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Benchmarking of pluck lesions at slaughter as a health monitoring tool for pigs slaughtered at 170 kg (heavy pigs)

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Abstract

Abattoir post-mortem inspections offer a useful tool for the development and monitoring of animal health plans and a source of data for epidemiological investigation. The aim of the present work was to develop an abattoir benchmarking system which provides feedback on the prevalence and severity of lesions of the pluck (lung, pleura and liver) in batches of pigs to inform individual producers and their veterinarians of the occurrence of pathological conditions affecting their herds. The weekly collection of data throughout a year (from September 2014 to September 2015) supported the further aim of providing benchmark values for the prevalence of lesions and their seasonality in Italian heavy pig production. Finally, correlations and redundancies among different lesions were evaluated. In total, 727 batches of heavy pigs (around 165 kg live weight and 9 months of age) derived from 272 intensive commercial farms located in Northern Italy were monitored. Within each batch, an average number of 100 plucks was individually scored, assigning a value for lesions of lungs (0-24), pleura (0-4) and liver (1-3). Presence of lung scars, abscesses, consolidations, lobular/chessboard pattern lesions and pleural sequestra was also recorded. Statistical analysis showed a strong farm effect (36-68% of variation depending of the lesion) and a seasonal effect on all lesions. Winter showed the lowest percentage of severe lung and pleural lesions ($P<0.001$ and $P = 0.005$), whereas lung scars from older lesions ($P = 0.003$), as well as severe hepatic lesions ($P<0.001$), were reduced in autumn. In order to allow effective benchmarking of each farm in a determined health class, scores for each quartile of the population are reported. Whilst such a benchmarking scheme provides useful data for herd health management, challenges of repeatability of scoring and cost of implementation need to be overcome.

Keywords: Pig; Slaughter; Pluck lesions; Benchmarking system; Season

Introduction

Disease surveillance is a first step to understand the animal health situation of a country (OIE, 2012). Improving animal health surveillance, and the identification of simple and reliable indicators for animal health, are priorities for the European Union and its animal health strategy (European Commission, 2007). This is particularly important for notifiable infections (e.g. Classical and African swine fever, Aujeszky's disease), but the same approach might be useful for the monitoring of production diseases, which have minor importance in current European Union surveillance programs but a great influence on economic return and antibiotic use of farms. Abattoir inspections offer a useful tool for animal health monitoring and a source of data for epidemiological investigation, and represent an opportunity for disease surveillance which is more cost-effective for many pathologies than the collection of data on farm. A good example of collective use of abattoir health data are the health schemes adopted in some countries (Willeberg et al., 1984; Elbers et al., 1992; Sanchez-Vazquez, 2011; see below). These initiatives provide feed-back of results from the abattoir inspections to the farmers and their herd veterinarians, contributing to their awareness of the occurrence of these diseases in their herds and tackling important health problems affecting efficiency of production and/or animal welfare (Sanchez-Vazquez et al., 2011).

In recent years, in Italy there is a growing interest from abattoirs, analytical laboratories and farmers to implement a system for the monitoring of lesions in pigs at slaughter similar to that of many other European countries. After the first Scandinavian programme in the 1970s (Willeberg et al., 1984) and the subsequent Dutch Integrated Quality Control programme later in the 1980s (Elbers et al., 1992), a more developed and integrated scheme started in England in 2005 with the BPEX Pig Health Scheme (BPHS) (Sanchez-Vazquez, 2011). These schemes record the presence and severity of various lesions of the pluck at post-mortem inspection at the abattoir of clinically healthy pigs destined for human consumption. The observed lesions are usually associated with diseases known to cause a reduction in animal performance.

Following initial development work of Merialdi et al. (2012), a pilot project on monitoring of lesions on several organs began in 2014 to recreate in Italy a monitoring scheme at slaughter similar to that already applied in other countries. Since then, the scheme has seen addition of the monitoring of many different lesions (e.g. gastric ulcers - Gottardo et al., 2017 - atrophic rhinitis, skin lesions, index of dermatitis, pericarditis etc.), but the main lesions are those affecting the lungs, pleura and liver. This is because respiratory disorders and the presence of parasites in the liver are among the diseases with great economic impact in modern pig production (Sorensen et. al, 2006; Stewart and Hoyt, 2006) and usually result in macroscopic lesions which can be detected at routine post-mortem inspection. Although several studies have previously been conducted on these lesions at the slaughterhouse, there is still limited information on the benchmarks for systems of heavy pig production, which predominates in Italy, where requirement for the production of Protected Designation of Origin (PDO) hams (Bosi and Russo, 2004) result in an extended fattening period until slaughter at about 160–170 kg live body weight and 9–10 months of age. Furthermore, there are few surveys (Done, 1991; Elbers et al., 1992) that take into account the seasonal occurrence of the lesions which can arise in different organs, and the inter-organ correlations of lesions. Understanding the temporal model of a disease, and the subsequent expression of its lesion characteristics, is essential for the understanding of its epidemiology. Last, but not least, to have seasonal values for each lesion score facilitates development of a decision support tool available to the farmer that can highlight the strengths and weaknesses of each farm’s health management throughout the year. The aim of this work was to describe and develop a benchmarking system useful for producers and their veterinarians, and applicable in conventional European abattoirs. Moreover, the study was designed to provide prevalence benchmarks and assess seasonal variations for lesions in the lungs, pleura and liver of pigs slaughtered at heavy weights, and to determine the correlations among lesions detected on different organs. Finally, the possible redundancies between different parameters recorded at the abattoir were evaluated in order to select measurements which give unique information on the health status of the organ and increase the time-efficiency of data collection without reducing information.

