Universidade de Trás-os-Montes e Alto Douro

Evaluation of tail biting in pigs at the abattoir

- Final Version -

Master's Dissertation in Veterinary Medicine

Alice Teresa Carneiro Gomes

Advisor: Professor Doctor Maria Madalena Vieira-Pinto

Universidade de Trás- Os-Montes e Alto Douro

Vila Real, 2022

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Jury Composition:

President: Professor Doctor João Filipe Martins Freire Requicha

Universidade de Trás-os-Montes e Alto Douro

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Direção Geral de Alimentação e Veterinária

Professor Doctor Maria da Conceição Medeiros Castro Fontes

Universidade de Trás-os-Montes e Alto Douro

Professor Doctor Maria Madalena Vieira-Pinto

Universidade de Trás- Os-Montes e Alto Douro

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Para aqueles que sempre me apoiaram

“The three great essentials to achieve anything worthwhile are, first, hard work; second, stick-to-itiveness; third, common sense.”

Thomas A. Edison

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Abstract

Tail biting has been recognised as an emerging problem in pig production. In Europe, tail docking is regularly performed on conventional swine farms to decrease the prevalence of tail damage. However, this procedure should be applied only as last resource, being imperative to consider its negative impact on animal welfare. During meat inspection, tail assessment can be challenging and lead to an underestimation of tail biting prevalence. This study aimed to evaluate tail biting occurrence in slaughtered pigs, analyse the association of tail lesions with production system and tail length, explore the relationship between *post mortem* findings, carcass condemnations and tail damage and assess the importance of creating a more detailed tail score classification that includes scarred lesions.

Information on a total of 9189 pigs from 73 batches with different tail lengths (undocked, docked mid-length, fully docked) and from distinct production systems (conventional, conventional without the administration of antimicrobials and organic) was collected at a Spanish abattoir.

The probability of observing tail lesions varied with length (p=0.0001), with undocked pigs having higher odds of showing severe lesions when compared to the other two production systems (OR=3.11, OR=2.10). No significant differences were observed between docked at mid-length or fully docked carcasses regarding the occurrence of tail lesions. Batches with higher lesions scores presented a greater chance of total condemnation (p=0.014, OR = 1.81), being even more associated with scarred lesions (p=0.0002, OR=3.24). Pyemia was influenced by tail lesions (p=0.013, OR=2.06) and presented an even stronger relationship with scarring scores (p=0.0002, OR=3.86). The within-batches probability for local condemnations (all p<0.05) and local condemnation by abscesses (p<0.0001, OR=3.65) increased significantly with higher scarring scores. Tail length was also significant, with docked at mid-length and undocked carcasses having more odds to show abscess condemnations than fully docked (p=0.0002, OR=2.10 and OR=1.70). Organic farms showed a higher probability for total condemnation (p=0.0263)

This research concludes that the tail scarring score presented a close relationship with *post mortem* findings and total/local condemnations, presenting a more relevant role when compared to non-scarring lesions, which proves that it should be included in the tail surveillance program. There is the need to upgrade the current lesion scoring method to help pinpoint carcasses at risk for condemnations, working as a potential welfare indicator. This study also indicates that if tail docking is performed, it can be beneficial to resect a smaller proportion of the tail as an alternative to a shorter resection.

Keywords: abattoir, animal welfare, meat inspection, swine, tail biting

Resumo

A mordedura de cauda foi reconhecida como um problema emergente na produção de suínos. Na Europa, o corte de cauda é regularmente realizado em explorações de suínos para diminuir a prevalência de lesões. No entanto, este procedimento deve ser sempre aplicado como último recurso, sendo imperativo considerar o seu impacto negativo no bem-estar animal. Durante a inspeção higio-sanitária, a avaliação da condição da cauda pode ser desafiante e conduzir a uma subestimação da prevalência real de mordedura. Há a necessidade de criar um método detalhado de classificação de lesões da cauda, para ajudar a identificar carcaças em risco de rejeição, de modo a funcionar como um potencial indicador de bem-estar.

Os objetivos deste estudo são avaliar a prevalência da mordedura de cauda nos porcos abatidos, analisar a associação entre as lesões da cauda e entre os diferentes comprimentos da mesma e o sistema de produção, explorar a relação entre os achados *post mortem*, rejeição de carcaça e lesões de cauda e avaliar a importância da adoção de um sistema mais detalhado para pontuação da condição da cauda que inclua lesões cicatrizadas.

Informações sobre um total de 9189 suínos de 73 lotes, com diferentes comprimentos de cauda (inteira, cortada a meio, totalmente cortada) e de sistemas de produção distintos (convencional, convencional sem a administração de antimicrobianos e orgânico) foram recolhidas num matadouro espanhol.

A probabilidade de observar lesões da cauda variou significativamente com o comprimento da mesma ($p=0.0001$), com animais de cauda intacta a apresentarem uma maior probabilidade de desenvolverem lesões severas quando compradas com os outros dois sistemas de produção ($OR=3.11$ e $OR=2.10$). Não foram observadas diferenças significativas entre carcaças com caudas cortadas a meio ou caudas totalmente cortadas relativamente à ocorrência de danos na cauda. Lotes com classificação de lesão superior apresentaram uma maior probabilidade de serem totalmente rejeitados ($p=0.014$, $OR=1.81$), estando fortemente associados à cicatrização ($p=0.0002$, $OR=3.24$). A piemia mostrou uma associação significativa com lesões da cauda ($p=0.013$, $OR=2.06$) e ainda mais significativa com a cicatrização da mesma ($p=0.0002$, $OR=3.86$). A probabilidade de rejeições locais (todos, $p<0.05$) e rejeições locais por abcessos ($p<0.0001$, $OR=3.65$) aumentou significativamente com a cicatrização, não sendo alterada pelas lesões da cauda. O efeito do comprimento nas lesões da cuada também foi significativo (p=0.0002), com carcaças com caudas cortadas a meio e caudas não cortadas a apresentar mais probabilidade de serem localmente rejeitadas por abscessos (OR = 2.10 e OR = 1.70).

Este estudo conclui que o parâmetro "cicatrização" das lesões da cauda apresentou uma relação próxima com achados *post mortem* e rejeições, quer totais quer parciais, apresentando um papel mais relevante quando comparada com a clássica classificação de lesão da cauda, comprovando que a cicatrização deve ser incluída no programa de vigilância de mordedura. Também indica que, se o corte da cauda for realizado, pode ser benéfico amputar uma proporção menor da cauda.

Palavras-chave: matadouro, bem-estar animal, inspeção de carne, suínos, mordedura de cauda

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Abbreviations, acronyms and symbols

% – percentage

ADG – Average Daily Gain

AM – antimicrobials

AMI – *ante mortem* inspection

ANPROGAPOR –*Asociación Nacional de Productores de Ganado Porcino*

ASF - African Swine Fever

CH^4 - methane

cm – centimetre

CO – carbon monoxide

CO2 – carbon dioxide

DEFRA - *Department for Environment Food & Rural Affairs*

EFSA – *European Food Safety Authority*

EU – European Union

EUA – United States of America

FAO – Food and Agriculture Organization of United Nations

INE – Instituto Nacional de Estatística

Kg - kilogram

m2 – square meter

MAPAMA – Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente

MI – Meat inspection

NH^3 – ammonia

ºC –Celsius degrees

OECD – *Organisation for Economic Co-operation and Development*

OIE – World Organisation for Animal Health

OR – Odds ratio

OV – Official Veterinarian

PMI – *post mortem* inspection

ppm – parts per million

SH^2 – hydrogen sulphide

TNZ – Thermoneutral Zone

UK – United Kingdom

VOI – Visual-only inspection

I. Introduction

Harmful social behaviour, in particular tail biting, has been recognised as a common problem in pig production. It is an animal welfare issue since pigs suffering from tail injuries present pain, stress and frustration (de Briyne *et al.*, 2018; EFSA, 2007). It also leads to further costs for the farmers as a result of increased healthcare, additional animal management, decreased animal performance and higher prevalence for carcass condemnation, either total or local, mostly related to abscessation (Valros *et al.*, 2004, 2020; vom Brocke *et al.*, 2019). Several authors have demonstrated that tail bitten carcasses were sold for a lower value when compared to intact tail pigs, probably due to mortality and total or local condemnations (Li *et al.*, 2017). In 1999, the UK registered a 4-million-euro expense related to tail biting due to reduced weight gain, veterinary treatments and carcass condemnations (Moinard *et al.*, 2003). This behaviour can spread quickly through pens and be quite challenging to stop (de Briyne *et al.*, 2018), leading to cannibalism in an advanced stage, especially in the nursery and growing units (EFSA, 2007).

Tail biting became more frequent over time, as production intensified, and the environment became increasingly artificial. It is described as a multifactorial problem and is known to be triggered by a wide range of factors such as high stocking density, slatted floors, lack of bedding material, feeding-related issues, incorrect or imbalanced temperature or gas levels, poor ventilation, stress, genetic problems, hierarchy establishment, lack of environmental enrichment or health problems (de Briyne *et al.*, 2018; Moinard *et al.*, 2003; Taylor *et al.*, 2010; Widowski, 2002). This behaviour is often seen in conventional indoor husbandry systems (Valros *et al.*, 2004). However, it has also been documented in outdoor herds (Hansson *et al.*, 2000; Walker & Bilkei, 2006) and in organically raised swine (Alban *et al.*, 2015; Kongsted & Sørensen, 2017), which indicates that tail biting is not exclusive of conventional husbandry system. Up to date, there is no reported evidence for tail biting behaviour in non-domesticated swine species (Taylor *et al.*, 2010).

In Europe, pigs are regularly exposed to docking to prevent tail damage later in life. The farmer mainly performs this procedure during the first week of the animal's life without anaesthetics. If it is done later, it needs to be performed by a veterinarian with the administration of analgesia/anaesthesia to provide pain relief, following the EU pig

Directive (Council of the European Union, 2008). This procedure cannot be done routinely, and it is only allowed if there is evidence of tail biting. It should be applied as a last resource, and other measures related to environmental conditions, space allowance or enrichment material must be taken first (Council of the European Union, 2008). However, according to de Briyne *et al.* (2018), it is necessary to consider that tail docking is a welfare problem in itself since the procedure causes pain in piglets, can lead to the development of spinal abscesses, facilitates suboptimal production methods from a welfare point-of-view and does not extinguish the occurrence of tail biting. For that reason, it is imperative to consider the benefits and negative impacts of both tail docking and tail biting.

Based on several studies, Valros & Heinonen (2015) reported that tail docking reduced the occurrence of severe lesions by 50%. In 2015, a study in Ireland where 99% of the pigs were docked still showed a prevalence of 72.5% for tail damage (with mild lesions included) along with a 2.5% incidence for severe lesions (Harley *et al.*, 2014). Two Irish studies also showed that the frequency for severe tail lesions could be as high as 3.1% (van Staaveren *et al.*, 2017), while it may rise to 72.0% for mild lesions (Teixeira *et al.*, 2016) in docked animals. Being that said, it can be concluded that tail docking itself does not eliminate tail biting completely.

Tail biting can represent a problem at slaughterhouses since it originates pathological findings which imply total or local condemnations (Kritas & Morrison, 2007; Valros *et al.*, 2004). Abscesses, arthritis and member inflammation seemed more frequent in carcasses from tail bitten pigs (Marques *et al.*, 2012; vom Brocke *et al.*, 2019). A recent study conducted at a Finnish abattoir concluded that both mild and severe lesions were associated with an increase in local carcass condemnations, and severe lesions were also associated with nearly all meat inspection findings (Valros *et al.*, 2020).

The relation between secondary infections and reduced body condition with tail damage can lead to substantial economic losses for farmers (Kritas & Morrison, 2007). Severe tail lesions have been closely related to local condemnations of the carcass, therefore representing a cause of financial loss for the farmer and the abattoir due to the extra labour (Harley *et al.*, 2014). Also, this extra labour could result in the need to stop and sanitise the slaughter line and its utensils when a tail biting case is associated with osteomyelitis. Carcass condemnations are therefore accountable for significant financial losses (Harley *et al.*, 2012; Valros *et al.*, 2004).

Tail biting is frequently recorded at abattoirs during meat inspection in some countries (e.g. Norway, Sweden), including in Portugal (Direção Geral de Alimentação e Veterinária [DGAV], 2019; Keeling *et al.*, 2012). The occurrence of tail biting can be considered an indicator of the pig's welfare by reflecting housing conditions or animal management practices (Keeling *et al.*, 2012). However, abattoir data for tail biting are not very accurate and tend to underestimate tail damage (Harley *et al.*, 2014; Keeling *et al.*, 2012). A Danish study that included 111 herds showed that tail lesions, evaluated by clinical examination of animals on the farm, were actually double the number detected by meat inspection at the abattoir (Busch *et al.*, 2004). Hence, it is likely that meat inspection records at the abattoir detect only severe cases associated with ongoing infections and condemnations (Taylor *et al.*, 2010), creating a need to improve the tools for tail inspection. However, despite these limitations, recording the tail at the abattoir during meat inspection may be considered a monitoring/surveillance cost-effective tool, functioning as an iceberg indicator for problems at farm-level.

