Economic efficiency of animal health interventions

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Introduction

The practice of food animal veterinary medicine has changed dramatically in the last 50 years. Arguably, the biggest changes that have occurred in that time are due to economics rather than advancements in science. Specifically, the consolidation of swine and other food animal industries has led to fewer and bigger farms, which in turn has meant fewer and more specialized decision makers. In 1994, 27 percent of the annual pig crop in the United States was produced on operations with at least 5,000 head. By 2014, the percentage of the annual pig crop produced on operations with at least 5,000 head had risen to 93 percent (NASS, 2015). A similar consolidation trend is occurring globally. Swine veterinarians now practice population or herd medicine almost exclusively, a single animal health decision may involve millions of animals and the decisions increasingly are driven by economics. The cost of making economically poor animal health decisions has gotten very large and it is no longer acceptable to rely on an educated guess.

The tools to make economically good animal health decisions already exist. A cost-benefit analysis (CBA) is a systematic process for calculating and comparing benefits and costs of a decision. Both the cost and the benefit are calculated in a common unit, which is money in the local currency. When the cost and the benefit of an animal health intervention occur close in time, such as within one year of each other, the time value of money may be ignored. Otherwise, future benefits, or costs, may be discounted to estimate all costs and benefits at their present value. For many animal health interventions, including vaccines and antimicrobials, the costs and benefits occur close in time and the time value of money may be ignored.

CBA can be used to determine if decisions to implement animal health interventions are good economic decisions. CBA can also be used to compare alternative animal health interventions when more than one is under consideration. CBA may be performed prospectively to determine what the expected costs and benefits would be if an intervention is implemented or retrospectively to determine if the expected costs and benefits of an intervention was achieved after it was implemented. The primary difference between a prospective and retrospective analysis is the sources of data used to estimate the benefits, and in some cases the costs, and the analysis of the data.

Estimating the cost of animal health interventions either prospectively or retrospectively is generally easier and more certain than estimating the benefit. For example, the cost of vaccinating one thousand pigs with a single dose of a vaccine that costs €1 per dose is €1,000 plus some additional labor. While the cost of other interventions may be somewhat more complicated to calculate and not as certain, they are generally much easier to calculate and more certain than the benefits.

The primary benefit of animal health interventions is the improvement in productivity that results from reducing the burden of disease. Other benefits may include reduced antimicrobial treatment, diagnostic and veterinary costs. In addition, reductions in inter-pig variation in growth and weights may result in lower feed and other input costs and higher revenues as more pigs may be sold in the target weight range at higher prices.

Calculating the economic benefit of improved productivity involves a two-step process. First, estimate the changes in productivity attributed to the intervention and, second, estimate the economic value of the productivity changes. For a retrospective CBA, historical production records may be used to estimate the productivity changes that occurred after the intervention was implemented. When historical data are used retrospectively to estimate productivity changes attributed to the intervention, the analysis may be described as a quasi-experimental design, sometimes called the pre-post–intervention design. The quasi-experimental design is a non-randomized study design which makes it prone to confounding. For example, consider the weight of pigs at placement. In a randomized controlled study, if weight at placement may be associated with the outcome, every effort will be made to make sure there was not any systematic allocation of pigs to study groups that results in one treatment group of pigs that are heavier than another at placement. In non-randomized studies the opportunity to deal with confounding variables in the study design is absent but confounding variables may be included in the statistical analysis. If the confounding effects are adequately represented in the statistical analysis, the remaining differences in the productivity changes, adjusted for the other confounding effects, between the pre- and post- intervention periods may be more confidently attributed to the intervention. It is, however, impossible to account for all potentially confounding effects in a pre-post-intervention study design. Diagnostic and clinical data collected pre-intervention, post-intervention or both may also be used to estimate the severity of the pathogen burden and disease to support the attribution of productivity improvements to the intervention.

To estimate the economic value of productivity changes attributed to an intervention for a retrospective CBA, all other variables, such as production outcomes not impacted by the intervention, pig prices, diet prices and the size of the herd, must be held constant. Budgeting models may be used to isolate the economic value of productivity changes. Budgeting models are a set of equations that calculate how profit changes as productivity outcomes change. Pig prices, diet prices, the size of the herd, and other variables not impacted by the intervention may be held constant for both before and after intervention scenarios so that the estimated change in profit is due to changes in productivity outcomes only.

