The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK

Animal Welfare 2008, 17: 61-69
ISSN 0962-7286

Tail and ear biting lesions in pigs: an epidemiological study

D Smulders*†, V Hautekiet†, G Verbeke‡ and R Geers†

† Katholieke Universiteit Leuven, Laboratory for Quality Care in Animal Production – Zootechnical Centre, Bijzondere Weg 12, B-3360 Lovenjoel, Belgium
‡ Katholieke Universiteit Leuven, Biostatistical Centre, Kapucijnenvoer 35, B-3000 Leuven, Belgium
* Contact for correspondence and requests for reprints: dennis.smulders@gmail.com

Abstract

*Tail and ear biting lesions have a negative effect both on the animal welfare status of pigs (*Sus scrofus*) and the economical revenue of the pig farm. Tail biting behaviour is an unpredictable, abnormal behaviour that is thought to have a multifactorial origin. On-farm factors influencing tail biting have been described, but the real triggers are poorly understood. Much of the research into tail biting has been done on a small scale within a well-controlled environment and small sample sizes. This well-controlled environment is not always representative of the contemporary commercial conditions. Therefore, an observational epidemiological approach at farm level was adopted to gain a better insight into the factors influencing the occurrence of tail and ear biting lesions. Tail and ear biting lesions were observed at pen level three times a year on sixty farms across Belgium. A questionnaire was conducted to build a multifactorial model indicating different risk factors concerning the lesions scored. The temperature and the number of feeding places per animal in the nursery, the percentage of floor space covered with slats in the farrowing unit, the feed type in the growing unit and the overall hygiene policy were the most important indicators for the appearance of tail and ear biting lesions during fattening. The leave-one-out cross validation of the model demonstrated an intraclass correlation coefficient of 0.55 between the predicted model outcomes and the observed data. This epidemiological study provides important potential risk factors in relation to the incidence of tail and ear biting lesions. However, experimental and/or longitudinal studies have to confirm that the correlations found in this work are causal factors.*

Keywords: *animal welfare, behaviour, ear biting, epidemiology, pig, tail biting*

Introduction

The tail biting syndrome was already recorded in the 19th century, although at the time it was not seen as a big problem (Sambraus 1985). The syndrome was only recognised when the pig industry was characterised by an extreme intensification (Dougherty 1976). The problem of tail biting is at least as worse as it was a decade ago; recent numbers indicate an increase during the last few years. In 1994 the Danish Bacon and Meat Council revealed tail lesions or abscesses in the tail region in 0.22% of the 20 million pigs slaughtered. In 1998 this percentage was 0.62% (Anon 1998). This represents an increase of two hundred percent. Similar patterns are described by Elbers *et al* (1990), Guise and Penny (1998) and Hunter *et al* (1999, 2001). These figures indicate the growing awareness of this economical and welfare-related problem. The increasing pattern could be due both to a growing tail biting prevalence and to more intense and accurate monitoring systems that have been developed to detect tail biting lesions.

Tail and ear biting are regarded to have a major impact on intensive pig husbandry, and considered an abnormal behaviour resulting from disharmony between the animal and its environment. This behaviour has a considerable impact on animal welfare, as not only do bitten animals suffer the pain from the biting activity but there is also the possibility of the spread of infection to various bodily organs. As well as the impact on animal welfare, this behaviour also affects the economic profitability of the sector. The overall income can be decreased by tail and ear biting through increased production costs, especially during nursing and growing phases due to lower daily gains, a greater incidence of secondary infection and the decreased market value arising from less-uniform batches (Fraser & Broom 1990; Anon 2001).

Outbreaks of tail and ear biting are sporadic, neither tail docking nor the isolation of wounded animals can guarantee prevention of outbreaks of the syndrome; these measures are merely symptomatic solutions to the problem (Hunter *et al* 2001; Schrøder-Petersen & Simonsen 2001; Moinard *et al* 2003). Although the underlying motivation of tail and ear biting is not yet entirely understood, it is generally accepted that some external (Huey 1996; Arey 1991; Guise & Penny 1998) and genetic (Breuer *et al* 2005) factors give rise to an increased incidence of tail biting. Since past research demonstrated that provoking tail and ear biting is fraught with difficulty (van Putten 1968; Ewbank 1973), it is thought that an epidemiological approach, as adopted in this study, can help gain a better insight into the on-farm factors influencing tail and ear biting.

Much of the research into tail biting has been done on a small scale within a well-controlled environment and with small sample sizes, ie unrepresentative of the interacting commercial conditions. Therefore, an extensive, observational epidemiological study was adopted to gain a better insight into the on-farm management and housing factors influencing the occurrence of tail and ear biting lesions.

Materials and methods

Selection procedure

A list of 200 farrow-to-finish pig herds was randomly selected from a pool of Belgian farmers from the same slaughterhouse co-operative. All of these farms were contacted by telephone and informed of the project and 60 of those who were willing to co-operate were selected at random. Each farm was visited three times over a one-year period (from July 2003 until July 2004). Only one farm was reluctant to co-operate after the first visit and was visited once.

Data collection

A pig house is usually divided into different rooms consisting of a number of pens housing animals of the same age group that are physically separated from pens in other rooms. Rooms accommodating animals of the same age on the same farm can differ in terms of housing condition. Therefore, on each farm, pigs of one system were selected to ensure similar animal treatments. A system is defined as one or more rooms with pigs of similar age, sex ratio, group size, pen design, ventilation, lighting and feeding systems and management (Moinard *et al* 2003).

