The relationship between infectious and non-infectious herd factors with pneumonia at slaughter and productive parameters in fattening pigs

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Abstract

This paper explores the relationship between infectious and non-infectious herd factors with the occurrence of pneumonia at slaughter and productive parameters in fattening pigs on 39 fattening herds. A questionnaire was used to obtain environmental and management factors (non-infectious factors). Blood samples and lungs were obtained from 35 pigs in each herd at slaughter. Serological testing was performed for antibodies against three respiratory pathogens (infectious factors): porcine reproductive and respiratory syndrome virus (PRRSV), Mycoplasma hyopneumoniae (Mh) and Aujeszky’s disease Virus-gE protein (ADV-gE). Lung lesion classifications were catarrhal-purulent bronchopneumonia (CPBP), pleuropneumonia (PLP) and pleuritis. A mean lesion value (MLV) was calculated for each lesion. ANOVA and logistic regression assessed statistical associations among MLV, average daily gain (ADG) and feed conversion ratio (FCR) (dependent variables) with infectious and non-infectious factors (independent variables). Mh vaccination was associated with a significant decrease in CPBP; high Mh seroprevalences was associated with an increased level of CPBP. FCR was negatively related with high seroprevalences for ADV-gE and Mh. No significant associations were seen for ADG.

Keywords: Swine; Pneumonia; Slaughter; Daily weight gain; Feed conversion ratio

Introduction

Respiratory disease in fattening pigs is a common health problem all over the world in intensive production systems. It causes important economic losses that are associated with lower growth performance, and with high costs of medication and increased mortality (Maes et al., 2000). Respiratory disease is influenced by environmental and management factors (non-infectious factors); for infection there is the inevitable influence of the nature of the respiratory pathogens to which the pigs are exposed (infectious factors). However, many respiratory infections are subclinical in nature. The response to this is to replace treatment of clinically affected individuals with a planned approach to prevention and control that affects large populations. Prior to implementation of these programmes it is useful to quantify the effect of factors that may be related to pneumonia.

To achieve this, inspection of pigs at slaughter has been widely used in epidemiological studies of risk factors associated with raised prevalence of lesions, especially pneumonia. The presence of lung inspections permits an investigation of the quantitative association between the
occurrence of pneumonic lesions and production parameters, especially average daily gain (ADG) and the feed conversion ratio (FCR) (Pointon et al., 1990).

Some of the most important infectious agents involved in respiratory disease in finishing pigs are porcine reproductive and respiratory syndrome virus (PRRSV), Mycoplasma hyopneumoniae (Mh) and Aujeszky’s disease virus (ADV). These agents are distributed worldwide and are known to play an important role in the appearance of pneumonia (López, 2001).

A cross-sectional multivariate study in a large number of fattening herds has been used in a number of epidemiological studies to investigate a wide range of factors (Hurnik et al., 1994; Maes et al., 2001). However, the conclusions may not be generalizable to other countries because of differences in the type of farms, husbandry systems, measurement procedures of lung lesions and respiratory agents targeted. Therefore, the objective of this work was to investigate and quantify the possible relationships between non-infectious and infectious herd factors with pneumonia and productive parameters (ADG and FCR) in fattening pigs at slaughter.

Material and methods

Selection of herds

Ninety percent of the fattening farms located in the study area used an integrated production system where the facilities and labour were supplied by the farmer, while pigs, feed and veterinary practices were supplied by vertically integrated companies. The companies were invited to collaborate and the six that agreed to do so are designated A–F. Two companies were not interested in the study, and two others were not selected because they sent their pigs to slaughterhouses at a considerable distance.

Because the selected companies had a variable number of fattening farms during the study, it was not possible to know in advance which farms would be studied. Therefore, companies were contacted every month to find out which farms were going to send finishing pigs to the abattoirs located in the study area. For the analysis, 39 finishing pig farms were studied. No differential selection criteria were established regarding the respiratory episodes which occurred during the fattening phase.

