frontiers | Frontiers in Animal Science

TYPE Original Research
PUBLISHED 02 February 2023
DOI 10.3389/fanim.2023.1064933

OPEN ACCESS

EDITED BY
Genaro C. Miranda-de La Lama,
University of Zaragoza, Spain

REVIEWED BY
John Michael Gonzalez,
University of Georgia, United States
Flaviana Gottardo,
University of Padua, Italy

*CORRESPONDENCE
Marlyn H. Romero
marlyn.romero@ucaldas.edu.co

SPECIALTY SECTION
This article was submitted to Animal Welfare and Policy, a section of the journal Frontiers in Animal Science

RECEIVED 08 October 2022
ACCEPTED 10 January 2023
PUBLISHED 02 February 2023

CITATION
Hernandez RO, Romero MH and Sanchez JA (2023) Assessment of slaughterhouse-based measures as animal welfare indicators in fattening pigs. *Front. Anim. Sci.* 4:1064933.
doi: 10.3389/fanim.2023.1064933

Assessment of slaughterhouse-based measures as animal welfare indicators in fattening pigs

Rick Obrian Hernandez[1], Marlyn H. Romero[2*] and Jorge A. Sanchez[2]

[1]Cienvet Research Group, Faculty of Agrarian and Animal Sciences, University of Caldas, Manizales, Colombia, [2]Department of Animal Health, Faculty of Agrarian and Animal Sciences, University of Caldas, Manizales, Colombia

In recent years, there has been growing interest in the assessment of animal welfare in slaughterhouses. The aim of this study was to determine the effectiveness of slaughter-based measures as animal welfare indicators and evaluate the relationships between these indicators and the sociodemographic characteristics of livestock drivers and transport conditions for fattening pigs in a commercial slaughterhouse. A total of 1,161 heavy pigs (105.6 ± 14.15 kg), from 22 commercial farms, were evaluated. Pigs were assessed ante mortem, during lairaging, by evaluating the number, location, and color of skin lesions, tail length, and the presence or absence of biting lesions, lameness, cough, rectal or vaginal prolapse, and umbilical hernia. Pulmonary lesions, pleuritis, pericarditis, and liver lesions were also recorded postmortem. A descriptive analysis was performed on antemortem and postmortem indicators to estimate their prevalence, and the relationships among antemortem and postmortem indicators were analyzed using two multilevel mixed-effects models—a linear regression and a logistic regression analysis— with the farm of origin as a fixed effect. Cough was present in 18.9% (n = 219) of pigs, whereas the prevalence of tail biting lesions (4.6%, n = 53), rectal prolapse (0.1%, n = 11), and vaginal prolapse (0.1%, n = 11) was low. As regards lesion shape, linear lesions accounted for the majority of skin lesions (55.8%, n = 648), followed by comma-shaped (34.7%, n = 403), diffuse (6.9%, n = 80), and rectangular lesions (2.5%, n = 29). Only 25.2% (n = 512) of lesions were bright red. At postmortem, pulmonary lesions were noted in 34.2 ± 13.5 (mean ± SEM) pigs, and were more prevalent in the cranial (11.9 ± 4.9) and medium lobes (12.2 ± 5.2); the caudal (5.3 ± 2.7) and accessory lobes (1.6 ± 1.6) were less affected. The number of skin lesions was significantly associated with drivers' age, job experience (years), and marital status ($p \leq 0.001$). The presence or absence of tail lesions was strongly associated with the number of skin lesions, scoring of pulmonary lesions, and animal live weight ($p \leq 0.001$). Antemortem and postmortem indicators at slaughterhouses with low annual slaughter volumes can provide key information for disease monitoring and animal welfare.

KEYWORDS

swine welfare, meat inspection, skin lesions, fattening pigs, indicators

1 Introduction

Public perception and awareness of animal welfare in swine production systems have undergone a dramatic change in recent years (Estévez-Moreno et al., 2022; García Castro et al., 2022). Several factors have motivated meat-producing countries to develop animal welfare protocols in response to the different demands of the market, which have required them to incorporate or consider, for example: (a) components of quality and safety assurance programs (Edge and Barnett, 2009); (b) market differentiation (Stafford, 2014; de Luca et al., 2021); (c) consumers' informed decisions to choose and pay more for animal-sourced foods produced in accordance with good safety and welfare practices (Vargas-Bello-Pérez et al., 2017; Alonso et al., 2020); (d) the demands of social movements raising awareness about animal suffering (Nurse, 2016); and (e) sanitary requirements with a chain approach (Stafford, 2014). Governments, international organizations, non-governmental organizations (NGOs), and producers have developed animal welfare standards for different purposes according to their respective interests and needs, and their routine implementation can help participants in the pork supply chain to assess the effectiveness of management practices, identify associated risk factors, and achieve better production results (Fisher and Mellort, 2002).

Recently, there has been a increase in data collection at slaughterhouses to monitor animal welfare at the farm as well as during transport and subsequent stages; nevertheless, the impact of such data collection depends on the strategies used to communicate the results to producers, veterinarians, and health officials (Stärk et al., 2014; Alonso et al., 2020). The process of veterinary inspection at slaughterhouses was initially developed to evaluate meat fitness for human consumption and measure the progress of disease control in primary production systems (Harley et al., 2012; Ninios et al., 2014), but it is evolving, and it now also functions as a surveillance system that monitors multiple aspects of the health and welfare of animals (Ninios et al., 2014). The information collected routinely during this inspection can be useful in the evaluation of on-farm, pre-slaughter animal welfare and the monitoring of animal welfare strategies implemented by farmers (Grandin, 2017; vom Brocke et al., 2019), using reliable and valid animal-based indicators as reviewed in pigs (van Staaveren et al., 2017; Heinonen et al., 2021) and other species, such as cattle, by Losada-Espinoza et al. (Losada-Espinosa et al., 2021; Losada-Espinosa et al., 2021). The use of this monitory surveillance systems strategy is advantageous to animal welfare improvement efforts under commercial conditions, as it allows inspectors, during one inspection, to obtain information from several farms (Maisano et al., 2020), and, therefore, the reduction of routine on-farm and transport evaluation inspection costs. In addition, it helps to prevent the transmission of infectious diseases between different farms caused by biosecurity risk assessments conducted during pig farm animal welfare on-person evaluations (Dalmau, 2014).

Different European countries have adopted systems based on nationwide slaughterhouse inspections as a tool to monitor pig health and welfare (Stärk et al., 2014). For example, Denmark, Scandinavia, Northern Ireland, Great Britain, Scotland have established integrated monitoring systems that collect information on, for example, pigs' respiratory diseases, tail damage, peritonitis, pericarditis, and liver conditions (Sanchez-Vazquez et al., 2011; Nielsen et al., 2015). All these systems are available, and results are reported to swine producers and veterinary advisors for several purposes, such as addressing health problems that occur on farms; controlling respiratory diseases, monitoring and follow-up of vaccination plans; adjusting sanitary and animal welfare practices; and management tools to reduce problems that cause significant economic losses, such as tail biting and the occurrence of hematomas or body injuries (de Luca et al., 2021).

In Colombia, and in other Latin American countries, there has been an increase in societal awareness of animal welfare conditions, consolidated by research into, and legislation which promotes the improvement of, these conditions (Gallo et al., 2022), be they on the farm (with good farming practices), during transportation, or slaughter (Vargas-Bello-Pérez et al., 2017; Gallo and Tadich, 2018). Nevertheless, there is still a need to develop solutions which apply the results of animal welfare-based research commercial everyday conditions, allowing stakeholders to minimize costs while at the same time implementing animal welfare strategies. Furthermore, this study aimed to determine the effectiveness of slaughter-based measures as animal welfare indicators and evaluate the relationships between these indicators and the sociodemographic characteristics of livestock drivers and transport conditions for fattening pigs in a commercial slaughterhouse.

2 Materials and methods

The study was carried out in a commercial slaughterhouse in Colombia's Central Andean region, from August 2020 to October 2020. The animals were transported and slaughtered in compliance with national regulations for research and commercial slaughtering (Colombian Ministry of Health and Social Protection, 2007). The present study was approved by the Ethics Committee for Animal Experimentation of the University of Caldas (Activities with Minimal Risk) and the Human Ethics Committee (Act 15/06/2021). Drivers were fully debriefed about the purpose of the study, they read or listened the content of the consent form and signed an informed consent form, and gave us authorization to use their data.