Farmers chose a preferred day for the visit and strict levels of biosecurity were applied. On each farm visit, a face-to-face questionnaire was conducted, to ensure a high response rate, and on-farm animal observations were performed on an average of 20 randomly selected pens per system (for each farm) containing an average of 11 animals per pen with an average weight of approximately 80 kg. Due to the time-consuming nature of the animal observations, this study focused on animals in the latest stage of the production process. It must be noted that it was impossible to identify every mild lesion generated during the early stages of the production process as a percentage would have almost certainly healed by the time of observation. However, severe lesions generated in the earlier stages of life and a proportion of mild lesions induced early on in life, which develop into severe lesions in later stages should tail and ear biting behaviour continue, would still be detectable later on. In this study, animals were observed on farm rather than at slaughter to ensure that all the observed animals were housed under similar housing and management conditions. In total 3,590 pens and 38,559 animals were observed.

The questionnaire and the animal observations were piloted on three farms to optimise data collection.

The questionnaire

The farmer was interviewed and the farm was inspected. This inspection served as a method of verification for the answers which could be corrected if needed. The questionnaire consisted of six different topics covering a detailed range of farm and management characteristics: general information about the farm, hygiene and illness prevention measures, general management practices, climate, feeding management and production traits of the observed animals. Table 1 summarises the content of the face-to-face questionnaire. In total, 150 potential risk factors were included in the questionnaire.

The animal observations

Tail and ear biting lesions were recorded by a binomial division of the pens. During a five-minute observation of the animals in their home pen, a pen was marked '1' if there was at least one animal showing tail or ear biting lesions and '0' if there were none. An animal with a tail or ear lesion was defined as either an animal with superficial scratches or blood on tail or ears, or as one for which parts of tails or ears were missing due to severe biting behaviour. All the observations took place using live observations performed by an observer standing very still and the pen was only entered when the severity of the lesion was in doubt eg in the case of soiled tails, to minimise the disturbance. The five-minute observation period was sufficient because the maximum number of animals per pen was 19.

To gain a better insight into the severity of on-farm tail and ear biting lesions, these lesions were divided into four categories for tail and ear lesions, separately. The number of animals per category was registered in the same five-minute observation period to obtain the binomial parameter to score the pens. The distinction between the different categories was dependant on the severity of the injury. The first category included those animals without any lesions, category 2 contained animals with only superficial scratches, category 3 consisted of animals with deep lesions and bleeding tails or ears and, finally, category 4 animals had severe lesions where parts of the tail or ears were missing. Completely healed but clearly shortened tails are recorded under category 4. A superficial scratch is defined as a scratch without apparent signs of blood.

The inter-observer repeatability of this observational method was perfect; the intraclass correlation coefficients calculated were equal to one (Smulders *et al* 2006). The validity of the method used in this work was also demonstrated by Smulders *et al* where several behavioural observations, including the scoring of tail and ear biting lesions, were linked to individual physiological characteristics (salivary cortisol and urinary adrenaline and noradrenaline).

Data handling

Statistical model building was carried out by a generalised linear mixed model using the nlmixed procedure of the statistical package SAS 9.1 (SAS Institute Inc, USA). Good overviews as well as general theoretical developments and examples of non-linear mixed models are provided by

https://doi.org/10.1017/S0962728600031997 Published online by Cambridge University Press

Table 1 The face-to-face questionnaire.

Category	Question
General information	Number of fattening places
	Number of sow places
	Time spent on pig farming
	Educational level of the farmer
	Age of the compartments*
	Type of flooring*
	Available space*
	Group size
Hygiene and illness prevention measures	Are the sows showered before entering the farrowing crate?
	Technique and frequency of cleaning and disinfecting compartments*
	Number of days that a compartment stays empty after cleaning*
	The state of the disinfectant foot baths
	Vaccination scheme
	Worming scheme
	Scabies treatment scheme
	Were observed animals afflicted by any diseases?
	Presence of a sick bay
General management practices	Buy and sell policy
	All-in-all-out policy or not
	Presence of a quarantine compartment
	Are gilts bred or bought from other farms?
	Is three-week system applied or not?
	Tail docking applied?
	Teeth clipping carried out?
	Number of inspection rounds per day*
	Policy on visitors
	Frequency and age at which mixing is applied
	Duration of fasting prior to transportation to the slaughterhouse
Climate	Type of ventilation ie natural/mechanical, automated or not, type of air in- and outlet*
	Type of heating*
	Frequency of adjusting the ventilation*
	Ventilation band width*
	Measured temperature*
	Type and duration of the available light*
Feeding management	Salt concentration of the feed?
	Antibiotic (if present) concentration of the feed*
	Crude protein percentage of the feed*
	Crude fibre percentage of the feed*
	Dry matter percentage of the feed*
	Structure of the feed*
	Dry or wet feeding*
	Number of feeding and watering places*

* Pertaining to questions which are repeated for the different stages in the production process (sow unit, farrowing unit, nursery unit, growing unit and fattening unit). The nursery houses animals from a weight of approximately 8 to 20 kg and in the growing unit animals start at 20 kg and rise to approximately 40 kg. Pigs heavier than 40 kg are housed in the fattening unit.

Table 2 Percentage of animals affected by the different categories of tail and ear biting lesions and the tail and ear biting incidence expressed as a percentage of observed pens with at least one affected animal.