Study population

The work was performed in Eastern Spain (in the provinces of Castellón and Valencia) from 2002 to 2004. All herds participating in the study were finishing pig herds with an all-in/all-out (AIAO) management. This meant that farms did not acquire new piglets until all the pigs of the herd were sent to slaughter. Pigs were placed on site with an average liveweight of 18.1 kg (standard deviation (SD): ±3.9), and remained in the herd until slaughter. Two farms had a wean-to-finish management where piglets arrived at the fattening farm with an average liveweight of 5.2 kg.

All farms used preventive medication at the start of the fattening period which consisted of administering broad-spectrum antibiotics in the feed against respiratory and enteric diseases, and anthelmintics. All herds had a cleansing and disinfection protocol and a minimum 7-day stand-empty period. According to the producers’ information, two doses of ADV attenuated vaccine were given during the fattening period. Protocols varied depending on the farm.

Herd data collection

Once the farms were selected, herd data were collected using a questionnaire completed during a visit to the farm. This questionnaire had precise definitions of the data to record. The number of questions was restricted, and only closed questions for different categories were included. They were summarised into continuous variables (herd size, stocking density, number of pigs per compartment, and pig density in the municipality) and categorical variables (month of slaughter, company, PRRSV and Mh vaccination programmes, purchase policy of pigs, wean-to-finish management, biosecurity, type of ventilation, floor and feeding system), following the criteria described by Maes et al. (2001) with a few modifications. Stocking density was calculated in m²/pig. A compartment was defined as a subdivision of a building with its own ventilation system. Vaccination against Mh (inactivated) and PRRSV (live vaccine) was administered at the farm of origin during the lactation and nursery phases, respectively.

The purchase policy of piglets was categorised as a purchase from a single source or from various sources. Only two herds used wean-to-finish management. Biosecurity was recorded positively when herds had a perimeter fence, lorry wheel dips with disinfectant and anti-bird mesh in windows and air chimneys at the same time. Ventilation systems were classified as (1) automatic/manual windows and (2) the presence/absence of air chimneys in the roof of the building. The type of floor was divided into fully-slatted, partially-slatted and non-slatted. The type of feeding was registered as (a) restricted/ad libitum; (b) dry/wet and dry” feed (water nipple placed inside the feeder) and (c) grinding/pelleting feed. ADG (g/day) and FCR for each farm were supplied by the company, and pig density in the municipality (pigs/km²) was supplied by the local government.

Slaughter inspection

Fattening pigs from the selected farms were slaughtered at 6–7.5 months of age with an average liveweight of 103.7 kg (SD ± 3). Pigs from the same farm showed different growth rates and were sent to slaughter in different groups depending on their weight (100 kg approx.). Moreover, groups from the same farm were sent to different abattoirs in accordance with market conditions. For this reason, only one group of pigs per farm was examined at slaughter. Groups sent to abattoirs at a considerable distance from our region could not be studied. Therefore, the first group of pigs sent to any abattoir located in our area was studied. Hence in some herds, the best growing pigs were investigated, whereas pigs with lower growth performance were investigated in other herds. For this reason, the group order analysed at slaughter (first/second/third/fourth) was recorded and included in the statistical analysis to study possible differences in lung lesions and serology between groups from different farms for each herd.

For each group, the first 35 pigs were blood sampled at slaughter. Afterwards, 35 lungs were collected from the same group of slaughtered pigs. Because of changes in the order of carcasses on the slaughter line, it was not possible to ascertain which blood samples and lungs belonged to each pig. Lungs were palpated and visually appraised by the same person to detect pneumonia and pleuritis lesions. Lung lesions were classified as catarhal-purulent bronchopneumonia (CPBP), pleuropneumonia (PLP) and pleuritis (Taylor, 1996). CPBP consisted of cranioventral consolidation, with a red/pink or grey-colouring, demarcated from the normal tissue, with a mucous to purulent exudate within the Airways. PLP included one consolidated focus or more in different lobes, principally in caudal lobes, which were red-black coloured, with fibrinous pleuritis in some cases, and which presented haemorrhages and necrosis on cut-sections. Pleuritis was classified into grades 0–1–2 following the criteria described by Wallgren et al. (1994) with minor modifications. Grade 0 represents an absence of pleuritis. Grade 1 includes lesions affecting <5 cm² of the pleural surface, or adhesions between different lung lobes. Grade 2 consists of lesions exceeding a surface area of 5 cm², or adhesions of lung lobes to the thoracic wall, the pericardium or to the mediastinum.