This study aimed to:

- Evaluate the level of tail biting occurrence in slaughtered pigs.
- Analyse the association of tail lesion score with the production system and tail length.
- Explore the relationship between *post mortem* findings, carcass condemnations (either total or local) and tail lesion evaluation.
- Assess the importance of creating a detailed tail score classification that includes scarred lesions.

II. Bibliographic review

1. The importance of pig meat: production and consumption

Globally, meat is considered a vital source of nutrition. Over the past 50 years, the demand for meat made the industry quadruple its production. Regionally, Asia has grown into the largest meat producer owning 40 to 45% of the output, as, in the 60's, it produced only 12%. On the other hand, Europe and North America declined, since in 1961 they had 42% and 25% of the worlds' meat output, respectively, and now they account with namely 19% and 15%. However, this percentage reduction did not reflect a drop in meat output: Europe's meat production has doubled over the years, and North Americans output had a 2.5-fold increase. However, Asia had an astonishing development by presenting a 15-fold increase in meat production since the early '60s (Ritchie & Roser, 2017).

In 2018, approximately 1.5 billion pigs were slaughtered for meat production (Ritchie & Roser, 2017). In 2020, global pork meat production was estimated at 109.2 million tonnes, with a drop of 0.8% from 2019, mainly due to the African Swine Fever (ASF) outbreaks in China, the Philippines and Viet Nam. On the contrary, Brazil, Canada, Chile, the European Union (EU), the United States of America, the Russian Federation and Mexico presented growth in pig meat production (FAO, 2021).

China still stands as the leading pig meat producer even with the reduction in meat output compared to previous years. As stated above, this was a consequence of the ASF outbreak in late 2018, which made East Asia decline its production, mainly due to China, where ASF led to the death of 950 000 swine and consequently affected the production index (FAO, 2019). This out-going crisis will continue to affect many countries in the following years, with China, the Philippines and Viet Nam suffering most of the impact (FAO & OECD, 2021). It is anticipated that the ASF outbreaks will continue to maintain global pig meat production lower than previous peak levels until 2023, which is then projected to increase. In regions affected by the ASF, pig meat production growth will result from a shift from backyard productions to commercial production facilities (FAO & OECD, 2021).

In the EU, production rose driven by relevant output developments in some member countries, such as Denmark and Spain, due to the ASF-free status and easy access to Asian markets in need. Pork meat is expected to decrease as public and environmental concerns limit its expansion in the EU.

To date, the leading pig meat producers and their respective production quotas are represented in Figure 1. Pig meat output is expected to increase to 127 million tonnes by 2030 and accounts for 33% of the total growth in meat consumption (FAO & OECD, 2021).

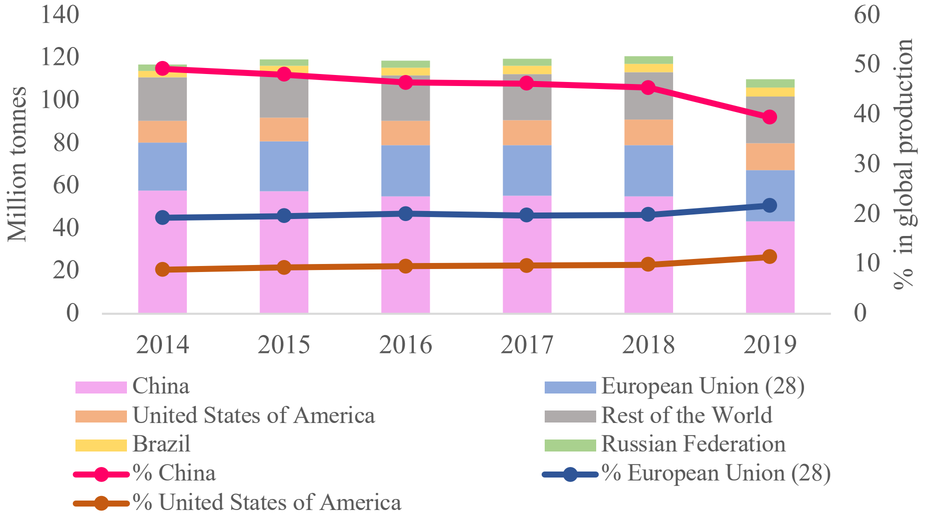

Figure 1 - World's pig meat production from 2014 to 2019, in millions of tons (left-hand axis) and share of total production in % (right-hand axis) of the main producers (adapted from FAO, 2021).

In 2020, the EU produced 24141 thousand tonnes of pork meat (FAO, 2021). Interim data show Spain accounting with more than 56.4 million slaughtered swine and about 5 million tonnes of pig meat produced. During 2020, pork production grew 8.2%. Within the EU, Spain stands in second place with 21.8% of total pig production (Subdirección General de Producciones Ganaderas y Cinegéticas *et al.*, 2021). Last year, Portugal produced around 379832 tonnes of pork meat, representing a fall of 2.1% of the country's output (INE, 2021).

If we consider a global average, pig meat is the most popular in terms of *per capita* consumption (Ritchie & Roser, 2017). According to FAO & OECD (2021), pork meat consumption *per capita* worldwide in 2020 was estimated at 10.7 kg. In 2020, each Spanish citizen consumed approximately 49.6 kg *per capita* of pig meat. (Subdirección General de Producciones Ganaderas y Cinegéticas *et al.*, 2021). Last year, the average Portuguese citizen consumed about 41,4 kg of pork meat, representing 36% of total meat consumption in Portugal (INE, 2021).

Graphs for pig meat consumption *per capita* worldwide and specific regions are described in Figure 2.

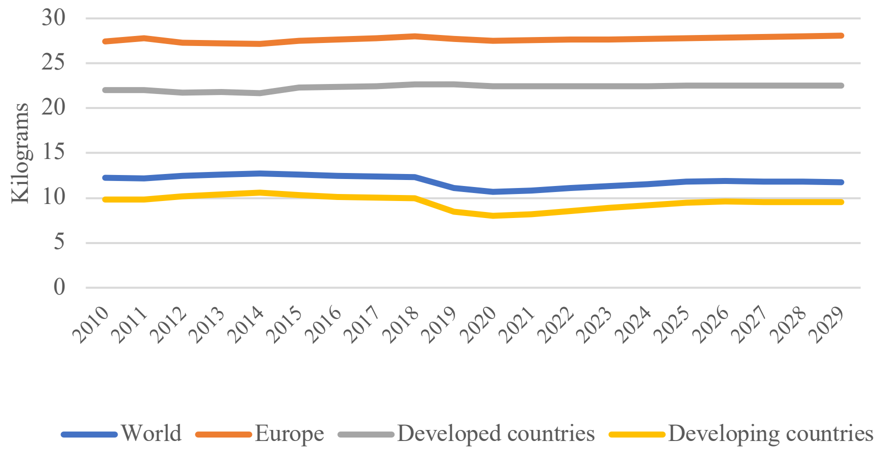

Figure 2 - Prediction for pig meat consumption per capita, in kilograms (left-hand axis), in the world, Europe, developed countries and developing countries from 2010 to 2029 (adapted from OECD & FAO, 2020)

Spain's pork meat consumption totalised 2347.6 thousand tonnes in the last year. The data also shows a reverse in the downward trend for pork meat, with a growth of 14% due to greater domestic consumption. Spanish's self-supply rate is likely to increase significantly due to the enormous growth in exports throughout the year, accounting for an increase of 214% (Subdirección General de Producciones Ganaderas y Cinegéticas *et al.*, 2021). In the previous year, Portugal's pig meat consumption was estimated at 426 thousand tonnes, representing 36% of all meat consumption, a decreased of 7,4% from 2018. The Portuguese self-supply rate increased from 2019, being estimated at 79.3% (INE, 2021).

In the EU, meat consumption has shifted towards poultry since it is a cheaper choice, allied to its perception as a healthier food choice. The predictions for pig meat consumption worldwide and specific regions are represented in figure 3 (FAO & OECD, 2021).

International meat prices declined due to the repercussion of the COVID-19 pandemic since some dominant consuming and importing countries shortened their demands temporarily due to economic downturns, transport logistics or increased domestic availabilities. The annual average pig meat price declined 3.6% (FAO, 2021).

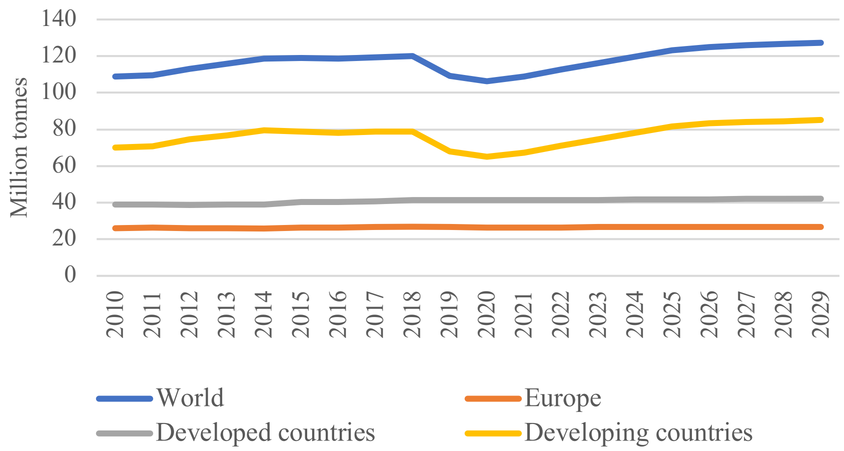

Figure 3 - Prediction for pig meat consumption, in millions of tons (left-hand axis) in the world, Europe, developed countries and developing countries from 2010 to 2029 (adapted from OECD & FAO, 2020).

This recession in global meat prices would have been more significant if China had not increased the import demand due to the ASF outbreak, which persists in limiting local production (FAO & OECD, 2021).

For Spain, the previous year started with stability in pig meat price, followed by a seasonal increase that usually occurs later in spring due to the adjustment of supply at a national level. Posterior, with COVID19-related lockdowns, the carcasses price fell drastically until June, remaining stable until the last weeks of the year. High demand in international markets, mainly from China, has been the pillar that maintained the markets throughout 2020 despite the health crisis. In the last weeks of 2020, pig meat value was set at 1.36€ per kg for class E carcasses (Subdirección General de Producciones Ganaderas y Cinegéticas *et al.*, 2021). In Portugal, the average price for a pig's carcass was 1,74€ per kg (INE, 2021).

In terms of environmental impact, animal-based foods tend to have a higher footprint when compared to plant-based. Pig meat stands for one of the lowest footprints (6 kg CO2-equivalents), along with poultry (7 kg CO2-equivalents), an appellative factor to societies' environmental concerns (Ritchie & Roser, 2020).

2. Meat Inspection

Meat inspection (MI) is usually described as the sanitary control of slaughtered animals and their meat (Herenda *et al.*, 1994). Under the current EU legislation, MI protocols should ensure safe meat for human consumption, concerning animal health and animal welfare (Alban *et al.*, 2017; Luukkanen *et al.*, 2015). These protocols should be performed according to the most recent and relevant information, being possible to adapt them throughout new discoveries (Alban *et al.*, 2017).

MI's primary objective is to identify animals unfit for human consumption and remove them from the food chain. It strengthens animal disease control, contributing with information of notifiable diseases, zoonoses or endemic production diseases. It can also help to detect and indict animal welfare issues (Stärk *et al.*, 2014).

2.1. MI and slaughter procedures at the abattoir

MI tasks include a range of activities before and after stunning/death, *ante mortem* and *post mortem* inspection (AMI, PMI) (Stärk *et al.*, 2014; The European Comission, 2014).

Figure 4 schematises the slaughter process and important tasks performed at the Spanish abattoir.

Figure 4 – Process of pig slaughtering process at the Spanish abattoir. Note: Orange – Dirty zone; Yellow - Clean zone.

Firstly, the animals arrive at the abattoir and are unloaded into the lairage. The official veterinarian (OV) must check if the documents are in accordance with the animals' identification and vehicle transportation license, namely the Food Chain Information (FCI) and the transportation guide (Ministerio de La Presidencia, 2009; The European Commission, 2019b).

The pigs are housed in the lairage, where they have access to water and are subjected to an automatic shower system for welfare bases (in the summer, the water is cold and in the winter the water is warm). Animals which have not been slaughtered within 12 hours of their arrival shall be fed and provided with bedding or an equivalent material in order to provide comfort. After their arrival, animals should be slaughtered as soon as possible (The Council of The European Union, 2009).

