumn (A) = from October to December. The average age of the pigs (in months) was also calculated in each batch, recording the letter impressed on each thigh, according to the Parma Ham protocol, and then as the difference between the month of birth and the month of slaughter.

Recorded lesions and parameters

The parameters recorded in the study (anatomopathological lesions, tail lesions and carcass trimming) are reported in Table 1.

Carcass traits

The carcass trait measurements involved cold carcass weight and lean meat percentage. Both were automatically recorded by the abattoir. A fat-o-meater (F-O-M) was used to calculate lean meat percentage. The data regarding carcass traits were expressed as the mean of the batch. The age at slaughter was recorded and the following score was assigned: 0 = pigs slaughtered at the age of 9 months (which is the minimum required by the Parma Ham Consortium); 1 = pigs slaughtered at more than 9 months of age.

Statistical analysis

The experimental unit was the batch. Descriptive analysis was carried out using Excel software. For the

Table 1. List of parameters measured in the study, with references and descriptions.

| Item | Reference | Parameter | Description |
|-------------------------|-------------------------|--|---|
| EP-like lesion (EP) | Madec and Derrien 1981 | MADEC score | Each lobe (for a total of 7 lobes per pig) was scored from 0 to 4 (0 = absence of lesions; 1 = <25% of lesions in the lobe; 2 = 26–50% lesions; 3 = 51–75% lesions; and 4 = >75% of lesions), and the score were summed to a minimum/maximum score of 0/28 for each lung. An average MADEC score was then calculated (sum of lung EP score/number of scored lungs in the batch). |
| Chronic pleuritis (CP) | Dottori et al. 2007 | Prevalence of EP Scars | Prevalence of lungs having MADEC ≥ 1 in each batch |
| | | Lung abscess | Percentage of lungs showing scars in each batch |
| Chronic pleuritis (CP) | Dottori et al. 2007 | SPES score | Percentage of lungs in each batch having an abscess |
| | | Prevalence of CP | The SPES grid has 0 to 4 scores, briefly: 0 = absence of CP; 1 = ventro-cranial lesion; 2 = dorso-caudal unilateral focal lesion; 3 = type 2 bilateral lesions or an extended unilateral lesion; 4 = severely extended bilateral lesion. SPES average prevalence was calculated summing each lung score/the number of lungs scored. |
| | | APPI (<i>A. pleuropneumoniae</i> index) | Percentage of pleura having SPES ≥ 1 in each batch. The <i>A. pleuropneumoniae</i> index (APPI) describes the prevalence and severity of dorso-caudal pleuritis, and was calculated as follows: [(% SPES pt.2 + % SPES pt.3 + % SPES pt.4)/number of lungs receiving SPES pt.2,3,4]. The APPI ranges between 0 (no carcass showing dorso-caudal pleuritis) to 4 (all carcass with severely extended bilateral dorso-caudal pleuritis). |
| Pericarditis | – | Prevalence of pericarditis | Presence/Absence. Prevalence of pericarditis observed at the batch level. |
| Peritonitis | – | Prevalence of peritonitis | Presence/Absence. Prevalence of peritonitis observed at the batch level. |
| White spot on the liver | Luppi et al. 2014 | White spot lesion score | The livers were examined for white spot (WS) lesions using a quantitative lobar scoring system. Each, of the four principal lobes (lobus sinister lateralis and medialis; lobus dexter medialis and lateralis) were scored giving a score from 0 to 3. Score 0 (no WS); score 1 (1–5 WS); score 2 (6–10 WS) and score 3 (>10 WS). |
| | | Prevalence of White spot lesions | The sum of the scores obtained in each of the four-lobes was divided for the number of livers showing the characteristic lesions. |
| Carcass trimming | – | Total carcass trimmed | Presence/Absence. Prevalence of liver having white spot lesions observed at the batch level. |
| | | Reason for exclusion | For each carcass removed from the dressing line, the reason for exclusion (e.g. abscesses, disease, etc.) and the treatment (trimming or condemnation) was recorded. The prevalence of carcass trimming and condemnations were calculated on the total number of carcass in the batch. |
| Tail lesions | Welfare Quality® (2009) | Tail lesion score | Prevalence of the reason for exclusion was calculated on the total number of carcass removed in each batch. |
| | | Prevalence of tail lesions TLI (tail lesion index) | Percentage of the tails in each batch having one of the following score: 0 = absence of lesions; 1 = superficial biting along the length of the tail but no evidence of swelling or blood; 2 = fresh blood visible on the tail, or the presence of a scar, swelling, or a missing a part of the tail. Prevalence of tails having >1 score in each batch. Calculated as follow: [prevalence of TL score.1+ (2* prevalence of TL score 2)] |
| | Vitali et al. (2020) | Prevalence of tail lesions TLI (tail lesion index) | |