The objective of this case study was to conduct a CBA to compare productivity and profitability of growing pigs in the nursery and finishing phase of production before, during and after interventions to control respiratory disease were implemented in a 3,600 sow production system in Spain. The interventions were made to stabilize the sow farms for porcine reproductive and respiratory syndrome virus (PRRSV), to produce pigs that were negative for the virus at weaning, and to uniformly vaccinate all gilts and pigs for *Mycoplasma hyopneumoniae* (*Mhp*) so the pigs from all 3 sow farms could be comingled into a single nursery.

Methods

Production system

A 3,600 sow production system in Spain with 3 sow farms, 2 nursery sites and multiple finishing sites was the subject of this case study. The inventory of each sow farm varied; Sow 1 (1,430 sows), Sow 2 (980 sows) and Sow 3 (1,200 sows). Prior to implementation of the interventions, pigs from 2 sow farms were comingled into one nursery and pigs from the other sow farm were raised in a second nursery. During and after implementation of the intervention, pigs from all 3 sow farms were comingled into a single nursery with 10 rooms and 1,800 pigs per room. Hypor females and Danbred sire lines were used. Pigs were weaned at approximately 3 weeks of age.

Production, clinical and diagnostic data

Nursery and finishing data was provided by the production system. The data included 126 completed batches of nursery pigs closed out between March 2014 and February 2017 and 174 batches of finishing pigs closed out between November 2013 and February 2017.

A diagnostic and clinical survey was also completed prior to implementation of the intervention to evaluate the burden of respiratory disease in the system. Lung lesions suggestive of *Actinobacillus pleuropneumonia* (*APP*) and *Mhp* were evaluated at slaughter. *APP* lesions were evaluated with the slaughterhouse pleuritic evaluation system (SPES) (Dottori etal., 2007), which was based on the extension and location of pleural adhesions. *Mhp* was scored on a scale from 0 to 5 based on the percentage of lesion-affected lung surface (Bollo etal., 2008).Clinical signs associated with *APP*, *Mhp*, porcine circovirus (PCV) and PRRSV were also observed. Serum was collected from pigs at birth, weaning and the end of the fattening period. *APP* antibody response at the end of the fattening period was measured with an ELISA (Idexx APXIV). Presence of PCV at birth and PRRSV at weaning was measured by PCR (LSI VetMAX™ Porcine Circovirus Type 2) (LSI VetMax™ PRRSV EU/NA). Finally, PRRSV antibodies were assessed in pigs at birth, weaning and at the end of the fattening period by ELISA (Ingezim PRRS 2.0).

Comparison periods and summary of intervention and vaccine use

The comparisons made were between the three periods described in Figure 1. In April 2015, the intervention was initiated to improve productivity and reduce antibiotic use in the finishing phase of production. The vaccination program for PRRSV, PCV and *Mhp* during each comparison period is summarized in Table 1. Prior to initiation of the intervention (Before Intervention), PRRSV vaccination was done to acclimate replacement gilts prior to entry and in sows to maintain immunity in the sow herd. In April 2015, when the intervention was initiated, the PRRSV vaccine was changed from Vaccine A to Porcilis® PRRS (MSD Animal Health). In addition, piglets were vaccinated with Porcilis PRRS at 14 to 21 days of age during the intervention period (Intervention), starting in May 2015. The PRRSV vaccination program in gilts and sows during the intervention was continued after the intervention (After Intervention) but PRRSV vaccination of pigs was discontinued. The productivity of batches of nursery and finishing pigs during the Intervention and After Intervention periods were compared to the productivity of batches prior to initiation of the intervention (Before Intervention). The vaccination program for PCV and *Mhp* varied during each period as outlined in Table 1.

