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The welfare of growing pigs in five different production systems in France and Spain: assessment of health

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Abstract

This study was carried out to compare the health of growing pigs in five different production systems in France and Spain using measures provided by the Welfare Quality® protocol. A total of 11,647 pigs housed on 91 commercial farms were evaluated over a two-year period (2007–2009). Farms considered as conventional were close to the European dominant production system, rearing 'white' pigs (eg Large White; Landrace × Pietrain) housed on concrete floors. Systems considered as differentiated had specifications to distinguish them from the conventional one. Farms that housed 'white' breeds of pigs on straw were then considered as a different production system. Mallorcan Black pigs managed extensively on family farms in the Balearic islands represented a third production system. The remaining two systems assessed were represented by the methods used for Iberian pig rearing extensively or intensively. Multiple Generalised Linear Mixed Models were performed for each animal-based measure of health. The straw-bedded and the conventional systems did not differ in the prevalence of any animal-based measures. Mallorcan Black pigs and Iberian pigs kept extensively had a lower prevalence of severe wounds than pigs in the conventional system and the lowest prevalence of tail biting. Focusing on pigs housed in the conventional system, several possible causal factors (such as the feeding system and the type of floor) were identified relating to severe wounds, tail biting and lameness. Therefore, the recording of simple environmental-based factors can be useful in detecting farms that are more likely to show these problems.

Keywords: *animal welfare, causal factors, growing pig, health, housing systems, Welfare Quality®*

Introduction

Health refers to the state of the body and brain in relation to the effects of pathogens, parasites, tissue damage or physiological disorder. Since all of these effects involve pathology (that is the detrimental derangement of molecules, cells and functions that occurs in living organisms in response to injurious agents or deprivations), the health of an animal is its state as regards its attempts to cope with pathology (Broom 2006). Health is, therefore, a significant component of welfare (Broom 2010) and must be considered properly in a welfare assessment. The Farm Animal Welfare Council (1992) provides a narrower definition of health as the absence of pain, injuries or diseases. Injuries and diseases can cause acute or chronic pain which, in turn, is defined as an aversive emotional experience (Molony & Kent 1997; Rainville 2002). It should be emphasised that a light difficulty in coping with pathology may not be detected using this previous definition.

Animal health depends on several influencing factors and may vary according to the production system. For growing pigs, farms with concrete floors and relatively high stocking densities greatly predominate throughout Europe and can be considered as conventional. Recently, consumer concerns regarding animal welfare have led to a growing interest for alternative production systems. Several studies have been conducted to compare the prevalence of health indicators — such as skin lesions, tail biting and lameness — in conventional-system and straw-bedded accommodation (Lyons *et al* 1995; Guy *et al* 2002; Scott *et al* 2006; Courboulay *et al* 2009). At present, around 7% of growing pigs in France are housed on straw bedding while very few Spanish farms use deep-litter systems because of it's *a priori* incompatibility with high environmental temperatures and limited availability of the material. Pigs housed on conventional and straw-bedded farms are usually 'white' breeds of pigs selected for their high growth speed or high conversion index and their adaptability for indoor husbandry. At the same time, increasing attention is being given to outdoor production systems, which are usually found in specific geographical areas. Mallorcan Black and Iberian pigs represent approximately 15% of the overall population of growing pigs in Spain. Both autochthonous breeds are rustic animals derived from the Mediterranean line characterised by a dark-grey skin colour. Mallorcan Black pigs are grown in the Balearic islands while Iberian pigs are traditionally found in the south-west of the Iberian peninsula. Both breeds are traditionally reared under extensive conditions in specific ecosystems, taking advantage of the existing natural resources. There are differences in the way these animals are housed, fed and managed as well as in the nature of the final product (Jaume & Alfonso 2000; Rodríguez-Estévez *et al* 2009). Mallorcan Black pigs are produced on family farms with traditional social structures where the pig enterprise is never the main activity of the farm. Preservation of Mallorcan Black pig is mainly sustained by the utilisation of pure-bred animals in the elaboration of the 'Sobrassada de Mallorca de Porc Negre Mallorqui', a kind of cured sausage with paprika qualified as a Protected Geographical Indication. This breed is always reared extensively and the feeding regime is based on pasture, cereals (barley and rye), legume seeds, almonds and several Mediterranean shrubs. The most common practice with Mallorcan Black Pig is slaughtering animals at heavy live weight, around 150 kg. The traditional rearing system of the Iberian pig is linked to the 'dehesa' (*Quercus ilex* and *Quercus suber*). The abundance of food provided by acorn ripening is used by the Iberian pigs during the late fattening phase, which is called 'montanera' and takes place from early November to late February, when the diet is based only on natural resources. This system has its own legal regulation (the Quality Standards for Iberian Pork and Cured Products), which specifies a stocking rate of less than two pigs per hectare and that animals must be slaughtered above 14 months of age (approximately 150 kg live weight) (MAPA 2007). The growing demand from the consumers for Iberian pig meat products such as the Iberian dry-cured hams and shoulders has led recently to an intensification of the production cycle. Indeed, taking advantage of this market niche, some 'white' pig producers started to rear purebred Iberian or Iberian × Duroc crossbred with the aim of producing high quality meat products. Intensification of the Iberian pig system has led to a reduction in length of the production cycle (slaughtering at 10 months of age, approximately) and the systematic use of fodder resulting in the total independence of seasonality ('montanera period'). Iberian pigs in intensive conditions can, thus, be reared elsewhere in Spain. Intensive Iberian pigs are housed in a wide variety of accommodations ranging from indoor-slatted pens to outdoor paddocks. Such intensification is associated generally with a decrease in animal welfare; however, much knowledge still remains to be transferred (Aparicio Tovar & Vargas Giraldo 2006).