association study, a logistic regression model was built in the R environment (R Core Team 2017), using the lme4 package (Bates et al. 2015). Lung lesion scores were first clustered on a binary distribution (according to the epidemiological data reported on the same category of pigs in Italy) as follows:

- MADEC grid: 0 = <0.91 score; 1 = ≥ 0.91 score (Pangallo et al. 2019)
- SPES grid: 0 = <0.85 score; 1 = ≥ 0.85 score (Merlaldi et al. 2012)

Table 2. Descriptive results of the study. The results are based on the scores obtained at the batch level ($n=79$) for each of the lesions considered.

| | um | Mean | Sd | Median | Min | Max |
|---------------------------------|----|-------|-------|--------|------|-------|
| Lung lesions | | | | | | |
| EP prevalence | % | 30.21 | 14.94 | 29.59 | 2.94 | 74.56 |
| MADEC score | pt | 0.91 | 0.77 | 0.69 | 0.12 | 4.87 |
| Pulmonary abscess | % | 1.61 | 4.19 | 1.01 | 0.00 | 38.00 |
| Pulmonary scars | % | 1.55 | 3.06 | 0.00 | 0.00 | 14.49 |
| Pleuritis | | | | | | |
| CP prevalence | % | 38.07 | 15.86 | 37.21 | 5.00 | 69.23 |
| SPES score | pt | 0.83 | 0.39 | 0.84 | 0.07 | 1.61 |
| APPI score | pt | 0.71 | 0.39 | 0.66 | 0.00 | 2.15 |
| Pericarditis prevalence | % | 5.50 | 3.74 | 5.00 | 0.00 | 17.02 |
| Peritonitis prevalence | % | 1.09 | 0.64 | 1.00 | 0.00 | 5.10 |
| White spots on the liver | | | | | | |
| White spots score | pt | 0.02 | 0.04 | 0.00 | 0.00 | 0.21 |
| White spots prevalence | % | 12.94 | 23.60 | 0.00 | 0.00 | 90.91 |

- APPI (*A. pleuropneumoniae* index) grid: 0 = <0.62; 1 = ≥ 0.62 score (Luppi et al. 2016)

The threshold chosen regarding the MADEC and the APPI grids was based on the Italian distribution published regarding EP-like lesions and APPI values. The distribution in classes or quartiles of EP-like lesions and APPI values can be used as a tool for ranking a batch with respect to the general population. The threshold chosen for the SPES grid was based on and adapted from the data reported by Meriardi et al. (2012).

For the other parameters, the threshold was chosen based on the distribution of prevalence in the present paper as no previous data had been found regarding the same population.

The prevalence of pericarditis and white spots on the liver was clustered on a binary distribution as follows: 0 = <5% prevalence and 1 = $\geq 5\%$ prevalence. The prevalence of peritonitis was very low, and this parameter did not undergo additional analysis.

The reasons for carcass trimming which showed a prevalence above 1% were considered; therefore, only total trimming and abscessation were clustered in a binary distribution considering 0 = prevalence <1% and 1 = prevalence $\geq 1\%$. The prevalence of condemned carcass was very low; therefore, this parameter did not undergo statistical analysis.