2.1 Study description

The study was conducted in two stages: (1) an antemortem inspection was performed during unloading and lairage, and (2) a postmortem evaluation was conducted during the evisceration process and carcass inspection before refrigeration. Data were collected from 1,161 gilts and barrows (one batch per farm) from commercial lineages that were being transported directly from the farms (n = 22) (Caldas and Quindío Departments in Colombia) to the slaughterhouse. These farms are responsible for 6.0% and 1.6% of national pig production, respectively (Martinez et al., 2022). A large proportion of these farms in this region are certified in good farming practices (Martinez et al., 2022) and it has one of the largest pig slaughter operations in the country (Pastrana-Camacho et al., 2023). Pigs were transported in single-deck and double-deck trucks equipped with passive ventilation systems. The pigs were unloaded from the trucks by personnel contracted by the slaughterhouse. The trucks were equipped with an adjustable slope metal ramp with an anti-skid floor, and the pigs were kept with familiar groups during lairage (5 ± 2 h), and then put into lairage pens (4.3 m × 1.8 m) with *ad libitum* access to water through a nipple drinker. At the end of the lairage period, pigs were driven to an electrical stunner and restrained in a single animal box. Following stunning, pigs were vertically exsanguinated (5 ± 2 s) and carcasses were placed in a dehairing machine at 62°C for 5 minutes. The residual hair was removed using a knife and flame; carcasses were then eviscerated and split before being placed in a chiller set at 4°C for 24 h. The slaughterhouse had a system for identifying the pigs, whose individual number was assigned during weighing and maintained throughout the process. The assigned number was marked using a tattoo on the back of the live animals, as well as an elastic band located on the carcass to guarantee a match between the viscera and the carcass of each pig during antemortem (AM) and postmortem inspection.

Data collection was performed on 30 non-consecutive days between June 2020 and September 2020. A scheme based on visual inspection was used to assess specific lesions and conditions during both antemortem and postmortem evaluation. To control selection and information bias, the inclusion criterion was the origin of the pigs from fattening farms, which were certified in good animal husbandry practices. Pigs that were not followed with their corresponding postmortem evaluation and culling pigs were excluded from the study.

2.2 Demographic information about the livestock drivers

This investigation included 22 livestock drivers who transported fattening pigs to the slaughterhouse. In interviews, truckers were asked about their age, educational status (i.e., elementary, high school, community college, and university), animal transport training (y/n), years of experience, and knowledge of Colombian transportation (y/n) and animal welfare legislation (y/n), as well as their perception of the animals' capacity to feel pain and stress using two questions with responses measured a Likert-based scale that ranged from 1 to 5 (i.e., strongly disagree to strongly agree).

2.3 Farm and transport conditions

During unloading at the slaughterhouse, the following truck features were evaluated through direct observation by a trained veterinarian: type of bodywork (i.e., wood, metal, or mixed), number of decks (i.e., single or double), the presence of water sprinkling devices (y/n), and type of ventilation (active or passive). In addition, truck drivers were interviewed to determine the following characteristics: (a) farm name, (b) use of loading ramp (y/n), (c) transport time (h), (d) specialized transport (y/n), (e) stopovers (y/n), and (f) Type of roads is a separate category, type of roads (i.e., rural or highway).

2.4 Antemortem and postmortem inspection

During lairage, all pigs were individually identified by numbers painted on their sides and rump with washable spray used for animal marking, and weighed before slaughter. The identification assigned by the slaughterhouse during weighing was recorded to track the viscera and carcasses of the animals selected for the study. Pigs were evaluated antemortem during lairage by two trained veterinarians on weekdays from 3:00 a.m. to 5:00 p.m. All pigs had the same lairage time (5 ± 2 h) and were evaluated 3 h after unloading. Table 1 shows the description of the antemortem and postmortem indicators evaluated (Welfare Quality, 2009). The shape of the skin lesions was evaluated to establish their possible cause. Comma-shaped skin lesions, located in different areas and ranging in size from 2 to 5 cm, are characteristic of those produced by bites during antagonistic encounters between pigs (these encounters often occur during social regrouping). Linear skin contusions (long and thin), with sizes between 10 and 15 cm, located on the ham and shoulders of the animals, are caused by the hooves of the pigs during mounting rectangular and diffuse contusions may be related to the use of blunt objects during handling (Varón-Álvarez et al., 2014). The evaluation of tail length, tail injury, and lameness was performed according to the guidelines suggested by Valros (Valros et al., 2004).

Postmortem (PM) inspection was performed by a trained veterinarian in the eviscerating area evaluating the lung score according to Goodwin et al. (1969) (Goodwin et al., 1969), for *Mycoplasma hyopneumoniae* by quantification of the affected lung area by the mean of 0–10 points (cranial and medial lobes) or 0–5 points (caudal and accessory lobes). Points were then summed up to provide an overall compromised lung area score (i.e., 0–55 points) (see Table 1).

2.5 Statistical analysis

Data analyses were conducted using Stata® software, version 13.0 (StataCorp LP, College Station, TX, USA). In this study, the experimental units were individual pigs. A normality test of the evaluated variables was carried out. The variables with non-normal distribution were transformed by the means of a natural logarithm (i.e., weight, the lung score, and number of skin lesions), and these values were later used for regression analyses; results were transformed back to the original units of measures. Categorical variables regarding the driver (i.e., age, educational status, animal transport training, years of experience, level of education, transport training, and perception of animal welfare), the truck (i.e., type of bodywork, number of decks, water sprinkling devices, and type of ventilation) and transportation (i.e., use of loading ramp, transportation time, stopovers, and type of roads) were subjected to descriptive statistical analysis and presented as a proportion of answers means and, when applicable, the variability was expressed in ranges.

For the identification of the relationship between categorical antemortem (i.e., lameness, umbilical hernia, inguinal hernia, tail length, tail lesion, rectal prolapse, vaginal prolapse, cough, and weight) and postmortem (i.e., pleurisy, pericarditis, and liver lesions) variables, a chi-squared analysis was performed. A Spearman correlation matrix was done to preliminarily inspect the correlation among antemortem and postmortem variables. The Wilcoxon–Mann–Whitney U-test was used to measure the

TABLE 1 Description of antemortem and postmortem indicators evaluated in the present study.

Indicator	Description	Scale
Antemortem		
Skin lesions	One or more deep lesions measured on the side of a body	Number of lesions
Region affected by skin lesions	Area of the body affected by skin lesions	1, ears; 2, neck; 3, mid-section; 4, rump; and 5, legs
Skin lesions shape	Shape of the skin lesions	1, comma; 2, linear; 3, rectangular; and 4, diffuse
Color of skin lesions	Color: (1) bright red, and (2) dark red	1, 2
Lameness	(0) normal gait, (1) lame—minimum weight-bearing on affected limb; and (2) no weight-bearing on affected limb—inability to walk.	0–1–2
Umbilical/inguinal hernia	Presence of umbilical or inguinal hernia (y/n)	0–1
Tail length	Length of tail: (0) fully docked; (1) docked at mid-length; and (2) undocked.	0–1–2
Tail lesion	Presence of inflammation, infection, fresh blood in the tail—(0) healthy; (1) healed tail injury (healed); and (2) fresh tail biting wounds (fresh)	0–1–2
Rectal prolapse	When internal tissue extrudes from the rectum (y/n)	0–1
Vaginal prolapse	When vaginal tissue extrudes from the vulva (y/n)	0–1
Cough	Presence of cough in undisturbed animals that last more than five minutes (y/n).	0–1
Animal live weight	Weight in kilograms	kg
Postmortem		
Pulmonary Goodwin score	Level of pulmonary compromise using the Goodwin scale	0–55 points
Pleurisy	Presence of pleurisy (adherences)	0–1
Pericarditis	Presence of pericarditis (adherences)	0–1
Liver lesions	Presence of "milk spot" lesion indicative of *Ascaris* spp.	0–1

differences between the distribution of skin lesions according to body region (i.e., ears, neck, midsection, rump, and legs) and their color (i.e., bright or dark red). The Spearman correlation was used to measure the differences between the distribution of pulmonary lesions scores (cranial, middle, caudal, and accessory lobes). A multilevel, mixed-effects lineal regression model analysis was performed to identify variables associated with the number of skin lesions (dependent variables) with the sociodemographic characteristics of the truck drivers and transport conditions (independent variables), controlling for the effect of the farm of origin (fixed effect). A multilevel, mixed-effects logistic regression analysis was performed to identify variables associated with tail lesions as binary variables (i.e., absence or presence; dependent variables) with the antemortem and postmortem indicators (independent variables) to control the effect of farm of origin. The model included the live weight of animals as a covariate. The confounding effect was considered present when the estimates changed by at least 20%. The number of decks was evaluated as a confounding variable but was removed from the model because the principal variation source was the effect of the farm of origin. A probability level of $p < 0.05$ was chosen as the limit for statistical significance in all tests, and probability levels of $p \leq 0.10$ were considered as a tendency.