From the lairage, pigs are led by batches into a cooridor which terminates in the CO^2 gas chamber. The chamber has 5 cages in a rotatory system, with a capacity of 4 pigs per cage, so there are always 20 animals in the system. Following the OIE (Organisation for Animal Health) recommendation, the CO^2 concentration usually stands at 92 % with the temperature set as 23ºC, being the animals exposed to that concentration for at least 3 minutes (World Organisation for Animal Health [OIE], 2021). Per hour, 256 pigs are stunned.

After the stunning, the pigs are manually hoisted into the slaughter line and bleeding is immediately performed through the cut of the carotid arteries (The Council of The European Union, 2009). This abattoir plant is vertical, which means that after the bleeding animals are hoisted to the upper level.

Firstly, the carcasses encounter the first whipping machine, which is an equipment designed for brushing and cleaning to remove dirt and filth from the carcass using flagellators. In the next stage, carcasses enter a tunnel where scalding is performed. This is a vertical steam-based scalding where carcasses are subjected to temperatures of at least 62ºC for an average of 5 minutes. Afterwards, they are introduced to the dehairing process carried by an automatic machine. The manual heating torch is performed by trained abattoir personnel to the critical areas that still present hair after the dehairing process (e.g. head, skin folds, etc.). Subsequently, a second whipping is necessary before the singeing. Next, carcasses are submitted to a singer burner, which is a machine designed for flaming and sanitizing the carcasses after dehairing. This mark the entrance to a tunnel where the carcases will be submitted to flagellators for the third time (whipping machine) and flaming (singeing) once again, as last. The end of this processes states the beginning of the clean zone.

The remaining nails and ear tags are manually removed by the abattoir employees. Then, the evisceration takes place. If the carcass is male, the testicle and penile area are removed. The white viscera (stomach, intestines, bladder, spleen and pancreas) goes to the inspection tray and the red viscera (tongue, oesophagus, trachea, heart, thoracic aorta, lungs, liver and part of the diaphragm) are put on a hock on the same tray, which accompanies the carcass along the slaughter line.

The carcass is divided in two with a chain saw, stopping at the head part. Afterwards, there is a control point where staff searches for faecal/biliary contamination or any abnormal process, under the OV's supervision. After this, the carcass is fully sectioned with the head staying attached on the right part of carcass. On the following station, the kidneys and flare fat are removed and placed in the tray with the other viscera.

The final-check station is where a trained abattoir worker, with the supervision of the OV, excludes the carcasses and respective viscera that needs to be put aside for detailed inspection. When carcasses are excluded, the OV performs a detailed inspection to the carcass and respective viscera and issues a sanitary decision, which can reside in a total or local condemnation. According to the OV's decision, the slaughterhouse staff disposes the carcasses and viscera which are unfit to human consumption or performs the local condemnations by removing the affected areas and relocating the carcass to the slaughter line. The approved viscera are transported to the respective sections for processing and commercialization.

After being inspected, the flare fats are cleaned more meticulously and the carcass is presented to the Fat-O-Meat'ers™, which commercially classifies the pig carcasses by measuring back fat thickness and loin muscle depth.

Finally, the health mark is attributed, indicating the origin country, the national approval number of the facility where the food was processed and the letters "EC" for European Community (European Parliament & Council of the European Union, 2004). Next, the carcass is weighted, and a sample is taken from a pillar of the diaphragm in order to proceed with the *Trichinella* search, as the specific rules on official controls indicate (The European Commission, 2015). The *Trichinella* search is performed on all the carcasses.

At last, the carcasses initiate the cooling phase, which consists in two stages. Firstly, they enter a freezing circular tunnel, where they are constantly moving for 1 hour and 30 minutes at extremely low temperatures. Then, they are transferred to the stabilizing chamber, where they remain at low temperatures until the following day. After 24h they are relocated into the fresh meat cutting room.

2.2. Official Veterinarian

Audits and inspection practices at the abattoir are the OV's responsibility, who has the obligation to verify the Food Chain Information (FCI), the abattoir's compliance with animal welfare rules, the proper use or discarding of animal by-products and any necessary additional sampling and laboratory tests. It is the OV who carries out the AMI and PMI, always considering the previously mentioned assessments, as well as any other pertinent information (The European Commission, 2019a).

2.3. Food Chain Information

FCI is a document who shares important information on livestock between farms and abattoirs. This exchange of data displays an important role in detecting animal health or welfare problems, safety concerns and in maintaining meat quality (Ninios *et al.*, 2014).

FCI must be presented to the slaughterhouse operator and OV 24h prior the arrival of the animals at the slaughter facilities. If the animals have undergone AMI at the farm, the FCI could be presented only when the arrival of the animals, along with a certificate signed by the veterinarian who performed the exam (European Parliament & Council of the European Union, 2004).

This document includes data relating the status of the farm or the regional animal health status, the animal's health status, any administered pharmaceuticals within a relevant period and with a withdrawal time greater than zero (with the indication of the administration dates), occurrence of diseases that may jeopardize meat safety, production data when this might indicate the presence of disease, name and address of the private veterinarian who normally attends the animals, relevant reports of any analysis relating diagnosed diseases that could affect meat quality and reports relating previous AMI and

PMI of the animals from the same holding of prevenance (European Parliament & Council of the European Union, 2004; Ninios *et al.*, 2014). If the animals are not accompanied by the respective FCI, the slaughter shall not take place until the OV's permission. (European Parliament & Council of the European Union, 2004).

However, the current FCI is considered to provide insufficient data for modern MI of swine (EFSA Panel on Biological Hazards [BIOHAZ], 2011; Felin *et al.*, 2016) . The majority of the zoonoses related to pig meat safety appear as latent infections, so as the animals are asymptomatic, the current FCI is not offering any useful data to monitor these biological threats. To identify the affected animals, FCI should contain monitoring data, for example, serological monitoring reports of pigs raised on the same farm (Felin *et al.*, 2016).

2.4. *Ante mortem* inspection

The aim of this exam is to detect, before slaughter, any sign of health/welfare issues, abnormality or disease that could make fresh meat unsuitable for human consumption or might negatively impact animal health. Special attention should be given the detection of zoonotic diseases, the use of prohibited or unauthorised substances, misuse of veterinary pharmaceutical or the presence of chemical residues or contaminants (Ninios *et al.*, 2014; The European Commission, 2019a).

AMI is usually performed in the abattoir by the OV although, in some cases (mainly in poultry MI), it can be made on the farm by the farm veterinarian who must sign a certificate validating the examination, which will accompany the FCI (Ninios *et al.*, 2014). It is performed within 24 hours of the animals' arrival at the lairage and less than 24 hours before slaughter. The abattoir facilities should enable an easy AMI, allowing each animal to be easily examined and identified (European Parliament & Council of the European Union, 2004; Ninios *et al.*, 2014). Separate pens for sick or suspect animal are required (Ninios *et al.*, 2014).

When performing AMI, the OV should evaluate the animal's behaviour, clinical health status, their cleanliness and identification (Ninios *et al.*, 2014). The OV emits a sanitary decision and could decide based on the AMI whether the animal is appropriate or unfit for human consumption. If abnormalities are observed during the exam, the animal is excluded and should be killed separately or be slaughtered at the end of normal slaughtering. This examination allows the OV to choose which animals should be slaughtered first or last, taken into count the amount of dirt or any clinical conditions (Ninios *et al.*, 2014).

However, AMI fails to identify asymptomatic carriers of some infectious/zoonotic diseases. In an ideal situation, the FCI should contain more useful information, for example, the results of control programs regarding certain pathogenic microorganisms, which could be an indicator that those animals are not fit for consumption, even if the AMI is normal (Ninios *et al.*, 2014).

Animal welfare is also an important concern since AMI may be the only event during the animal's life when they are individually examined alive by a person other than the producer (Figure 5). The animals' body condition, size relating to age, dirtiness, injuries, or illnesses can provide information relating welfare at farm-level (Ninios *et al.*, 2014). Bitten tails can be an indicator that the animals are subjected to poor welfare conditions (de Briyne *et al.*, 2018; EFSA, 2007; Ninios *et al.*, 2014; Valros *et al.*, 2020). During the unloading of the animals, the OV must also look for stress behaviour or fresh lesions which could reflect poor ventilation and overcrowded vehicles. Dead animals during transport suggests contagious diseases or animal welfare problems at farm-level (Ninios *et al.*, 2014). Water should always be available and the room's temperature and ventilation suitable. Animals should be handled with calm, in order to avoid excessive stress. When necessary, animals should be fed. Tired animals should have the opportunity to rest before being slaughtered. If any of these rules is disrespected, the OV must register the occurrence and notify the business operator, so that corrective measures take place immediately (Ninios *et al.*, 2014).

Figure 5 – Swine at the lairage facility where the OV performs AMI.

2.5. *Post mortem* inspection

PMI demands high professional and technical abilities. It is necessary to demonstrate proper knowledge on the slaughtered specie's anatomy, pathology, and epidemiology (Ninios *et al.*, 2014). All swine must be inspected in accordance with the current European legislation (The European Commission, 2019a). After 2014, the EU required visual-only inspection (VOI) for all swine herds slaughtered that met particular epidemiologic and animal rearing conditions, in order to minimize microbiological contamination of the carcass through incision and manipulation (Riess & Hoelzer, 2020; The European Commission, 2019a).

PMI must include a visual inspection of the (The European Commission, 2019a):

- head and throat;
- mouth, fauces and tongue;
- pericardium and heart;
- diaphragm;
- liver and the hepatic pancreatic lymph nodes (*Lnn. portales*); gastro-intestinal tract, the mesentery, the gastric and mesenteric lymph nodes (*Lnn. gastrici, mesenterici, craniales and caudales*);
- spleen, kidneys, pleura and peritoneum;
- genital organs (except for the penis, if already rejected);
- udder and its lymph nodes (*Lnn. Supramammarii);*
- umbilical region and joints of young animals.

Incision and palpation of the carcase and offal can be performed when there are indications of a possible risk to public or animal health and/or welfare, which can include (The European Commission, 2019a):

- an incision and inspection of the submaxillary lymph nodes (*Lnn. Mandibulares*);
- a palpation of the lungs and the bronchial and mediastinal lymph nodes (*Lnn. bifurcationes, eparteriales and mediastinales*). The trachea and the main branches of the bronchi shall be opened lengthwise and the lungs shall be incised in their posterior third, perpendicular to their main axes;

- an incision of the heart lengthwise so as to open the ventricles and cut through the interventricular septum;
- a palpation of the liver and its lymph nodes;
- a palpation and/or incision of the gastric and mesenteric lymph nodes;
- a palpation of the spleen;
- an incision of the kidneys and the renal lymph nodes (Lnn. renales);
- an incision of the supramammary lymph nodes;
- a palpation of the umbilical region and joints of young animals and, if necessary, incision of the umbilical region and opening of the joints.

The implementation of VOI should be associated with a complete FCI system, serological monitoring programs, correct risk assessment of herds and additional critical analysis of systemic issues in meat production that can jeopardize food safety and public health (Riess & Hoelzer, 2020).

PMI is known to detect classical zoonotic diseases, such as tuberculosis, who have become controlled in several regions where modern husbandry systems, disease control programs and animal health care were established. Other visible meat quality-related unconformities such as pale, soft and exudative or dark, firm and dry meat are also detected during the inspection. Septicaemia caused by pathogenic microorganisms in the blood (*Streptococcus suis, Erysipelotrix rhusiopathie, Salmonella* Typhimurium *and Bacillus anhtracis)* can contribute to acute and systemic carcass lesions, which are also identified during the exam. However, under abattoir conditions, it is not possible do differentiate the organism causing septicaemia. As previously mentioned, some animals can carry pathogenic microorganisms and not show any clinical symptom or carcass abnormality (*Salmonella* spp*., Y. enterocolitica and Toxoplasma gondii*), which creates a serious difficulty since current MI is not prepared to identify and/or eliminate these agents. Poor illumination, excessive background noise, small available working space and the high speed of the slaughter line can also negatively influence PMI (EFSA Panel on Biological Hazards [BIOHAZ], 2011).

Procedures documented at MI must be capable of detecting animal welfare issues such as tail lesions caused by biting. Additionally, the data collected must be openly communicated to producers, enabling them to act on the information received and improve farm conditions (Devitt *et al.*, 2016).

3. Tail docking

3.1. Current practice

Tail docking in pigs is regularly performed on conventional swine farms because it can decrease the prevalence of tail biting, a harmful and undesirable behaviour. This procedure implies resecting part of the animal's tail (Sutherland & Tucker, 2011). It is usually performed by the farmer or its employees in the piglet's first days, along with other standard practices such as iron administration or corner teeth reduction. The most common methods for tail docking include blunt trauma cutters such as scalpels, scissors/wire cutters or by cautery with a hot iron. Commonly, no anaesthetic or analgesic is administered to reduce the pain. When blunt trauma cutters are used, they are usually dipped in an antiseptic for disinfection, but none is applied on the tail before or after docking (EFSA, 2007; Marchant-Forde *et al.*, 2009). The size of the tail can vary. It is common to leave approximately 2 cm in length (Sutherland & Tucker, 2011).