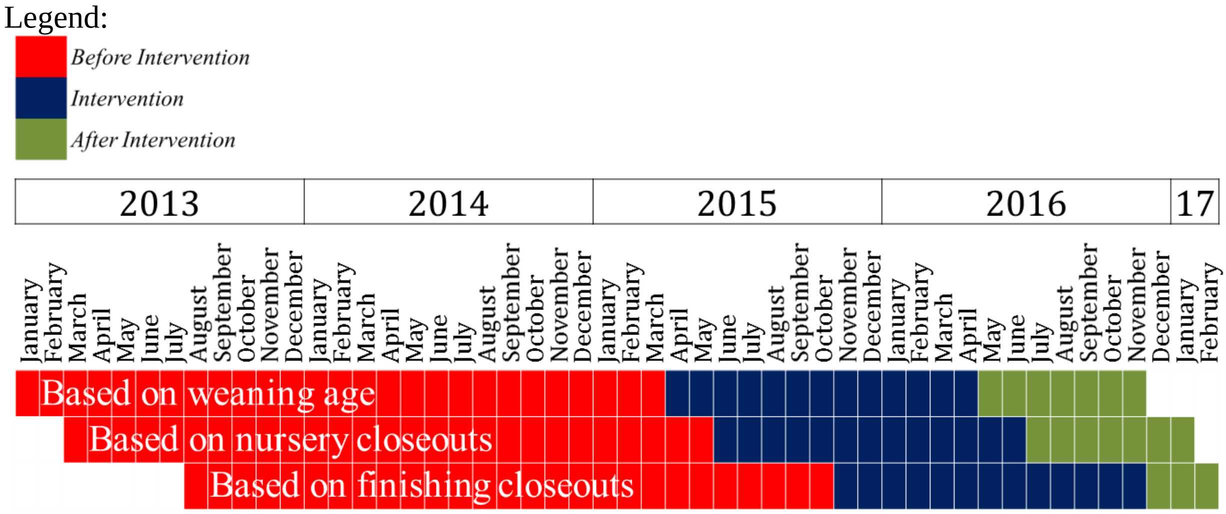

Figure 1. Timeline of comparison periods evaluated.

Table 1. Summary of respiratory vaccine programs for each comparison period.

Vaccine program for PRRSV

		Comparison Period		
Animal	**Vaccination Details**	**Before Intervention**	**Intervention**	**After Intervention**
Replacement gilts	Vaccine	PRRSV Vaccine A	Porcilis PRRS	Porcilis PRRS
	Number of vaccinations	2 doses prior to entry	2 doses prior to entry	2 doses prior to entry
Sows	Vaccine	PRRSV Vaccine A	Porcilis PRRS	Porcilis PRRS
	Number of vaccinations	Mass vaccination, 3x/year	Mass vaccination, 3x/year	Mass vaccination, 3x/year
Pigs	Vaccine		Porcilis PRRS	
	Number of vaccinations		1 dose at 14 to 21 days of age	

Vaccine program for PCV and *Mhp*

Animal	**Vaccination Details**	**Before Intervention**	**Intervention**	**After Intervention**
Replacement gilts	Vaccine	*Mhp* Vaccine A[1] and Porcilis PCV	*Mhp* Vaccine A and Porcilis PCV; Porcilis PCV M after January 2016	Porcilis PCV M
	Number of vaccinations	2 doses prior to entry	2 doses prior to entry	2 doses prior to entry

Pigs	Vaccine	*Mhp* Vaccine A[1] and Porcilis PCV	*Mhp* Vaccine A and Porcilis PCV; Porcilis PCV M after January 2016	*Mhp* and PCV Vaccine B
	Number of vaccinations	1 dose at weaning	1 dose at weaning	1 dose at weaning

[1] Sow 1 and Sow 2 only. Replacements gilts and pigs for Sow 3 were not vaccinated for Mhp.

Analysis of production data

The simple unadjusted averages of key productivity outcomes in the nursery and finishing phase were calculated by comparison period (Before Intervention, Intervention and After Intervention) using pivot tables in Microsoft Excel® (Excel 2016). To assess the statistical significance of differences in the average values of key productivity outcomes between comparison periods, key productivity outcomes in the nursery and finishing phase were analyzed as response variables in linear regression models in JMP (SAS Institute). Comparison period and other potentially confounding variables were included as explanatory variables to account for differences in key productivity outcome between comparison periods that may not be due to the vaccine changes and efforts to control respiratory disease. In the nursery phase, explanatory variables included comparison period, sow farm from which the majority of pigs were sourced, whether the males were castrated or intact, the average days on feed and the month the batch was closed. Weight of pigs at entry into the nursery was also analyzed as a response variable with the same explanatory variables except for average days on feed. For the finishing phase, explanatory variables included comparison period, feed type, genetics of the dam, days on feed and month the batch closed. Weight of pigs at entry into the finisher was analyzed as a response variable with the same explanatory variables except for feed type and average days on feed.