Despite a general interest in comparing production systems, few studies have been undertaken on commercial farms across countries. One of the main reasons is the lack of harmonised information that enables reliable comparison of data from different sources. Welfare Quality® protocols provide the tool that makes possible the assessment of farms through Europe in a standardised way by observers that receive an identical training. Moreover, this assessment system should be applicable and valid in a wide variety of farming systems (Blokhuis 2008). Welfare Quality® is based on four main principles of animal welfare: i) good feeding; ii) good housing; iii) good health; and iv) appropriate behaviour. Each of these four principles comprises several independent but complementary criteria (Botreau *et al* 2007) in turn characterised by one or various measures. The principle labelled as 'good health' includes three different criteria: absence of injuries (such as wounds on the body, lameness, tail biting, etc), absence of disease (such as respiratory problems, enteric disorders, skin conditions, etc) and absence of pain induced by management procedures (such as tail docking or castration practices). Preference was given to animal-based measures for being more valid when measuring the state of the animal as regards its attempts to cope with its environment (Capdeville & Veissier 2001; Whay *et al* 2003). Animal-based measures give an indication of the performance of a husbandry system at a certain moment of the production cycle. A Welfare Quality® protocol has not been thought as a risk assessment tool. Instead, it aims to detect farms or housing and management systems with particular welfare problems. Welfare concerns may indeed have more severe consequences in one production system than in another. It is essential though to identify which factors are the main sources of variation within each system. Knowledge about the possible causes of impaired welfare is essential to drive improvement in animal welfare (Whay 2007) and to prevent misinterpretations (Temple *et al* 2011a). For that reason and to ensure proper feedback to farmers (Blokhuis 2008), simple design measures were incorporated into the Welfare Quality® protocol.

To sum up, the aim of this study was to compare the health of growing pigs reared in five different production systems using the Welfare Quality® assessment protocol. It provides data about the prevalence and distribution of several welfare outcomes on a wide range of commercial farms with a view to possible causal factors. The overall Welfare Quality® protocol was applied on 91 commercial farms in France or in Spain and this study presents a benchmark description of several health measures.

Materials and methods

Farm selection and production systems

A total of 91 commercial farms of growing pigs (from 28 days old) were assessed applying the Welfare Quality® protocol over a two-year period. Sixty-one farms were evaluated in Spain and 30 in France. Choice of farms was based on management practices, farm size and veterinary records in order to obtain a large variety of situations. Farm sampling concerned the five main production systems of growing pigs found in France or in Spain.

Farms considered as conventional were close to the Europe-wide dominant production system aiming at the lowest possible production costs. Fifty-two Spanish and French farms with concrete floor were categorised as conventional farms. Systems considered as differentiated had specifica-

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tions to distinguish them from the conventional one with one or several claims among the following: animal welfare, eating quality, nutritional quality, environment, organic production, local production. Four other production systems were differentiated in the present study: the straw-bedded system (eight farms assessed in France); the intensive Iberian pig system (ten farms assessed in Spain); the extensive Iberian pig system (eleven farms assessed in Spain) and the extensive Mallorcan Black pig system (ten farms assessed in Spain).

Sampling of pigs and pens

On each intensive farm, ten pens of growing-finishing pigs from different ages were selected randomly. Hospital pens were not sampled; however, their presence/absence was recorded. If there were 15 or fewer pigs in a pen/group, all pigs were assessed, whereas if there were more than 15 pigs in the pen/group, 15 were selected arbitrarily. Pigs were categorised into three growing stages:

• Early growing stage: at the beginning of the growing process (less than 90 days old);

• Mid growing stage: mid growing period from 90 to 130 days old; and

• Final growing stage: at the end of the growing process and before leaving to the slaughterhouse (from 130 to 194 days old).

Among intensive Iberian pigs as well as extensive pigs, a fourth category included pigs older than 194 days. Information on whether pigs were castrated or not was also taken into account. Pigs were assessed at least ten days after arrival at the farm to avoid the sensitive period around mixing.

Data regarding the floor type (fully slatted floor, solid concrete floor, straw, or sand) and the feeding system (trough, dry hopper, wet feed hopper, Turbomat [Roxell®, Maldegum, Belgium], on the ground, on pasture) were collected. Space allowance was calculated and the average environmental temperature was noted down.

Pigs' and pens' characteristics

A total of 11,647 pigs from 719 pens or paddocks were evaluated.

In the conventional system, 7,030 pigs with a mean (± SD) age of 109 (± 34) days ranging from 29 to 180 days old were assessed in 530 pens. Pigs were housed in groups of average 16 (± 7) ranging from 6 to 67 animals per pen. The majority of growing pigs on conventional farms come from a maternal line Large White × Landrace. The paternal line mainly used was the Pietrain. However, in some farms, the Duroc breed was used as a paternal line. On any given farm, growing pigs could have different origins and genetics. Overall, 60% of the farms housed castrated males. Pigs were kept on concrete flooring whether fully or partly slatted and the average space allowance was 0.66 (± 0.20) m^2 per pig. The majority of pigs were fed *ad libitum* via a dry or wet-feed hopper. Some animals were liquid-fed in troughs from two to four times a day or via Turbomat once or twice daily. In these two feeding systems, food was restricted in time but not in quantity. The Turbomat is a circular trough with four or six drinking nipples above it where feed is available for ten pigs simultaneously. Table 1 provides more descriptive data on pen characteristics. The mean (± SD) environmental temperature was 23.4 (± 2.3)ºC. Hospital pens were present in 70% of the conventional farms. French and Spanish conventional systems were considered as the same production system; however, some differences in the distribution of a number of explanatory variables should be considered. More than 90% of concrete floors on French farms were fully slatted; liquid-feeding systems in troughs and Turbomat systems were only seen in France; all the temperatures were recorded above 21ºC in France and all males were castrated in France while 30% of Spanish farms housed castrated males.

In the straw-bedded system, 1,110 pigs at a mean (± SD) age of 112 (± 42) days, ranging from 41 to 194 days old were assessed in 74 pens. Pigs were housed in groups of 38 (± 15) ranging from 18 to 83 animals per pen. As with conventional farms, pigs on straw-bedded systems were 'white', from different genetic lines. On any given farm, growing pigs could have different origins and genetics. The average space allowance was 1.52 (± 0.96) m^2 per pig. All the males were castrated. Pigs were fed *ad libitum* via dry or wet-feed hoppers or liquid-fed in troughs from two to four times a day (Table 1). The mean (± SD) environmental temperature was 23.4 (± 4.5)ºC. Hospital pens were present on 43% of the farms.

A total of 1,255 Iberian pigs kept in intensive conditions were evaluated in 58 pens or paddocks. The mean (± SD) pig age was 250 (± 97) days and ranged from 37 to 280 days of age. Pigs were housed in groups of 115 (± 91), ranging from seven to 320 animals per pen. On any given farm, pigs could be purebred Iberian or Iberian × Duroc crossbred. All the males were castrated. Pigs were housed on a wide range of floor types (Table 1). The average space allowance was 1.9 m^2 per pig, ranging from 0.30 to 5.4 m^2 per pig. All the pigs were dry fed *ad libitum* via dry hopper or trough (Table 1). The mean (± SD) environmental temperature was 20.5 (± 3.3)ºC. Hospital pens were present on 90% of the farms.