3.2. Legal framework and recommendations

The Council Directive 2008/120/EC clarifies that all procedures that result in damage or loss of a sensitive part of the animal's body or alteration of bone structure are strictly prohibited; it is only allowed to intervene for therapeutic/diagnostic purposes or the identification of the pigs according to the legislation. However, some known exceptions include corner teeth reduction of piglets, tail docking, castration of male pigs or nose-ringing animals kept in outdoor husbandry systems. Teeth reduction and tail docking should not be performed routinely, but only where there is evidence of damage to the sows teats or the ears or tails of other swine. Before carrying out these procedures, additional measures should be considered in order to prevent tail biting, such as environmental factors, stocking density and farm management to reverse inadequate conditions (Council of the European Union, 2008).

All the procedures mentioned above must be performed by a veterinarian or by an experienced worker used to carry out such techniques with appropriate methods and under hygienic conditions. Anaesthetic and additional prolonged analgesia must be mandatorily used if castration or docking of the tail is performed after the 7th day of life (Council of the European Union, 2008). Thus, tail docking should not be performed routinely in EU countries.

At farm-level, tail docking practice has increased due to enhanced tail biting problems following an industrialisation of swine production. Nowadays, the percentage of tail docked pigs varies with husbandry systems and legislation, being almost 0% in countries where tail docking is strongly discouraged or prohibited and 100% in countries where it is permitted (EFSA, 2007). Figure 6 represents a survey that points out the percental differences between undocked animals in several countries.

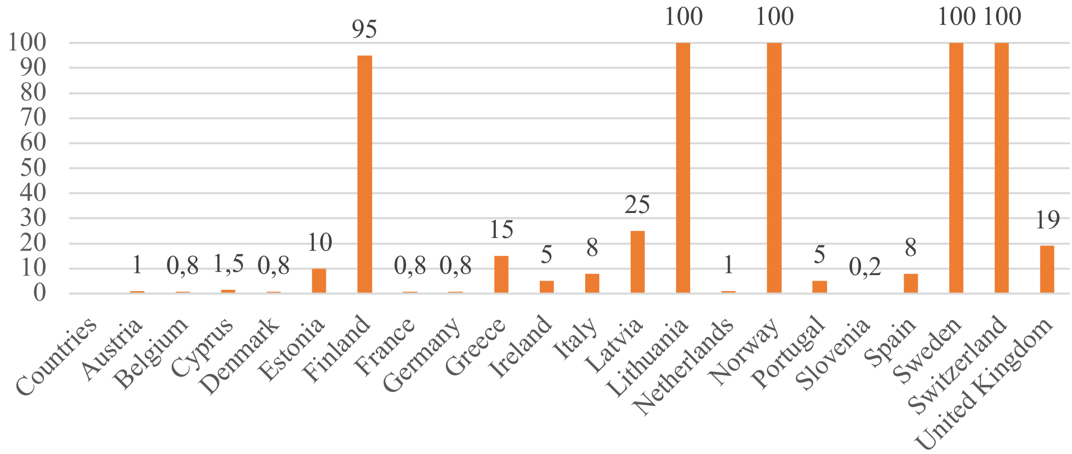

Figure 6 – Percentage of undocked swine in several EU countries. Adapted from EFSA, 2007.

Denmark, Sweden, Finland, Lithuania, Switzerland and Norway are some of the countries where legislation is stricter than the EU directive (Table 1). However, in the EU, over 90% of the animals are tail docked, Denmark included (EFSA, 2007). Table 1 lists countries where legislation is stricter than the EU Council Directive 2008/120/EC.

On March 8th 2016, was issued the Commission Recommendation (EU) 2016/336 (Commission Recommendation (EU) 2016/336 of 8 March 2016 on the Application of Council Directive 2008/120/E.C.). On that recommendation, EU member states are challenged to develop national programs to decrease risk factors associated with biting behaviour rather than adopt tail docking as the primary strategy. Each country must ensure that farmers conduct a risk assessment of the frequency for tail damage, grounded on animal and non-animal-based indicators. According to the results, countries must implement the necessary measures to reduce the risk factors for tail biting and, therefore, the need to rely on tail docking.

Table 1 - List of countries where legislation is stricter than the EU Council Directive 2008/120/EC of 18 December 2008 (adapted from de Briyne *et al.*, 2018; Nannoni *et al.*, 2014)

Country	Legislation stricter than EU Directive
Denmark	When performed after the 4th day of the piglet's life, long-lasting analgesia must be administered; Tail should not be docked more than half in an attempt to amputate little as possible
Estonia	Veterinarians must make the decision
Finland	Tail docking is prohibited, except when performed by a veterinarian due to medical purposes
Germany	Tail docking is only permitted up to the age of 4 days. When performed after, it must be done by a veterinarian with anaesthesia; Recommendation to dock no more than 1/3 of the tail
Norway	When tail amputation is performed for medical reasons, it can only be done by veterinarians, with the administration of anaesthesia and prolonged analgesia
Sweden	Tail docking is prohibited
Switzerland	Docking is removed from the list of mutilations that can be performed without anaesthesia
Lithuania	Tail docking is prohibited

In April 2017, the Ministerio de Agricultura y Pesca & Comunidades Autónomas y Asociación Nacional de Productores de Ganado Porcino [ANPROGAPOR] (2017) created the "*Documento sobre la gestión de las explotaciones porcinas para evitar la caudofagia*" which is a national program to prevent systematic tail docking. In Portugal, the Direção Geral de Alimentação e Veterinária (DGAV, 2019) also conceived a program for the prevention of tail biting and reduction of routine tail docking, from 2018 to 2020.

3.3. Welfare consequences

According to Marchant-Forde *et al.* (2009), tail docking is known to cause pain, discomfort, and distress to piglets who have the freedom to express their normal behaviour denied since, based on Nannoni *et al.* (2014), the missing tail is a tool of communication and interaction amongst them.

Several plasmatic indicators for stress (adrenocorticotropin, cortisol, glucose and plasma lactate) were measured in 1-day old piglets by Prunier *et al.* (2005), who found no effects on these parameters right after tail docking. The authors elaborated different hypotheses to justify this conclusion, namely:

- The possibility of the hypothalamic-pituitary-adrenal axis not being reactive to stress in 1-day-old piglets.
- The possibility of the hypothalamic-pituitary-adrenal axis being highly reactive but the animal manipulation associated with blood sampling might mask the effects of the procedure.
- The hypothalamic-pituitary-adrenal axis activity being greatly stimulated around birth and not being able to respond to any further stimulus.
- The nociceptive stimulation attributed to docking being insufficient to evoke a physiological stress response.

However, data was insufficient to discuss this matter in further detail.

Recently, Morrison & Hemsworth (2020) stated that tail docking in 2-day old piglets using either clippers or a cauteriser increased the piglets' cortisol concentrations at 15- and 30-minutes post-treatment compared to the control group. Tail docked animals also exhibited increased behaviours characteristic of pain both during the procedure and in the first 60 minutes after, spending more time standing with their heads lowered. Piglets subjected to tail docking vocalised longer and showed additional escape responses during the procedure than piglets in the control treatment, clearly showing signs of distress. After 24 hours, the behavioural responses in the tail docking and control group were similar, which intends that pain had diminished by this time.

According to Herskin *et al.* (2016) tail docking seems to cause behavioural changes, such as sudden movements, escape attempts and vocalisation up to 5 hours following treatment. When local anaesthesia was used (e.g., lidocaine), the piglet's reaction to acute pain seemed to diminish.

Neuroma formation can be a consequence of this procedure, being that its development can occur up to 4 months after docking (Sandercock *et al.*, 2016). In human medicine, neuromas have been linked to a significant cause of pain (di Giminiani *et al.*, 2017). Currently, no studies prove tail docked pigs are subjected to chronic pain; however, neuromas are associated with it (Spinka, 2017).

Other consequences can include the risk of infections, primarily if the procedure is performed under poor hygienic conditions (Valros & Heinonen, 2015). The growth rate can also be affected (Marchant-Forde *et al.*, 2009).

4. Tail biting

The nomenclature "tail biting" is widely used to characterise a varied range of abnormal behaviour in pigs, ranging from minimal oral manipulation of the tails to biting, which causes skin injuries or loss of tissue/portions of the tail (Taylor *et al.*, 2010).

A predecessor for tail biting is the tail-in-mouth behaviour, which is described as an oral manipulation of the pigs' tail by another and never leads to visible trauma, in contrast to biting (Schrøder-Petersen *et al.*, 2003; Schrøder-Petersen & Simonsen, 2001). This syndrome frequently begins in the weaning stage and peaks in the finishing phase (Haigh & O'Driscoll, 2019).

Tail biting is a multifactorial syndrome, and the factors that influence it are often related to environmental aspects. However, the causal factors on one farm may not be the reason for biting outbreaks on other farms (Schrøder-Petersen & Simonsen, 2001; Taylor *et al.*, 2010). This syndrome is considered an animal welfare issue since a pig exposed to tail injury presents pain and distress (de Briyne *et al.*, 2018; EFSA, 2007). Due to the injuries caused, biting implies increased healthcare, additional animal management costs and decreased animal performance, therefore, further costs for the farmers (Valros *et al.*, 2020).

Due to the inability to prevent tail biting outbreaks, especially in conventional production, tail docking was widely adopted as a preventive measure (EFSA, 2007). However, as previously mentioned, tail docking itself has its limitations.

4.1. Types of tail biting

Understanding the different behaviour patterns for tail biting may unveil distinct aetiologies of the problem, illustrating several ways to resolve them (Taylor *et al.*, 2010).

There are two distinct stages for tail biting. In the first stage or "pre-injury" stage, pigs are often seen rooting and gnawing on body parts of other pigs from their pen. This behaviour is classified by Van Putten (1980) as a "quiet" activity that displays the pig's natural tendency to root or chew surrounding objects being redirected towards pen mates, probably due to the lack of suitable enrichment objects. This behaviour may be observed while both animals are lying down (van Putten, 1980).

Spinka (2017) classified pigs based on their involvement while displaying tail biting behaviour. Therefore, animals are defined as biters (pigs who perform tail biting), receptor or victims (pigs who are bitten or present tail lesions) and control or neutral (pigs that do not bite and do not present lesions).

There are three types of biting that appear to be distinct, namely, "two-stage", "sudden-forceful", and "obsessive" (Taylor *et al.*, 2010). There are distinct environmental and husbandry factors that affect each type, demonstrating why this is a complex field to study and why it is commonly challenging to retrieve conclusions from research (Taylor *et al.*, 2010).

The “two-stage” biting, as the name suggests, involves two stages: pre-injury and injury stage. At the pre-injury stage, there is manipulation without tail damage or lesions, and usually, both animals are lying down or standing still. This stage never causes visible trauma and is commonly referred as "tail-on-mouth" behaviour (Schrøder-Petersen & Simonsen, 2001). The victims do not avert the biter, adopting a passive behaviour. This initial non-damaging manipulation is justified as an extension of pigs natural exploratory and foraging behaviour. When in lack of adequate enrichment material/substrates at the farm, animals redirect this boredom towards other pen mates (Taylor *et al.*, 2010). At some point, this tail manipulation evolves into biting and perforate the skin, creating a lesion (Figure 7 and 8). The bleeding can lead to other pigs being attracted to the tail, worsening the problem (Taylor *et al.*, 2010). In this scenario, the victim is likely to deter the biter and may present signs of discomfort or become lethargic.

The second category is the “sudden-forceful”, as the name suggests, the biter pig yanks and forcefully bites the tail of the victim pig without establishing a period of gentle manipulation, demonstrating a more aggressive approach. The victim presents an avoidance reaction and vocalises. This type of bite is less frequently described in literature and is either less common or most likely not detected or undifferentiated from the “two-stage” tail biting (Taylor *et al.*, 2010). The “sudden-forceful” bite is typically triggered by inadequate resource access (e.g. feeders), and it is more common in moving or standing animals (Taylor *et al.*, 2010). Widowski (2002) also considered this type of tail biting an aggressive response due to frustration.

The last type of tail biting is the "obsessive" form, where a considerable amount of forceful tail biting is performed by one or various pigs that yank tails, sometimes taking part of the skin or even amputating the tail. Nonetheless, this behaviour differs from the "sudden-forceful" as obsessive tail biters seem to be focussed on persistently biting tails, looking for another victim once one has been attacked. The association between obsessive biters and the two previously described categories is unclear. It is suggested that some animals perform "sudden-forceful" biting to access a resource but find biting their mates more rewarding hence, tail biting itself becomes a consummatory behaviour. Removing these individuals from the group will substantially reduce other animals' risk of displaying the same behaviour (Taylor *et al.*, 2010).