3 Results

3.1 Livestock drivers and transport conditions

All drivers (n = 22) were male with 46.4 (± 6.4 years) and an average of 6.5 (± 8.3 years) of experience transporting animals; all of them had high school studies and only 50% (n = 11) had specialized training in animal transportation. Only four drivers had knowledge of Colombian animal welfare law, and 12 drivers had knowledge about Colombian animal transportation law. All drivers strongly agreed that animals have the capacity to feel pain and can suffer from stress.

Regarding truck features, all trucks were metal and wooden structures, six trucks were double-decked, whereas the remaining 16 were single-deck trucks, and only six trucks had water sprinkling systems. The evaluated trucks used a passive ventilation system. All trucks were used exclusively for livestock transport and loading ramps were used at all farms. The average transportation time from farms to the slaughterhouse was 1.92 h (± 1.01 h), with a minimum time of 0.5 h and a maximum time of 4 h, and only seven drivers stopped during transportation for more than 10 min to take a break. The type of road was 31.8% rural, and 68.2% highway (Table 2).

3.2 Antemortem and postmortem indicators

Pigs presented with an average weight of 105.6 kg (± 14.1 kg), with an average of 10.5 (± 9.8) lesions on their bodies. These lesions were located mainly on the midsection (36.1%, *n* = 732), neck (27.9%, *n* = 566), and rump (21.7%, *n* = 440), followed by the ears (12.9%, *n* = 261) and legs (1.3%, *n* = 26). Most lesions presented a dark-red color (74.7%, *n* = 1,513); the remainder were bright red (25.2%, *n* = 512) ($p \leq 0.001$) (Figure 1). The most common skin lesion shape was linear (55.8%, *n* = 1,130), followed by comma-shaped (34.7%, *n* = 703), diffuse (7%, *n* = 140), and rectangular (2.6%, *n* = 52).

Only 0.9% (*n* = 11) of the pigs evaluated came from farms where tail docking was not practiced, whereas the remaining pigs had undergone caudectomy procedures (Table 3). Tail biting lesions were present in 4.7% (*n* = 55) of the pigs evaluated. Cough was present in 18.9% (*n* = 222) of the pigs evaluated, while vaginal prolapse 0% (*n* = 1), rectal prolapse 0.1% (*n* = 2), and lameness 1.3% (*n* = 16) were less prevalent (Table 3).

At PM evaluation, pigs presented an average of 34.2 (± 13.5) pulmonary lesions, and, according to the Goodwin scale, these were most prevalent on the medial and cranial lobes (12.2 ± 5.2 and 11.9 ± 4.9, respectively), followed by the caudal and accessory lobes (5.3 ± 2.6 and 1.6 ± 1.7, respectively) ($p \leq 0.001$). Pleurisy and pericarditis were present in only 9.9% (*n* = 115) and 2.7% (*n* = 32) of the evaluated pigs, respectively, whereas lung abscesses and liver lesions were present and the presence of lung abscesses and liver lesions was negligible (0.3%, *n* = 4, and 0%, *n* = 1, respectively) (Figure 2).

3.3 Relationship between indicators

The multilevel, mixed-effects lineal regression analysis identified that the number of skin lesions observed during lairage was related to the driver's age, marital status, and job experience ($p \leq 0.001$) (Table 4). In this analysis, transport conditions were not related to the number of skin lesions. The tail lesions (i.e., presence or absence) were significantly associated with the number of skin lesions, the scoring of pulmonary lesions, and animal live weight ($p \leq 0.001$) (Table 5). However, the residual analysis of the two models indicated that the variability was significant, indicating the existence of characteristics related to the farms of origin, transport conditions, driver characteristics, and animal welfare indicators identified in the antemortem and postmortem inspection, which were not taken into account in these analyses and could explain, at least in part, the variations in the number of skin and tail lesions.

4 Discussion

Veterinary inspection during pig slaughter is a method used to ensure meat safety for human consumption (Buncic et al., 2019). Recently, however, it has also been recognized as a system to evaluate more aspects of animal health and welfare conditions (Ninios et al., 2014). Disease is an important welfare indicator because it is associated with pain, discomfort, and distress; however, the

TABLE 2 Percentage of responses characterizing sociodemographic variables of the driver (i.e., marital status, training in animal transport, level of education, knowledge of Colombian animal welfare law, and animal transportation law), truck (i.e., type of bodywork, number of decks, water sprinkling device, ventilation system, and use of loading ramp), and transportation (i.e., stopovers, and type of roads), as estimated by descriptive statistics.

Driver	*n*	%	Truck	*n*	%	Transportation	*n*	%
Marital status			Type of bodywork			Stopovers		
Single	7	31.8%	Wood	0	0%	0	15	68.2%
Married	7	31.8%	Metal and wood	22	100%	1	5	22.7%
Common-law partners	8	36.4%	Number of decks			2	2	9.1%
Formal training in animal transport			Single deck	16	72.7%	Type of roads		
Yes	11	50%	Double deck	6	27.3%	Rural	7	31.8%
No	11	50%	Water sprinkling device			Highway	15	68.2%
Level of education			Yes	6	72.7%			
Elementary school	0	0%	No	16	27.3%			
High school	22	100%						
Do you know the Colombian animal welfare law?			Ventilation system					
Yes	4	18.2%	Active	0	0%			
No	18	81.8%	Passive	22	100%			
Do you know the Colombian animal transportation law?			Use of loading ramp					
Yes	12	54.5%	Yes	22	100%			
No	10	45.5%	No	0	0%			

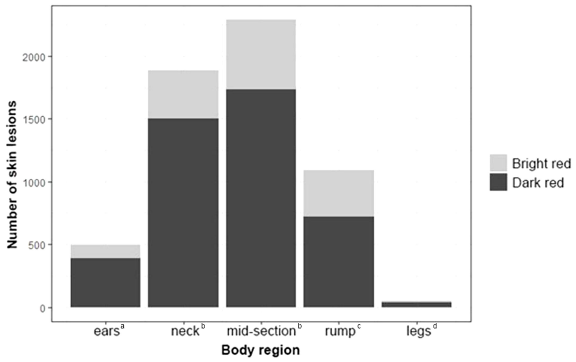

FIGURE 1
Distribution of skin lesions according to the body region and color in fattening pigs in a Colombian slaughterhouse. [a,b,c,d]Different lower-case superscripts indicate statistically significant differences ($p \leq 0.001$). The differences were obtained by the Wilcoxon–Mann–Whitney U-test.

separation and individual clinical evaluation of pigs on farms is sometimes complex because it demands time and careful management of the affected animals (Dalmau, 2014). Sanitary inspection in slaughterhouses allows for the monitoring of the development of major diseases over time, the results of efforts to the monitoring of the development of major diseases over time, as well as the evaluation of efforts to contain them; and facilitates compliance with animal welfare standards during prelsuaghter (Guardone et al., 2020), and the detection of subclinical diseases that are not easily diagnosed in live animals (Scollo et al., 2017).

4.1 Livestock drivers and transport conditions of pigs

The characteristics of livestock drivers in this study, namely sex (n = 22), age (46.4 ± 6.4 years), and education were similar to those in other

TABLE 3 Percentage of responses characterizing antemortem (i.e., tail length, tail lesion, cough, umbilical hernia, rectal prolapse, lameness, and vaginal prolapse), and postmortem (i.e., pleuritis, lung abscess, pericarditis, and liver lesions) indicators of fattening pig's animal welfare, as estimated by descriptive statistics, in a Colombian slaughterhouse (n = 1,161 pigs).