Lesion and category	Percentage of animals affected	Percentage of pens with at least one affected animal
Tail biting lesions (category 2)	1.26	8.3
Tail biting lesions (category 3)	0.40	2.7
Tail biting lesions (category 4)	0.46	3.3
Ear biting lesions (category 2)	2.90	13.5
Ear biting lesions (category 3)	0.08	0.7
Ear biting lesions (category 4)	0.19	0.7

In total 38,559 animals were observed, spread among 3,590 pens and 60 different farms. Category 2: animals with only superficial scratches, category 3: animals with deep lesions and bleeding tails or ears, category 4: animals with severe lesions where parts of the tail or ears were missing.

Table 3 The statistical generalised linear model indicating the significant parameters influencing the incidence of tail and ear biting lesions on farrow-to-finish pig herds.

Parameter	Estimate	SE	*P*-value
Intercept	–5.465	1.118	< 0.0001
Number of feeding places per animal in the nursery	–1.290	0.400	0.0029
Temperature in the nursery (in °C)	0.105	0.040	0.0106
Percentage of the farrowing unit floor space covered with slats (scale 0 to 1)	0.0194	0.005	< 0.0001
Dry feeding in the growing unit	0.407	0.190	0.0346
Wet feeding in the growing unit	0	0.190	0.0346
No boot bath between reproduction and fattening facilities	0.91	0.288	0.0020
Boot bath between reproduction and fattening facilities	0	0.288	0.0020

Vonesh and Chinchilli (1996). The model-building process started with a screening of all single explanatory variables. Therefore, each factor obtained from the questionnaire was introduced separately into the model as a fixed effect. Significant factors ($P < 0.05$) with a minimum of 85% of the observations present were subjected to further analyses. In this first step, 5% of the factors were selected as erroneous because a significance level of 0.05 is applied. This potential problem will be omitted in the following steps. The next step in the model-building process consisted of a backwards elimination of variables. In this step, multiple explanatory variables were simultaneously tested to achieve a significant general non-linear mixed model with 'visit' and 'farm' introduced as a random effect to account for clustering at the herd level, 'visit' indicating if a system was observed for the first, second or third time. Factors found to be significant at the 0.05 level were combined to fit a final model. Two-way interactions with a biologically meaningful interpretation were tested between main effects that remained in the model. All statistical model building processes were performed using data collected on pen level.

The validation of the final model was accomplished by performing a leave-one-out cross-validation (Effron 1979). For each farm, the model estimates were recalculated using a dataset where the data of that particular system were excluded. Thereby, it was possible to calculate a predicted model outcome for each farm. A summation of the intercept, the estimates for the binomial factors and the product of the estimate and the exact value of the continuous factor is conducted to become a log value ($\Pi_i /1–\Pi_i$), from which the probability of finding a pen with at least one animal with tail or ear lesions (Π_i) can be calculated. These predicted outcomes were pairwise compared to the observed average number of pens scored 1 for each farm by calculating an intraclass correlation coefficient, where the average number of pens scored 1 for each farm is to be interpreted as the probability of finding a pen with at least one animal affected by tail or ear lesions. The intraclass correlation coefficients (ICC) (Fleiss & Cohen 1973; Snedecor & Cochran 1989) is determined by the covariance parameter estimates of the fitted general linear mixed model with random intercept and a farm number introduced as a random factor. This farm number is a unique number for each of the incorporated farms.

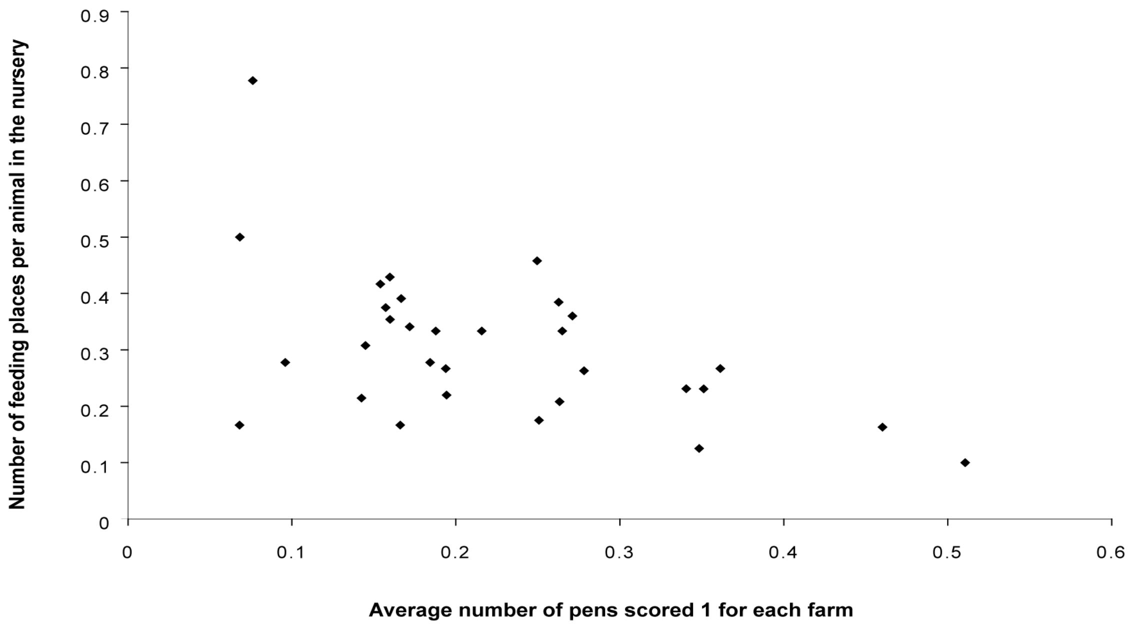
Results

Tail and ear biting prevalence

Table 2 depicts the average percentage of animals affected by tail or ear biting lesions per category and the percentage of pens with at least one affected animal. 24.5 percent of the pens contained at least one animal which was affected by tail or ear lesions. Both tables show a higher prevalence of more severe lesions (category 3 and 4) on the animals' tails compared to the ears whereas mild lesions (category 2) are more prevalent on the ears.