Usually, biter pigs are likely to be smaller. Even though "obsessive" tail biting could suggest a behavioural approach, enabling smaller individuals to compete with larger and faster pen mates, the occurrence and intensity of this behaviour are more evocative of abnormal behavioural syndromes, implying a pathological association. If the individuals are smaller, this could be linked to diet, health and metabolism factors, relating tail biting to these parameters. This type of obsessive behaviour could be encountered in animals with poor health at a critical stage in their development, such as weaning (Taylor *et al.*, 2010). Edwards (2006) stated that an altered protein metabolism could pathologically affect neurotransmitter balances in the central nervous system, corroborating a pathological association.

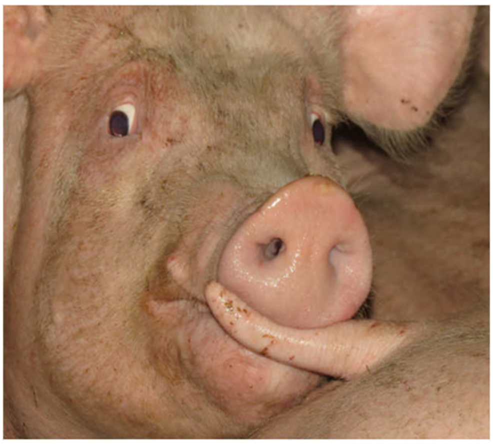

Figure 7 - Animal performing tail biting on pen mate's tail (available at: http://pigstraining.welfarequalitynetwork.net/Pages/19)

Figure 8 - Animal biting on a long tail (available at: http://pigstraining.welfarequalitynetwork.net/Pages/21)

4.2. Risk factors

Tail biting is considered a multifactorial syndrome that can be challenging to prevent due to its sporadic and unpredictable occurrence (Edwards, 2006; Moinard *et al.*, 2003; Schrøder-Petersen & Simonsen, 2001; Taylor *et al.*, 2010). Most researchers accept that the appearance of tail biting implies that some or all pigs within the farm are experiencing poor housing conditions and therefore reduced welfare (Schr øder-Petersen & Simonsen, 2001; Widowski, 2002).

Tail biting is often seen in conventional indoor husbandry systems (Valros *et al.*, 2004) with higher stocking densities, poor housing conditions (Moinard *et al.*, 2003), lack of substrate or enrichment material (Spoolder *et al.*, 2011; Taylor *et al.*, 2010), deficiencies in feed quality/quantity, health problems (Moinard *et al.*, 2003; Taylor *et al.*, 2010) or competitive behaviour (Schrøder-Petersen & Simonsen, 2001). However, tail biting has also been documented in outdoor herds (Hansson *et al.*, 2000; Walker & Bilkei, 2006) and in organically raised swine (Alban *et al.*, 2015; Kongsted & Sørensen, 2017), which indicates that tail biting is not exclusive of conventional husbandry system. Up to date, there is no reported evidence for tail biting behaviour in non-domesticated swine species (Taylor *et al.*, 2010).

4.2.1. Animal characteristics

Phenotypical characteristics have been linked to the predisposition of developing biting behaviour. Thus, it is essential to consider the breed, genetics, gender and the individuals' size (Schrøder-Petersen & Simonsen, 2001; Spoolder *et al.*, 2011).

It has been described by some authors that Large White swine seem to be more prone to becoming victims when compared to Landrace. An experimental study demonstrated that the prevalence of displaying tail biting behaviour was higher in Landrace pigs, being the heritability significative, whereas, in Large White, it did not seem to exist (Breuer *et al.*, 2005; Sinisalo *et al.*, 2012). Duroc pigs have also been described as more active and curious than Landrace or Large White, which could indicate a precursor for harmful behaviour towards pen mates (Breuer *et al.*, 2003). Breuer *et al.* (2005) also found an association between tail damage, leanness, and less back fat, increasing the odds for those animals to become victims. Although there are some genetic influences, the effects are unclear and can be influenced by external factors (EFSA, 2007).

Gender can also be a determinant genetic factor, with neutered males appearing to be bitten more often than females (EFSA, 2007; Kritas & Morrison, 2004; Valros *et al.*, 2004). It is suggested that females are more likely to bite their pen mates, because they are more active than males when they reach puberty and may become more interested in the genital area (Schrøder-Petersen & Simonsen, 2001). At abattoir-level, this tendency has also been confirmed, with Harley *et al.* (2012) finding a greater prevalence for tail lesions in uncastrated males than females and Kritas & Morrison (2007) observing more carcass lesions in castrated males than females.

In terms of group arrangement, the proposition of each gender can influence tail biting. There was a higher tail lesions prevalence in groups constituted exclusively by females than mixed or male-exclusive groups. In the mixed groups, males display more tail lesions than females (Schrøder-Petersen *et al.*, 2003). However, Schrøder-Petersen *et al.* (2003) found that "tail-in-mouth" behaviour was more frequent in mixed groups rather than the same gender ones.

Age and weight influence tail biting, which does not occur with the same frequency throughout the animal's life (Schrøder-Petersen & Simonsen, 2001). In the early days, soon after weaning, "tail-in-mouth" behaviour is explicit (EFSA, 2007). The frequency of which is displayed increases with age, becoming more common after weaning (Naya, 2018; Schrøder-Petersen *et al.*, 2003). In a Zonderland *et al.* (2003) study, weaned piglets initiated tail biting 5 days after weaning, but the behaviour disappeared when they were transferred to the finishing unit. In an epidemiologic study developed by Moinard *et al.* (2003), the pattern for tail biting outbreaks described by the producer was sporadic and irregular, being established after weaning until about 140 days of age. In a study conducted in a partially slatted floor system, tail manipulation was higher when the animals presented 45kg, having decreased with weight gaining (van de Weerd *et al.*, 2005). Lahrmann *et al.* (2017) compared tail lesions prevalence among swine in function of weight from weaning to slaughter. These authors observed a higher prevalence of tail biting in animals with 30 to 60 kg (growing stage) and the lower with pigs weighing 60 to 90 kg (finishing stage). In Italy, Scollo *et al.* (2013) conducted a study with a heavy pig (170kg) production where finishing pigs presented a higher prevalence for tail damage at 14 weeks and a lower at week 22.

4.2.2. Farm characteristics

Tail biting prevalence seems to be higher in farms with a superior number of animals (Grümpel *et al.*, 2018), with bigger production companies (e.g. five production units or more) displaying a superior risk for damaged tails (Moinard *et al.*, 2003). However, it must be noted that the influence of the husbandry system, degree of automation or any other external factors can interfere with each other's influence (EFSA, 2007).

In terms of housing conditions, the percentage of slatted floor is significantly associated with tail biting (Hevia, 2012; Kallio *et al.*, 2018; Moinard *et al.*, 2003). These floors are used for their economic benefits however, the quantity of substrates that can be used is limited (D'Eath *et al.*, 2014). Van de Weerd *et al.* (2005) found that pigs housed on slatted floor spent more time displaying tail-directed activity towards other pen mates when compared to pigs housed in straw bedding parks (Figure 9). Moinard *et al.* (2003) stated that the risk for biting behaviour increase 3-2 times more in total or partially slatted floor systems when compared to solid/concrete floor productions.

Figure 9 – Swine housed in fully slatted floor without bedding. Adapted from Hevia, 2012.

As previously mentioned, the husbandry system has been associated with tail biting, with closed-cycle pig farms (where the complete exploitation process is carried out in the same industrial unit) showing a higher prevalence than finishing farms. This can be due to the different management systems, where the continuous flow of filling sections in closed cycle farms can cause group mixing and compromise the social environment for the various animal's sizes (Valros *et al.*, 2004).

4.2.3. Farm management

Farm management is also vital since the stockman ratio to the number of animals seems to be a risk factor (Moinard *et al.*, 2003). As farm size increases, the number of animals to be supervised increases as well. When farm workers do not keep up with the demand, it can be hard to detect tail lesions and intervene appropriately (D'Eath *et al.*, 2016; Moinard *et al.*, 2003). Valros *et al.* (2016) conducted an inquire to farmers who described the stockman's role as being crucial since any alteration in his routine could turn out to be a risk factor.

4.2.4. Environment, Ventilation and Light

The farm's atmosphere is one of the most important precursors for tail biting (Taylor *et al.*, 2010), being considered the most relevant one by Dutch farmers (Bracke *et al.*, 2013). Adverse housing conditions can lead to discomfort and chronic stress (Taylor *et al.*, 2010). Tail biting also seems to be affected by artificial regulated internal and external temperatures (Schrøder-Petersen & Simonsen, 2001). Geers *et al.* (1989) found that for animals between 30 – 40 kg and 90 – 100 kg, the optimal temperature to prevent tail biting was 20 and 22ºC, respectively.

Seasonality also seems to influence biting behaviour, both for heat and cold motivated stress (Schrøder-Petersen & Simonsen, 2001). Blackshaw (1981) stated that biting behaviour developed more frequently in colder months of the year. During the summer season, slower air circulation combined with higher temperatures can lead to animals spending more time laying down in the excrement area, bad pen hygiene, slower growth rates and higher tail biting prevalence (Sällvik & Walberg, 1984). The airflow and sudden temperature variations can develop seasonal differences in tail biting prevalence since climatic regulating systems may be less efficient during specific periods (D'Eath *et al.*, 2014).

Natural ventilation systems show a reduced impact in tail damage and a positive influence on productions housing intact tail pigs (Hunter *et al.*, 2001). The chosen ventilation system must allow air circulation in all pens without creating air flows (Schrøder-Petersen & Simonsen, 2001) since these flows seem to be risk factors (EFSA, 2007). During winter, to allow temperature maintenance, a reduction of the building's ventilation is necessary, leading to lower air quality, thus increasing tail biting risk

(EFSA, 2007). Stress due to poor air quality could be due to higher ammonia concentrations (Scollo *et al.*, 2016) since levels of > 20ppm cause adverse effects on pig physiology and behaviour (Spoolder *et al.*, 2011).

The document released by MAPAMA *et al.* (2017) stated that gas concentrations are associated with air flows and exemplify several diagnostics means available to identify air-related irregularities (Table 2).

Table 2 - Limit levels for gases and dust in swine production (adapted from MAPAMA *et al.*, 2017).

Element	Level	Diagnose
CO^2	2000-2500ppm	Ventilation efficacy
NH3	< 10ppm	Manure handling: hygiene
CO	< 10ppm	Heating combustion
CH^4	0ppm	Manure handling: fermentation
SH^2	0ppm	Risk and toxicity in people or animals
Dust	< 2,4mg/m3	Particle's size and concentration

Note: CO^2 – carbon dioxide; NH^3 – ammonia; CO – carbon monoxide; CH^4 - methane; SH^2 – hydrogen sulphide; ppm – parts per million

The Department for Environment Food & Rural Affairs [DEFRA] (2003) suggested that new buildings must be projected with efficient ventilation in accordance with species, size and number of animals, thus avoiding excessive air flows. Efficient insulation must be applied to avoid heat loss, and a system for cooling should be available when in need. They also released temperature recommendations for each swine category (Table 3). Sudden thermal fluctuations should be prevented since cold/heat stress can lead to tail biting outbreaks (Department of the Environment Food and Rural Affairs [DEFRA], 2003). According to Houghton (2018), the type of floor (with straw, solid, metal or slatted floor) and the animal's weight (5 to 90 kg) creates the need to adjust mean temperatures, so these stay within the limits of the thermoneutral zone (TNZ) of the animals (Table 4).

Table 3 - Temperature recommendations for each swine category (adapted from DEFRA, 2003).

Swine category	Temperature (ºC)
Sows	15-20
Lactating piglets	25-30
Weaned piglets (3-4 weeks)	27-32
Weaned piglets (+5 weeks)	22-27
Finishing pigs (100kg)	15-21

Table 4 - Temperatures of TNZ according to pig's weight and floor type (adapted from Houghton, 2018).

Pig's weight	With straw (ºC)	Solid (ºC)	Slatted metal (ºC)	Slatted (ºC)
5	27-30	28-31	29-32	30-32
10	20-24	22-26	24-28	25-28
20	15-23	16-24	19-26	19-25
30	13-23	14-24	18-25	17-25
90	11-22	12-23	17-25	15-24

Erstwhile, dim light or even darkness was commonly used to diminish the prevalence of tail biting (EFSA, 2007). Nowadays, the European Union (Council of the European Union, 2008) states that pigs should be kept in light with an intensity of at least 40 lux for a minimum period of 8 hours per day. Spoolder *et al.* (2011) stated that the minimum light period per day should be 14 hours when artificial light is used. It was proven that, when farms used only artificial lighting rather than mixed or only natural lighting, the tail lesion prevalence was higher (Moinard *et al.*, 2003). When animals are subjected to a light intensity of more than 80 lux during activity periods rather than 40 lux, the aggression prevalence is lower (Spoolder *et al.*, 2011).