Under extensive conditions, 1,428 Iberian pigs at a mean (± SD) age of 250 (± 97.3) days and ranging from 42 to 420 days, were assessed in 31 different paddocks. Pigs were kept in groups of an average of 170 (± 116) animals, ranging from 12 to 470 per paddock. All animals assessed were pure Iberian pigs and all the males were castrated. The average space allowance per pig was 430 (± 578) m^2, ranging from 83 to 2,500 m^2 per pig. On the months of assessment, pigs were supplemented with fodder as the availability of natural resources was insufficient. Supplementation was given manually once or twice a day on the floor (55% of the paddocks), in a trough (26% of the paddocks) or in dry hoppers (19% of the paddocks).

Mallorcan Black pigs, reared extensively, represented the second extensive system assessed. A total of 824 Mallorcan Black pigs, average 220 (± 100) days of age and ranging from 75 days to 405, were evaluated in 24 paddocks. Pigs were kept in groups of 58 (± 37) animals, ranging from 11 to

Table 1 Description of variables collected on the growing pig pens of the three intensive production systems studied.

Variable	Conventional (n = 530 pens)	Straw bedded (n = 74 pens)	Intensive Iberian (n = 58 pens)
Space allowance (m^2 per pig)			
Mean (± SD)	0.66 (± 0.20)	1.52 (± 0.96)	1.86 (± 1.32)
Minimum	0.2	0.3	0.3
Q1	0.58	0.7	0.8
Median	0.68	1.2	1.4
Q3	0.75	2.9	2.6
Maximum	1.56	3.0	5.4
Temperature (°C)			
Mean (± SD)	23.4 (± 2.3)	23.2 (± 4.5)	20.5 (± 3.3)
Minimum	16.0	15.0	12.0
Q1	21.0	20.0	19.0
Median	23.0	23.0	22.0
Q3	25.0	24.0	23.0
Maximum	29.0	40.0	24.0
Feeder type (% of pens)			
Trough	23%	19%	11%
Dry hopper	38%	59%	89%
Wef-feed hopper	37%	22%	
Turbomat	2%		
Floor type (% of pens)			
Partly slatted	40%		24%
Fully slatted	60%		27%
Concrete with resting area			37%
Outdoor on deep bedding			12%
Hospital pen (% of farms)			
Presence	70%	43%	90%
Absence	30%	57%	10%

Upper limit of the first quartile (Q1) and third quartile (Q3).

170 per paddock. All animals assessed were Mallorcan Black pigs and all the males were castrated. The average space allowance per pig was 692 (± 818) m^2, ranging from 130 to 4,000 m^2 per pig. All pigs were on pasture and supplemented with household refuge (such as water-melon/melon/orange/lemon peels, vegetables, etc), bran, legume seeds, cereals and figs. Supplementation was carried out manually, once or twice a day, on the floor (23% of the paddocks) or in a trough (35% of the paddocks) and given *ad libitum* by dry hopper (37% of the paddocks). In the remaining 5% of paddocks, pigs were reliant entirely on pasture. During assessment days, the average environmental temperature was 18 and 25ºC in extensive Iberian and Mallorcan Black pigs, respectively. Sick animals were usually kept in small provisional areas of a paddock, however the presence/absence of hospital pens as such could not be recorded properly in extensive conditions.

Measurements

Assessments were performed by four observers, two of them in Spain and the other two in France. In order to minimise differences between observers and to standardise the scores from the visits, observers followed the same training prior to beginning the assessment and repeatability among them was assessed. The training consisted of a set of 40–60 video clips and images for each measure included

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into the protocol as well as training on a commercial farm. If the observer did not reach an acceptable agreement with the golden standard (in the case of images or videos) or with the silver standard (in the case of live animals), a set of extra images and animals were assessed until a good level of repeatability was achieved.

Severely wounded animals

Pigs were encouraged to stand up in order to make the body more clearly visible. One side of the pigs' body was inspected visually for the presence of lesions and/or penetration of the muscle tissue, considering five separate regions: i) ears; ii) front (head to back of shoulder); iii) middle (back of shoulder to hindquarters); iv) hindquarters; and v) legs (from the accessory digit upwards). The tail zone was not considered here. Any scratch longer than 2 cm as well as any round lesion smaller than 2 cm was given a lesion score of 1. A round lesion ranging from 2 to 5 cm in diameter or more than 5 cm and healed was given a lesion score of 5. A round lesion of more than 5 cm, deep and opened, was given a lesion score of 16. Each zone was considered separately. Animals were considered affected (severely wounded animals) when presenting more than ten lesions on at least two zones of the body or any zone with more than 15 lesions.

Tail biting

Severe tail biting was considered when fresh blood was visible on the tail; when there was evidence of a degree of swelling and infection or when part of the tail tissue was missing and a crust had formed.

Lameness

Animals were observed individually during walking from inside the pen or paddock. A pig was considered lame when it presented with minimum weight-bearing on the affected limb or when it was unable to walk.

Skin condition

Each animal was inspected visually and considered using the following individual scale: 0) no evidence of skin inflammation or discoloration; 1) (localised), up to 10% of the skin was inflamed, discoloured or spotted; and 2) (widespread), more than 10% of the skin had an abnormal colour or texture. The number of animals in each category was considered.

Scouring

Scouring was measured at pen level instead of individual level. The observer looked at areas in the pen/paddock where faecal deposits were visible. When liquid and fresh manure was visible, the pen was considered to be a pen with scouring. In extensive conditions, loose faecal material around the anal region helped in the detection of diarrhoea. When scouring could not be evaluated properly for feasibility reasons (ie dirty pens), the pen was considered as a missing value.

Pumping (laboured breathing), twisted snout, rectal prolapse and hernia

Pigs with heavy and laboured respiration were defined as pumping animals. Pigs that presented a nasal distortion that was characteristic of atrophic rhinitis were considered as pigs with twisted snouts. To detect rectal prolapse, pigs were examined from behind, checking for presence of swelling and extrusion of tissue from the rectum. To detect hernias, the animals were observed from the front, back and side. Hernias with a bleeding lesion or hernias that affected the behaviour of the animal were recorded.

More detailed information about the overall methodology of assessment of health measures can be found in the Welfare Quality® Assessment Protocol for Pigs (2009).