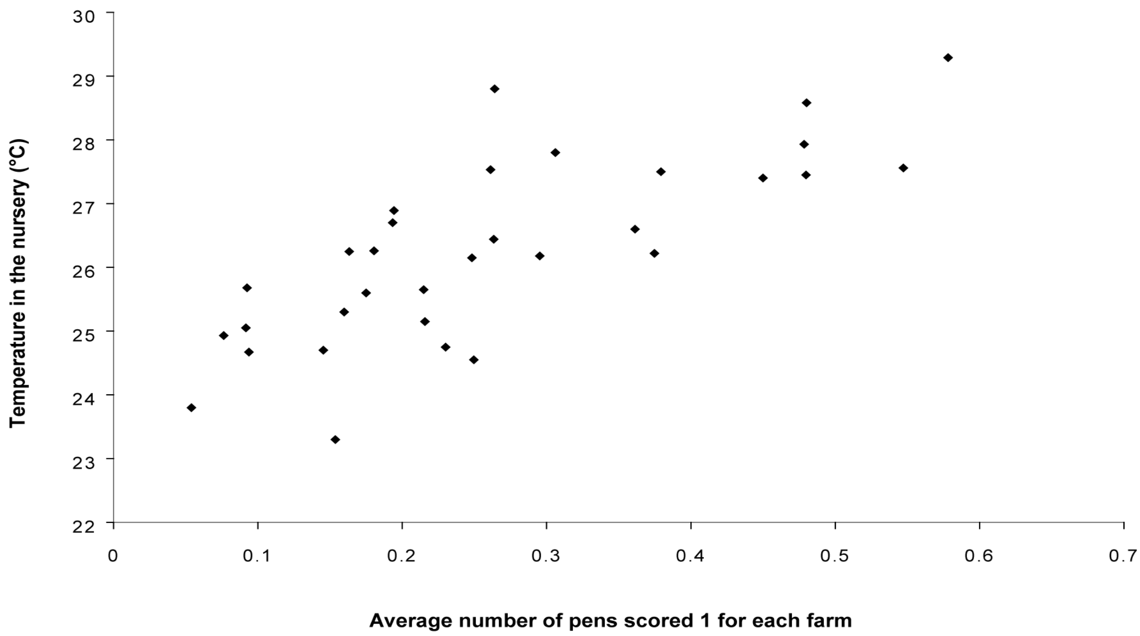
https://doi.org/10.1017/S0962728600031997 Published online by Cambridge University Press

Figure 1



The average number of pens scored 'I' concerning tail and ear biting lesions for each farm (on a scale of zero-to-one) in relation to the number of feeding places per animal in the nursery.

Figure 2



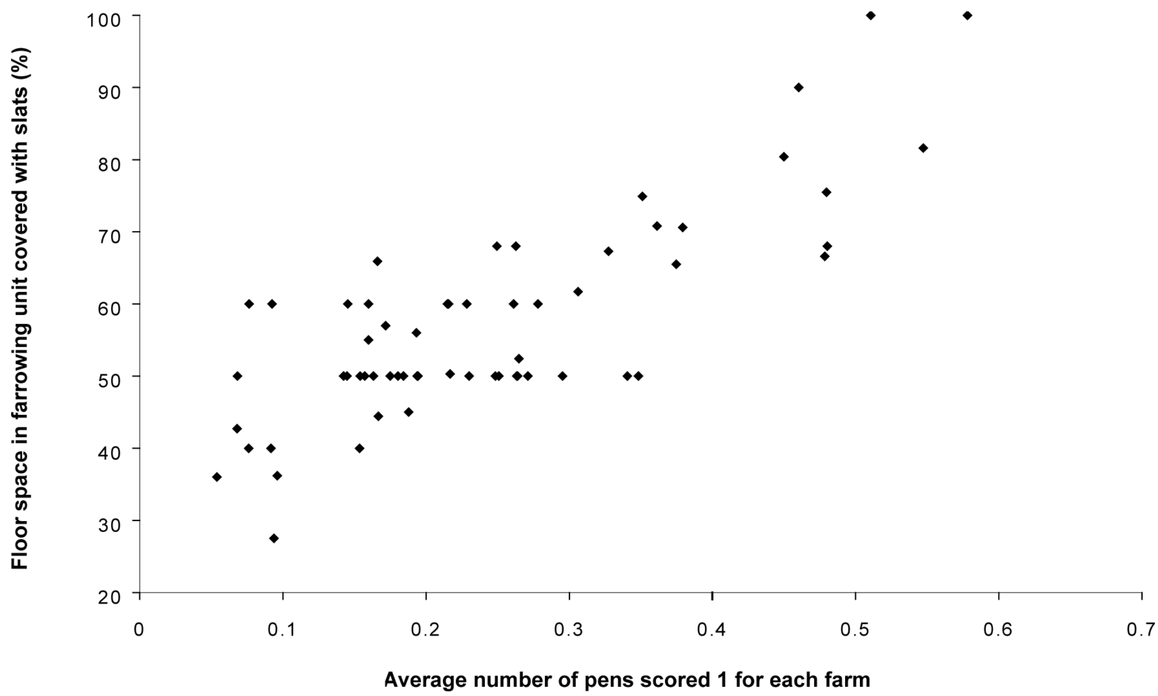
The average number of pens scored 'I' concerning tail or ear biting lesions for each farm (on a scale from zero to one) in relation to the observed temperature in the nursery in °C.