Indicators	*n*	%	Indicators	*n*	%
Tail length			Skin area affected		
0	11	0.9%	Ears	750	12.9%
1	945	81.4%	Neck	1,621	27.9%
2	205	17.6%	Mid-section	2,098	36.1%
Tail lesion			Rump	1,267	21.7%
0	1,106	95.3%	Legs	76	1.3%
1	53	4.5%	Skin lesions shape		
2	2	0.2%	Comma	2,016	34.7%
Cough			Linear	3,237	55.7%
No	939	81%	Rectangular	151	2.6%
Yes	222	18.9%	Diffuse	406	7%
Umbilical hernia			Pleuritis		
No	1,158	99.9%	No	1,046	90.1%
Yes	2	0.1%	Yes	115	9.9%
Rectal prolapse			Lung abscess		
No	1,159	99.9%	No	1,157	99.7%
Yes	2	0.1%	Yes	4	0.3%
Lameness			Pericarditis		
No	1,145	98.7%	No	1,128	97.3%
Yes	16	1.3%	Yes	33	2.7%
Vaginal prolapse			Liver lesion (milk spot)		
No	1,161	100%	No	1,161	100%
Yes	0	0%	Yes	0	0%

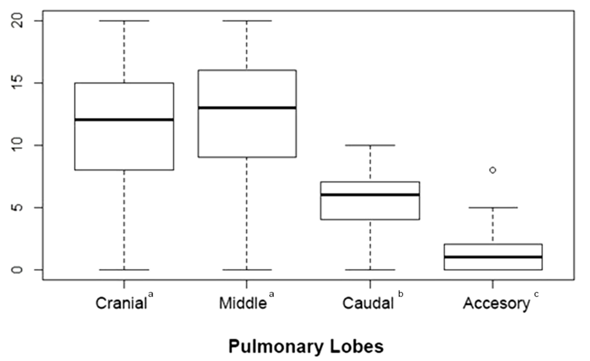

FIGURE 2
Distribution of pulmonary lesions scores in fattening pigs in a Colombian slaughterhouse according to the Goodwin scale (n = 1,161). [a,b,c]Different lower-case superscripts indicate statistically significant differences ($p \leq 0.001$). The differences were obtained by the Spearman correlation.

studies conducted under commercial conditions in Mexico (Valadez-Noriega et al., 2018) and Colombia (Romero et al., 2022). The formal training and instruction of drivers in animal transportation at Latin America is not yet a common practice (Romero and Sánchez JA, 2011), usually, the drivers are hired as multipurpose drivers, with responsibilities other than the transportation of animals only 50% (n = 11) of drivers were trained in animal transportation and only 18% (n = 4) stated that they had knowledge of Colombian animal welfare-specific regulations. This lack of training has also been observed in drivers responsible for the commercial transportation of other species in Colombia, such as cattle (Romero and Sánchez JA, 2011). This effect responds to multifactorial conditions such as jobs in the animal transportation sector not being specialized and exclusive, that is, usually, the drivers are hired as multipurpose drivers (Romero et al., 2018), and animal welfare policies and regulations are being implemented more slowly in developing countries than in developed ones (Gallo and Tadich, 2018). This same issue affects the trucks used for animal transportation, where the use of trucks is regularly non-exclusive.

In this study, 72.7% of trucks were single-decker, with metal and wood bodywork. However, other studies in Colombia have found that there is more heterogeneity among trucks (Romero et al., 2018). Nevertheless, besides confirming, in line with previous research, that transportation is a known stressor for pigs that affects their welfare and behavior (Schwartzkopf-Genswein et al., 2012), our results did not show that truck type had a significant impact on the prevalence of animal welfare indicators. However, the lack of evidence pertaining to this effect may be owing to the short transportation times (1.92 ± 1.01 h) observed in this study.

4.2 Prevalence of antemortem and postmortem indicators

Tail biting is considered an indicator of reduced welfare and production performance in pigs, and it is associated with condemnations in ham (Sinisalo et al., 2012). In this study, we found a prevalence of biting lesions of 4.7% (n = 55). This prevalence is high compared with other reports from studies performed in Colombia (0.7%) during on-farm evaluations (Martinez et al., 2022). Likewise, the prevalence found was lower than that reported in Portugal (Franco et al., 2021). The discordant results could be explained by differences in the farm of origin (Horst et al., 2019); tail-docking techniques (Martinez et al., 2022); the presence or absence of caudectomy (vom Brocke et al., 2019; Heinonen et al., 2021); placement on the slaughter line when assessments are conducted (before or after scalding and dehairing) (Carroll et al., 2016); tail length and healing scores (Gomes et al., 2022); and swine system managements, the last of which is dependent on the region (Martinez et al., 2022). Tail docking is prohibited by the European Union (de Briyne et al., 2018), but is legal under Colombian law, which stipulates that the procedure must be performed with anesthesia and analgesia by trained personnel under the supervision of veterinarians (Colombian Agricultural and Rural Development Ministry, 2020). Nevertheless, although the practice is still

TABLE 4 Results from a multilevel mixed-effects linear regression model of the relationship between the number of skin lesions and sociodemographic characteristics in fattening pigs in a Colombian slaughterhouse.

Variable	Number of skin lesions		
	β	SE	*p*-value
Drivers' age	**0.31**	**0.07**	< 0.001
Marital status	**–0.27**	**0.01**	< 0.001
Experience in the job	**0.01**	**0.003**	< 0.001

TABLE 5 Results from a multilevel mixed-effects logistic regression model of the relationship between presence/absence of tail lesions and antemortem and postmortem indicators of animal welfare in fattening pigs in a Colombian slaughterhouse.

Variable	Presence/absence of tail lesions		
	β	SE	*p*-value
Number of skin lesions	**0.05**	**0.01**	< 0.001
Scoring of pulmonary lesions	**–0.27**	**0.01**	0.04
Animal live weight (kg)	**–1.33**	**0.04**	< 0.001

controversial (Harley et al., 2012), it is reported that tail docking diminishes tail-directed behaviors on-farm (Thodberg et al., 2018) and since tail lesions are associated with on-farm health-related indicators (Franco et al., 2021), examining tail biting lesions during inspections could improve the efficacy of risk-based meat inspection programs and help farmers provide up-to-date feedback regarding on-farm animal welfare interventions that they have implemented. This was implemented in Germany with the use of a control program called Scchwanzbeiβ-INTERVENTIONS-Program (meaning 'tail biting intervention program'), which includes the monitoring of health and animal welfare indicators in slaughterhouses. The program has resulted in a decrease in tail biting in fattening pig farms (vom Brocke et al., 2019) and increased adherence to animal welfare plans by producers (Uehleke et al., 2021). In future studies, we suggest evaluating tail lesions during postmortem inspection, as they are more visible on the carcass (van Staaveren et al., 2017); likewise, a combination of lesion scoring and tail length measurement is required, especially when animals have intact tails (Valros et al., 2020).

Respiratory disease management represents one of the most challenging problems in the swine industry, because of the multifactorial etiology associated with respiratory diseases such as housing conditions on the farm, population density, and biosecurity (Ciuoderis-Aponte et al., 2022). Therefore, it is expected that pigs reared under commercial conditions have a high probability of developing respiratory compromise before slaughter (Rampelotto et al., 2022). These diseases affect pig growth and feed conversion, increase mortality and condemnation during slaughter, affect meat quality (Permentier et al., 2015) and, because of their high treatment costs, reduce overall profits (Cornelison et al., 2018). Respiratory diseases also represent a risk factor for the presence of non-ambulatory and dead-on-arrival pigs after transport (Romero et al., 2015). For instance, cough is an indicator of pulmonary disease used in clinical trials and on-farm observations (Nathues et al., 2012). The association between a cough and respiratory disease has been found to predict the prevalence and severity of pneumonia in pigs (Pessoa et al., 2021; Silva et al., 2022). In the present study, 18.9% of pigs presented coughing events during antemortem inspection, and a significant association with pulmonary compromise, manifesting mainly on the cranial lobes, and as pericarditis and pleuritic, was found PM. Pulmonary lesions in pigs are indicative of the presence of infectious agents of porcine respiratory disease complex, such as *M. hyopneumoniae, Bordetella bronchiseptica*, and *Actinobacillus pleuropneumoniae*, as well as porcine reproductive and respiratory syndrome virus (PRRSV), and the swine influenza virus all of which are transmitted thorugh close contact among pigs (Brockmeier et al., 2002). Although little research has been conducted into other transmission methods besides close contact among pigs, it is reported that these agents can spread *via* airborne through biosecurity hazards such as infected animals and contaminated vehicles or people (Dee et al., 2009; Maes et al., 2018). Therefore, coughing can be an indicator both of animal health and the management efficiency of farms, particularly as it relates to animal transport (Baraldi et al., 2019). However, despite these benefits, cough measurement is time-consuming, and this is an aspect that diminishes its utility in commercial scenarios. For this reason, the number of studies evaluating the ability of new technologies and computational devices to record measurements of coughing in pigs is increasing (Pessoa et al., 2021), showing that producers have new alternatives which can enhance the utility of their monitoring surveillance systems for animal welfare. The evaluation of cough during transport and lairage at the slaughterhouse could be strategic, as it would allow inspectors to determine the prevalence of respiratory diseases from several farms at once, in turn diminishing costs and providing feedback to the farmers, which could in turn enable them to develop strategies to improve on-farm health conditions and reduce the prevalence of non-ambulatory pigs after transportation (Kongsted and Sørensen, 2017).