Economic analysis

The average profitability of pigs in the nursery, finishing and wean-to-market (nursery and finishing combined) phases were estimated in a budgeting model, where the productivity outcomes for each comparison period could be entered. All other entered parameters in the model were held constant for all comparisons. Key parameter values that were held constant are summarized in Tables 2A for the nursery and 2B for finishing.

Table 2A. Standard values for key parameters in nursery budgeting model for the economic analysis.

Parameter	**Standard value in model**	**Source**
Target days on feed, nursery	44	Close-out data; average for all groups in dataset
Pigs placed per week	1,736	Assuming breeding female inventories for all 3 sow farms and 25 pigs/female/year
Nursery spaces available	11,500	Calculated as function of pigs placed per week and target days on feed
Price of weaned pig (€/pig placed)	€ 27.00	Company average, November 2013 to February 2017
Average nursery diet price (€/tonne of feed)	€ 500.00	Company average, November 2013 to February 2017

Capital investment in nursery buildings and improvements (€/pig space)	€ 250.00	Company average, November 2013 to February 2017
Feeder pig price (€/pig)	€ 50.00	Company average, November 2013 to February 2017
Average price of cull pigs (€/pig)	€ 0.00	Company average, November 2013 to February 2017

Table 2B. Standard values for key parameters in finishing budgeting model for the economic analysis.

Parameter	**Standard value in model**	**Source**
Target days on feed, finisher	129	Close-out data; average for all groups in dataset.
Pigs placed per week	1,685	Pigs transferred from nursery.
Finisher spaces available	34,000	Calculated as function of pigs placed per week and target days on feed
Carcass yield (% of live weight)	75%	Industry standard
Price of feeder pig (€/pig placed)	€ 50.00	Company average, November 2013 to February 2017
Average finisher diet price (€/tonne of feed)	€ 225.00	Company average, November 2013 to February 2017
Capital investment in finisher buildings and improvements (€/pig space)	€ 275.00	Company average, November 2013 to February 2017
Market pig price (€/kg carcass wt.)	€ 1.75	Company average, November 2013 to February 2017
Average price of cull pigs (€/pig)	€ 50.00	Company average, November 2013 to February 2017

The vaccine cost for the economic analysis for each comparison period is summarized in Table 3. In pigs and replacement gilts, multiple PCV and *Mhp* vaccines were used and the timing of when changes were made did not correspond with the timeline for the Before Intervention, Intervention and After Intervention periods. Therefore, for this analysis, a single generic vaccination program for PCV and *Mhp* was modeled. The cost of PCV and *Mhp* vaccination in replacement gilts and pigs was €1.30 / gilt or pig.

Table 3. Cost of the respiratory vaccines for replacement gilts, sows and piglets, (€/pig weaned).

	Before Interventio n	**Interventio n**	**Change from Before Interventio n**	**After Interventio n**	**Change from Before Interventio n**
Cost of PRRSV vaccines per pig weaned (€/pig)	€0.13	€1.29	€1.16	€0.17	€0.04
Cost of PCV and Mhp	€1.30	€1.30	€0,00	€1.30	€0,00

vaccines per pig weaned (€/pig)					
Total cost of all respiratory vaccines per pig weaned (€/pig)	**€1.43**	**€2.59**	**€1.16**	**€1.47**	**€0.04**

The productivity results in Tables 4A and 4B; standard values for other parameters in Tables 2A and 2B and vaccine costs in Table 3 were entered into the budgeting models. Separate analyses were conducted for the nursery, finishing and wean-to-market (nursery and finishing combined) phases of production. The number of pigs produced in the nursery phase was transferred to the finishing phase model. The same pig price (price of feeder pig) used to calculate revenue in the nursery model was used in the finishing model to calculate the cost of pigs placed (Tables 2A and 2B). For each phase of production, both unadjusted and adjusted means for the key productivity outcomes (Tables 4A and 4B) were analyzed. The productivity outcomes in Tables 4A and 4B were entered regardless of whether the difference between the comparison periods was statistically significant at $p<0.05$.