Tail and ear biting model

Table 3 shows the five most important significant factors influencing the incidence of tail and ear biting lesions in pigs. The first important factor is the number of feeding places in the nursery. The probability of tail or ear lesions increases when this value decreases. The relationship between the average number of pens scored '1' per farm and the number of feeding places in the nursery is shown in Figure 1.

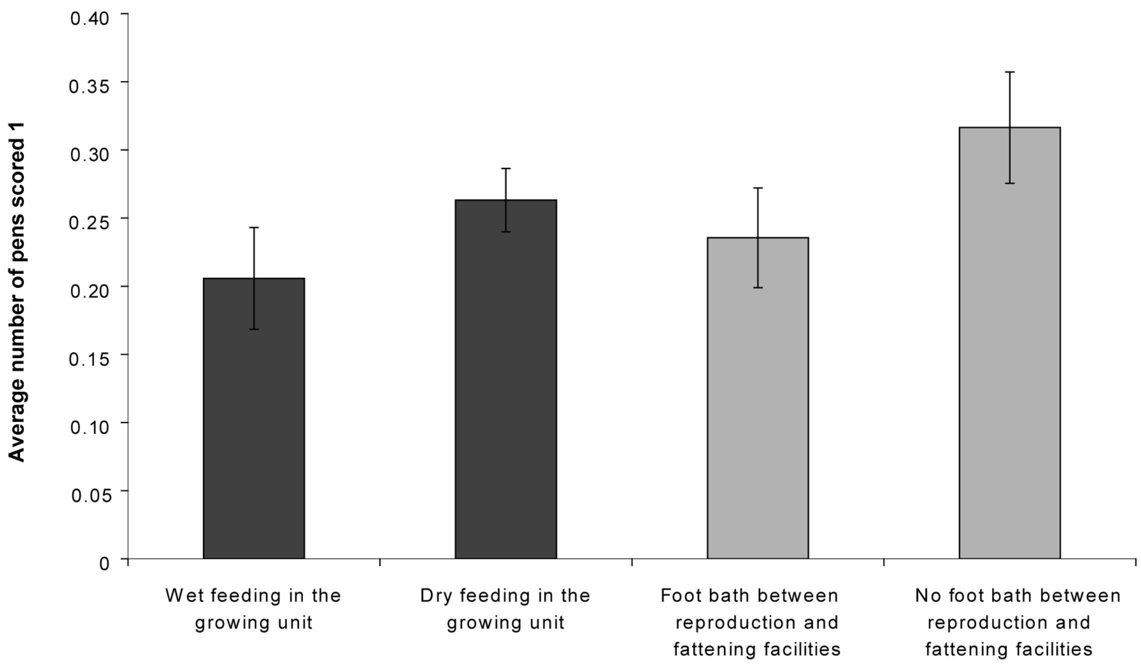
A second factor is the temperature in the nursery. In the nursery rooms, animals between approximately 8 and 20 kg are housed. There is a positive correlation (see Figure 2), between this factor and the probability of finding tail and

Figure 3



The average number of pens scored '1' concerning tail and ear biting lesions for each farm (on a scale from zero-to-one) in relation to the percentage of the farrowing unit floor space covered with slats.

Figure 4



The average number of pens scored '1' concerning tail and ear biting lesions for each farm (on a scale from zero-to-one) when wet and dry feeding is applied in the growing unit and whether or not a foot bath is present between reproduction and fattening facilities.

https://doi.org/10.1017/S0962728600031997 Published online by Cambridge University Press

ear lesions in the fattening period. In each nursery room the temperature was measured at the height of the pigs' noses in two pens and the average was used for further analysis.

A third factor influencing tail and ear lesions was the percentage of slats on the floor surface in the farrowing unit. The greater the slatted area, the greater the prevalence of tail and ear lesions (see Figure 3).

The feeding type is a fourth factor in the model presented in Table 3. Dry feeding in the growing unit, which is given in 73.33% of cases, increased the number of animals affected by tail and ear lesions compared to wet feeding (see Figure 4).

The on-farm hygiene policy is a fifth factor in the model describing tail and ear biting lesions in farrow-to-finish pig herds. If an operating, disinfectant foot bath was present between the reproduction facilities (sow housing and farrowing pens) and the fattening facilities (nursery, growing and fattening units), which was the case in 16.67% of farms, a significant decrease in the incidence of tail and ear lesions was observed, compared to farms with a less strict boot bath policy (Figure 4).

Validation

The Pearson correlation coefficient between the predicted model outcome for each system and the observed average number of pens scored 1 for each system is 0.55.