Materials and methods

Collection of data

The data used in this study were collected from September 2014 to September 2015. The monitoring of animals was carried out on a weekly basis (all the batches slaughtered on Monday) in an abattoir in Emilia Romagna (Società Cooperativa Agricola OPAS – Organizzazione Prodotto Allevatori Suini) which slaughters about 4,500 fatteners per day. Pigs (around 165 kg live body weight and 9 months of age) were delivered to the abattoir by trucks in batches of about 135 (minimum 130; maximum 140) animals derived from the same holding; all the pigs belonging to the same batch were consecutively slaughtered on the same day (Merialdi et al., 2012). In each batch, about 100 animals (minimum 95; maximum 105) were selected for the pluck evaluation, omitting carcasses at the beginning and end of each batch in order to avoid any risk of accidentally including pigs belonging to the previous or the next batch.

In total, 727 batches of heavy pigs (72,700 animals, with an average number of pigs per farm of 267 over the year of study) derived from 272 intensive commercial farms designated for the production of PDO ham were monitored. All the farms were located in the North of Italy, an area highly involved in the rearing of pigs for PDO ham and supplying 84.8% of the national production (Istat, 2011). In particular, farms involved in the study came from the four Italian regions with the highest density of pigs (Piemonte, Lombardia, Veneto and Emilia Romagna) and the greatest average farm sizes (Piemonte: 924 pigs per farm; Lombardia: 1840; Veneto: 527; Emilia Romagna: 1054; other Italian regions: 73) (Istat, 2011).

Pluck inspection

Speed of the slaughter line was 480 animals per hour and inspection of the pluck was performed directly during the slaughtering process, from a platform immediately after the evisceration area. The examination of the pluck of each animal was conducted by two veterinarians, trained to assign a score for each lesion (Table 1), who alternately worked side by side the government official veterinarians, but using different protocols of evaluation. The involvement of two veterinarians who alternately collected data on the platform guaranteed a good standard for attention in scoring across many batches throughout the day. To standardize the definition of the lesions across the inspectors, once in each season the two veterinarians underwent a refresher day where the same pigs were assessed on the abattoir line by both the assessors.

Examination of the pluck was conducted by visual inspection and manual palpation of the organs, without any incision. Scores were registered using a voice recorder placed in the upper pocket of the overalls, and were transcribed in an Excel file for analysis during intervals between work shifts.

Statistical methods

All the statistical analyses were performed in SAS (Inst. Inc., Cary, NC). For each batch, the average value for the lesion score of each organ was calculated, as well as the frequency of binary variables. Descriptive statistics of frequency of different scores for lesions were carried out (PROC UNIVARIATE). Data were analysed for their distributions. For normally distributed data an ANOVA was carried out with season as the fixed effect and farm as a random effect (PROC MIXED). For non-normally distributed data, an attempt was first made to normalise by transformation and, if this was not possible, the effect season was assessed using the non-parametric Kruskall-Wallis test (PROC NPAR1WAY). Season was categorised according to the solstices as: autumn (23 September-21 December), winter (22 December-20 March) spring (21 March-21 June), summer (22 June-22 September).

The relationship between the prevalence/score of the different lesions was assessed at the batch level using Spearman's rank correlation (PROC CORR). Possible redundancy between measures was evaluated using hierarchical Cluster analysis applied to the variables (PROC CLUSTER). The procedure grouped the variables progressively and iteratively on the basis of their similarity. As similarity coefficient the Spearman rank correlation was chosen and as agglomeration method the average linkage. The truncation criterion was based on entropy.

Results

Prevalence of lesions

Table 2 shows the distribution of prevalence for each lesion observed at slaughter, and the effect of season. The farm effect on all lesions of lungs, pleura and liver, when it could be estimated in the statistical model, was very significant, explaining 36-68% of variation in the fresh lesions. Among binary lesions, only scars from recovered enzootic pneumonia-like lesions occurred frequently (yearly average = 16.3 ± 9.8%), whereas others (abscesses, consolidations, lobular/chessboard pattern, and sequestra) were more sporadic (< 2%).

Statistical analysis showed that season had a very strong effect on almost all the measured lesions. Among the most frequent lesions, pigs slaughtered in summer had the greatest percentage of healthy lungs (*P*<0.001) and the lowest percentage of severe lesions and average lesion score (*P*<0.001), whereas scars from older lesions were reduced in autumn (*P* = 0.003). The prevalence of severe pleural lesions was higher in winter than in summer (*P* = 0.005), but there was no significant effect of season on mean pleural score. Severe hepatic lesions were reduced in the autumn (*P*<0.001), when there was also a lower percentage of total lesions and lower average score (*P*<0.001).