Statistical analysis

The pen or paddock was the experimental unit. Data, with the exception of scouring, were expressed as the number of animals affected out of the number of animals assessed in each unit. Scouring was expressed as presence or absence of diarrhoea at pen level. To account for possible dependence between observations on pens from the same farm, random farm effects were included in the model. Data were also clustered at pen level and modelled for over-dispersion. Multiple Generalised Linear Mixed Models for binomial data were performed separately for each welfare measure using the GLIMMIX procedure (SAS statistical package Version 9.1, SAS Inst Inc 2002, Cary, NC, USA). Residual pseudo-likelihood was used as estimation technique (Wolfinger & O'Connell 1993).

The general form of the model was:

$$\text{Logit}\ (y/n) = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki} + u_{farm\ (i)} + v_{pen\ (i)}$$

Where y is the number of animals affected, n the number of animals assessed, β_0 the intercept, β_k the regression coefficient predictors, X_{ki} the predictive factors. u_{farm} and v_{pen} are the residual variances of the random effects.

Models were first built to compare the five production systems: conventional, straw bedded, intensive Iberian, extensive Mallorcan Black pig, extensive Iberian. Then, separate models were developed for each intensive system (conventional, straw bedded, Iberian intensive) to identify possible causal factors, such as the type of floor, the feeding system, the growing stage, space allowance and ambient temperature. At the expense of discarding information, these two last continuous variables (space allowance and temperature) were converted into categorical variables by means of quartiles to avoid strong assumptions regarding the linear relation between the outcome measure and the predictive factor (Altman *et al* 1994). Possible causal variables were entered into the model as fixed effects.

Statistical analyses consisted of initial univariable screening to determine the variables associated statistically with each indicator of health. Variables were taken forward for multivariable analysis when significant at $P < 0.2$ (Dohoo *et al* 2009). Where variables were highly correlated (PROC SPEARMAN) or showed a strong association (PROC FREQ with the CHISQ option), the most biologically plausible variable was selected for inclusion in the final model. Stepwise backward selection was performed to identify the variables that had a significant association ($P < 0.05$) with the outcome measure. The country effect (Spanish vs French farms) was considered into each model of the conventional system. When the country effect

Table 2 Mean prevalence (% of pigs affected at pen level) and standard error of animal-based measures of health in five production systems. The number of pigs and pens/paddocks (n) assessed is shown for each production system.

Animal-based measure	Conventional 7,030 pigs (n = 530 pens)	Straw bedded 1,110 pigs (n = 74 pens)	Intensive Iberian 1,255 pigs (n = 58 pens)	Extensive Mallorcan Black 824 pigs (n = 24 paddocks)	Extensive Iberian 1,428 pigs (n = 31 paddocks)
Severely wounded	2.5 (± 0.35)[a]	1.4 (± 0.40)[ab]	0.1 (± 0.10)[b]	0.2 (± 0.13)[b]	0.4 (± 0.29)[b]
Tail biting	1.1 (± 0.27)	1.4 (± 1.26)	0.2 (± 0.30)	0.0 (± 0.0)	0.0 (± 0.0)
Lameness	1.2 (± 0.17)	2.3 (± 0.31)	1.0 (± 0.31)	0.1 (± 0.12)	0.4 (± 0.21)
Localised skin condition	1.6 (± 0.24)	0.5 (± 0.19)	0.4 (± 0.17)	0.2 (± 0.11)	1.3 (± 0.53)
Widespread skin condition	2.1 (± 0.28)	0.1 (± 0.09)	0.3 (± 0.17)	1.0 (± 0.49)	0.4 (± 0.33)
Scouring*	9.0 (± 0.2)[b]	15.9 (± 0.4)[ab]	53.9 (± 0.8)[a]	23.1 (± 0.8)[ab]	23.0 (± 0.8)[ab]
Pumping	0.2 (± 0.06)	0.2 (± 0.13)	0.2 (± 0.17)	0.0 (± 0.0)	0.0 (± 0.03)
Twisted snout	0.0 (± 0.00)	0.0 (± 0.0)	0.0 (± 0.0)	0.0 (± 0.0)	0.0 (± 0.0)
Rectal prolapse	0.0 (± 0.00)	0.0 (± 0.0)	0.0 (± 0.0)	0.0 (± 0.0)	0.3 (± 0.27)
Hernia	0.1 (± 0.04)	0.2 (± 0.13)	0.1 (± 0.0)	0.0 (± 0.0)	0.0 (± 0.0)

Different superscripts within rows define significant differences between systems at $P < 0.05$.
* Expressed in percentage of pens affected in relation to the number of pens assessed.

Table 3 Logistic-regression model of severely wounded animals and tail biting in growing-finishing pigs for production system. The last two rows display the estimates of the covariance parameters.

	Severely wounded[a]		Tail biting[b]	
System	**OR**	**CI**	**OR**	**CI**
Extensive Iberian	1		–	–
Conventional	4.1	1.3, 13.8*	1	
Straw bedded	2.9	0.7, 13.1	0.1	0.01, 1.8
Intensive Iberian	0.6	0.1, 3.8	0.9	0.2, 4.4
Extensive Mallorcan Black	0.6	0.1, 4.4	–	–
Random effect	*Estimate*	*SEM*	*Estimate*	*SEM*
Farm	1.3	0.4	2.2	0.6
Pen	1.2	0.1	1.3	0.1

[a] Intercept coefficient: –5.6; [b] Intercept coefficient: –5.3.
OR: Odds ratios; CI: 95% confidence intervals; SEM: standard error.
* The confidence interval (CI) does not include unity therefore the factor is significantly different from the reference category ($P < 0.05$).

vanished in the analysis while other factors were added to the model, 'country' ceased to be an interest as a separate factor. The observer effect (observer one vs observer two in Spain; and observer three vs observer four in France) was also considered into each final model and taken out when it did not alter the interpretation of fixed effect. The ratio of the generalised Chi-squared statistic and its degrees of freedom was considered to check how well the variability in the data had been properly modelled and that there was no residual over-dispersion. Goodness of fit was also assessed visually by means of standardised Pearson residuals (Lee *et al* 2006). When data did not allow a proper modelling, identification of predictive factors was not carried out.

Spearman correlation coefficients were calculated to investigate the association between the different animal-based measures of health.

Results

Severely wounded animals

The prevalence of pigs with severe wounds on the body (Table 2) was significantly higher in the conventional system compared with intensive Iberian pigs, extensive Iberian pigs, and extensive Mallorcan Black pigs. There was no significant difference in the prevalence of severely wounded animals between the conventional and the

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Table 4 Number and prevalence (%) of growing-finishing pigs in the conventional system with severe body wounds and tail biting by variable selected for multivariate analysis.