Results

Productivity

The resulting least squares means for each response variable represent the mean for each comparison period adjusted for the other explanatory variables included in the statistical model. The simple unadjusted means and adjusted means from the regression analysis are summarized in Table 4A for the nursery and 4B for finishing. In the nursery, least squares means of all production outcomes were higher for batches of pigs in the Before Intervention comparison period except mortality, which was lower. Differences between the Before Intervention comparison period and the Intervention and/or After Intervention were statistically significant ($p<0.05$) for average entry weight, mortality, feed conversion and average daily gain. In finishing, least squares means of all production measures were higher for batches of pigs in the Before Intervention comparison period except average daily gain, which was lower. Differences between the Before Intervention comparison period and the Intervention and/or After Intervention comparison periods were statistically significant for all of the production outcomes in finishing. Antimicrobial use in finishing, measured by medication costs, declined by €0.74 and €0.68 per pig started for the unadjusted and adjusted means during the Intervention period and by €1.16 and €0.85 per pig started in the After Intervention period.

Table 4A. Unadjusted and adjusted means for key productivity outcomes in nursery by comparison period. Statistical significance between comparison periods is indicated by different superscript[a,b,c] ($p<0.05$).

	Before Intervention	**Intervention**	**After Intervention**
Entry weight (kg / pig started)			
Unadjusted means	6.7	6.4	6.2
Least squares means[1]	6.6[a]	6.4[b]	6.4[b]
Mortality (% of pigs started)			
Unadjusted means	1.70%	2.54%	3.30%
Least squares means[2]	1.35%[a]	1.84%[a,b]	2.20%[b]

Runts (% of pigs started)			
Unadjusted means	1.24%	0.94%	1.91%
Least squares means[2]	1.52%[a]	0.83%[a]	1.39%[a]
Medication costs (€ / pig started)			
Unadjusted means	€ 0.95	€ 0.78	€ 0.65
Least squares means[2]	€ 1.05[a]	€ 0.94[a]	€ 0.85[a]
Feed conversion (kg feed / kg gain)			
Unadjusted means	1.673	1.588	1.636
Least squares means[2]	1.652[a]	1.518[b]	1.524[a,b]
Average daily gain (kg / day)			
Unadjusted means	0.37	0.33	0.28
Least squares means[2]	0.36[a]	0.32[b]	0.28[c]

[1]Adjusted for sow farm, males castrated or intact and month batch closed
[2]Adjusted for sow farm, males castrated or intact, days on feed and month batch closed

Table 4B. Unadjusted and adjusted means for key productivity outcomes in finishing by comparison period. Statistical significance between comparison periods is indicated by different superscript[a,b,c] ($p<0.05$).

	Before Intervention	**Intervention**	**After Intervention**
Entry weight (kg / pig started)			
Unadjusted means	21.9	20.6	17.1
Least squares means[1]	22.3[a]	20.8[b]	17.8[b]
Mortality (% of pigs started)			
Unadjusted means	4.95%	2.51%	1.83%
Least squares means[2]	4.80%[a]	2.67%[b]	3.01%[b]
Runts (% of pigs started)			
Unadjusted means	2.10%	1.22%	1.23%
Least squares means[2]	2.15%[a]	1.27%[b]	1.21%[a,b]
Medication costs (€ / pig started)			
Unadjusted means	€ 1.44	€ 0.70	€ 0.28
Least squares means[2]	€ 2.08[a]	€ 1.40[b]	€ 1.23[b]
Feed conversion (kg feed / kg gain)			
Unadjusted means	2.792	2.650	2.541
Least squares means[2]	2.726[a]	2.593[b]	2.471[c]
Average daily gain (kg / day)			
Unadjusted means	0.72	0.77	0.84
Least squares means[2]	0.74[a]	0.78[b]	0.83[c]

[1]Adjusted for genetics of the dam and month the batch closed
[2]Adjusted for feed type, genetics of the dam, days on feed and month the batch closed

Economic outcomes

The results of the economic analyses for the nursery, finishing and wean-to-market phases of production are summarized in Table 5 on a €/pig started basis. In the nursery phase, profitability changed relatively little during the Intervention or After Intervention Periods compared to the Before Intervention period. The decline in the Intervention period was less than €1 per pig placed when either raw means or adjusted least squares means for production outcomes were entered in budgeting model. Profitability in the After Intervention period increased by just over €1 per pig started when either raw means or adjusted least squares means were entered in the budgeting model. Compared to the Before Intervention period, profitability in finishing increased by €13.10 and €11.64 per pig started, for unadjusted and adjusted means respectively, during the Intervention period and by €17.48 to €14.34 per pig started in the After Intervention period. For the combined wean-to-market phase, profitability increased by €12.19 and €11.09 per pig started in the Intervention period and by €17.67 and €15.30 per pig started in the After Intervention period relative to the Before Intervention period.