Discussion

Until very recently, little research had been done on the relative importance of different management factors in reducing tail and ear biting lesions. Therefore, an epidemiological approach is an important step in helping clarify a multifactorial problem such as the occurrence of tail and ear biting lesions, as this is an approach which tackles the problem as a whole, taking as many interactions and variables as possible into account. Although no causal relationships can be demonstrated with an epidemiological approach, this type of study can infer risk factors which may be investigated in depth by a focused, follow-up experimental approach. Hence, future on-farm longitudinal or experimental studies should aim to determine whether the potential risk factors in relation to tail and ear biting were causal or not.

In this study, 2.12% of the animals were affected by tail biting lesions; a prevalence considerably higher than figures seen for other studies (Elbers *et al* 1990; Anon 1998; Hunter *et al* 1999, 2001). These numbers stress the importance of scientific research concerning the determination of on-farm risk factors.

Tail biting, which in the worst instances can lead to cannibalism (van Putten 1968), is considered to be one of the greatest contributors to increased production costs and decreasing animal welfare, especially in the nursery and growing unit (Fraser & Broom 1990; Anon 2001). The importance of the early stages of the production process in the development of negative social behaviour such as tail biting is also demonstrated by Ekkel *et al* (1995), Petersen (1995) and Simonsen (1995) and can be confirmed by this study. A maladjusted environment at these stages of life is thought to be very important in the development of abnormal behaviour which can result in tail and ear lesions. The effect of this environment can have either a short-term effect, resulting in tail and ear lesions in even these early stages of life or a long-term effect. The enhanced complexity of the early environment could exert generalised effects on pigs' long-term social behaviour, cognitive functioning, and/or stress susceptibility, making them them less likely to exhibit tail biting or other abnormal or damaging behaviours when exposed to particular environmental and social conditions (Schouten 1991; De Jonge *et al* 1996; Cox & Cooper 2001; Moinard *et al* 2003). Schrøder-Peterson and Simonsen (2001) concluded it was reasonable to assume that both the rearing environment and subsequent conditions are related to tail biting. In this study it was impossible to determine the exact moment in the production process at which lesions were developing. Therefore no distinction can be made as to whether the rearing environment has a short or a long-term effect on the development of tail and ear biting lesions.

This study revealed three important risk factors related to housing and management during the early stages of life which affect the incidence of tail and ear biting lesions at 80 kg: the flooring type in the nursery, the temperature in the nursery and the application of wet or dry feeding in the growing unit. The importance of the floor type, particularly the percentage of floor space covered with slats in the farrowing unit, is demonstrated as a risk factor in this study (Table 3, Figure 3). Weaning age is thought to be a crucial stage in the consideration of tail biting. Suckling is an essential behaviour. If piglets are weaned prior to 17 weeks of age (the natural weaning age; Jensen 1988), the motivation to suckle will remain high. In a poor environment, even stimuli such as pen-mates' tails will be the focus of this suckling behaviour (Algers 1984). The flooring is an important environmental factor in the development of tail biting, especially when slats are used (Hansen & Hagelsø 1980; Moinard *et al* 2003). The slatted floor can cause high concentrations of noxious gases (van Putten 1969) which can result in irritation and restlessness, facilitating negative social behaviour such as tail and ear biting. Hansen and Hagelsø (1980) stated that slippery slatted flooring may hamper the development of a stable social hierarchy; this can have a short and/or a long term impact on the animal's biting behaviour.

The interior climate has been revealed as being an important risk factor influencing the incidence of tail and ear biting lesions in this and other studies (Gadd 1967; Penny *et al* 1981; Sällvik & Walberg 1984; Geers *et al* 1985). Climate is an extremely complex issue. When thoroughly characterising 'climate', measures of air changes and changes in temperature per hour, humidity, dust and ammonia levels should be established. Due to the cost and time constraints, these measurements, as seen in this study, are often not incorporated. However, our study demonstrated that a relatively simple measure such as temperature can have implications for the incidence of tail and ear lesions later in life.

https://doi.org/10.1017/S0962728600031997 Published online by Cambridge University Press

In this study, a high environmental temperature in the nursery was the most important factor influencing the incidence of tail and ear biting lesions in later stages of life (Table 3, Figure 2). At high temperatures, pigs avoid physical contact with pen mates (Geers *et al* 1986) and become more restless (Penny *et al* 1981) which might result in irritation and a rise in aggressive behaviour which, in turn, can result in tail and ear biting lesions. When pigs experience such a discomfort or when they are not able to adapt to the high environmental temperatures, abnormal biting behaviour may occur there and then or in the later stages of life. Our findings are also confirmed by Lohse (1977) who stressed the negative effect of high temperatures on aggressive behaviour and tail and ear biting behaviour. However, it must be stressed that this is only a hypothetical explanation and further research is advised especially when the time span between the risk factor and the dependant variable is seen to increase. The greater this time span, the more uncontrollable factors arise which can hamper the interpretation of the results.

The final important environmental risk factor in the early stages of life affecting the incidence of tail and ear biting lesions is whether wet or dry feeding is applied in the growing unit (Table 3, Figure 4). In the wet feeding type, the water nipple is placed in the feeding trough. This type of feeding can decrease the dust concentration thereby ameliorating the climate. High dust concentration can result in irritation of the respiratory system which can lead to restlessness and enhances the susceptibility to respiratory disease. Schrøder-Petersen and Simonsen (2001) stated that the health status of both the biter and the victim, may affect tail biting. A correlation between respiratory problems and ear and tail biting was found by Elst *et al* (1998) and Moinard *et al* (2003). Both tail and ear biting and the occurrence of diseases act as a stressor, facilitating the development of both. Hunter *et al* (2001) also found an effect of feeding type on the occurrence of tail biting.