For CPBP and PLP, the percentage of pneumonia (lung score) was calculated by weighing lungs separately (without trachea, bronchi and other mediastinal visera), and thereafter the pneumatic area which was cut out separately (Hill et al., 1992). Although the slaughter protocol was highly standardised between slaughterhouses, differences in weight between lungs due to insufficient bleeding or the drying of tissues could
Serological testing

The potential infections herd factors were studied using serological profiles. Thus, antibodies to PRRSV, Mh and ADV were detected using commercial tests. Other respiratory pathogens, like Actinobacillus pleuropneumoniae or swine influenza virus, were not studied for reasons of cost.

The presence of antibodies against PRRSV was determined with an indirect ELISA (CIVTEST suis PRRS, Hipra). A competition ELISA was used to detect antibodies against Mh. This test detected antibodies against a specific protein of Mh (p74), avoiding a cross-reactivity with other species of Mycoplasma spp. (CIVTEST suis Mycoplasma hyopneumoniae, Hipra). The presence of gE-antibodies against ADV wild virus was determined with a competition ELISA (HerdChek Anti-ADV gpl, Idexx).

Statistical analysis

Statistical analyses were carried out using SAS (release 8.02, SAS Institute). Associations were considered significant at the 0.05 level. However, given the moderate number of herds involved in this study (39), significant associations at the 0.10 level were included and considered as a trend in the statistical results (Maes et al., 1999a). Analysis of variance was used to analyse the continuous dependent variables assuming normality, and a logistic regression was deployed to analyse dichotomous dependent variables.

The relationship between lung lesions (dependent variables) and infectious and non-infectious herd factors (independent variables) using the herd as the experimental unit was studied by different methods. Analysis of variance (PROC GLM) was used for the MLV of both CPBP and pleuritis. The variable MLV for pleuritis was transformed by the formula arcsinus square root in order to improve its normality. However, the variable MLV for PLP could not be transformed into a normal distribution by any method. For this reason, it was considered as a dichotomous variable (presence or absence), and a logistic regression procedure (PROC LOGISTIC) was used for this analysis. Logistic regression was also used to assess the association between the proportion of seropositive pigs in a herd for PRRSV, Mh and ADV-gE (dependent variables) and non-infectious herd factors (independent variables). As previously explained, the variable “group order examined at slaughter” was included as an independent variable in all these models.

Associations between FCR and ADG (dependent variables) and non-infectious herd factors (independent variables) were tested at the herd level using analysis of variance (PROC GLM). Lung lesions were included as the MLV for CPBP, PLP and pleuritis. The two farms using a wean-to-finish management were eliminated. They were not comparable with the other the herds because the age, weight and growth rate of piglets at the beginning of this phase differed greatly from those pigs starting the feeder-to-finish phase. Moreover, only one farm for each company of two companies (E and F) was investigated. Therefore, these two farms were also eliminated from the analyses to avoid possible biases. Consequently, for this analysis only 35 farms were included.

For logistic regressions, a forward stepwise procedure was used to explore the main explanatory variables, which were significant (P < 0.10). A co-linearity test was used (PROC CORR) to analyse the possible correlations between the significant independent variables obtained in each model. Significant correlations were considered if the Pearson’s correlation coefficient was >0.75.