Regarding noises, pigs should not be submitted to more than 80 dB (Spoolder *et al.*, 2011).

4.2.5. Social environment

The stocking density, referred to as the number of individuals per area unit, could be decisive in tail biting development. The Council Directive 2008/120/EC has established minimum standards for pig production relating housing conditions and farm practices. Pigs weighing more than 85kg but not more than 110kg should have available an area of 0,65m^2, while a pig weighing more than 110kg should have at their disposal an unobstructed area of 1m^2 (Council of the European Union, 2008). Moirnard *et al.* (2003)

found that a density of 110kg/m^2 or more during the growing and finishing phase led to an increase of the risk for tail damage by 2.7 times.

According to Gottardo *et al.* (2017), a deficit in the minimum legal requirements for animal density is an essential factor for tail biting development. A German study conducted in tail docked weaner pigs recorded a higher tail biting prevalence when there was a higher stocking density per pen (Grümpel *et al.*, 2018). In several studies where the aim was to study how Finnish producers assessed the effectiveness of different preventive measures for tail lesions and what strategies they thought were most effective when tail docking was prohibited, stocking density was considered one of the ten most important factors (Bracke *et al.*, 2013; Valros *et al.*, 2016).

The animal's size discrepancy within a group can also trigger tail biting since this behaviour can result from a strategy for the smaller animals to compete with the larger ones (Taylor *et al.*, 2010). Mixing groups after weaning or in different phases of the animal's life can also lead to competitive behaviour to re-establish social hierarchy, thus increasing tail damage. However, other factors can coincide (e.g. weaning and separation from the sow, transfer to a new pen or diet change) being hard to dissociate these from those caused by the mixing (EFSA, 2007). It is advised that the animals from different groups and sizes shall not be mixed to assure the social hierarchy and equal access to resources (Scollo *et al.*, 2016).

4.2.6. Environmental enrichment

Environmental enrichment can be defined as modifications or additions to the pigs' space to improve the welfare of the animals by inciting the demonstration of natural behaviours. Practically speaking, it is the introduction of new objects or materials for animals to investigate and manipulate to keep them occupied and entertained (Agriculture and Horticulture Development Board, 2017).

Domestic swine species still demonstrate a strong motivation for rooting (Figure 10), so essential to the survival of its ancestor (wild boar) and, in the impossibility of performing it on the environment, they redirect it to their pen mates (Holm *et al.*, 2008; Taylor *et al.*, 2010). Therefore, the need for rooting material is considered a crucial preventive measure to reduce tail biting risk (EFSA, 2007; Spoolder *et al.*, 2011).

According to the Commission Recommendation (EU) 2016/336, enrichment materials should be safe, eatable (to be smelled or eaten, if possible, with nutritional benefits), chewable, investigable and manipulable. The material should be provided in enough quantity, cleaned, capable of inciting an exploratory behaviour, regularly replaced or renewed when necessary and display destructible components (Commission Recommendation (EU) 2016/336 of 8 March 2016 on the Application of Council Directive 2008/120/E.C.; Spoolder *et al.*, 2011).

Figure 10 - Swine normal exploratory behaviour (available at: http://pigstraining.welfarequality network.net/Pages/4). Note: left – rooting; centre – chewing; right – sniffing)

These enrichment materials can be divided into three categories (optimal, suboptimal and materials of marginal interest). An optimal material should possess all the aforementioned characteristics and can be used alone (e.g., straw, vegetable roots, hay). A suboptimal material also possesses all the listed characteristics but should be combined with other materials (e.g., wood shaving or pellets, soil, sand, shredded paper). Materials of marginal interest are the ones that provide entertainment for the animals but should not be considered sufficient to fulfil the pigs' needs, therefore, other optimal/suboptimal materials must the added (e.g. metal or rubber chains, wood pipes, salt bocks) (The European Commission, 2016). It was demonstrated that pigs on straw present a reduced prevalence for tail biting (Day *et al.*, 2002; van de Weerd *et al.*, 2005; Zonderland *et al.*, 2008) and stay occupied longer than when they are offered manipulable objects (e.g., hanging toys) (Scott *et al.*, 2006). Swedish farmers rear undocked pigs without major complications relating to tail biting (Wallgren *et al.*, 2016).

Due to logistical reasons associated with the provision method and the clogging of liquid manure handling systems, it is convenient to prefer chopped straw rather than the long (EFSA, 2007). However, a study found that straw chopping could reduce its positive effect and increase the risk of abnormal behaviour, thus being inadvisable (Day *et al.*, 2008). Hunter *et al.* (2001) suggested that pigs with limited and punctual straw supply displayed a reduced risk for tail lesions compared to pigs from non-straw systems, probably due to daily provision (Figure 11). The daily supply of clean, palatable straw reduces the risk for biting behaviour (Moinard *et al.*, 2003; Zonderland *et al.*, 2008).

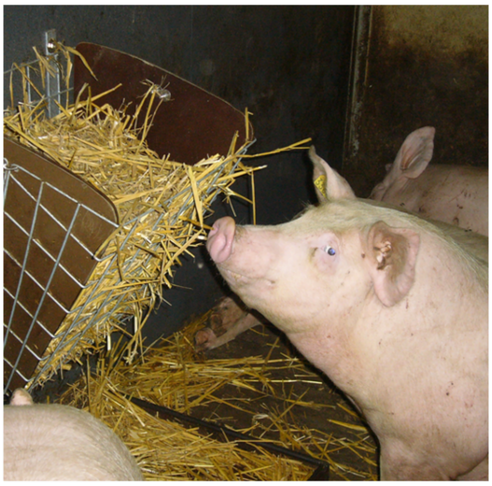

Figure 11 - Straw rack with straw on slats (available at: http://pigstraining.welfarequalitynetwork.net/Pages/13)

Due to the logistics associated with the supply of substrates in slatted floors and liquid manure handling systems, there have been many attempts to create alternatives that can be equally effective as straw in terms of enrichment (e.g., suspended plastic objects) (EFSA, 2007). However, Wallgren, Westin and Gunnarsson (2016) showed that it is possible to use straw in partly slatted floors since, in their study, the registered obstruction for the handling systems had a low incidence.

Rooting materials (e.g. soil) are less used but can also reduce tail lesions (EFSA, 2007). Scott *et al.* (2006) demonstrated that rooting material allowed a higher entertainment percentage for swine housed in fully slatted floors, although it remained at a lower ranking than straw.

Metal chains are familiar in intensive production and seem to provide entertainment in some circumstances (Figure 12; EFSA, 2007). Plastic pipes are also used as enrichment material (Figure 13). However, both chains and rubber hoses seem ineffective in reducing biting behaviour compared to straw provision (Zonderland *et al.*, 2008). Bracke and Koene (2019) questioned several international welfare specialists who considered the branched-chain design (longer chain with several free branches ending at the nose height of the pigs) a viable alternative to increase swine welfare. Guy, Meads, Shiel and Edwards (2013) compared the efficiency of 4 materials (chains, ropes, wood shaving and sawdust), concluding that ropes were the most manipulated material.

Figure 12 - Swine chewing on metal chain (available at: http://pigstraining.welfarequalitynetwork.net/Pages/10)

Figure 13 - Swine chewing on plastic piping (available at: http://pigstraining.welfarequalitynetwork.net/Pages/10)

Up to date, straw remains the most effective material to prevent tail biting (Figure 14; Lahrmann *et al.*, 2019). In a recent study, some non-straw enrichment materials were found effective in reducing tail biting significantly (e.g., roughage, hessian sacks, compost, freshly cut wood, horizontal and vertical space dividers, rope) although the remaining levels of tail lesions could still be high in undocked pigs (Buijs & Muns, 2019).

In order to avoid competitive behaviour in pen (Figure 15), it is necessary to consider the number of enrichment devices, besides the quality (Taylor *et al.*, 2010).

Figure 14 - Pig rooting in straw (available at: http://pigstraining.welfarequalitynetwork.net/Pages/6)

Figure 15 - Competition for enrichment material (available at: http://pigstraining.welfarequalitynetwork.net/Pages/16)

4.2.7. Diet

The importance of feed has been highlighted by producers (Valros *et al.*, 2016). The risk factors associated with biting behaviour are provision method, accessibility, deficiencies in the quantity or quality or the incorrect diet adequacy to the animal's age and needs (Palander, 2016). A deficient diet can affect “two-stage” tail biting due to the relation between foraging behaviour, feed selection and gut satiety (Taylor *et al.*, 2010). In order to obtain an optimal diet, wild species recur to foraging behaviour. However, in confined pigs, this foraging behaviour is frequent and when there is a necessity for more food or to obtain a specific nutrient (Jensen *et al.*, 1993).

In a conventional production system, feed is generally provided via single-space dispenser, and competitive behaviour can occur when there are lesser feeding spaces than animals (Palander, 2016). Moinard (2003) found that five pigs or more per space seemed to raise tail biting odds 2,7 times. The solution could be double or multi-space feeders, which seem to reduce tail biting incidence (Hunter *et al.*, 2001). Valros *et al.* (2016) inquire concluded that Finnish producers with undocked tail pigs considered diet a crucial factor, taking special care in providing sufficient feeding spaces.

An animal subjected to tail biting could reduce its feeding frequency in an attempt to avoid the biting (Valros & Heinonen, 2015). Palander (2016) found that when tail biting occurred, pigs who were not involved (control group) had gastrointestinal disorders, probably indicative of some level of anorexia, thus, it is likely that these animals had reduced their feeding to avoid being bitten. An absence or delay in feeding provision could increase the exploratory behaviour, leading to frustration and competitive interactions. Once the food arrives, animals will compete for feed spaces (Taylor *et al.*, 2010).

When feed is supplied several times a day, there is a higher probability of tail biting, which indicates that dividing feed into various smaller portions could lead to hunger, increasing the probability of competitive behaviour (Palander, 2016). Scollo *et al.* (2016) found that an incongruency in the feeding provision schedule was associated with a higher prevalence of tail lesions.

Switching diet in a phased manner according to the animal's need is not always adopted, leading to deficits or excesses of specific nutrients (Palander, 2016). For farmers, alterations in feed formula appears to be an essential factor associated with tail lesions (Day *et al.*, 2002). Nutritional deficits could result in a higher foraging activity to seek food and correct the nutritional imbalance (Taylor *et al.*, 2010).

Sows demonstrate abnormal oral behaviour more frequently when there is insufficient fibre or gutfill in the feed, and it was also proven that high-fibre diets reduce misdirected foraging (Taylor *et al.*, 2010). Fibre diet levels have also been associated with tail biting outbreaks (EFSA, 2007). Schrøder and Simonsen (2001) stated that straw bedding could act as a source of gut fill and provide satiation.

In an experimental study, animals subjected to a low-protein diet reflected a stronger preference for chewing blood-soaked tail models (Fraser *et al.*, 1991; McIntyre & Edwards, 2002), indicating a relation between tail biting and low-protein diets.

Imbalances of amino acids may also be associated with tail damage. A diet with an optimal tryptophane level seems to provide a calmer behaviour and better sleep patterns, and supplementation with lysine and arginine was demonstrated to decrease stress response during transport (Taylor *et al.*, 2010).

Salt levels can also affect biting behaviour, and farmers usually provide it in the feed to reduce tail lesions (Taylor *et al.*, 2010). Pigs on a low-salt diet have displayed increased rooting behaviour, even though tail biting was not present (Beattie *et al.*, 2001). Beattie *et al.* (2005) carried out an experimental study with ropes soaked in saline solution, where the pigs' contact time with those ropes was significantly associated with tail and ear damage, which supports that those nutritional imbalances could be forerunners for this behaviour.

The water supply could also be relevant, where the *ad libitum* regime allows the animals to satisfy their needs and keeps them entertained. The water flow must be adapted to the watering equipment, animals' size and space allowance. Its correct functioning should be a concern since a deficient water supply increases the risk for fighting and biting behaviour (Ministerio de Agricultura y Pesca & Comunidades Autónomas y Asociación Nacional de Productores de Ganado Porcino [ANPROGAPOR], 2017).

4.2.8. Health

Swine with retarded growth seem to have a greater predisposition to exhibit biting behaviour (EFSA, 2007). Poor health likely culminates in a lower growth rate, creating a size discrepancy within the group and making it more difficult for the smallest to access resources (e.g. feed, water), thus increasing tail biting (Taylor *et al.*, 2010).

The health status of the farm is also relevant (D'Eath *et al.*, 2014), where Moinard *et al.* (2003) found a positive association between farms with respiratory syndromes, rectal prolapses and a higher mortality rate since weaning to finishing. Respiratory diseases have also been linked to restlessness, thus increasing tail biting risk (Walker & Bilkei, 2006). The infections caused by tail biting can also lead to respiratory diseases, being this last not only a triggering factor but also a consequence (Kritas & Morrison, 2007; Moinard *et al.*, 2003). Although only one author suggests parasitism can carry out some influence in tail biting behaviour, in that study, tail lesions diminished after anthelmintic administration (D'Eath *et al.*, 2016).