Correlation between different lesions and redundancy of parameters

The correlations between different lesion parameters are shown in Table 3. Many correlations were statistically significant, although the absolute r values were low, as a consequence of the large dataset processed. A cluster analysis (Figure 1) was used to identify possible redundancy within the measures reported. In this specific case, cluster analysis was used to determine the autocorrelation among variables. The similarity decreases along the y axis. When the variables are grouped near to a similarity equal to 1, they are strongly correlated (e.g. % pleura severe lesions and pleura APP index) and very similar (redundant). Therefore the assessment of one of the two variables reflects the same information of the other. The black horizontal line represents the point at which the tree could be truncated (based on the maximum entropy), identifying the groups of variables associated below this line which are more similar to each other. Five clusters of variables were identified: First group: % sequestra, % pleura severe lesions and pleura APP index; second group: % lungs severe lesions and % lungs scars; third group: % liver severe lesions and % liver total lesions; fourth group: % lung abscesses; fifth group: % healthy lungs. This indicated strong clustering of the different measurements of hepatic lesions, of the different measurements of current lung severe lesions together with scars, and of the different measurements of pleural lesions together with sequestra.

Quartiles for benchmarking purposes

Table 4 are shows quartile ranges in the studied population for the average scores for lungs, pleura and liver, considering the seasonal effects.

Discussion

The registration of lesions at the abattoir is a tool that has been previously adopted across Europe because it provides valuable feedback from the abattoir to the farm in order to make available knowledge upstream of the production cycle that is otherwise unavailable for management purposes (Willeberg et al., 1984; Elbers et al., 1992; Sanchez-Vazquez et al., 2011). In a British study, it was observed that companies that paid attention to the feedback received with the report from the slaughterhouse improved their scores over time, presumably associated with improved measures in disease management (Sanchez-Vazquez et al., 2012).

In the present study, a benchmarking system useful for heavy pig producers, but potentially applicable also in conventional European abattoirs, was developed and described. It is important to highlight its different purposes compared to the post-mortem inspection carried out by government official veterinarians: the former aims to provide management information useful for the farmer and herd veterinarian, while the latter assures meat consumers about the safety and hygiene of the meat. The Italian official procedures for meat inspection follow the EU Regulations in force (Reg. 216, 217, 218, 219/2014 of 7th March 2014) and check for signs of abnormalities that would present a public health risk. In contrast, a monitoring system for farmers checks lesions that are not strictly linked to carcass condemnation and might be compatible with meat approved for the market, but which might represent a sign of inefficiency in the farm managerial plan. For this reason, the benchmarking system described in this paper was implemented by specially trained veterinarians working separately from the official veterinarian.

Analysis of the data collected in this study showed that a large part of the variance in lesion scores was attributable to the effect of farm, highlighting the value of the scoring system in characterizing a farm health status. In order to use such information in a farm specific context, taking into account the differences of specific country and production system, it is clearly imperative to know the typical ranges for each lesion score to be able to position the farm within the overall population. By presenting quartile values for each lesion, the addressee of the health report can locate each farm in a determined class, furnishing the target to improve health management and move to a better quartile. Previous epidemiological studies have highlighted how the large variation in scores among farms might be due to different farm-related risk factors influencing the prevalence of lesions. For example, Sanchez-Vazquez et al. (2010b), identified geographical location, type of floor, increasing number of finishing pigs in the farm, and density of pig farms in the area of rearing as predisposing factors for lung and pleura lesions.

This paper also provides the most comprehensive report to date on the prevalence of different lesions, and their interrelationships, in Italian heavy pig production. Prevalence results (lungs with any lesion was 61.4% and with more severe lesions was 9.6%) are comparable to those in the earlier study of Ostanello et al. (2007) (any lesion 59.6%, more severe lesions 13.9%), but higher than those of a more recent study (Merialdi et al., 2012: any lesions 46.4%). The mean lung score in the current study of 1.9, shows the same comparative differences in relation to these earlier studies (Ostanello et al., 2007 - 2.1; Merialdi et al., 2012 - 1.0). A likely explanation for these differences lies in the time of the study. Whilst the sample of Ostanello et al. (2007) was taken across 12 calendar months, as in the present study, Merialdi et al. (2012) sampled only from April-June. Results from the current study indicate that prevalence of lesions is lower over this season, confirming other previous studies from different countries (Straw et al., 1986; Done, 1991; Elbers et al., 1992; Sanchez-Vasquezet al., 2012) which explained how pigs that spend the winter in conventional intensive housing are the ones most affected by poor air quality due to the reduction of ventilation rate for the maintenance of internal temperatures.