Results

Herd data

Categorical variables pertaining to non-infectious herd factors are summarised in Table 1. Those herds with PRRSV-vaccinated pigs were originally from the same farm and belonged to the company A. Mh-vaccinated pigs pertained to three integration companies (C–E). Only one herd used a grinding dry feed system, and two farms employed a restricted dry feeding system twice a day. Two herds applied wean-to-finish management and belonged to the company “B”. The average and SD for FCR and ADG were 2.8 (±0.2) and 657.8 (±50.6), respectively (Figs. 1 and 2). For other continuous variables, the average and SD were: pigs/km² 306 (±189.3), herd size 1124.7 (±620.3), pigs/compartment 480.4 (±301.1) and stocking density 0.7 (±0.1).

Slaughter inspection

Regarding the MLV of lung lesions at a herd level, CPBP showed an average of 8.4% (±5.1), PLP revealed an average of 0.4% (±0.9), whereas pleuritis obtained an average of 0.3% (±0.2) (Figs. 3 and 4). The first group of pigs sent to the slaughter was analysed on 9 farms (23.1%), the second group on 12 farms (30.8%), the third group on 11 farms (28.2%) and the fourth group on 7 farms (17.9%).

<table>
<thead>
<tr>
<th>Non-infectious factors</th>
<th>Categories&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration company</td>
<td>A 13 (35.9), B 12 (30.8), C 10 (25.6), D 2 (2.6), E 1 (2.6), F 1 (2.6)</td>
</tr>
<tr>
<td>Slaughter season</td>
<td>Spring 6 (15.4), Summer 8 (20.5), Autumn 10 (25.6), Winter 15 (38.5)</td>
</tr>
<tr>
<td>PRRS vaccination</td>
<td>No 33 (84.6), Yes 6 (15.4)</td>
</tr>
<tr>
<td>Mh vaccination</td>
<td>No 30 (76.9), Yes 9 (23.1)</td>
</tr>
<tr>
<td>Multiple origins</td>
<td>No 22 (56.4), Yes 17 (43.6)</td>
</tr>
<tr>
<td>Wean to finish</td>
<td>No 37 (94.9), Yes 2 (5.1)</td>
</tr>
<tr>
<td>Biosecurity</td>
<td>No 24 (61.5), Yes 15 (38.5)</td>
</tr>
<tr>
<td>Slat</td>
<td>Partial 23 (59), Total 14 (35.9), Not slatted 2 (5.1)</td>
</tr>
<tr>
<td>Air chimneys</td>
<td>No 9 (23.1), Yes 30 (76.9)</td>
</tr>
<tr>
<td>Automatic window</td>
<td>No 24 (61.5), Yes 15 (38.5)</td>
</tr>
<tr>
<td>Wet and dry feeding</td>
<td>No 16 (41), Yes 23 (59)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Number and percentages (in brackets) of herds in each category.
Serological testing

The average herd-level seroprevalences for PRRSV, Mh and ADV-gE at slaughter were 96.1% (±16.3), 43.4% (±34.8) and 31.1% (±44.8), respectively. Serological studies for PRRSV revealed that only two farms (5.1%) showed seroprevalences <97.1%, but no farm was completely seronegative. Serology for Mh revealed that 10.3% of farms were entirely seronegative and only 2.6% (one farm) was completely seropositive. Depending on the herd, a highly heterogeneous pattern was seen for the distribution of prevalences at the herd level for Mh. Serological analysis for ADV-gE indicated that 59% of the farms were entirely negative and 25.6% were completely positive. The herd-level prevalences for ADV-gE showed a bimodal distribution with only 13% of the herds in the seroprevalence range of 1–90%.

Statistical analysis

Significant associations obtained by analysis of variance (linear models) are represented in Table 2. No significant associations were found using the logistic regression analysis or co-linearity tests. FCR was significantly higher on farms with high seroprevalences for ADV-gE. An increased FCR was found in herds with high seroprevalences for Mh, and also on those farms where piglets were previously vaccinated against PRRSV. No significant associations were found for ADG. The observation of CPBP increased significantly on those farms with high seroprevalences against Mh, and a lower number of these lesions was detected on farms with piglets previously vaccinated against this agent.