4.3. Consequences of tail biting

Tail biting induces inflammation, triggering an acute-phase systemic response with severe infection involving abscess formation and chronic pain (Heinonen *et al.*, 2010; Li *et al.*, 2017). This behaviour can be persistent in several cases since victims seem to be bitten multiple times (Brunberg *et al.*, 2011). When subjected to tail biting, some individuals react to being bitten whilst other pigs present no adverse reaction. This lack of response could be linked to lameness, other painful conditions or pre-existing lesions (Taylor *et al.*, 2010).

Reduction in weight gain can be a consequence of biting behaviour due to the discomfort caused by the lesions, stress, secondary infections and less feed intake. Several authors found victimised pigs to maintain a lower average daily gain (ADG) than the pen mates (Li *et al.*, 2017; Sinisalo *et al.*, 2012). Several researchers justify this loss due to the reluctance of bitten animals to approach the feeder, decreasing diet intake and ADG (Munsterhjelm *et al.*, 2015b; Wallenbeck & Keeling, 2013).

Marques *et al.* (2012) reported that 75% of deceased pigs presented tail lesions, being in accordance with Kritas & Morrisons (2004), who acknowledged that 60% of observed deceased animals presented severe tail lesions. Lee & Veary (1993) established that 94% of carcasses with severely bitten tails were condemned for pyemia.

4.4. At the abattoir

Tail biting can represent a problem at slaughterhouses since it originates pathological findings which imply total or local condemnations (Kritas & Morrison, 2007; Valros *et al.*, 2004). Abscesses, arthritis and member inflammation seemed more common in carcasses from tail bitten pigs (Marques *et al.*, 2012; vom Brocke *et al.*, 2019). A recent study conducted at a Finnish abattoir concluded that both mild and severe lesions were associated with an increase in local carcass condemnations and severe lesions were also associated with nearly all MI findings (Valros *et al.*, 2020).

The relation between secondary infections and reduced body condition with tail damage can lead to substantial economic losses (Kritas & Morrison, 2007). Severe tail lesions have been closely related to local condemnations of the carcass, therefore representing a cause of financial loss not only for the farmer but also to the abattoir due to the extra labour (Harley *et al.*, 2014). Also, this extra labour could result in the need to stop and sanitize the slaughter line and its utensils when a tail biting case is associated with osteomyelitis (Figure 16 and 17).

Several authors have demonstrated that tail bitten carcasses were sold for a lower value when compared to intact tail pigs, probably due to mortality and total or local condemnations due to abscesses (Li *et al.*, 2017; Munsterhjelm *et al.*, 2015a). Even in the absence of condemnations, where the *post mortem* weight is not compromised, the economic losses can occur at farm-level due to the increased administration of pharmaceuticals and man labour (Marques *et al.*, 2012). Carcass condemnations are therefore accountable for significant financial losses (Harley *et al.*, 2012; Valros *et al.*, 2004).

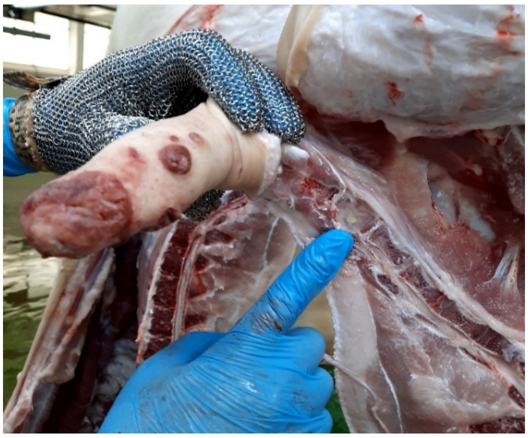

Figure 16 – Severely bitten tail detected at PMI with the presence of osteomyelitis.

Abattoir data can contribute to information relating to tail biting through sex, season, tail docking practice and other carcass damage (Widowski, 2002) but fails to identify the factors contributing to tail biting on farm-level (Taylor *et al.*, 2010). Also, tail assessment at the slaughter line can be challenging when the demand is high (Valros *et al.*, 2004). Sometimes it is not possible to be sure that tails have been docked or if they were initially undocked and were posteriorly bitten and shortened, creating an overestimation of tail docking prevalence (Harley *et al.*, 2012). At farm-level, the mortality of severely affected animals or the resolution of previous tail lesions at an early stage of the animal's life can mask the detection of damaged tails during PMI, thus establishing an underestimation of tail biting at the farm (Lahrmann *et al.*, 2017; Marques *et al.*, 2012). At abattoir-level, it is impossible to verify whether mild wounds were more severe at an earlier stage (Taylor *et al.*, 2010) or even if they occurred during transport or at the lairage, thus instituting an overestimation of tail lesions at farm-level (Harley *et al.*, 2012).

Although sanitary inspection is a great tool to evaluate and monitor tail biting and swine welfare (Teixeira *et al.*, 2016), the detected prevalence may not represent the actual problem extent at the farm (Harley *et al.*, 2012).

There is a need for a detailed lesion scoring method to help pinpoint carcasses at risk for condemnations, working as a potential method for a welfare estimation (Valros *et al.*, 2020) considering not only fresh wounds but also healed lesions (Spoolder *et al.*, 2011) and different lengths size when undocked animals are assessed (Valros *et al.*, 2020).

Figure 17 – Carcass with a scarred tail presenting osteomyelitis.

III. Material and Methods

From November 2020 to January 2021, data from MI of 9189 pigs from 73 batches was collected in one finishing pig abattoir located in the north of Spain. In this company, animals from 3 different production systems are slaughtered, namely: conventional indoor, conventional indoor without the administration of AM and organic. Depending on the productions system, different requirements must be fulfilled (Table 5).

Table 5 - Requirements descriptions of the three different pig production systems*

<table>
<tr><th></th><th colspan="3">Production system</th></tr>
<tr><th>Requirements</th><th>Conventional [1]</th><th>Conventional without AM [1]**</th><th>Organic [2][3]</th></tr>
<tr><td>Born outdoor/indoor</td><td colspan="3">indoor</td></tr>
<tr><td>Age at weaning</td><td colspan="3">21-25 days</td></tr>
<tr><td>Tail docking</td><td colspan="2">allowed, but as last resource measure</td><td>prohibited but exceptions granted*</td></tr>
<tr><td>Teeth reduction</td><td colspan="3">grinding or partially cut only if necessary, within the first 3 days</td></tr>
<tr><td>Resting area with bedding</td><td colspan="3">required</td></tr>
<tr><td>Floors</td><td colspan="2">slat/solid floor</td><td>slat/solid floor - at least 50% of the required minimum area should have solid floor</td></tr>
<tr><td>Access to an outdoor facility</td><td colspan="2">optional</td><td>required</td></tr>
<tr><td>Batch mixing</td><td>allowed</td><td colspan="2">not allowed</td></tr>
<tr><td>Area required per pig</td><td colspan="2">0.65 m^2/head</td><td>indoor area - 1,1m^2/head; outdoor area – 1m^2/head</td></tr>
<tr><td>Access to roughage</td><td colspan="2">optional</td><td>required</td></tr>
<tr><td>Treatment with AM</td><td>allowed</td><td>prohibited from 65 days of life</td><td>prohibited***</td></tr>
<tr><td>Withdrawal time related to AM</td><td>if the medication does not indicate the withdrawal time, it has got be at least 28 days</td><td colspan="2">twice as long as the legislation indicates (if the time indicated by the medication is too short - at least 48h)</td></tr>
</table>

AM - antimicrobials
[1] – (Ministerio de Agricultura Pesca y Alimentación, 2002)
[2] – (The Council of the European Union, 2007)
[3] - (The Commission of the European Communities, 2008)
* Although most of the organically raised animals in this study presented docked tails, this is stated in the European regulation.
** Conventional without AM is a commercial category established by the producing company.
*** Declassified as organic pig if: 3 or more treatments with AM within 12 months OR 1 or more treatment if its productive life cycle is less than 1 year.

1. Data collection

Data was collected at two levels: batch and individual. For each of the examined batches, the following information was recorded: farm identification number, type of production system, tail length (fully docked, docked at mid-length or undocked), number of total animals in the batch, number and causes of total condemnations and number, causes and areas of local condemnations. Locally condemned parts included posterior thirds, anterior thirds, head, ribs, shoulders, hock, ham and *rabada.* (Figure 18). *Rabada* is a cut commonly used in Coren slaughterhouses and involves the intrapelvic part of the external obturator muscle, the medial ventral sacrocaudal muscle, the coccygeal muscle, sacrum and the tail. The veterinarian registered the condemned areas on official records.

Since the abattoir did not record all the data relating to *post mortem* lesions, a subset of 3636 pigs from the 73 batches was examined at the individual level (mean: 50 pigs/batch; range: 31 – 59 pigs/batch). For these animals, the following data were collected on-site during PMI by the same observer: tail lesion and scarring scores (see next paragraph for details), presence/absence of costal pleurisy, lung condition and pericarditis. Lung condition was recorded in two categories: pneumonia (all types, excluding the presence of abscess or purulent pneumonia) and pneumonia with abscess formation or purulent pneumonia. Due to the speed of the slaughter line, pleurisy was only recorded when an adherence in the costal pleura was observed with or without the adherence of the lungs.

Table 6 represents all the possible causes for condemnations of carcasses parts during slaughterhouse MI. Abscess was only considered an eligible cause for local condemnation if it was found fully encapsulated and in a single area, with no signs of systemic infection. Regarding purulent contamination, as the name suggests, the area was rejected not by the presence of the abscess itself but due to the leak of purulent content which defiled the area. Regarding the hock region, if it presented septic arthritis with the presence of pus it counted as an abscess, whereas other type of arthritis and bursitis were considered as inflammation.

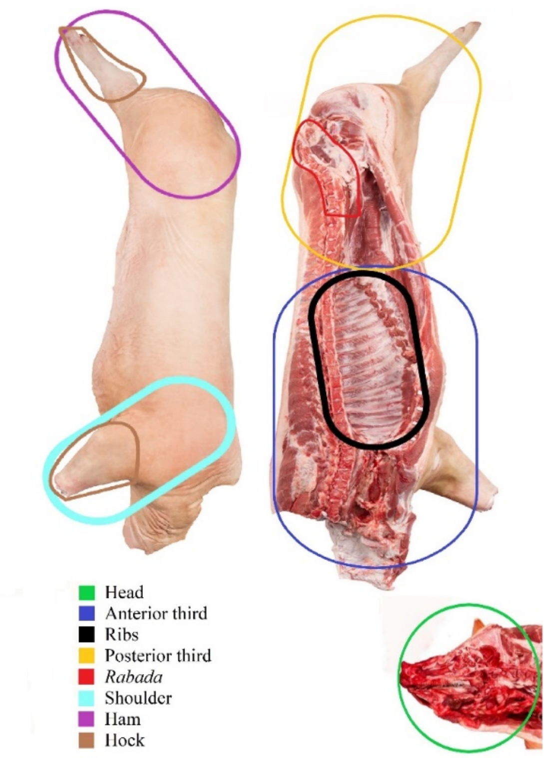

Figure 18 - Possible areas for local condemnations. (Green) Head. (Blue) Anterior third/Forequarters. (Black) Ribs. (Yellow) Posterior third/Hindquarters. (Red) Rabada. (Light blue) Shoulder. (Purple) Ham. (Brown) Hock.

Table 6 - Causes for local condemnation of carcasses parts.

Anterior third	Pneumonia, abscess
Posterior third	Abscess
Head	Abscess
Ribs	Pneumonia, abscess, purulent contamination
Rabada	Abscess
Hock	Abscess, inflammation

Tail scores

Each tail was classified based on two different lesion scores: tail lesion and tail scarring. The first one was categorised as follow: (0) No evidence of tail biting; (1) Superficial lesions only, without the evidence of perforation or presence of blood; (2) Presence of puncturing wounds associated with tail bites, with possible presence of blood or inflammation; (3) Extensive lesion associated with chewing - partial loss of tail tissue but with no loss of tail length; (4) Extensive lesion associated with chewing - partial or total loss of tail length. (Figure 19).

Tail scarring score was categorised as follow: (0) No scar; (C1) Visible scar with no tissue lost or alteration of tail length – mild scarring; (C2) Visible scar with presumable loss of tail length – severe scarring (Figure 20).

The lesion score was adapted from Harley, S. *et al.* paper (Harley *et al.*, 2012). The tail scarring score was based on a previous study developed by the authors. Based on the subset of animals examined at the individual level and their assigned scores, for each batch, a batch-level tail lesion score and scarring score (defined hereafter as batch scores) were derived by applying the following equation ∑(proportion of pigs with scorei X scorei).