	Conventional (n = 530 pens)			
	Pigs affected with severe wounds		Pigs affected with tail biting	
Variable	Number	%	Number	%
Growing stage (days old)				
Early: < 90 days old	75	4	4	0.2
Mid: 90–130 days old	62	2.6	49	1.7
Final: 131–180 days old	37	1.8	22	1.1
Feeding system				
Liquid feed in-trough	60	4.1	33	2.2
Dry hopper	78	3.4	19	0.7
Wet-feed hopper	19	0.8	22	0.9
Turbomat	17	9.4	1	0.6
Temperature (°C)				
1st Q: 16–20.9	13	1	18	1.2
2nd Q: 21–22.9	45	2.8	24	1.4
3rd Q: 23–24.9	30	2.7	27	2.4
4th Q: 25–29	87	4	5	0.2
Castration				
No	13	0.5		
Yes	162	4.1		

straw-bedded systems. The risk of being severely wounded was estimated as being 4.1 times greater in those pigs housed in the conventional system than in extensive Iberian pigs (Table 3).

The prevalence of animals with severe wounds on the body in the conventional system varied by growing stage, feeding system, temperature levels and castration state as shown in Table 4. In this system, the risk of severe body wounds (Table 5) was higher in pigs early in the growing period (average 68 days of age) compared with older pigs. The risk of wounds on the body also increased when pigs were fed via Turbomat compared with the other feeding systems and in liquid-fed pigs compared with dry and wet-feed hoppers. Finally, there was a trend for increased body wounds in pens with castrated pigs; however, the confidence interval (CI) included unity ($P > 0.05$).

In straw bedding, the highest prevalence of wounds (3.4%) was found in pigs within the lowest stocking densities (first quartile: 0.3–0.7 m^2 per pig). Model fitness did not allow an appropriate analysis for pigs with severe body wounds in the straw-bedded system.

Tail biting

No case of tail biting was registered among extensive Iberian and extensive Mallorcan Black pigs (Table 2). The incidence of tail biting did not differ significantly between the three intensive systems studied, as the confidence intervals (CI) included unity (Table 3). The amount of variation of tail biting accounted for by 'farm' was large (estimate [± SEM] = 2.2 [± 0.6]) (Table 3).

The prevalence of tail biting in the conventional system varied by growing stage, feeding system and temperature levels as shown in Table 4. In this production system, the risk of tail biting (Table 5) was higher in pigs in the mid growing period (average 107 days of age) compared with pigs early in their growing period. Moreover, there was a significantly increased risk of tail biting in liquid-fed pigs in-trough compared with dry hopper. Finally, there was a significantly increased risk of tail biting associated with the lowest environmental temperatures (average 20ºC) compared with pigs housed within the highest environmental temperatures (average 26ºC).

Almost all the cases of tail biting in pigs in the straw-bedded system were associated with pigs in the mid growing period (4.6%), housed within the highest densities (5.1%) and under the highest environmental temperatures (5.8%). Model fitness did not allow a risk factor analysis for tail biting among pigs in the straw-bedded system.

Table 5 Multivariate logistic binomial mixed models of possible causal factors associated with severely wounded animals and tail biting in pigs in the conventional system. The last two rows display the estimates of the covariance parameters.

	Conventional			
	Severely wounded[a]		Tail biting[b]	
Variable	**OR**	**CI**	**OR**	**CI**
Growing stage (days old)				
Early: < 90 days old	1		1	
Mid: 90–130 days old	0.4	0.2, 0.7*	5.0	1.4, 17.5*
Final: 131–180 days old	0.3	0.2, 0.5*	3.0	0.8, 11.0
Feeding system				
Liquid feed in-trough	1		1	
Dry hopper	0.5	0.3, 0.95*	0.4	0.1, 1.5
Wet-feed hopper	0.2	0.1, 0.5*	0.2	0.1, 0.8*
Turbomat	4.2	1.2, 14.8*	0.3	0.1, 6.2
Temperature (°C)				
1st Q: 16–20.9	1		1	
2nd Q: 21–22.9	1.6	0.7, 4.0	0.4	0.2, 1.0
3rd Q: 23–24.9	0.5	0.2, 1.6	0.3	0.1, 1.2
4th Q: 25–29	0.6	0.2, 1.7	0.1	0.02, 0.4*
Castration				
No	1			
Yes	3.0	0.9, 10.0		
Random effect	*Estimate*	*SEM*	*Estimate*	*SEM*
Farm	1.3	0.4	2.3	0.8
Pen	1.2	0.1	1.2	0.1

[a] Intercept coefficient: – 2.5; [b] Intercept coefficient: 7.1.
OR: Odds ratios; CI: 95% confidence intervals; SEM: standard error.
* The confidence interval (CI) does not include unity therefore the factor is significantly different from the reference category ($P < 0.05$).

Table 6 Logistic-regression model of lameness as well as localised and widespread skin condition of growing-finishing pigs for production system. The last two rows display the estimates of the covariance parameters.

	Lameness[a]		Localised skin condition[b]		Widespread skin condition[c]	
System	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Extensive Iberian	1		1		1	
Conventional	3.0	0.7, 13.4	0.8	0.2, 4.9	3.6	0.2, 59.9
Straw bedding	3.8	0.7, 21.1	0.6	0.1, 7.6	0.5	0.1, 44.9
Intensive Iberian	2.9	0.5, 18.0	0.6	0.1, 6.9	1.6	0.1, 60.5
Extensive Mallorcan Black	0.8	0.1, 1.7	0.3	0.1, 5.6	3.9	0.1, 139.1
Random effect	*Estimate*	*SEM*	*Estimate*	*SEM*	*Estimate*	*SEM*
Farm	1.0	0.3	4.7	1.0	2.7	0.6
Pen	0.7	0.1	0.4	0.1	0.6	0.1

[a] Intercept coefficient: –4.7; [b] Intercept coefficient: –5.4; [c] Intercept coefficient: –6.0.
OR: Odds ratios; CI: 95% confidence intervals; SEM: standard error.
* The confidence interval (CI) does not include unity therefore the factor differs significantly from the reference category ($P < 0.05$).

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Table 7 Number and prevalence (%) of growing-finishing pigs in the conventional system with lameness and widespread skin condition by variable selected for multivariate analysis.