In a previous study carried out on heavy pigs (Dottori et al., 2007), the authors showed that the mean Madec score of animals weighting 160 kg was 1.8 times lower than the mean score measured at 100 kg. This supported the hypothesis of a healing process occurring until the pigs reach 160 kg of body weight. However, even if it is not possible to directly compare the results of the present study with lesions in lighter pigs, average scores recorded here appear to be not so different from those reported in other studies conducted in younger pigs (Madec score 1.88 vs. Fraile et al., 2010 - 3.3, and Meyns et al., 2011 - 0.62; SPES score 0.88 vs. 0.50 and 0.92). Further studies are needed to better understand the healing process and the correlation between lesion scores and body weight, but it should be considered that the intensive production of the heavy pig might present challenging conditions in the late rearing phase (e.g. animal density). This presumably interferes with the healing process or influences late co-infections (e.g. with Porcine Respiratory and Reproductive Virus, Influenza virus) due to a more critical management of climate parameters and ventilation in the barn at high rearing density.

Risk of respiratory tract lesions was greater in winter, and animals slaughtered in this season showed more recently formed lesions. However, it is important to emphasize that the observation of the nature of the lesions at the abattoir can give information about what happened in the respiratory tract earlier in the life of the animal. The significant occurrence of pneumonia scar tissue in spring, and extending into summer, confirms what was reported by Caswell and Williams (2007) and Maes et al. (2008) regarding lesion healing times. Whilst the EP-like lung lesion is visible on the pluck by two weeks after infection and for at least two months, if the lesions occurred earlier in time, the pluck will show only a scar. Such information reported from the slaughterhouse to the farmer can therefore help to pinpoint in time the presence of a new infectious challenge or the need for ventilation improvement in buildings.

Lesions of the pleura showed a similar, but less pronounced seasonal effect, with a lower prevalence of serious lesions in summer than in winter. The mean score (0.84) and the APP index value (0.75) are comparable to those reported earlier by Merialdi et al. (2012), 0.83 and 0.61 respectively. This similarity of findings, in contrast with the poorer correspondence in lung lesions cited above, might reflect the less pronounced seasonal effect on pleura lesions.

This would appear to be the first report on the prevalence of hepatic lesions in Italian heavy pig production. The prevalence observed (23.93% of livers with score 2 or greater) is higher than many other reports, e.g. 9% of Goodall et al., (1991) and 4.4% of Sanchez-Vasquez et al. (2010a). Roepstorff et al (1998) found a mean prevalence of 13% of Ascaris worm burden amongst late finishing pigs based on faecal egg count, with a range of 2-20% in different Nordic countries. Even if it is not possible to directly compare studies due to the different scoring system and methods adopted, the hypothesis of a higher prevalence of liver lesions in heavy pig may reflect evidence of a recent (time of healing lesions 3-6 weeks; Eriksen et al., 1992; Stewart and Hoyt, 2006) within-herd parasite transmission in the slaughtered pigs due to the prolonged finishing period which offers the possibility for reinfection to occur at a later stage of production. The existence of this high level of liver injury indicates a lack of, or inadequacy in, parasite control plans in many farms.

In contrast to respiratory diseases, summer gave more hepatic lesions. The result is in agreement with previous abattoir studies (Goodall et al., 1991; Sanchez-Vazquez et al., 2010a), and a farm survey which noted higher prevalence of infestation in the final part of the year (October-December) (Roepstorff et al., 1998). Nansen and Roepstorff (1999) explain this finding because embryonation and larval development of Ascaris are dependent on temperatures that should exceed 15°C, which are easily reached in Italy.

A positive interaction between migrating *A. suum* larvae and occurrence of pneumonia in pigs has been reported previously (Flesjå and Ulvesæter, 1980; Martinsson et al., 1991). However in this study, as well as in the study of Elbers et al (1992) and the machine learning analysis of Sanchez-Vasquez et al. (2012), no association was found between the prevalence of recent lung lesions and liver lesions within a batch of pigs. The observed association of hepatic lesions with lung scars might reflect the different timing of the lesions. In fact, *restitutio ad integrum* of liver lesions is achieved in about 3-4 weeks after the Ascaris migration (Greve, 2012), until two months in case of nodules. Considering the observation of Dottori et al. (2007), who showed a greater level of fresh lung lesions in 100 kg live body weight pigs rather than in 160 kg, it is possible that insurgence of parasitosis might be located after the middle or the end of the respiratory pathological process, when healing process of lung lesions has already started. While lung lesions heal, liver lesions increase and are more present in association with scars than with fresh lung lesions. Moreover, an association between EP-like lung lesions and pleurisy was shown, in agreement with most studies (Flesjå and Ulvesæter, 1980; Willberg et al., 1992; Sanchez-Vasquez et al., 2012), and reflects the fact that both respiratory conditions share common husbandry risk factors and some causal pathogenic agents (Enoe et al., 2002).