Table 5. Summary of economic analysis of the value of productivity changes in the Intervention and After Intervention periods compared to Before Intervention; profit and change in profit (€/pig started in nursery).

	Before Intervention	**Intervention**	**Change from Before Intervention**	**After Intervention**	**Change from Before Intervention**
Nursery					
Unadjusted means	€ 6.93	€ 6.52	-€ 0.40	€ 8.27	€ 1.34
Least squares means[1]	€ 7.35	€ 7.08	-€ 0.27	€ 8.92	€ 1.57
Finishing					
Unadjusted means	€ 10.53	€ 23.64	€ 13.10	€ 28.01	€ 17.48
Least squares means[2]	€ 13.43	€ 25.06	€ 11.64	€ 27.77	€ 14.34
Wean-to-market (combined nursery and finishing					
Unadjusted means	€ 17.15	€ 29.34	€ 12.19	€ 34.82	€ 17.67
Least squares means[1,2]	€ 20.39	€ 31.48	€ 11.09	€ 35.69	€ 15.30

[1]*Production outcomes in nursery adjusted for sow farm, males castrated or intact, days on feed and month batch closed*

[2]*Production outcomes in finishing adjusted for feed type, genetics of the dam, days on feed and month the batch closed*

Benefit:cost ratios for the Intervention and After Intervention periods are shown in Table 6. To calculate benefit:cost ratios, the cost of the intervention was calculated as the additional respiratory vaccine costs per pig started relative to the Before Intervention period. The benefit was the change in profit per pig started relative to the Before Intervention period.

Table 6. Benefit:Cost ratio using the value of adjusted least squares means productivity improvements.

	Before Intervention	**Intervention**	**Change from Before Intervention**	**After Intervention**	**Change from Before Intervention**
Wean-to-market profit per pig started (€/pig)	€ 20.39	€ 31.48	*Benefit of intervention:* € 11.09	€ 35.69	*Benefit of intervention:* € 15.30
Total cost of all respiratory vaccines per pig started (€/pig)	€1.43	€2.59	*Cost of intervention:* €1.16	€1.47	*Cost of intervention:* €0.04
Benefit:Cost ratio			**9.6:1**		**382.5:1**

Discussion and conclusions

This study demonstrates the use of historical production data, and an enterprise budgeting model to conduct a retrospective CBA to assess the economic efficiency of animal health interventions. The interventions included stabilization of the sow farms for PRRSV, vaccination of growing pigs for PRRSV and vaccination of all gilts and pigs for *Mhp* so the pigs from all 3 sow farms could be comingled into a single nursery. The interventions were made to improve productivity and reduce use of antibiotics in the finishing phase of production, which they did. The approach to estimate the economic value of those changes addresses the challenge of isolating changes in productivity outcomes attributed to an animal health intervention from those attributed to other causes. The benefit:cost ratios estimated for the Intervention and After Intervention periods, 9.6:1 and 382.5:1 respectively, were relatively large and demonstrated that the interventions were successful from an economic perspective. Although antimicrobial use in finishing was not measured directly, medication costs in finishing, declined by €0.68 to €0.74 per pig started during the Intervention period and by €0.85 to €1.16 per pig started in the After Intervention period.

Limitations of the analysis include the short duration of time for which data were available following the intervention which made it challenging to isolate the impact of the intervention. In addition, other confounding variables that were not measured and not included in the analysis may have explained, in part, some of the changes in the productivity outcomes.

Acknowledgments

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References

1. National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA). Overview of the United States Hog Industry. October 29, 2015. http://usda.mannlib.cornell.edu/usda/current/hogview/hogview-10-29-2015.pdf (Accessed February 20, 2018).
2. Dottori M., Nigrelli A.D., Bonilauri P., Merialdi G., Gozio S., Cominotti F. 2007. Proposta per un nuovo sistema di punteggiatura delle pleuriti suine in sede di macellazione. La griglia SPES (Slaughterhouse Pleurisy Evaluation System). Large Animal Review 13, 161–165.
3. Bollo JM, Menjón E., Calvo E. 2008. Review of the 0 to 5 scoring method for enzootic pneumonia