	Conventional (n = 530 pens)			
	Lame pigs		Pigs affected with widespread skin condition	
Variable	**Number**	**%**	**Number**	**%**
Growing stage (days old)				
Early: < 90 days old	18	0.9	7	1.2
Mid: 90–130 days old	31	1.1	36	4.4
Final: 131–180 days old	35	1.7	91	8
Space allowance (m² per pig)				
1st Q: 0.2–0.58	39	1.9	1	0.4
2nd Q: 0.59–0.68	20	1.3	26	5.6
3rd Q: 0.69–0.75	20	1.2	64	8.5
4th Q: 0.76–1.56	7	0.5	45	4.3
Floor type				
Partly slatted	5	0.2	88	5
Fully slatted	79	1.9	48	6.2
Hospital pen				
Presence	37	1.9		
Absence	47	2.5		

Table 8 Multivariate logistic binomial mixed models of possible causal factors associated with lameness and widespread skin condition in the conventional system. The last two rows display the estimates of the covariance parameters.

	Conventional			
	Lameness[a]		Widespread skin condition[b]	
Variable	**OR**	**CI**	**OR**	**CI**
Growing stage (days old)				
Early: < 90 days old	1		1	
Mid: 90–130 days old	2	1.1, 3.7*	1.5	0.5, 4.9
Final: 131–180 days old	2.7	1.5, 5.0*	3.9	1.2, 12.6*
Space allowance (m² per pig)				
1st Q: 0.20–0.58	1		1	
2nd Q: 0.59–0.68	0.8	0.4, 1.6	8	0.9, 70.0
3rd Q: 0.69–0.75	0.6	0.3, 1.1	7.8	1.0, 62.9
4th Q: 0.76–1.56	0.4	0.2, 0.9*	3.8	0.4, 33.2
Floor type				
Partly slatted	1		1	1
Fully slatted	6.3	2.6, 15.3*	0.6	0.3, 1.2
Hospital pen				
Presence	1			
Absence	2.1	1.2, 3.8*		
Random effect	*Estimate*	*SEM*	*Estimate*	*SEM*
Farm	0.3	0.2	2.6	1.1
Pen	0.8	0.1	0.8	0.1

[a] Intercept coefficient: –6.4; [b] Intercept coefficient: –3.4.
OR: Odds ratios; CI: 95% confidence intervals; SEM: standard error.
* The confidence interval (CI) does not include unity therefore the factor differs significantly from the reference category ($P < 0.05$).

Lameness

There was no significant effect of the production system on the prevalence of lameness (Table 2). The risk of being lame was estimated as being approximately three times greater in pigs housed in the three intensive systems than in extensive Iberian pigs, however this difference was not significant as the confidence intervals (CI) included unity (Table 6).

In the conventional system, the prevalence of lameness varied by growing stage, stocking density, type of floor and availability of hospital pens (Table 7). In this system, the risk of lameness (Table 8) increased with the age of the pigs. There was also an increased risk of lameness associated with the most tightly stocked pigs compared with pigs housed in the lowest stocking densities. Moreover, pigs housed on fully slatted floors presented a significantly higher risk of lameness than pigs housed on partly slatted floors. Finally, there was an increased risk of lameness in pigs housed in conventional farms without hospital pens.

Among pigs in the straw-bedded system and intensive Iberian pigs no causal variable of lameness could be detected.

Skin condition (localised and widespread skin discolouration)

There was no significant effect of the production system on the prevalence of localised (score 1) and widespread (score 2) skin conditions (Table 2). According to the estimates of the covariance parameters, both types of skin condition presented over-dispersion and a large variability between farms (Table 6).

In the conventional system, the prevalence of widespread skin condition had a high association with the observer. Observer number two evaluated 5.4% of pigs affected, while observers one, three, and four found 0.0, 0.1 and 0.05% of widespread skin condition, respectively. For that reason, the detection of possible causal factors for widespread skin condition was developed only for pigs in the conventional system evaluated by the observer number two. Revision in light of this revealed the prevalences of widespread skin condition detailed in Table 7. In the conventional system, and fixing the observer, there was an increased risk of widespread skin condition (Table 8) in pigs in the final growing stage compared to those early in the growing stage.

No causal variables were identified for localised skin condition in any of the production systems.

Scouring

There was no significant difference in the prevalence of scouring between pigs on conventional farms, pigs in the straw-bedded system, extensive Iberian pigs and extensive Mallorcan Black pigs (Table 2). The prevalence of scouring was significantly greater in intensive Iberian pigs compared with pigs in the conventional system. For feasibility reasons, 33% of the pens could not be evaluated in intensive Iberian pigs, 16% in extensive Iberian pigs, 8% in the conventional system, 7% in the straw-bedded system and 0% in extensive Mallorcan Black pigs.

In the conventional system, the highest prevalence of scouring was found in the youngest pigs (15%) while the lowest was found in finishing pigs (2%). In this system, there was a significant increased risk of scouring in pigs early in the growing period compared with finishing pigs (OR 20.1; CI 6.1, 70.7).

In the straw-bedded system, the highest prevalence of scouring was also registered among the youngest pigs (36%) while finishing pigs presented a lower prevalence (5%). Among pigs on straw, the risk of scouring was also significantly higher in pigs early in the growing period compared with finishing pigs (OR 15.3; CI 2.0, 121.7).

No possible causal variable was identified in intensive Iberian pigs.

Pumping (laboured breathing), twisted snout, rectal prolapse and hernia

Prevalences of pumping, twisted snout, rectal prolapse and hernia were below 1% and no significant differences were found between systems for any of these measures. The highest prevalence was seen in extensive Iberian pigs with rectal prolapse (0.3%).

Identification of possible causal variables was not possible for these measures.

Association between animal-based measures of health

In the conventional system, the strongest statistical correlation was found between both scores of skin condition ($r = 0.2$, $P < 0.001$). In the straw-bedded system, localised skin condition and widespread skin condition were also correlated ($r = 0.4$; $P < 0.001$). No significant association between measures was found in intensive Iberian pigs.

Associations between possible causal variables, and observer effect

In the straw-bedded system, the growing stage and the space allowance were highly correlated ($r = 0.7$, $P < 0.001$). This correlation was weak in pigs in the conventional system ($r = 0.3$, $P < 0.001$). Among intensive Iberian pigs, there was a strong association between the type of floor and the space allowance. Fully and partly slatted floors were associated with lower space allowance while concrete flooring with bedding or outdoor access and outdoor deep bedding floors housed pigs with a higher space allowance (Chi-squared = 63, df = 9, $\varphi = 0.9$; $P < 0.001$).

Inclusion of the observer effect did not alter the interpretation of any of the fixed effect except widespread skin condition. The country effect (France vs Spain) was included in the final model of scouring.