Besides a possible effect on the climate, the feeding system can also influence the feeding and social behaviour of pigs. This study demonstrated the importance of the allocation of adequate amounts of feeding space in order to reduce the prevalence of tail and ear biting lesions (Figure 1). A restriction in feeding space can lead to tail biting since feeding is a socially facilitated behaviour in pigs (Hsia & Wood-Gush 1982; Moinard *et al* 2003). A lack of feeding space can lower food intake and create high levels of stress and frustration for those individuals unable to eat simultaneously with the others.

The overall on-farm hygiene protocol is the final very important risk factor concerning the incidence of tail and ear biting lesions demonstrated by this study. Only twelve percent of the farms visited in this study applied a strict hygiene policy with the provision of disinfectant foot baths between reproduction and fattening facilities. These farms were characterised by lower incidences of tail and ear biting lesions (Figure 4). This parameter could, however, be representative of the overall management practise bring applied on a particular farm thereby linking the incidence of tail and ear biting lesions to general management practices. The implementation of strict hygiene policy can limit the introduction and subsequent spreading of disease, which can, as stated previously, act to enhance the incidence of outbreaks of tail and ear biting behaviour (Moinard *et al* 2003).

Most of the factors identified as being important in relation to tail and ear biting in previous studies were incorporated in this study. However, the effect of mixing frequencies on tail biting behaviour, as shown by Arey (1991), could not be explored here, nor could the effect of the salt concentration in the feed (Fraser 1987). Breed type is believed to be a causal factor in the tail-biting syndrome (Sambraus 1985; Peterson 1994) although Lund and Simonsen (2000) did not find any difference in the frequency of tail biting in their preliminary study on Danish Landrace and Duroc pigs. In this study, all farms utilised Piétrain pigs as the paternal breed and, although information about the maternal breeding lines was gathered, it was difficult to interpret as 68% of the farms produced their own maternal breeding lines.

Regarding the model validation, an intraclass correlation coefficient of 0.55 between the predicted model outcome and the observed average number of pens with tail or ear lesions could be obtained. This value is relatively high for an epidemiological study. On the other hand, it is necessary to stress the possible effect of other parameters not included in our model on tail and ear biting lesions.

Animal welfare implications

Tail and ear biting lesions are considered to have a detrimental effect on animal welfare. The results of this study show that an epidemiological approach can infer risk factors through various interactions within normal farming circumstances. Moreover, these findings could be explained and supported by results obtained within experimental work. Hence, this complementary information on aspects of housing and management should motivate consumers and farmers to improve the welfare of pigs by reducing the incidence of tail and ear biting lesions. Future work should focus on experimental and longitudinal studies identifying causal links between the welfare-related tail and ear biting syndrome and on-farm housing and management factors. Once a causal link has been demonstrated, measures can be taken to minimise the incidence of tail and ear biting, thereby enhancing on-farm animal welfare.

Acknowledgements

The project was funded by IWT-Vlaanderen (Institute for the Promotion of Innovation through Science and Technology in Flanders) and Katholieke Universiteit Leuven.

The participating farmers and COVAVEE staff are acknowledged for excellent collaboration.

References

Algers B 1984 Animal health in flat-deck rearing of weaned piglets. *Journal of Veterinary Medicine A 31*: 1-13

Anonymous 1998 *The Danish Bacon and Meat Council.* The veterinary and food section: Copenhagen, Denmark

Anonymous 2001 Scientists' assessment of the impact of housing and management on animal welfare. *Journal of Applied Animal Welfare Science 4*: 1-52

Arey DS 1991 Tail-biting in pigs. *Farm Build Progress 105*: 20-23

Breuer K, Sutcliffe MEM, Mercer JT, Rance KA, O'Conell NE, Sneddon IA and Edwards SA 2005 Heritability of clinical tail-biting and its relation to performance traits. *Livestock Production Science 93*: 87-94

Cox LN and Cooper JJ 2001 Observations of the pre- and post-weaning behaviour of piglets reared in commercial indoor and outdoor environments. *Animal Science* 72: 75-86

de Jonge FH, Bokkers EAM, Schouten WGP and Helmond FA 1996 Rearing piglets in a poor environment: developmental aspects of social stress in pigs. *Physiology and Behavior 60*: 389-396

Dougherty RW 1976 Problems associated with feeding farm livestock under intensive systems. *World Review of Nutrition and Dietetics 25*: 249-275

Effron B 1979. Computers and the theory of statistics: thinking the unthinkable. *SIAM Review 21*: 460-480

Ekkel ED, Van Doorn CEA, Hessing MJC and Tielen MJC 1995 The specific-stress-free housing system has positive effects on productivity, health, and welfare of pigs. *Journal of Animal Science 73*: 4-6

Elbers ARW, Cromwijk JMA, Hunneman WA and Tielen MJM 1990 Keeping records for pig finishing herds as part of integrated quality control I: Use of drugs and vaccines. *Tijdschrift voor Diergeneeskunde 115*: 249-261