In Italy, the described monitoring system with a seasonal report has been developed due to a growing interest shown by some slaughterhouses and private companies. For example, abattoirs assembled by cooperatives of farmers have introduced and funded the monitoring of pluck lesions to increase services to their members. The service is completed by assistance to the farmer in interpreting reports and monitoring results over time. Furthermore, some analytical laboratories have introduced the service as a supplementary tool offered for diagnosis and epidemiological investigation of the health situation in a herd, especially in case of respiratory disease. During the development of the present work, costs related to the benchmarking system were about 0.18 €/pig slaughtered on the monitored day. Considering that one day (Monday) per week was selected in order to concentrate farms requiring monitoring in a single operative day, costs for the abattoir spread over the total weekly amount of slaughtered pigs were about 0.04 €/pig. The farmers' interest in the service seems to be strongly connected to the presence of a veterinarian with the capacity to interpret the results of the monitoring report and communicate these to the farmer, enhancing their value. A lack of such interpretation might be one reason why farmers, who should be the main beneficiary of the report, often seem not disposed to directly pay for it. For this reason, it is important to not only provide the benchmarks for each lesion score, but also to enhance communication between the abattoir and farmers/farm veterinarians. This is highlighted by Lam et al. (2011), who describe how such good communication is a fundamental tool to improve health in the farm. This requires a simplified interpretation of results, and classification of each farm in quartiles due to its score might be more intuitive for the addressee. Moreover, cluster analysis indicated some significant redundancy in variables collected in the present study. Whilst this does not affect the data collection process, it suggests that the output returned to farm veterinarians could be simplified. In particular, to report both the percentage of severe lesions and the total lesions in the liver is redundant and might be confusing for the recipient. In the same way, it is not necessary to show both the APP index and the percentage of severe lesions in the pleura. In contrast, changes in procedure based on the less strong apparent redundancy between severe lung lesions and lung scars might be less desirable, since useful biological information on the time course of infection could be lost in some situations. Similarly, changes based on the less strong apparent redundancy between severe pleural lesions (or APP index) and sequestra might be not so advantageous.

Considering possible critical points of the benchmarking system developed in the present study, there is the choice to score the pluck by manual palpation in addition to visual inspection. Even if EU Regulation 218/2014 of 7th March 2014 guides official authorities to perform palpation of organs only in case it is deemed necessary, the manual exploration allowed a more precise scoring, especially of the lungs which often hide EP-like lesions in the notch between cranioventral and dorsocaudal lobes (Leneveu et al., 2016). Moreover, the benchmarks shown might be subject to inter-abattoir variation due to possible influences of mechanical procedures during slaughtering (e.g. scalding water temperature, stunning methods or different lights), and inter-observer variation. In order to reduce this limitation, a good veterinarian training should include the recognition of abattoir-related artifacts. Moreover, as in the present study, a refresher day should be seasonally organized between veterinarian assessors to standardize the definition of the lesions across the inspectors and time. It is desirable to carry out such standardization exercises among assessors working in different abattoirs in the case of wider adoption of the benchmarking system, as already arranged by the BPHS and the Wholesome Pigs Scotland (WPS) schemes (Sanchez-Vazquez, 2011).

Among possible future implications of the described benchmarking system, its involvement in a 'big data' analysis might be considered. Big data, involving massive bodies of digital data collected from all sorts of sources, are increasingly being involved in the research and business communities. Such approaches have recently been applied in healthcare to guarantee human public health, moving toward evidence-based medicine which involves systematically aggregating individual medical data sets into big data algorithms, reviewing clinical data and making treatment decisions based on the best available information (Jee and Kim, 2013). As big data have been already introduced in agriculture and livestock (Keogh, 2016), it might be interesting to investigate the eventual value and opportunities to apply them also at the slaughterhouse.

Conclusions

The benchmarking system developed and described in the present work was successful in responding to the interest of abattoirs and private companies in Italy by evaluating practical aspects connected to a lesion scoring system. The monitoring process throughout a year provided data on national prevalence for lung, pleura and liver lesions, which has increased knowledge of the epidemiological situation on Italian farms and provided benchmarks in the form of seasonally adjusted quartiles to help report interpretation by farm veterinarians and drive health improvements. Knowledge of such data is of value, as these lesions can be reflective of subclinical disease status not easily detected in the live animal, but causing significant reduction in animal performance and herd profitability.

Conflict of interest statement

Società Cooperativa Agricola OPAS (Organizzazione Prodotto Allevatori Suini, Carpi, Modena, Italy) hosted and funded the operative part of this study, but played no role in the study design nor in the collection, analysis and interpretation of data, nor in the decision to submit the manuscript for publication. None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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Table 1

The scoring system used for pluck lesions evaluation at slaughter in Italian heavy pigs from September 2014 to September 2015. In total, 727 batches of heavy pigs (around 165 kg live body weight and 9 months of age) were monitored, where each batch comprised a group of about 135 (minimum 130; maximum 140) pigs from the same holding that were slaughtered on the same day.

Lesions	Scale	Description
Lungs		
Lung score (Madec score)	0-24	Pneumonic lesions (enzootic pneumonia-like, often due to *Mycoplasma Hyopneumoniae*: purple to grey rubbery consolidation, increased firmness, failure to collapse and marked edema) were scored according to Madec's grid (Madec and Derrien, 1981). Each lobe, except the accessory lobe, was scored from 0 to 4, to give a maximum possible total score of 24.
Absence of lesions	0-1	Lungs in which all the lobes, except the accessory one, received score 0.
Severe lesions	0-1	Lungs with a Madec score ≥5/24.
Scars	0-1	Presence of recovered enzootic pneumonia-like lesions, with thickened interlobular purple to grey (depending from the age) connective tissue which appears as retracted tissue.