Discussion

This study formed part of a larger study which was conducted to assess the welfare of growing pigs in five different production systems found in France and Spain using the Welfare Quality® protocol and focused on the discussion of animal-based measures related to health.

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Contrary to the previous findings on 'good housing' (Temple *et al* 2012), health data assessed in the present study differed to a limited extent between production systems. When focusing on the conventional system, the majority of health indicators did not differ significantly between farms studied in France and Spain. With the exception of scouring, all other measures of health presented low prevalences, as the highest one was 2.5% of conventional pigs with severe wounds on the body. As a result of the large sample size and relatively high variability of the data, the detection of possible causal factors for several measures was achieved mainly in the conventional production system.

Severely wounded animals

The prevalence of severely wounded animals differed between production systems. Extensively kept pigs, as well as intensive Iberian pigs, presented a lower prevalence of severely wounded animals than pigs in the conventional system. Aggression between individuals is infrequent and rarely injurious among pigs housed under semi-extensive conditions (Stolba & Wood-Gush 1989). However, low prevalences of wounds in intensive Iberian pigs were less expected as aggression was much more frequent in intensive Iberian pigs than in extensive ones (Temple *et al* 2011b). Therefore, wounds on the body did not appear to be a sensitive indicator of the level of aggression in intensive Iberian pigs. Only severely injured pigs (eg those with more than 15 lesions on a given body zone) were recorded later than ten days after mixing. This relatively high threshold may not allow for the detection of more 'gentle' aggression. According to Turner *et al* (2006), for example, behaviours that do not lead to physical injuries, such as pushing, are not quantifiable using skin-lesions score. Furthermore, it should be emphasised that the level of skin lesions may have been underestimated in Iberian pigs due to their dark skin. Breed is an important confounding factor that should be considered when comparing the benchmark of wounds between production systems. No significant difference was observed between the conventional and straw-bedded systems for the prevalence of wounds, in accordance with Scott *et al* (2006).

When focusing on pigs in the conventional system, several possible causal factors could be identified. Severe wounds on the body decreased with the age of the pigs indicating the harmful effects of fighting among newly mixed pigs and the relative stability that followed hierarchical formation (Lyons *et al* 1995). To make the assessment more reliable when achieving social stability, the evaluation was carried out ten days after arrival. This interval appeared to be too short to avoid the sensitive period around mixing in the conventional system. Seventy-two hours after mixing, dominance hierarchy is known to be defined (Meese & Ewbank 1973); however, in some cases, exhaustion or starvation of the animals may have delayed the increase in fighting until recuperation. Competition for food has been shown to have negative effects on growing pigs, resulting in more skin injuries when fed restrictedly or when the feeding area is limited (Botermans & Svendsen 2000). In the present study, liquid-feeding in-trough lead to an increased risk of severely wounded animals compared with dry or wet hoppers. Liquid food was provided from two to four times per day (restricted in time) whereas pigs were fed *ad libitum* in dry or wet-feed hoppers. This difference in food management may explain the increasing risk of wounds in liquid-fed pigs in-trough. Additionally, the significantly highest prevalence of wounds was recorded on pigs fed via Turbomat. As well as being a restricted feeding system in terms of time, providing food once or twice a day, Turbomat may have a lower food accessibility enhancing competition between pigs. Mounting behaviour can cause lesions in the posterior of the body. Several studies reported that entire males are more aggressive and sexually active than castrates (Cronin *et al* 2003; Fredriksen *et al* 2008). A higher prevalence of skin lesions would thus be expected in pens that housed entire males. In the present study, however, there was a trend for an increased risk of wounds in pens that housed castrated males. From that, one cannot suggest that castration induces aggression, but that castration may be used as a possible solution on farms with persistent problems with aggression and subsequent body lesions.

Tail biting

Tail biting is a serious form of harmful social behaviour (van de Weerd *et al* 2005) resulting from disharmony between the animal and its environment. This behaviour has been described mainly in commercial indoor environments (Schrøder-Petersen & Simonsen 2001) although it has also been reported in outdoor herds (Walker & Bilkei 2006). In the present study, tail biting was associated with intensive production systems as no tails with blood or crust were recorded in extensive conditions. Some types of tail biting originate as misdirected foraging behaviour when there is a lack of adequate environmental stimulation (Fraser & Broom 1990; Taylor *et al* 2010). Many studies have shown that the provision of straw reduces behaviour directed at pen-mates or tail-biting levels (Fraser *et al* 1991; Lyons *et al* 1995; Beattie *et al* 2000; Scott *et al* 2006). However, no significant differences in the prevalence of tail biting were observed among the three intensive production systems studied. Intensively kept pigs appeared to chew tails even when other substrates were present, indicating that pigs were housed in several inappropriate environments independently of the intensive production system studied. It should be considered, though, that outbreaks of tail biting are usually described on affected farms (Paul *et al* 2007). This characteristic increases the between-farm as well as the between-pen variability, which together with the relatively low prevalence of tail biting can complicate the differentiation between production systems. In addition to tail biting associated with rooting behaviours, other types of tail biting are seen in situations of competitiveness and frustration (Taylor *et al* 2010). The access to a desired resource such as feeders can give rise to such situations (van de Weerd & Day 2009). In the conventional production system, liquid-feeding in-trough was associated with a higher risk of tail biting compared to the wet-feed hopper. Chambers *et al* (1995) reported similar observations; however other farm surveys (Hunter *et al* 2001; Moinard *et al* 2003) found lower levels of tail biting when pigs were liquid-fed rather than fodders. Restriction of food in time in the liquid-feeding system may confound the effect of the meal *per se*. Indeed, provision of food in too many meals per day is known to promote disturbance in the pen (Hessel *et al* 2006) and possible instances of tail biting. High stocking density may either contribute to enhance situations of frustration or represent a stressful factor by itself as it increases disturbance into groups. Even though high stocking density was not identified as a possible causal factor in the conventional system, it was associated with a high prevalence of tail biting in pigs in straw bedding. The significant effect of densities on the appearance of tail biting was supported by several studies (Arey 1991; Beattie *et al* 1996; Moinard *et al* 2003); but others such as Chambers *et al* (1995) did not find any association. Thermal stress, resulting from temperatures that are higher or lower than the pigs' thermal comfort zone, also increases tail biting (Geers *et al* 1989; Schrøder-Petersen & Simonsen 2001; Taylor *et al* 2010). Estimations of the thermal comfort zone range from 15 to 24ºC and from 14 to 21ºC in growing and finishing pigs, respectively (Gonyou *et al* 2006). The highest room temperatures recorded in pigs in straw bedding (24–40ºC) were out of the upper limit of the thermal comfort zone and contained all the cases of tail biting in that system. Lohse (1977) also reported higher prevalence of tail biting at high temperatures (35ºC). The straw-bedded system was, in the present study, associated with increased environmental temperatures which may have contributed to produce outbreaks of tail biting. On the contrary, on conventional farms, the temperature range (16–29ºC) was closer to the thermal comfort zone and pigs housed in the lowest room temperatures (16–21ºC) presented a higher risk of tail biting than pigs housed in the highest ones. An increased activity of the animals under cooler room temperatures may have increased the risk of tail biting in the conventional system. Finally, the age of the pigs was a relevant internal factor of tail biting. Pigs in the conventional and the straw-bedded systems reached their predilection age for tail biting during the mid-growing phase as also commented by Bracke *et al* (2004). Likewise, Sambraus (1985) observed that tail biting is not a common problem before pigs reach of 90–120 days old. The age of the pigs should therefore be taken into account when interpreting the level of tail biting in on-farm assessments.