Anatomopathological lesions and the reasons for carcass trimming were considered to be dependent factors and season of slaughtering to be an independent factor, while farm of origin was considered to be a random effect. Analysis of variance (ANOVA) was then carried to compare the different classes, using the lsmean package (Lenth 2016).

To investigate the effect of anatomopathological lesions and carcass trimming on carcass weight, age at slaughter and lean meat percentage, logistic

regression in a generalised linear mixed model (GLMM) was applied, considering carcass weight, age at slaughter and lean meat percentage as dependent variables, anatomopathological lesions as the covariate and farm of origin as a random effect. The carcass data were divided into a binary distribution, i.e. cold carcass weight: 0 = average carcass weight below 140 kg and 1 = average cold carcass weight over 140 kg. Lean meat percentage was classified as: 0 = below 50% and 1 = over 50%. Statistical significance was set at $p \leq .05$ in all the analyses.

Results

Anatomopathological lesions

EP-like lesions were observed in 30.20% (± 14.94) of the lungs inspected, with an average MADEC score of 0.91 (± 0.77). Lung abscesses were observed in 1.61% (± 4.19) of cases, and lung scars in 1.55% (± 3.06) (Table 2).

The prevalence of CP was 38.07% (± 15.86), with an average SPES score of 0.83 (± 0.34) and APPI values of 0.71 (± 0.39) (Table 1). The classes of severity are represented in Figure 1.

The prevalence of pericarditis was 5.5% (± 3.73) and peritonitis 1.09% (± 0.64). The prevalence white spots on the liver was 12.94% (± 23.60), and the average score was 0.02 (± 0.04) (Table 2).

Tail lesions

The tail lesion results showed that only 9 batches had less than 10% of pigs with an undocked tail. The prevalence of the tail lesions was 34.08% (± 11.21); the 29.64% (± 11.21) showed moderate damage (score 1), and 4.44% (± 5.02) severe damage (score 2). The distribution of the tail lesion score is reported in Table 3. On average, the tail lesion index (TLi) was 38.52 (± 15.13).

Carcass trimming and carcass traits

The average cold carcass weight was 139.73 kg (± 6.52) with a lean meat percentage of 51.27% (± 1.29). During all the observations, one carcass was destroyed (corresponding to the 0.001% of the carcass inspected). The percentage of carcass removed from the dressing line was 0.97% (± 1.09). The main reason for removal was the need for additional cleaning (51.81% ± 45.41) whereas trimming was mainly due to the presence of abscesses (34.01% ± 43.62); other defects were below 5% on average (Table 4).

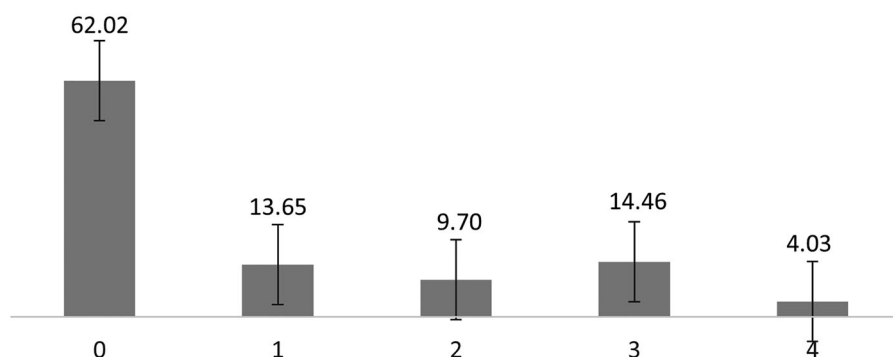


Figure 1. Class distribution of chronic pleuritis (CP). CP was assessed using the SPES grid, using a 0 to 4 score. The average prevalence of this score and minimum or maximum prevalence observed, considering all the batches ($n = 79$), was reported.