Discussion

The present study attempts to evaluate different infectious and non-infectious factors associated with the appearance of pneumonia at slaughter and their production impact reflected in FCR and ADG. It is important to clarify that it is possible that the results may not necessarily be extrapolated to other farms since herds were not randomly selected. Moreover, some risk factors may not appear significant because of a loss of variation in the independent variables cannot be ruled out since not all the companies working in our area participated in the study.

Lung inspection revealed that prevalence and the severity of CPBP were much higher than those reported in other studies (Hurnik et al., 1994; Maes et al., 2001; Andreasen et al., 2001b), but lower than those described by Wallgren et al. (1994). The results of PLP and pleuritis were similar to previous reports (Maes et al., 2001; Andreasen et al., 2001b), although a direct comparison of the results of these studies should be made with caution because some studies comprised farrow-to-finish pig farms (Maes et al., 2001; Andreasen et al., 2001b), or were based on different types of herds (Hurnik et al., 1994; Wallgren et al., 1994).

The method of pneumonia quantification, particularly concerning CPBP and PLP, must also be considered carefully. Some methods were based on the measurement of the surface area of lung parenchyma affected by pneumonia (Morrison et al., 1985). However this could underestimate the real percentage of affected parenchyma (Maes et al., 1996). For this reason, a method based on the weight of

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Fig. 1. The distribution of the feed conversion ratio (FCR) values at a farm level.

Fig. 2. The distribution of the average daily gain (ADG) values at a farm level.

Fig. 3. The distribution of mean lesion values (MLV) for catarrhal-purulent bronchopneumonia (CPBP) and pleuropneumonia (PLP) at a farm level.

Fig. 4. The distribution of mean lesion values (MLV) for pleuritis at a farm level.
affected parenchyma was described as being more accurate for assessing the relationship between pneumonia and production (Hill et al., 1994). In order to avoid interpretative subjectivity, lung inspection was carried out by the same investigator. On the other hand, no statistical differences in lung inspections were found between farms for the order of groups analysed at slaughter. Thus, the analysis at slaughter of the best growing pigs or of pigs with a lower growth rate from the same farm did not account for differences with the rest of the farms for lung lesions.

Seroprevalence of PRRSV, Mh and ADV-gE were comparable to those found in other studies. Seroprevalence of PRRSV at slaughter showed that almost all the herds had a seroprevalence close to 100%, as reported by Noddelijk et al. (1997). Thus, no association between PRRSV seroprevalence and pneumonia with productive parameters could be established. Therefore, the time when this seroconversion occurred might have influenced the productive parameters.

Serological studies for Mh and ADV showed that seroprevalences were lower than those reported by other authors (Wallgren et al., 1993; Maes et al., 1999a, 2000). Although it is important to take into account the year when these studies were performed, it would seem that the application of eradication programmes (ADV) in our study area, the improvement of management practices (AIAO management, Mh vaccination, strategic medication and biosecurity measures) and farm facilities (many of the studied farms were of new construction) in the last decade have improved some aspects of swine respiratory disease, particularly in relation to the two agents.

The distribution of seroprevalences against Mh at the herd level showed a highly heterogeneous pattern depending on the farm. Thus, Mh colonisation and seroconversion are greatly influenced by the effect of the individual farm (Sibila et al., 2004). On the other hand, vaccination of piglets against PRRSV and Mh did not appear to be related with the seroprevalences against these agents at slaughter.

Despite the application of vaccination programmes for the eradication of ADV, the bimodal distribution of herd-level seroprevalences for this agent indicated that, in general, the majority of the pigs seroconverted within infected herds. In this sense, ADV vaccination plays an important role in the transmission of the virus. Although producers stated that there were two vaccinations during the finishing period, the efficacy of vaccination schemes was not studied. Hence in the studied farms, incorrect applications of vaccination protocols that could have influenced seroconversion against ADV-gE cannot be ruled out.