Lameness

Lameness was not influenced significantly by the production system. On one hand, there was no indication that extensively reared animals were associated with an increased prevalence of lameness. Similar results were reported by Kilbride *et al* (2009) in outdoor housing. On the other hand, prevalences of lameness were similar between the three intensive systems studied. Similarly, Cagienard *et al* (2005) did not find any significant differences in the risk of lameness between 'animal-friendly' and traditional systems in Switzerland. The relatively low prevalence of lameness, due partially to the fact that only severely lame animals were recorded, may complicate the discrimination between systems. Taking into account moderate lameness, other studies (Mouttotou *et al* 1998; Jørgensen 2003) found lower prevalences of lameness in straw-bedded systems.

Although lameness was not associated with a particular production system, a strong relationship was seen between the prevalence of lameness and fully slatted floors in the conventional system. Slatted floors have been highlighted as a risk for lameness in previous studies (Jørgensen 2003; Kilbride *et al* 2009) and partly slatted floors appeared to reduce considerably the prevalence of lameness in the present study. Slats placed too wide apart or in worn and damaged condition can lead to severe foot injuries. Management, quality and design associated with fully slatted floors are crucial to prevent those lesions. Higher stocking densities increased the risk of lameness in the conventional production system as also commented by Jørgensen (2003). The increase in the prevalence of lameness with the age of conventional pigs might be due to the longer period of time spent on slatted floors or to the increased pressure exerted on the feet as pigs get heavier. Certain foot lesions, such as wall separation, for example, are known to be associated with an increased bodyweight. Finally, the presence of hospital pens should be considered carefully when interpreting prevalence of lameness on farm units. Conventional farms that provided hospital pens presented a significantly lower risk of lameness. As hospital pens were not included in the sample of pens assessed, this last result indicates that farmers correctly isolate severely lame animals. An incorrect management of hospital pens or a lack of availability therein increases the prevalence of lameness assessed by means of the Welfare Quality® protocol. As proposed by Scott *et al* (2007), removed or treated animals should be taken into account to have a better understanding of high prevalence of lameness on conventional farms.

Skin condition (localised and widespread skin discolouration)

Skin condition is an unspecific measure that can be the symptom of a variety of different diseases. Local effects, such as ear necrosis, systemic infection, such as PRRS, and environmental diseases, such as sunburn, are a few examples of diseases of the skin (Cameron 2006). Both types of skin condition were correlated moderately in the straw-bedded system and weakly in the conventional system; these correlations were not strong enough to create the need for them to be analysed as a sole measure. When comparing production systems, no significant differences could be detected, the between-farm variability was important and both types of skin condition presented over-dispersion. Skin condition is more likely to sporadically affect a farm, independently of the production system. The high variability between farms (and between paddocks) leads towards large confidence intervals that include unity, especially in extensive pigs for which few farms have been assessed. This high variability between farms may suggest that classifying farms by production system is less informative than individual management considerations.

Focusing on the conventional system, no possible causal factor could be detected for localised skin condition. As for widespread skin condition, it was highly dependent of one of the four observers implicated in the assessments, whether because of a low inter-observer reliability or because of an association between the observer and the farms affected by that type of problem. Having controlled for the observer effect, discolouration of the skin on more than 10% of the body was associated with pigs that finalised their growing period. However, a specific cause for the problem was not studied in the present work.

Scouring

Scouring was a welfare concern particularly in intensive Iberian pigs that presented a much higher prevalence of pens affected (54%) compared with pigs in the conventional system (9%). Pigs in straw bedding, extensive Mallorcan Black pigs and extensive Iberian pigs presented similar prevalences. It should be considered that more than 30% of the pens or paddocks assessed could not be evaluated in intensive Iberian pigs for feasibility reasons. Faeces can become liquid when mixed with urine in some conditions of humidity and can hide the evaluation of scouring, especially in dirty pens, affecting the feasibility and the validity of this measure in some production conditions. A wide range of factors are implicated in diarrhoea disorders (Thomson *et al* 1998; Pearce 1999). Still, the sole significant possible causal factor identified in the conventional and the straw-bedded systems was the age of the animals. Younger animals were associated with an increased risk of scouring. Changes in environments, whether in post-weaned piglet or pigs early in the growing stage, may cause a stress response which is known to be involved in the incidence and severity of enteric diseases (Pearce 1999). Among intensive Iberian pigs, no possible causal factors could be identified. All the important enteric pathogens in pigs rely on faeco-oral transmission for propagation, and the identification of factors linked to the environmental contamination should provide a more effective prediction of scouring problems.

Animal welfare implications and conclusion

In general, the health measures from Welfare Quality® protocol assessed in the present study differed to a limited extent between the five production systems. Similarly, the straw-bedded and the conventional systems did not differ in the prevalence of any animal-based measures from the 'good health' principle. Low prevalences, in addition to high between-farm or between-pen variabilities, may explain, in part, this homogeneity across systems. For some animal-based parameters, such as skin condition, the high variability between farms may suggest that classifying farms by production system may be less informative than individual management considerations. However, Mallorcan Black pigs and Iberian pigs kept extensively showed the lowest prevalence of tail biting and a lower prevalence of severely wounded animals than pigs in the conventional system. In addition, intensive Iberian pigs presented a higher prevalence of scouring compared to pigs in the conventional system. Several possible causal variables for severely wounded animals, tail biting and lameness were identified in the conventional system. The recording of simple environmental-based factors can be useful to detect farms that are more likely to show one of these health problems.

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