Liver lesions, such as those produced by *Ascaris* spp., and lung abscesses had a low prevalence, meaning that some sanitary practices were effective. In this study, no liver lesions caused by migrating *Ascaris* spp. were observed. In contrast, a retrospective observational study carried out in Italy, which evaluated the records of animals postmortem inspection, found that the first cause of partial seizure was "liver milk spot" (91.79% of seizures), which suggests a lack or inadequacy of parasite control plans in farms, which is likely due to the low commercial value of liver in Italy (Guardone et al., 2020) (an issue that does not exist in Colombia, where the consumption of viscera is a common practice). Likewise, other indicators such as vaginal prolapse, rectal prolapse, and lameness were less prevalent, and these results could be explained by the joint effort made by the health authorities and the swine producers' association in the implementation and certification of good farming practices and animal welfare programs (Martinez et al., 2022). Similarly, Australia has a pig health monitoring scheme in which producers participate, which includes training in on-farm antemortem inspection. In this context, a study was conducted to evaluate the effectiveness of antemortem inspection of pigs by producers, which showed that they were more competent than slaughterhouse inspectors in identifying diseased pigs and in detecting lesions affecting the pigs' fitness for transport, considering that they knew the health history of the animals and performed the observation of pigs prior to the pigs being transported, and being subject to any additional illness or disease that could take place en-route (Jackowiak et al., 2006). These results are interesting and demonstrate that joint work between innovative producers and health authorities is effective in improving the epidemiological surveillance of animal health and welfare problems. However, they are limited to technology driven production systems with good risk management.

Skin lesions are used as indicators of health, animal welfare and aggression in pigs (Driessen et al., 2020a). In this study, skin lesions inspected AM were found mainly on the midsection and were mostly linear or comma shaped; these lesions are produced by agonistic behaviors such as mounting or fights (Teixeira and Boyle, 2014; Liu et al., 2022). Mounting behavior is a normal sexual display in pigs; nevertheless, it is undesired on commercial farms, where pigs are heavy, and because of the pressure applied by the sternum during this activity, mounting can cause lameness and the formation of carcass lesions on the midsections of pigs. On the other hand, the lesions on the head, neck, and front section of the body were the second most prevalent and they are more representative of reciprocal fighting due to agonistic interactions on-farm, during transport, or lairage. (Driessen et al., 2020b) evaluated 4,507 pig carcasses in a Belgian slaughterhouse and suggested that the most prevalent skin lesions were related to social mixing on the farms. All those interactions have been proven to happen more often in farms with low enriched environments or pens with only males or a higher male-to-female ratios (Teixeira and Boyle, 2014). In this study, there were no on-farm records, so it is not possible to assert that there was an increase in these behaviors, but other authors have reported that a high incidence of these behaviors in groups of male pigs is associated with higher skin lesion scores both prior to and post slaughter (Teixeira and Boyle, 2014).

The color of the lesions in this study were predominantly dark red (74.7%, n = 566) which suggests that the wounds were inflicted on the farm or during transportation. A recent on-farm study evaluated the skin lesions of 532 pigs at 7, 9, and 10 weeks of age (early life), and at 15 and 20 weeks of age (later life). The evaluated pigs were followed up post slaughter to determine if lesions that had been acquired during different stages of production remained visible on the carcass (Carroll et al., 2018). This study found that lesions that occurred 11 weeks prior to slaughter remained visible on the carcass in the form of healed (non-red) skin lesions. These findings suggest that carcass-based assessments of these types of lesions reflect lifetime animal welfare status (when pigs are slaughtered at a standard commercial age), rather than simply reflecting welfare in the period prior to immediate slaughter. However, if the objective is to assess these injuries to reflect levels of on-farm aggression, a comprehensive and robust scoring system is required (Driessen et al., 2020b).

4.3 Relationship between indicators

In the analysis of the relationships between skin lesions with the indicators evaluated during transport, and the sociodemographic characteristics of the drivers, as well as tail lesions with the welfare indicators in the antemortem and postmortem inspection, the effect of the farm was included using multilevel analysis. As the prevalence observed can differ depending on the type of production systems, geographical location, number of pigs, management conditions, the health status of the herd, shipping and unloading conditions, and sanitary programs, among others (Horst et al., 2019). The two selected models showed significant variability in the analysis of residuals, indicating that other variables not evaluated in the study could explain the variation in the number of skin lesions and the presence of tail lesions. Other authors have also used multivariate statistical analysis to control for the effect of the farm of origin because, as in our case, no measurements were made at this level (Scollo et al., 2017). Likewise, pig weight was included as a covariate in the multilevel, mixed-effects, logistic regression analysis.

Studies that have evaluated human–animal interaction during the preslaughter of cattle and swine have shown that it is a multifaceted work activity and that workers who are in direct contact with the animals modify the animals' responses to the preslaughter procedures, and that this affects workers' productivity, job performance, and personal satisfaction, as well as product quality (Pastrana-Camacho et al., 2023). Skin lesions were associated with truck driver characteristics such as age, marital status, and job experience. The drivers evaluated generally had little training in animal welfare and a general lack of knowledge of the regulations related to animal transport, an aspect that could have influenced the results of the present study, taking into account that the level of knowledge about pig behavior and the driving skills of the driver directly influences animal welfare (Fitzgerald et al., 2009). Many factors have been associated with the effect of driver characteristics on animal welfare in preslaughter: these include their attitude and empathy (Leon et al., 2020), years of experience as a truck driver (Valadez-Noriega et al., 2018), driving style, education and training (Rioja-Lang et al., 2019), work pressure, and interpersonal relations background (Hemsworth PH, 2011). These characteristics of the drivers have been identified as risk factors that increased the probability of finding higher total transport losses (dead pigs and non-ambulatory pigs) (Romero et al., 2022) and with the prevalence of skin lesions in Colombia (Varón-Álvarez et al., 2014). Other studies in Colombia outlined four profiles of workers in swine preslaughter: the first was composed of workers who relate to the animals and their work in a mechanical way, the second by professional workers who were emotionally close to the animals, the third by those who were committed to the animals and their work, and the fourth was composed of workers who were apathetic toward both the animals and the work activity (Pastrana-Camacho et al., 2023). Similar results have been reported in sheep transporters in Mexico (Pulido et al., 2018). These profiles provide a basis for designing training and mitigation strategies to address animal handling and welfare problems, a strategy which could be particularly useful to Colombia and other Latin American countries, where animal welfare sanitary legislation is in the process of being updated and implemented (Martinez et al., 2022).

Tail biting is considered a harmful behavior in pigs, which has been correlated with the prevalence of herd health problems, particularly respiratory, enteric, and locomotor diseases (Boyle et al., 2022). In this study, tail lesions were associated with the scoring of pulmonary lesions and skin lesions. However, it is important to note that, while tail lesion records in slaughterhouses provide a large database, their usefulness is restricted because the environmental and animal husbandry factors associated with biting behavior are unknown. This information would only be possible to obtain through the development of prospective on-farm studies (Carroll et al., 2018), or the systematic analysis of records from highly technologized farms (Taylor et al., 2010). Several authors have outlined the pathogenesis of tail lesions, providing a detailed description of the nature of the lesions and routes of infection, in turn indicating that, in addition to physical damage to the tail and hindquarters of the bitten pig, a local infection can spread systemically, leading to the presence of abscesses, especially in the lungs (Schrøder-Petersen and Simonsen, 2001; Harley et al., 2012).