Table 3. Distribution of the tail lesions.

| | um | Mean | Sd | Median | Min | Max |
|----------------------------|----|-------|-------|--------|-------|-------|
| Tail lesion | | | | | | |
| TL prevalence ^a | % | 34.08 | 11.21 | 32.00 | 11.00 | 68.00 |
| Absent (score 0) | % | 65.92 | 11.21 | 68.00 | 32.00 | 89.00 |
| Middle damage (score 1) | % | 29.64 | 8.54 | 28.00 | 9.00 | 50.00 |
| Severe damage (score 2) | % | 4.44 | 5.02 | 3.00 | 0.00 | 24.00 |
| TLi ^b | pt | 38.52 | 15.13 | 36.00 | 13.00 | 92.00 |

The tail lesions were scored on a 0–2 score (0 = absence; 1 = superficial lesion; 2 = deep lesion, swelling, scar or crust). ^aPresence of the lesion (score 1 + 2). ^bIndicates the prevalence and severity of the lesion (% of score 1 + 2*% of score 2).

Association study

Detailed results of the association study are shown in [Supplementary File 1](#).

White spots on the liver presented a significant association with season, having a higher occurrence in pigs slaughtered in the summer as compared to the autumn (OR = 0.2, 95% CI = 0.8, $p = .02$). In this study, the slaughter season was not associated with the EP-like lesion, CP, or with pericarditis, peritonitis and overall carcass trimming and abscessation prevalence.

The association study showed that the batches with a higher lean meat percentage were associated with higher APPI scores (OR = 25.6; 95% CI = 283.5, $p = .008$) while the batches with a higher prevalence of trimmed carcass were associated with lower lean meat percentages (OR = 0.3; 95%CI = 0.6, $p = .008$), even if the effect was of a small extent.

No significant associations were observed between season and carcass weight, lean meat percentage and the age of the pigs at slaughter ($p > .05$). Tail lesions were not associated with lung lesions, pericarditis and white spots in the liver or with carcass traits ($p > .05$). No other associations were found among the variables tested, the carcass traits and slaughtering age ($p > .05$).

Table 4. General description of the prevalence of carcass trimmings and reason for trimming. Data were recorded from the public veterinary inspectors.

| | um | Mean | Sd | Median | Min | Max |
|-------------------------------|----|-------|-------|--------|------|--------|
| Prevalence of carcass trimmed | % | 0.97 | 1.09 | 0.76 | 0.00 | 4.62 |
| Reason for trimming | | | | | | |
| Abscess | % | 34.01 | 43.67 | 0.00 | 0.00 | 100.00 |
| Tail abscess | % | 1.60 | 8.08 | 0.00 | 0.00 | 50.00 |
| Peritonitis | % | 3.19 | 16.17 | 0.00 | 0.00 | 100.00 |
| Kidney disease | % | 1.77 | 8.68 | 0.00 | 0.00 | 50.00 |
| Monorchidic | % | 1.42 | 6.80 | 0.00 | 0.00 | 33.33 |
| Pleuritis | % | 1.60 | 8.08 | 0.00 | 0.00 | 50.00 |
| Bursitis | % | 1.42 | 9.72 | 0.00 | 0.00 | 66.67 |
| Additional cleaning | % | 51.81 | 45.42 | 50.00 | 0.00 | 100.00 |
| NA | % | 3.19 | 16.17 | 0.00 | 0.00 | 100.00 |

A total of 79 batches were registered, corresponding to a total of 10,079 carcass inspected.

Discussion

The results of the study added updated data regarding the prevalence and severity of EP-like lesions and pleuritis in Italian heavy pigs. The prevalence of the EP-like lesions was 30.2%, showing a reduction when compared with the data published in 2008 (Merialdi et al. 2012) and 2018 (Pangallo et al. 2019), the registered prevalences of which were 46.4 and 46.0%, respectively. The average values of the EP-like lesions obtained in the present study (0.91) provided new data regarding the prevalence of EP in the Italian pig population. These results were similar to the results of previous studies in 2008 and 2019 which reported average values of EP-like lesions of 1.03 and 0.91, respectively (Merialdi et al. 2012; Pangallo et al. 2019). Other studies in Italy have reported higher values, for example, Ostanello et al. (2007) and Scollo et al. (2017) reported 2.1 and 1.9 values, respectively. The differences between the studies might be imputable to the effects of vaccination against *M. hyopneumoniae*, extremely diffuse in Italy in recent years. Moreover, differences regarding season or randomisation process should be taken into account. However, the prevalence of EP-like lesions is still elevated, and

more effort should be made to control *M. hyopneumoniae* infection, for example by implementing biosecurity, welfare and management.