From all the studied infectious and non-infectious herd factors that might be related to the appearance of lung lesions at slaughter, only two variables were statistically related with CPBP, namely “Mh seroprevalence” and “Mh vaccination”. As expected, Mh seroprevalence showed a positive association with CPBP as it is considered the most important agent involved in the appearance of this lesion (Taylor, 1996; Ross, 1999). Although Mh vaccination did not show a significant relationship with pneumonia, its application revealed a tendency to reduce the prevalence and severity of pneumonia-related lesions at slaughter, as reported by other authors (Le Grand and Kobisch, 1996; Maes et al., 1999b; Dawson et al., 2002; Sibila et al., 2007). One explanation for this tendency could be that farms which have had to deal with important respiratory problems were more likely to use vaccination schemes than farms without such problems. No statistical relationship was observed between the rest of infectious and non-infectious herd factors studied and the observation of lung lesions at slaughter. Therefore, it is possible that the effect of Mh vaccination could be sufficient to mitigate the possible effects exerted by other factors.

Mh seroprevalence was also negatively correlated with FCR. Although some authors did not find differences between seroconversion to Mh and productive parameters (Morris et al., 1995; Andreasen et al., 2001a), Wallgren et al. (1994) reported that pigs that seroconverted in the early phase of the fattening period had a lower growth rate. Since the spread of Mh infection within a herd is considered slow (Meyns et al., 2004; Vigre et al., 2004), a high seroprevalence at slaughter could suggest an early-stage circulation of the agent during the fattening period. In these herds, therefore, a large number of pigs could be affected by mycoplasmal pneumonia over lengthy periods of time, which could consequently decrease their feed conversion.

Moreover, high ADV-gE seroprevalences were also negatively related with ADG and FCR. This negative effect could be explained since ADV produces a decrease in the

### Table 2

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Significant independent variables</th>
<th>( \beta \pm \text{SE} (\beta) )</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCR</td>
<td>ADV-gE seroprevalence(^a)</td>
<td>0.03 (0.01)</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Mh seroprevalence(^a)</td>
<td>0.02 (0.01)</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>PRRSV vaccination(^b)</td>
<td>0.2 (0.1)</td>
<td>0.08</td>
</tr>
<tr>
<td>CPBP</td>
<td>Mh seroprevalence(^a)</td>
<td>2.09 ± 0.79</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Mh vaccination(^b)</td>
<td>−8.14 ± 4.02</td>
<td>0.06</td>
</tr>
</tbody>
</table>

\(^a\) Increase of 10% in seroprevalence.

\(^b\) Differences between non-vaccinated and vaccinated pigs.
pig growth rate and also induces an immunosuppressive state that is predisposed to infection by other infectious agents (Kluge et al., 1999). In this way, an improper application of vaccination schemes could also be involved, as previously discussed.

Another variable negatively related with FCR existed and negative results associated with “PRRS vaccination” should be considered with caution since all the piglets vaccinated against PRRSV came from the same farm of origin. This farm showed a poor health status, and PRRSV vaccination was applied in an attempt to improve the productive parameters of piglets. Therefore, in this case, the farm of origin could be taken as a confounding factor (Martin et al., 1997).

Finally, the observation of lung lesions at slaughter was not associated with a loss of productive parameters, nor was ADV-gE seroprevalence associated with the presence of pneumonia at slaughter. This could be explained by the temporary nature of lung lesions. Thus, the observation of lung lesions at slaughter and their impact on productive parameters could vary depending on the time that respiratory infections occurred (Sitjar et al., 1996). Moreover, other infectious and non-infectious factors that were not studied could be related with the appearance and duration of pneumonia lesions in fattening pigs.

Conclusions

High seroprevalences to Mh increased the risk of CPBP. However, a lower number of these lesions were observed when Mh vaccination was applied. Moreover, high seroprevalences to ADV and Mh were negatively related to FCR. Therefore, accurate vaccination programmes for ADV should be designed for each farm.

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