Abscesses	0-1	Presence of at least one abscess in the lungs.
Consolidations	0-1	Pneumonic lesions complicated by secondary bacterial pathogens (e. g. Pasteurella spp, Bordetella spp), more firm and heavy than enzootic pneumonia-like lesions. In the case of a cut surface, lesion was mottled by arborized clusters of gray-to-white exudate-distended alveoli, and mucopurulent exudate could be expressed from the airways (VanAlstine, 2012).
Lobular/chessboard pattern lesions	0-1	Presence of scattered multifocal spots of purple to grey discoloration indicative of probable co-existence of viruses (Porcine Reproductive and Respiratory Virus, Porcine Circovirus, Influenza Virus) and/or Mycoplasma spp. or foreign body (e. g. dust/particulate matter) (Leneveu et al., 2016).
Pleura		
Pleura score (SPES score)	0-4	SPES grid (Dottori et al., 2007). 0: Absence of pleural lesions; 1: Cranioventral pleuritis and/or pleural adherence between lobes or at ventral border of lobes; 2: Dorsocaudal unilateral focal pleuritis; 3: Bilateral pleuritis of type 2 or extended unilateral pleuritis (at least 1/3 of one diaphragmatic lobe); 4: Severely extended bilateral pleuritis (at least 1/3 of both diaphragmatic lobes). Most probable etiology: *Actinobacillus pleuropneumoniae*, *Heamophilus Parasuis*, Pasteurella spp, Bordetella spp., *Mycoplasma Hyorhinis*.

Severe lesions	0-1	Pleura with a SPES score ≥3.
Sequestra	0-1	Presence of at least one sequestra in the lungs (acute: firm, rubbery and mottled dark red purple to lighter white areas with abundant fibrin, and hemorrhagic, necrotic parenchyma; or chronic: resolution of non-necrotic areas from acute infections results in remaining cavitated necrotic foci that are surrounded by scar tissue). Often associated with *Actinobacillus pleuropneumoniae* infection (Gottschalk, 2012).
Actinobacillus pleuropneumoniae index (APP index)	0-4	Frequency of pleuritis lesions with a SPES score ≥2 in a batch mean pleuritis lesion score of animals with SPES ≥2. The APP index ranges from 0 (no animal in the batch showing dorsocaudal pleuritis) to 4 (all animals with severely extended bilateral dorsocaudal pleuritis) (Merialdi et al., 2012).
Liver		
Liver score	1-3	Scoring based on the number of milk spot lesions due to *Ascaris suum* presence and their migration. 1: no lesions or less than 4 lesions; 2: from 4 to 10 lesions; 3: more than 10 lesions.
Severe lesions	0-1	Livers with a score 3.
Total lesions	0-1	Livers with a score ≥2.

Table 2

The prevalence of different lesions of the pluck in 727 batches of heavy pigs (around 165 kg live body weight and 9 months of age) slaughtered from September 2014 to September 2015 at an Italian abattoir, and the effect of season. A batch comprised a group of about 135 (minimum 130; maximum 140) pigs from the same holding that were slaughtered on the same day. Yearly average data are shown as mean ± standard deviation. Seasonal values are shown as LS-mean ± standard error (normally distributed data, F statistic reported) or median and range in brackets (non-parametric data, K: Kruskall-Wallis test), both corrected for the effect of farm.

	Yearly average	Spring (n=174)	Summer (n=215)	Autumn (n=161)	Winter (n=177)	*P*-value season	*F* or *K*	Farm effect (% variation)
Lungs								
Mean score	1.9 ± 1.0	1.9 ± 0.1^{b}	1.6 ± 0.1^{c}	2.1 ± 0.1^{ab}	2.1 ± 0.1^{a}	<0.001	14.23	51
Absence of lesions (%)	38.3 ± 16.1	39.6 ± 1.3^{b}	44.8 ± 1.2^{a}	34.2 ± 1.3^{c}	34.1 ± 1.2^{c}	<0.001	24.29	46
Severe lesions (%)§	9.8 ± 8.5	9.6 (8.4-11.0)^{a}	7.41 (6.5-8.4)^{b}	10.9 (9.5-12.5)^{a}	11.1 (9.7-12.8)^{a}	<0.001	11.44	50
Scars (%)	16.3 ± 9.8	18.1 ± 0.8^{a}	16.4 ± 0.7^{ab}	14.2 ± 0.8^{b}	17.0 ± 0.8^{a}	0.003	4.74	20
Abscesses (%)*	0.5 ± 1.1	0 (0-3.3)	0 (0-3.2)	0 (0-6.2)	0 (0-14.6)	0.079	6.78	
Consolidations (%)*	0.9 ± 1.4	0 (0-7)^{b}	0 (0-8.4)^{b}	1.1 (0-10.8)^{a}	0 (0-9)^{b}	<0.001	19.75	