The prevalence of CP showed a reduction when compared to the data reported by Luppi et al. (2011) and Merialdi et al. (2012) in Italian heavy pigs (38.4% in the present study vs. 47.2 and 42.5%, respectively). It should be noted that, in the present study, the prevalence of dorso-caudal pleuritis (25.7%), the SPES score (0.83) and the APPI (0.70) are similar to those reported in previous studies (Luppi et al. 2011; Merialdi et al. 2012). The prevalence of dorso-caudal pleuritis, which is still high at present, confirmed that the presence of lesions suggestive of previous *Actinobacillus pleuropneumoniae* infections, still have a huge impact on pig health, without showing any improvement.

No previous data were found regarding pericarditis in Italian heavy pigs. In comparison to conventional lighter pigs (110–120 kg), fibrinous pericarditis has been recorded with different prevalences at slaughter in large-scale surveys worldwide: 13% (Buttenschøn et al. 1997, Denmark); 9% (Bonde et al. 2010, Denmark); 3.3% (Dalmau et al. 2016, average data from Portugal, Italy, Finland, Brazil and Spain) and 2.3% (Mathur et al. 2018, Germany). These differences may have been based on major differences in rearing systems and climate conditions between countries, and, in addition, they could have been influenced by the preventive measures carried out in each country. Moreover, the productive cycle of Italian heavy pigs is longer than that of conventional pigs and it might have exposed these animals longer to challenging environmental factors which could have affected the prevalence and severity of pericarditis.

White spots on the liver were present to a lesser extent (a prevalence of 12.3%) when compared to a previous study (Scollo et al. 2017) which reported a prevalence of 23.9%. This result was likely due to the positive attitude of breeders and farm owners regarding parasite control strategies as milk spot liver, caused by migrating *A. suum* larvae, is one of the most prevalent issues affecting pig productivity worldwide (Sanchez-Vazquez et al. 2011). Moreover, different randomisation methods in batch selection might have also contributed to differences in the results.

The present results showed that the majority of the batches observed in the present study in Italy were made up of tail-docked pigs, demonstrating that efforts were made to routinely reduce tail-docking in this country, and this effort should be increased. However, these results need to be taken cautiously,

and they do not represent the entire Italian situation as only one abattoir was considered, and commercial agreements between farms and abattoirs might lead to different results. Due to the strong prevalence of tail-docked pigs in the present study, the results were compared with existing data regarding tail-docked pigs. Tail lesions in Europe showed strong differences among countries, with values varying from a prevalence of 72.5% (Harley et al. 2014) to 20–30% (Carroll et al. 2016; Van Staaveren et al. 2017). The results of the present study showed a higher prevalence of tail lesions when compared to recent studies in Italy (Bottacini et al. 2018; Maisano et al. 2020). These differences were mainly based on the large variability observed among different farms and batches (Van Staaveren et al. 2017) which was also due to the multifactorial origin of this issue (Edwards 2006). Moreover, differences in the length of the tail after tail-docking (short, long-docked or tipped) could lead to different degrees of prevalence (Scollo et al. 2016). The position of the observer, and the conditions of assessment (such as distance from the tail and illumination of the room), can also influence the visibility of the lesions, and the outcome of the assessment (Honek et al. 2019).