Regarding the relationship between tail lesions and skin lesions found in this study, other authors have described the same results, as in the case of the study conducted by (van Staaveren et al., 2017), who visited 31 Irish farms at different stages of production and evaluated tail lesions, lameness, bursitis, body condition, and skin lesions. These same indicators were assessed during postmortem inspection and the authors concluded that tail lesions and skin lesions may be possible iceberg indicators of animal welfare on farms. Similarly, other authors have suggested that these damaging behaviors can occur simultaneously on farms and that their interpretation is associated with animal welfare problems (Carroll et al., 2018). Further longitudinal studies are required to assess skin and tail lesions at farms, transport, and lairage to establish the most accurate measurement scales and to control for measurement biases.

5 Conclusions

Swine health schemes based on antemortem and postmortem inspections at slaughterhouses provide valuable information for disease monitoring at the national level and have the potential to be a useful surveillance tool for emerging and zoonotic diseases. Additionally, they provide relevant information to provide feedback for on-farm animal welfare programs. In this study, the number of skin lesions was significantly associated with the age, experience, and marital status of the drivers. Likewise, tail lesions were associated with the number of skin lesions, the scoring of pulmonary lesions, and the weight of the pigs. Although the data presented in this study correspond to the prevalence of skin lesions found in slaughterhouses with low slaughter averages (5,194,315 pigs were slaughtered in Colombia in 2021), compared with other publications in Denmark, Italy, Great Britain, and Brazil, this information is useful because it allows for the understanding of disease monitoring from the perspective of smallholders, who do not have the resources to implement an individual surveillance system for their pigs. These data can also help in the analysis of findings related to production lines with different workloads and speeds, and low annual slaughter volumes. As the assessment of skin and tail lesions can vary across inspectors and producers, which in turn affects its usefulness as an indicator of animal welfare in slaughterhouses, further studies are needed to determine the appropriate scoring method to assess them. Effective communication between researchers and producers is vital at all stages of the dissemination of scientific findings, as well as for the acceptance and successful adoption of innovations or techniques by producers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The animal study was reviewed and approved by approved by the Ethics Committee for Animal Experimentation of the University of Caldas (-Activities with minimal risk-).

Author contributions

RH, MR, and JS assisted with the conception and design of the experiment, and the preparation of the figures and manuscript. RH prepared the data for analysis and analyzed data. MR, RH, and JS contributed to the interpretation of the results. RH, MR, and JS drafted and edited the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This work was funded by the Vice rectory of research and graduate studies of Caldas University -Research in the classroom program

Acknowledgments

The authors thank the University of Caldas animal welfare and public health undergraduate research groups for their support in data collection, as well as the slaughterhouse workers and management staff for their support.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Alonso, M. E., González-Montaña, J. R., and Lomillos, J. M. (2020). Consumers' concerns and perceptions of farm animal welfare. *Animals* 10, 1–13. doi: 10.3390/ani10030385

Baraldi, T. G., Cruz, N. R. N., Pereira, D. A., Galdeano, J. V. B., Gatto, I. R. H., Silva, A. F. D., et al. (2019). Antibodies against actinobacillus pleuropneumoniae, mycoplasma hyopneumoniae and influenza virus and their relationships with risk factors, clinical signs and lung lesions in pig farms with one-site production systems in Brazil. *Prev. Vet. Med.* 171, 104748. doi: 10.1016/j.prevetmed.2019.104748

Boyle, L. A., Edwards, S. A., Bolhuis, J. E., Pol, F., Šemrov, M. Z., Schütze, S., et al. (2022). The evidence for a causal link between disease and damaging behavior in pigs. *Front. Vet. Sci.* 8. doi: 10.3389/fvets.2021.771682

Brockmeier, S., Halbur, P., and Thacker, E. (2002). ""Porcine respiratory disease complex.,"," in *Polymicrobial diseases* (Washington DC: ASM Press).

Buncic, S., Alban, L., and Blagojevic, B. (2019). From traditional meat inspection to development of meat safety assurance programs in pig abattoirs – the European situation. *Food Control* 106, 106705. doi: 10.1016/j.foodcont.2019.06.031

Carroll, G. A., Boyle, L. A., Hanlon, A., Collins, L., Griffin, K., Friel, M., et al. (2018). What can carcass-based assessments tell us about the lifetime welfare status of pigs? *Livest Sci.* 214, 98–105. doi: 10.1016/j.livsci.2018.04.020

Carroll, G. A., Boyle, L. A., Teixeira, D. L., van Staaveren, N., Hanlon, A., and O'Connell, N. E. (2016). Effects of scalding and dehairing of pig carcasses at abattoirs on the visibility of welfare-related lesions. *Animal* 10, 460–467. doi: 10.1017/S1751731115002037

Ciuoderis-Aponte, K., Diaz, A., Muskus, C., Peña, M., Hernandez-ortiz, J., and Osorio, J. (2022). Farm biosecurity and influenza a virus detection in swine farms: A comprehensive study in Colombia. *Porc. Health Manag.* 8, 42. doi: 10.1186/s40813-022-00287-6

*Colombian Ministry of health and social protection. (*2007*). Decree 1500.* Available at: https://corponarino.gov.co/expedientes/juridica/2007decreto1500.pdf.

*Colombian Agricultural and rural development ministry. (*2020*). Regulation 136.* Available at: https://www.minagricultura.gov.co/Normatividad/Proyectos%20Normativos/Manual%20de%20Condiciones%20de%20Bienestar%20Animal,%20especie%20bovina,%20bufalina,%20aves%20de%20corral%20y%20animales%20acu%C3%A1ticos.pdf.

Cornelison, A. S., Karriker, L. A., Williams, N. H., Haberl, B. J., Stalder, K. J., Schulz, L. L., et al. (2018). Impact of health challenges on pig growth performance, carcass characteristics, and net returns under commercial conditions. *Transl. Anim. Sci.* 2, 50–61. doi: 10.1093/tas/txx005

Dalmau, A. (2014). Health and welfare management of pigs based on slaughter line records. *J. Dairy Veterinary Anim. Res.* 1 (3), 73–78. doi: 10.15406/jdvar.2014.01.00016

de Briyne, N., Berg, C., Blaha, T., Palzer, A., and Temple, D. (2018). Phasing out pig tail docking in the EU - present state, challenges and possibilities. *Porcine Health Manag* 4, 27. doi: 10.1186/s40813-018-0103-8

de Luca, S., Zanardi, E., Alborali, G. L., Ianieri, A., and Ghidini, S. (2021). Abattoir-based measures to assess swine welfare: Analysis of the methods adopted in European slaughterhouses. *Animals* 11, 226. doi: 10.3390/ani11010226

Dee, S., Otake, S., Oliveira, S., and Deen, J. (2009). Evidence of long distance airborne transport of porcine reproductive and respiratory syndrome virus and *Mycoplasma hyopneumoniae*. *Vet. Res.* 40, 39. doi: 10.1051/vetres/2009022

Driessen, B., van Beirendonck, S., and Buyse, J. (2020a). The impact of grouping on skin lesions and meat quality of pig carcasses. *Animals* 10, 544. doi: 10.3390/ani10040544

Driessen, B., van Beirendonck, S., and Buyse, J. (2020b). Effects of transport and lairage on the skin damage of pig carcasses. *Animals* 10, 1–15. doi: 10.3390/ani10040575

Edge, M. K., and Barnett, J. L. (2009). Development of animal welfare standards for the livestock transport industry: process, challenges, and implementation. *J. Veterinary Behavior: Clin. Appl. Res.* 4, 187–192. doi: 10.1016/j.jveb.2009.07.001

Estévez-Moreno, L. X., Miranda-de la Lama, G. C., and Miguel-Pacheco, G. G. (2022). Consumer attitudes towards farm animal welfare in Argentina, Chile, Colombia, Ecuador, Peru and Bolivia: A segmentation-based study. *Meat Sci.* 187, 108747. doi: 10.1016/j.meatsci.2022.108747

Fisher, M. W., and Mellort, D. J. (2002). The welfare implications of shepherding during lambing in extensive new Zealand farming systems. *New Z. farming Syst. Anim. welfare* 11, 157–170.