Lobular/chessboard pattern lesions (%)*	1.0 ± 2.0	0 (0-14)^{ab}	0 (0-14.3)^{b}	0.5 (0-10.1)^{a}	1 (0-15)^{a}	0.002	14.75	
Pleura								
Mean score	0.9 ± 0.5	0.9 ± 0.04	0.8 ± 0.04	0.8 ± 0.04	0.9 ± 0.04	0.083	2.24	68
Severe lesions (%)	18.5 ± 12.0	18.6 ± 0.9^{ab}	16.2 ± 0.9^{b}	17.1 ± 1.0^{ab}	19.3 ± 0.9^{a}	0.005	4.38	63
Sequestra (%)*	0.8 ± 1.6	0 (0-8.6)	0 (0-11)	0 (0-17)	0 (0-13.5)	0.165	5.09	
APP index	0.8 ± 0.5	0.8 ± 0.04	0.7 ± 0.04	0.7 ± 0.04	0.8 ± 0.04	0.123	1.94	67
Liver								
Mean score	1.3 ± 0.2	1.4 ± 0.02^{a}	1.4 ± 0.01^{a}	1.3 ± 0.02^{b}	1.3 ± 0.02^{ab}	<0.001	8.88	44
Severe lesions (%)§	9.5 ± 8.2	9.5 (8.4-10.8)^{a}	8.9 (8.0-9.9)^{a}	6.4 (5.6-7.2)^{b}	8.3 (7.4-9.4)^{a}	<0.001	9.98	36
Total lesions (%)	23.9 ± 13.7	26.8 ± 1.1^{a}	26.5 ±1.0^{a}	21.4 ± 1.1^{b}	23.8 ± 1.1^{ab}	<0.001	7.11	43

* Non parametric model (median and range)

§ back transformed data (lsmeans and 95% CI)

^{ab} values within the same row with different superscripts differ significantly (*P*<0.05).

Table 3

The correlations between different pluck lesions at slaughter for 727 batches of heavy pigs (around 165 kg live body weight and 9 months of age) slaughtered from September 2014 to September 2015 at an Italian abattoir. A batch comprised a group of about 135 (minimum 130; maximum 140) pigs from the same holding that were slaughtered on the same day.

	Lungs				Pleura				Liver		
	Severe lesions	Mean score	Scars	Abscesses	Severe lesions	Mean score	Sequestra	APP Index	Severe lesions	Total lesions	Mean score
Lungs											
Absence of lesions (%)	-0.798	-0.896	-0.301	-0.072	-0.216	-0.198	-0.139	-0.204	-0.071	0.046	0.019
	***	***	***	‡	***	***	***	***	ǂ	ns	ns
Severe lesions (%)		0.953	0.340	0.060	0.252	0.240	0.142	0.247	0.101	-0.001	0.022
		***	***	ns	***	***	***	***	**	ns	ns
Mean score			0.349	0.062	0.256	0.243	0.149	0.248	0.091	-0.013	0.016
			***	ǂ	***	***	***	***	*	ns	ns
Scars (%)				0.019	0.116	0.148	0.067	0.128	0.034	0.192	0.135

ns	**	***	ǂ	***	ns	***	***
Abscesses (%)	-0.017	-0.020	0.122	-0.021	0.048	0.053	0.048
	ns	ns	**	ns	ns	ns	ns
Pleura							
Severe lesions (%)		0.960	0.287	0.976	0.089	0.051	0.060
		***	***	***	*	ns	ns
Mean score			0.284	0.982	0.075	0.056	0.064
			***	***	*	ns	ǂ
Sequestra (%)				0.289	-0.032	-0.033	-0.034
				***	ns	ns	ns
APP index					0.091	0.058	0.067
					*	ns	ǂ
Liver							
Severe lesions (%)						0.826	0.904
						***	***

Total lesions (%)			0.960 ***

ǂ 0.05<P<0.10, * P<0.05, ** P<0.01, ***P<0.001

ns = not statistically significant (P > 0.05)

Table 4

Statistical descriptors (with Quartiles -Q), depending on season of the year, for batch average of pluck lesion scores† in different organs (lungs, pleura, liver) at slaughter for 727 batches of heavy pigs (around 165 kg live body weight and 9 months of age) slaughtered from September 2014 to September 2015 at an Italian abattoir. A batch comprised a group of about 135 (minimum 130; maximum 140) pigs from the same holding that were slaughtered on the same day.

	Min	Q1	Median (Q2)	Q3	Max
Lungs					
Spring	0.3	1.2	1.7	2.3	6.1
Summer	0.2	1.0	1.3	1.8	5.7
Autumn	0.2	1.3	2.0	2.6	7.4
Winter	0.2	1.4	2.0	2.7	5.9
Entire year	0.2	1.2	1.7	2.4	7.4
Pleura					
Spring	0.05	0.5	1.0	1.3	2.1
Summer	0.01	0.4	0.8	1.2	2.0
Autumn	0	0.4	0.8	1.2	2.4
Winter	0.04	0.6	0.9	1.3	2.3
Entire year	0.0	0.5	0.9	1.3	2.4
Liver					
Spring	1.07	1.20	1.32	1.47	2.11
Summer	1.00	1.22	1.32	1.46	2.23
Autumn	1.03	1.12	1.22	1.35	2.55