In the present study, tail lesions were not associated with other anatomopathological lesions recorded at the abattoir. This result was in contrast with what had been observed by Teixeira et al. (2016) but was in agreement with Kritas and Morrison (2007), and Van Staaveren et al. (2016), reflecting the complex scenario behind tail lesions and respiratory disease in tail-docked pigs. *M. hyopneumoniae* and *A. pleuropneumoniae*, the bacteria responsible for EP and pleuropneumonia, respectively, do not spread to the lungs via the blood (Kritas and Morrison 2007). Therefore, when the higher prevalence of bronchopneumonia and dorso-caudal pleuritis was observed in pigs originating from batches with higher tail lesion scores, this was more likely because they shared the same risk factors (EFSA 2007; EFSA 2014) than to the consequentiality of events.

Previous studies regarding tail-docked pigs (Carroll et al. 2016) have reported a close association between tail lesions and abscessation, both on the carcass and in the lungs, or even with the presence of pyaemia. However, in the present study, tail lesions were not associated with abscesses in the carcass. The lack of a relationship between tail lesions and abscesses could be explained by the fact that tail biting (and subsequent tail lesions) can occur during all phases of rearing (Schröder-Petersen and Simonsen 2001; Taylor et

al. 2010) and, therefore, some tail lesions may have healed before slaughter. This is particularly relevant in Italian heavy pigs in which the production system allows slaughter of pigs starting at 9 months of age. On the contrary, many of the lesions scored at the abattoir were recent lesions which did not have time to create an abscess, as demonstrated in other studies (Martínez et al. 2007). This consideration focuses on the issue of the absence of a reliable and suitable method of visually identifying in the slaughter line when a lesion has occurred along the market chain (Van Staaveren et al. 2017; Vitali et al. 2017) and, subsequently, of the need for a more informative scoring system for tail lesions (Honeck et al. 2019).

Interestingly, the association study revealed that batches with severe dorso-caudal lung lesions had a higher lean meat content. In PDO ham production, even if the pigs did not show a difference in carcass weight or slaughter age, this was qualitatively negative as carcass with scarce fat coverage indicated that the hams were not suitable for seasoning, leading to a significant economic loss. The presence of lean meat has a genetic basis; however, the same breed can show higher variations depending on many other parameters, such as pre-slaughter conditions (Gispert et al. 2000) and health status (Permentier et al. 2015). In addition, if some studies identify the quantitative trait loci (QTL) associated with high susceptibility to *A. pneumoniae* phenotypes (Reiner et al. 2014), to the best of the Authors' knowledge, no studies have investigated the effect of QTL correlated with lean meat content in the carcass. A study involving swine breeds (Hoeltig et al. 2009) has reported less susceptibility of the Hampshire breed (well known for its higher lean meat content) as compared to the Landrace and Pietrain breeds, without analysing carcass traits. However, the results of this study cannot be compared with the present results as the pigs for the production of Parma Ham are commercial hybrids derived from the Large white, Landrace and Duroc breeds (Parma Ham Consortium).

It could be hypothesised that chronic lesions in the pleura might have increased the lean meat content of the carcass, even if knowledge regarding the physiological mechanism is still uncertain. In fact, the data reported by Del Pozo Sacristán et al. (2014), who compared the effect of a vaccine against *A. pleuropneumoniae* on carcass traits in pigs, showed that pigs which were not vaccinated presented higher chronic pleuritis lesions and higher lean meat percentage as compared to vaccinated pigs. On the contrary, another study found a decrease in lean meat content in pigs with

chronic lung lesions (Čobanović et al. 2021). These studies were carried out on smaller populations; therefore, more epidemiological studies are needed to better understand the association between chronic pleuritis and meat quality traits, and the physiology of the disease.

Conclusions

The results of the present study reported new benchmarks regarding EP lesions, pleuritis, pericarditis and white spots on the liver in Italian heavy pigs slaughtered in 2019. Moreover, the close association between dorso-caudal lung lesions and lean meat emphasised the commercial impact of these lesions, and supported the need for preventive measures to reduce their occurrence in order to improve pig health and welfare. Finally, tail lesions were not associated with lung lesions, or meat quality and carcass trimming, showing that, even if these lesions can have similar predisposing factors, their occurrence showed a more complex aetiology.

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Disclosure statement

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author, [PT], upon reasonable request.

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