Fitzgerald, R. F., Stalder, K. J., Matthews, J. O., and Schultz Kaster CM, J. K. (2009). Factors associated with fatigued, injured and dead pig frequency during transport and lairage at a commercial abattoir. *J. Anim. Sci.* 87, 1156–1166. doi: 10.2527/jas.2008-1270

Franco, R., Gonçalves, S., Cardoso, M. F., and Gomes-Neves, E. (2021). Tail-docking and tail biting in pigs: Findings at the slaughterhouse in Portugal. *Livest Sci.* 254, 104756. doi: 10.1016/j.livsci.2021.104756

Gallo, C. S., and Tadich, T. G. (2018). "Perspective from Latin America," in *Advances in agricultural animal welfare* (Elsevier), 197–218. doi: 10.1016/B978-0-08-101215-4.00011-0

Gallo, C., Véjar, L., Galindo, F., Huertas, S. M., and Tadich, T. (2022). Animal welfare in Latin America: Trends and characteristics of scientific publications. *Front. Vet. Sci.* 9. doi: 10.3389/fvets.2022.1030454

García Castro, F. E., Medrano-Galarza, C., Cubides-Cárdenas, J. A., Zúñiga López, A., and Ahumada-Beltrán, D. G. (2022). Consumers perceptions about the welfare of farm animals in Colombia. *Agronomía Mesoamericana* 34 (1), 50817. doi: 10.15517/am.v34i1.50817

Gomes, A., Romeo, C., Ghidini, S., and Vieira-Pinto, M. (2022). The relationship between carcass condemnations and tail lesion in swine considering different production systems and tail lengths. *Animals* 12, 949. doi: 10.3390/ani12080949

Goodwin, R., Hodgson, R., Whittlestone, P., and Whoodhams, R. (1969). Some experiments relating to artificial immunity in enzootic pneumonia of pigs. *J. Hyg* 67, 465–476.

Grandin, T. (2017). On-farm conditions that compromise animal welfare that can be monitored at the slaughter plant. *Meat Sci.* 132, 52–58. doi: 10.1016/j.meatsci.2017.05.004

Guardone, L., Vitali, A., Fratini, F., Pardini, S., Cenci Goga, B. T., Nucera, D., et al. (2020). A retrospective study after 10 years (2010–2019) of meat inspection activity in a domestic swine abattoir in Tuscany: The slaughterhouse as an epidemiological observatory. *Animals* 10, 1907. doi: 10.3390/ani10101907

Harley, S., More, S., Boyle, L., Connell, N. O., and Hanlon, A. (2012). Good animal welfare makes economic sense: potential of pig abattoir meat inspection as a welfare surveillance tool. *Ir Vet. J.* 65, 11. doi: 10.1186/2046-0481-65-11

Harley, S., More, S. J., O'Connell, N. E., Hanlon, A., Teixeira, D., and Boyle, L. (2012). Evaluating the prevalence of tail biting and carcase condemnations in slaughter pigs in the republic and northern Ireland, and the potential of abattoir meat inspection as a welfare surveillance tool. *Veterinary Rec.* 171, 621–621. doi: 10.1136/vr.100986

Heinonen, M., Välimäki, E., Laakkonen, A.-M., Toppari, I., Vugts, J., Fàbrega, E., et al. (2021). Evaluation of tail lesions of finishing pigs at the slaughterhouse: Associations with herd-level observations. *Front. Vet. Sci.* 8. doi: 10.3389/fvets.2021.650590

Hemsworth PH, C. G. (2011). Human-livestock interactions: The stockperson and the productivity and welfare of intensively farmed animals. *2nd Ed. CABI*.

Horst, A., Gertz, M., and Krieter, J. (2019). Challenges and opportunities of using meat inspection data to improve pig health traits by breeding: A review. *Livest Sci.* 221, 155–162. doi: 10.1016/j.livsci.2019.02.001

Jackowiak, J., Kiermeier, A., Kolega, V., Missen, G., Reiser, D., and Pointon, A. (2006). Assessment of producer conducted antemortem inspection of market pigs in Australia. *Aust. Vet. J.* 84, 195–201. doi: 10.1111/j.1751-0813.2006.tb12798.x

Kongsted, H., and Sørensen, J. T. (2017). Lesions found at routine meat inspection on finishing pigs are associated with production system. *Veterinary J.* 223, 21–26. doi: 10.1016/j.tvjl.2017.04.016

Leon, A. F., Sanchez, J. A., and Romero, M. H. (2020). Association between attitude and empathy with the quality of human-livestock interactions. *Animals* 10, 1–17. doi: 10.3390/ani10081304

Liu, M., Xu, Q., Zhao, J., Guo, Y., Zhang, C., Cheng, M., et al. (2022). Pigs' skin lesions at weaning are primarily caused by standoff and being bullied instead of unilateral active attack at the individual level. *Appl. Anim. Behav. Sci.* 247, 105556. doi: 10.1016/j.applanim.2022.105556

Losada-Espinosa, N., Estévez-Moreno, L. X., Bautista-Fernández, M., Galindo, F., Salem, A. Z. M., and Miranda-de la Lama, G. C. (2021). Cattle welfare assessment at the slaughterhouse level: Integrated risk profiles based on the animal's origin, pre-slaughter logistics, and iceberg indicators. *Prev. Vet. Med.* 197, 105513. doi: 10.1016/j.prevetmed.2021.105513

Losada-Espinosa, N., Estévez-Moreno, L., Bautista-Fernández, M., Losada, H., María, G., and Miranda-de la Lama, G. (2021). Integrative surveillance of cattle welfare at the abattoir level: Risk factors associated with liver condemnation, severe hoof disorders, carcase bruising and high muscle pH. *Anim. Welfare* 30, 393–407. doi: 10.7120/09627286.30.4.003

Maes, D., Sibila, M., Kuhnert, P., Segalés, J., Haesebrouck, F., and Pieters, M. (2018). Update on mycoplasma hyopneumoniae infections in pigs: Knowledge gaps for improved disease control. *Transbound Emerg. Dis.* 65, 110–124. doi: 10.1111/tbed.12677

Maisano, A. M., Luini, M., Vitale, N., Rota Nodari, S., Scali, F., Alborali, G. L., et al. (2020). Animal-based measures on fattening heavy pigs at the slaughterhouse and the association with animal welfare at the farm level: a preliminary study. *Animal* 14, 108–118. doi: 10.1017/S1751731119001320

Martinez, A., Donoso, E., Hernández, R. O., Sanchez, J. A., and Romero, M. H. (2022). Assessment of animal welfare in fattening pig farms certified in good livestock practices. *J. Appl. Anim. Welfare Sci.*, 1–13. doi: 10.1080/10888705.2021.2021532

Nathues, H., Spergser, J., Rosengarten, R., Kreienbrock, L., and grosse Beilage, E. (2012). Value of the clinical examination in diagnosing enzootic pneumonia in fattening pigs. *Veterinary J.* 193, 443–447. doi: 10.1016/j.tvjl.2012.01.013

Nielsen, S. S., Nielsen, G. B., Denwood, M. J., Haugegaard, J., and Houe, H. (2015). Comparison of recording of pericarditis and lung disorders at routine meat inspection with findings at systematic health monitoring in Danish finisher pigs. *Acta Vet. Scand.* 57, 18. doi: 10.1186/s13028-015-0109-z

Lindén, J., Pohjola, L., Rossow, L., and Tognetti, D. (2014). Meat inspection lesions. In T. Ninios, J. Lundén, H. Korkeala and M. Fredriksson-Ahomaa (Eds.), *Meat Inspection and Control in the Slaughterhouse* (John Wiley & Sons Ltd.), pp. 163–198.