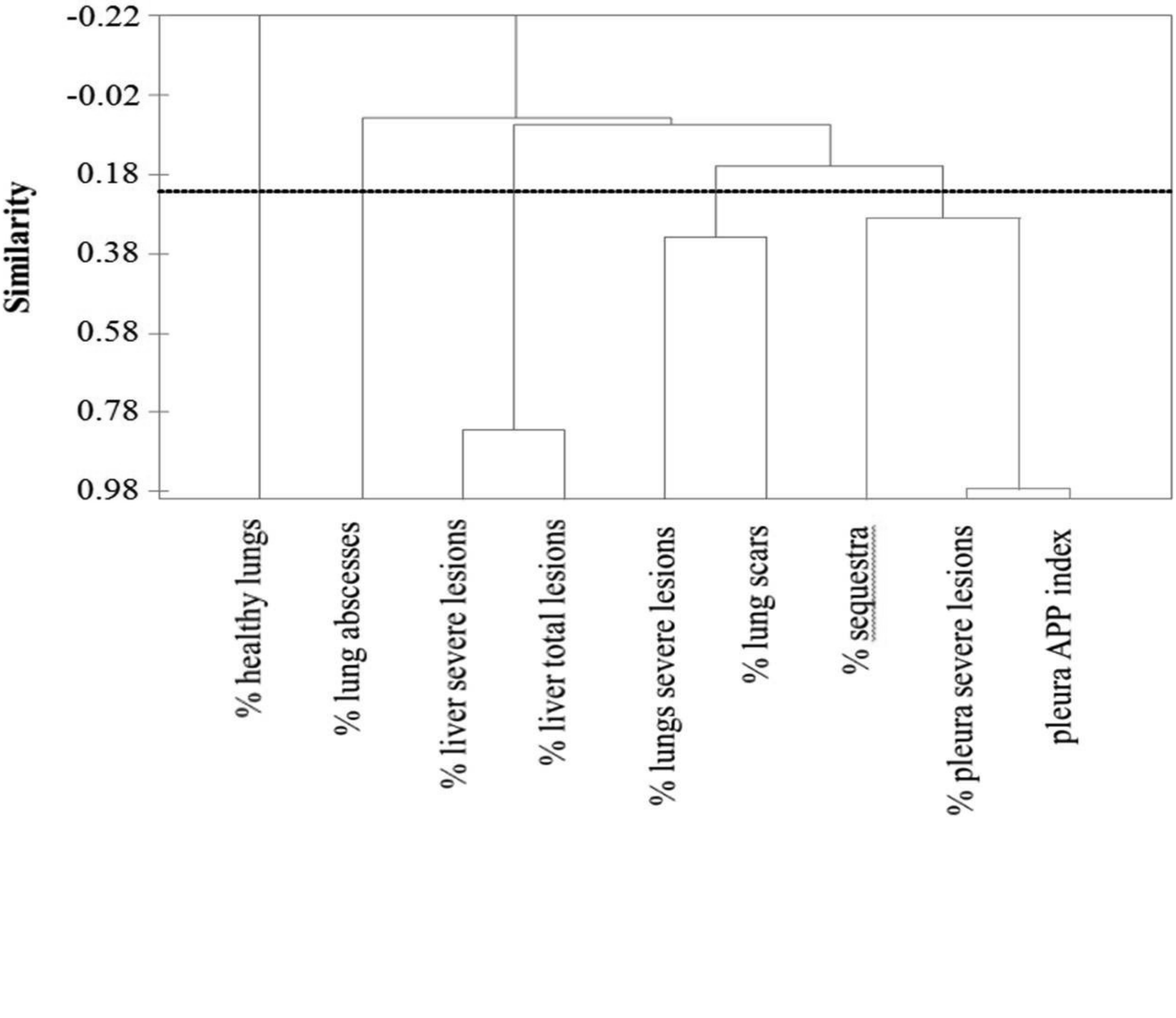
Winter	1.03	1.19	1.29	1.41	2.08
Entire year	1.0	1.2	1.3	1.4	2.6

† See Table 1 for score definitions

Figure legends

Fig. 1. Cluster analysis showing correlation of different pluck lesions recorded at an Italian abattoir in 727 batches of heavy pigs (around 165 kg live body weight and 9 months of age) from September 2014 to September 2015. A batch comprised a group of about 135 (minimum 130; maximum 140) pigs from the same holding that were slaughtered on the same day.

Fig. 2. Pluck lesions at an Italian abattoir in 727 batches of heavy pigs (around 165 kg live body weight and 9 months of age) from September 2014 to September 2015. A. Lung lesion, score 2 on the cranial lobe; B. Pleuritis on the dorsocaudal lobe (not possible to score without the other lung); C. Liver lesions, score 3; D. Lung scars on the cranioventral lobes; E. Lobular/chessboard pattern lesions on the lung; F. Sequestra in the lung after tissue incision.



Similarity
-0.22
-0.02
0.18
0.38
0.58
0.78
0.98
% healthy lungs
% lung abscesses
% liver severe lesions
% liver total lesions
% lungs severe lesions
% lung scars
% sequestra
% pleura severe lesions
pleura APP index