Elst WET, Vaessen MA, Vos HJMP, Binnendijk GP, Huirne REM and Backus GBC 1998 *Proefverslag – Varkensproefbedrijf – "Zuid-en-west-Nederland" No.P1. 200* pp 1-54. Sterksel: The Netherlands. [Title translation: Research report-pig research facilities-southern and western Netherlands]

Ewbank R 1973 Abnormal behaviour and pig nutrition. An unsuccessful attempt to induce tail biting by feeding a high energy, low fibre vegetable protein ration. *British Veterinary Journal 129*: 366-369

Fleiss JL and Cohen J 1973 The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability. *Educational and Psychological Measurement 33*: 613-619

Fraser D 1987 Mineral-deficient diets and the pigs attraction to blood implications for tail biting. *Canadian Journal of Animal Science 67*: 909-918

Fraser D and Broom DM 1990 *Farm animal behaviour and welfare, 3rd edition.* Bailliére Tindall: London, UK

Gadd J 1967 Tail-biting. *Pig Farming 15*: 55-58

Geers R, Berckmans D, Goedseels V, Maes F, Soontjens J and Mertens J 1985 Relationships between physical characteristics of the pig house, the engineering and control systems of the environment and production parameters of growing pigs. *Annales de Zootechnie 34*: 11-22

Geers R, Goedseels V, Parduyns G and Vercruysse G 1986 The group postural behaviour of growing pigs in relation to air velocity, air and floor temperature. *Applied Animal Behaviour Science 16*: 353-362

Guise HJ and Penny RHC 1998 Tail biting and tail docking in pigs. *Veterinary Record 142*: 46-46

Hansen LL and Hagelsø AM 1980 A general survey of environmental influence on the social hierarchy function in pigs. *Acta Agriculturae Scandinavica 30*: 388-392

Huey RJ 1996 Incidence, location and inter-relationships between the sites of abscesses recorded in pigs at a bacon factory in Northern Ireland. *Veterinary Record 138*: 511-514

Hunter EJ, Jones TA, Guise HJ, Penny RHC and Hoste S 1999 Tail biting in pigs: 1 The prevalence at six UK abattoirs and the relationship of tail biting with docking, sex and other carcass damage. *The Pig Journal 43*: 18-32

Hunter EJ, Jones TA, Guise HJ, Penny RHC and Hoste S 2001 The relationship between tail biting in pigs, docking procedure and other management practices. *Veterinary Journal 161*: 72-79

Hsia LC and Wood-Gush DGM 1982 The relationship between social facilitation and feeding behaviour in pigs. *Applied Animal Ethology 8*: 410-416

Jensen P 1988 *Maternal behaviour of free-ranging domestic pigs*. University Project. Swedish University of Agricultural Sciences, Faculty of Veterinary Medicine, Department of Animal Hygiene, Sweden

Lohse E 1977 Einfluss unterschiedlicher umwelttemperaturen auf die motorische aktivität von ferklen. *Institut für tierproduktion der technischen Universität Berlin Journal 925*: 68-71. [Title translation: Influence of different environmental temperatures on the 12 pig movement activities]

Lund A and Simonsen HB 2000 Aggression and stimulus-directed activities in two breeds of finishing pig. *The Pig Journal 45*: 123-130

Moinard C, Mendl M, Nicol CJ and Green LE 2003 A case control study of on-farm risk factors for tail biting in pigs. *Applied Animal Behaviour Science 81*: 333-355

Penny RHC, Walters JR and Tredget SJ 1981 Tail-biting in pigs: a sex frequency between boars and gilts. *Veterinary Record 108*: 35

Petersen V 1994 The development of feeding and investigatory behaviour in free ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science 42*: 87-98

Petersen V 1995 The effect of environmental stimulation on the development of behaviour in pigs. *Applied Animal Behaviour Science 45*: 215-224

Sällvik K and Walberg K 1984 The effects of air velocity and temperature in the behaviour and growth of pigs. *Journal of Agricultural Engineering Research 30*: 305-312

Sambraus HH 1985 Mouth-based anomalous syndromes. In: Fraser AF (ed) *Ethology of Farm Animals* pp 391-422. Elsevier: Amsterdam, The Netherlands

Schouten WGP 1991 Effects of rearing on subsequent performance in pigs. *Pig News and Information 12*: 245-247

Schrøder-Petersen DL and Simonsen HB 2001 Tail biting in pigs. *Veterinary Journal 162*: 196-210

Simonsen HB 1995 Effect of early rearing environment and tail docking on later behaviour and production in fattening pigs. *Acta Agriculturae Scandinavica, Section A 45*: 139-144

Snedecor GW and Cochran WG 1989 *Statistical Methods, 8th edition* pp 242-243. Iowa State University Press: Ames, USA

Smulders D, Verbeke G, Mormède P and Geers R 2006 Validation of a behavioral observation tool to assess pig welfare. *Physiology and Behavior 89*: 438-447

van Putten G 1968 *Een Onderzoek naar staartbijten bij mestvarkens.* Proefschrift Universiteit Amsterdam: Amsterdam, The Netherlands. [Title translation: A research into tail biting in fattening pigs]

van Putten G 1969 An investigation into tail biting among fattening pigs. *British Veterinary Journal 28*: 121-124

Vonesh EF and Chinchilli VM 1996 *Linear and nonlinear models for the analysis of repeated measurements.* Marcel Dekker: New York, USA

https://doi.org/10.1017/S0962728600031997 Published online by Cambridge University Press