Nurse, A. (2016). Beyond the property debate: animal welfare as a public good. *Contemp. Justice Review: Issues Criminal Social Restorative Justice* 19, 174–187. doi: 10.1080/10282580.2016.1169699

Pastrana-Camacho, A. P., Estévez-Moreno, L. X., and Miranda-de la Lama, G. C. (2023). What slaughterhouse workers' attitudes and knowledge reveal about human-pig relationships during pre-slaughter operations: A profile-based approach. *Meat Sci.* 195, 109017. doi: 10.1016/j.meatsci.2022.109017

Permentier, L., Maenhout, D., Deley, W., Broekman, K., Vermeulen, L., Agten, S., et al. (2015). Lung lesions increase the risk of reduced meat quality of slaughter pigs. *Meat Sci.* 108, 106–108. doi: 10.1016/j.meatsci.2015.06.005

Pessoa, J., Rodrigues da Costa, M., García Manzanilla, E., Norton, T., McAloon, C., and Boyle, L. (2021). Managing respiratory disease in finisher pigs: Combining quantitative assessments of clinical signs and the prevalence of lung lesions at slaughter. *Prev. Vet. Med.* 186, 105208. doi: 10.1016/j.prevetmed.2020.105208

Pulido, M. A., Mariezcurrena-Berasain, M. A., Sepúlveda, W., Rayas-Amor, A. A., Salem, A. Z. M., and Miranda-de la Lama, G. C. (2018). Hauliers' perceptions and attitudes towards farm animal welfare could influence the operational and logistics practices in sheep transport. *J. Veterinary Behavior: Clin. Appl. Res.* 23, 25–32. doi: 10.1016/j.jveb.2017.10.004

Rampelotto, P. H., dos Santos, A. C. R., Muterle Varela, A. P., Takeuti, K. L., Loiko, M. R., Mayer, F. Q., et al. (2022). Comparative analysis of the upper respiratory bacterial communities of pigs with or without respiratory clinical signs: From weaning to finishing phase. *Biol. (Basel)* 11, 1111. doi: 10.3390/biology11081111

Rioja-Lang, F. C., Brown, J. A., Brockhoff, E. J., and Faucitano, L. (2019). A review of swine transportation research on priority welfare issues: A Canadian perspective. *Front. Vet. Sci.* 6. doi: 10.3389/fvets.2019.00036

Romero, M., Castillo-Patiño, A., and Sánchez., J. A. (2018). Factores de riesgo asociados con la presencia de cerdos fatigados durante el transporte y sus implicaciones en el pH muscular alto. *Rev. Investig. Vet. Perú* 29 (4), 1315–1324.

Romero, M. H., Sánchez, J. A., and Hernandez, R. O. (2022). Field trial of factors associated with the presence of dead and non-ambulatory pigs during transport across three Colombian slaughterhouses. *Front. Vet. Sci.* 9. doi: 10.3389/fvets.2022.790570

Romero, M. H., and Sánchez JA, G. C. (2011). Evaluación de prácticas de bienestar animal durante el transporte de bovinos para sacrificio. *Rev. Salud Pública* 13, 684–690. doi: 10.1590/s0124-00642011000400013

Romero, M. H., Sanchez, J. A., and Martínez Hoyos, R. (2015). Factores asociados con la frecuencia de cerdos muertos durante el transportea una planta de beneficio. *CES Medicina Veterinaria y Zootecnia* 10, 132–140.

Sanchez-Vazquez, M. J., Strachan, W. D., Armstrong, D., Nielen, M., and Gunn, G. J. (2011). The British pig health schemes: integrated systems for large-scale pig abattoir lesion monitoring. *Veterinary Rec.* 169, 413–413. doi: 10.1136/vr.d4814

Schrøder-Petersen, D. L., and Simonsen, H. B. (2001). Tail biting in pigs. *Veterinary J.* 162, 196–210. doi: 10.1053/tvjl.2001.0605

Schwartzkopf-Genswein, K. S., Faucitano, L., Dadgar, S., Shand, P., González, L. A., and Crowe, T. G. (2012). Road transport of cattle, swine and poultry in north America and its impact on animal welfare, carcass and meat quality: A review. *Meat Sci.* 92, 227–243. doi: 10.1016/j.meatsci.2012.04.010

Scollo, A., Gottardo, F., Contiero, B., and Edwards, S. A. (2017). A cross-sectional study for predicting tail biting risk in pig farms using classification and regression tree analysis. *Prev. Vet. Med.* 146, 114–120. doi: 10.1016/j.prevetmed.2017.08.001

Silva, A. P. S. P., Storino, G. Y., Ferreyra, F. S. M., Zhang, M., Fano, E., Polson, D., et al. (2022). Cough associated with the detection of mycoplasma hyopneumoniae DNA in clinical and environmental specimens under controlled conditions. *Porcine Health Manag* 8, 6. doi: 10.1186/s40813-022-00249-y

Sinisalo, A., Niemi, J. K., Heinonen, M., and Valros, A. (2012). Tail biting and production performance in fattening pigs. *Livest Sci.* 143, 220–225. doi: 10.1016/j.livsci.2011.09.019

Stafford, K. (2014). Sheep veterinarians and the welfare of sheep: No simple matter. *Small Ruminant Res.* 118, 106–109. doi: 10.1016/j.smallrumres.2013.12.008

Stärk, K. D. C., Alonso, S., Dadios, N., Dupuy, C., Ellerbroek, L., Georgiev, M., et al. (2014). Strengths and weaknesses of meat inspection as a contribution to animal health and welfare surveillance. *Food Control* 39, 154–162. doi: 10.1016/j.foodcont.2013.11.009

Taylor, N. R., Main, D. C. J., Mendl, M., and Edwards, S. A. (2010). Tail-biting: A new perspective. *Veterinary J.* 186, 137–147. doi: 10.1016/j.tvjl.2009.08.028

Teixeira, D. L., and Boyle, L. A. (2014). A comparison of the impact of behaviours performed by entire male and female pigs prior to slaughter on skin lesion scores of the carcass. *Livest Sci.* 170, 142–149. doi: 10.1016/j.livsci.2014.09.026

Thodberg, K., Herskin, M. S., Jensen, T., and Jensen, K. H. (2018). The effect of docking length on the risk of tail biting, tail-directed behaviour, aggression and activity level of growing pigs kept under commercial conditions. *Animal* 12, 2609–2618. doi: 10.1017/S1751731118000563

Uehleke, R., Seifert, S., and Hüttel, S. (2021). Do animal welfare schemes promote better animal health? an empirical investigation of German pork production. *Livest Sci.* 247, 104481. doi: 10.1016/j.livsci.2021.104481

Valadez-Noriega, M., Estevez-Moreno, L., Rayas-Amor, A., Rubio-Lozano, M., Galindo, F., and Miranda-de la Lama, G. (2018). Livestock hauliers' attitudes, knowledge and current practices towards animal welfare, occupational wellbeing and transport risk factors: A Mexican survey. *Prev. Vet. Med.* 160, 76–84. doi: 10.1016/j.prevetmed.2018.09.023

Valros, A., Ahlström, S., Rintala, H., Häkkinen, T., and Saloniemi, H. (2004). The prevalence of tail damage in slaughter pigs in Finland and associations to carcass condemnations. *Acta Agric. Scand. A Anim. Sci.* 54, 213–219. doi: 10.1080/09064700510009234

Valros, A., Välimäki, E., Nordgren, H., Vugts, J., Fàbrega, E., and Heinonen, M. (2020). Intact tails as a welfare indicator in finishing pigs? scoring of tail lesions and defining intact tails in undocked pigs at the abattoir. *Front. Vet. Sci.* 7. doi: 10.3389/fvets.2020.00405

van Staaveren, N., Doyle, B., Manzanilla, E. G., Calderón Díaz, J. A., Hanlon, A., and Boyle, L. A. (2017). Validation of carcass lesions as indicators for on-farm health and welfare of pigs. *J. Anim. Sci.* 95, 1528–1536. doi: 10.2527/jas2016.1180

Vargas-Bello-Pérez, E., Miranda-de la Lama, G. C., Teixeira, D. L., Enríquez-Hidalgo, D., Tadich, T., and Lensink, J. (2017). Farm animal welfare influences on markets and consumer attitudes in Latin America: The cases of Mexico, Chile and Brazil. *J. Agric. Environ. Ethics* 30, 697–713. doi: 10.1007/s10806-017-9695-2

Varón-Álvarez, L., Romero, M., and Sánchez, J. (2014). Caracterización de las contusiones cutáneas e identificación de factores de riesgo durante el manejo presacrificio de cerdos comerciales. *Arch. Med. Vet.* 46, 93–101. doi: 10.4067/S0301-732X2014000100013

vom Brocke, A. L., Karnholz, C., Madey-Rindermann, D., Gauly, M., Leeb, C., Winckler, C., et al. (2019). Tail lesions in fattening pigs: relationships with postmortem meat inspection and influence of a tail biting management tool. *Animal* 13, 835–844. doi: 10.1017/S1751731118002070

Welfare Quality (2009). Welfare quality assessment protocol for pigs (sows and piglets, growing and finishing pigs). *Welfare Qual. consortium*, 1–123.