Figure 19 - Tail lesion scoring system. (0) No evidence of tail biting; (1) Superficial lesions only, without the evidence of perforation or presence of blood; (2) Presence of puncturing wounds associated with tail bites with possible presence of blood or inflammation; (3) Extensive lesion associated with chewing - partial loss of tail tissue but with no loss of tail's length; (4) Extensive lesion associated with chewing - partial or total loss of the tail (White) No lesion; score 0 (Yellow) Mild lesions; score 1 (Red) Severe lesions; score 2.

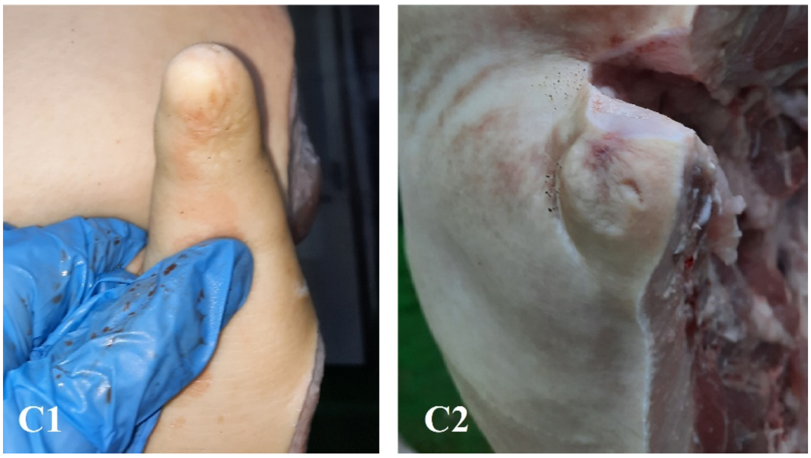

Figure 20 - Tail scarring scoring system. (C1) Visible scar with no tissue lost or alteration of tail length - mild scarring (C2) Visible scar with presumable loss of tail length - severe scarring.

2. Statistical analysis

Individual-level variation in tail lesions and scarring scores obtained from the observed animals (N=3636) were examined through two mixed ordinal logistic regressions, applying Laplace's method for penalised maximum likelihood estimation to reduce bias for rare events. For this analysis, tail lesions scores were aggregated in three classes: no lesions (tail score=0), mild lesions (score=1 and 2) and severe lesions (score=3 and 4). In both models, we examined the effect on scores of the production system (conventional, conventional without AM or organic), tail length (fully docked, docked at mid-length or undocked) and included the batch as a random intercept to account for variation within batches.

For each batch, based on the subset of examined animals, continuous batch-level tail lesion scores and scarring scores (defined hereafter as batch scores) were derived, applying the following equation ∑(proportion of pigs with scorei X scorei). Batch tail lesion scores and batch scarring scores showed only a weak correlation (Pearson's r=0.26), hence we included in each model both batch-level scores, the production system and tail length as a covariate. In all the batch-level logit models, Firth's penalised maximum likelihood estimation method was applied to account for quasi-separation of data and reduce rare events bias. Comparisons of significant variables with more than two levels were explored by means of Odds Ratio estimates (ORs) and their 95% Confidence Intervals (CI).

The probability for total condemnations counts was examined at batch-level (N=73) through two separate binomial logistic regressions using as response variables the no. of total and the no. of local condemnations on the total number of animals within the batch. Finally, we examined more in detail the relationship between pyemia (i.e. the most frequent reason for total condemnation), batch-level tail lesion and scarring scores, production system and tail length. Similarly, we also explored the effect of the same explanatory variables on the probability of condemning specific parts of the carcass and, lastly, for local condemnations due to abscesses.

It was also analysed through mixed logistic regressions whether the probability of observing specific *post mortem* findings (i.e. pleurisy, pneumonia, abscess pneumonia and purulent pneumonia, pericarditis) at the individual-level was related to tail lesions and scarring scores, the production system and tail length, including again batch as a random intercept.

All the analyses were carried out through PROC GLIMMIX and PROC LOGISTIC in SAS/STAT 9.4 software (Copyright © 2011, SAS Institute Inc., Cary, NC, USA).

IV. Results and Discussion

A total number of 9189 pigs from 73 batches were analysed in this study (Table 7). Of all animals, 39.6% (3636 pigs) were included in a detailed individual-level analysis.

Table 7 - Description of the study population (n=9189) with respect to the number of animals, batch size, production system and tail docking.

	N	**Percentage of total (%)**
Total number of animals	9189	100
Number of batches	73	100
Number of examined animals at individual-level	3636	39.57
Production system		
Conventional	2596	71.40
Organic	443	12.18
Conventional without antimicrobials	597	16.42
Tail docking		
Fully docked	2849	78.36
• Conventional	2142	
• Organic	356	
• Conventional without antimicrobials	351	
Undocked	429	11.80
• Conventional	194	
• Organic	87	
• Conventional without antimicrobials	148	
Docked at mid-length	358	9.85
• Conventional	260	
• Organic	0	
• Conventional without antimicrobials	98	

The most common production system was conventional (71.4%), followed by conventional without the administration of antimicrobials (16.4%) and organic production (12.2%). Carcasses with fully docked tails were more frequent for all production systems. Undocked tails were the second more frequent and were also seen in all production systems. Docked at mid-length carcasses were less frequent and were only seen in conventional and conventional without the administration of antimicrobials (Table 7).

Even though some animals are observed with an intact tail (undocked) or with a longer tail (docked at mid-length), which refers to the progressive disuse of docking practice following the European Commission directive (Council of the European Union, 2008), it seems that its application to a totality of the animals is far from being achieved, even in production systems with less animal density (i.e., organic production). Tail docking should not be performed as a routine procedure, only if there is clear evidence that other animals present ear or tail lesions (EFSA, 2007). Before its execution, preventive measures must be considered, such as reviewing stock density, empowering environmental enrichment, improving animal management, housing conditions or feed quantity/quality (Moinard *et al.*, 2003; Spoolder *et al.*, 2011; Taylor *et al.*, 2010; Valros *et al.*, 2004). In the EU, over 90% of the animals are tail docked (EFSA, 2007).

1. Individual-level analysis

1.1 Relationship between tail scores, production system and tail length

A detailed breakdown of individual tail score prevalence by production system and tail length in pigs slaughtered during the study period is reported in Table 8. A mixed ordinal logistic regression model exploring individual-level variation in tail lesions and scarring scores in pigs (N=3636) at the slaughterhouse was performed. Results are presented in Table 9.

Regarding tail lesions, the mild form was the most common finding (68.6%) and the severe form the rarest (1.7%; Table 8). The probability of observing tail lesions varied significantly with tail length (p=0.0001), with undocked pigs having higher odds of showing severe lesions than both pigs with fully docked tails and docked at mid-length (OR = 3.11 and 2.10, respectively; Table 9 and Figure 21). Indeed, undocked carcasses showed a higher percentage of mild and severe tail lesions (83% and 2.8%, in that order) compared to the other two categories (Table 8 and Figure 21).

On tail scarring, the most frequent was the absence of scars (86%), being severe scarring uncommon (2.7%; Table 8 and Figure 22). Tail scarring was not affected by any of the examined explanatory variables, although there was a tendency (p=0.069) for conventional production systems to have more severe lesions than both organic and conventional without AM farms (Table 9).

Table 8 - Prevalence of tail lesions and tail scarring scores by production system and tail-docking practice on pigs examined individually at the slaughterhouse (N=3636). Unless otherwise specified, 95% confidence intervals (CI) of the prevalence are reported within brackets.

		Tail lesions			Tail scarring		
	N (%)	0	Mild (1,2)	Severe (3,4)	C0	C1	C2
Examined pigs	3636	29.7% (28.2 – 31.2)	68.6% (67.1 – 70.1)	1.7% (1.3 – 2.1)	86% (85.1 – 87.3)	11.1% (10.0 – 12.1)	2.7% (2.2 – 3.2)
Production System							
Conventional	2596 (71.4)	29.0% (27.2 – 30.7)	68.9% (67.1 – 70.6)	2.1% (1.6 – 2.7)	84.9% (83.6 – 86.3)	11.9% (10.7 – 13.2)	3.1% (2.4 – 3.8)
Conventional without AM	597 (16.4)	29.5% (25.8 – 33.1)	69.8% (66.1 – 73.5)	0.7% (0 – 1.3)	88.8% (86.2 – 91.3)	9.7% (7.3 – 12.1)	1.5% (0.5 – 2.5)
Organic	443 (12.2)	34.1% (29.6 – 38.5)	65.5% (61.0 – 69.9)	0.5% (0 – 1.1)	90.3% (87.5 – 93.1)	7.7% (5.2 – 10.2)	2.0% (0.7 – 3.3)
Tail docking							
Fully docked	2849 (78.4)	32.8% (31.1 – 34.6)	65.5% (63.7 – 67.2)	1.6% (1.2 – 2.1)	86.6% (85.3 – 87.8)	10.5% (9.4 – 11.7)	2.9% (2.3 – 3.5)
Docked at mid-length	358 (9.8)	23.2% (18.8 – 27.6)	76.2% (71.8 – 80.7)	0.6% (0 – 1.3)	85.7% (82.1 – 89.4)	13.7% (10.1 – 17.3)	0.6% (0 – 1.3)
Undocked	429 (11.8)	14.2% (10.9 – 17.5)	83.0% (79.4 – 86.5)	2.8% (1.2 – 4.4)	84.4% (80.9 – 87.8)	12.3% (9.2 – 15.5)	3.3% (1.6 – 4.9)
AM - antimicrobials							

Table 9 – Mixed ordinal logistic regression model exploring individual-level variation in tail lesions and scarring scores in pigs (N=3636) at the slaughterhouse. The batch was included as a random intercept. For significant variables, odds ratio estimates (OR) and their 95% confidence interval (CI) are presented. Significant p-values and ORs are highlighted in bold.

Response variable	Explanatory variable	Statistic	p-value	Odds Ratios		
					Estimate	95%CI
Tail lesion score	Production system	χ^2_2=3.13	0.21			
	Tail length	χ^2_2=18.35	**0.0001**	undocked vs fully docked	**3.11**	**1.83 – 5.30**
				undocked vs docked at mid-length	**2.10**	**1.01 – 4.39**
				docked at mid-length vs fully docked	1.48	0.83 – 2.65
Scarring score	Production system	χ^2_2=5.34	0.069			
	Tail length	χ^2_2=2.04	0.36			

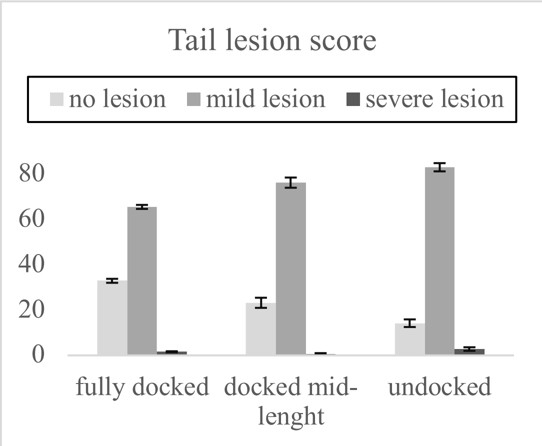

Figure 22 - Tail lesion score prevalence in relation to tail length on individually examined pigs at the slaughterhouse (N=3636).

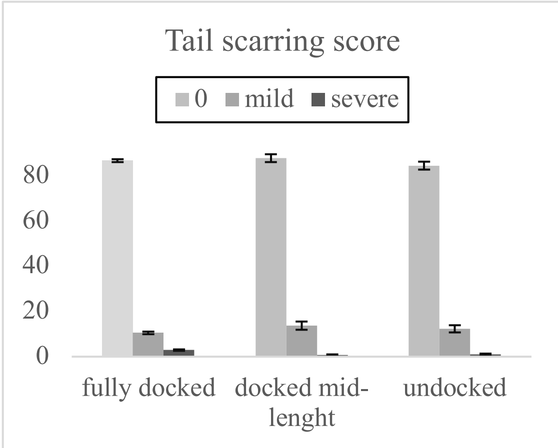

Figure 21 - Tail scarring score prevalence in relation to tail length on individually examined pigs at the slaughterhouse (N=3636).

These results follow the ones previously observed by researchers who stated that tail resection reduced the possibility of tail biting behaviour (Sutherland & Tucker, 2011) and would explain why undocked animals are more prone to develop tail lesions (Luhrmann *et al.*, 2017). The reason why tail biting incidence is lower when tail docking is performed is still not fully understood (Spinka, 2017). The tail may have become less attractive as it is shorter and without long hairs at the tip (EFSA, 2007; Spinka, 2017). Hunter *et al.* (2001) observed that docking procedure seemed to be the most effective way to reduce tail biting. Scollo *et al.* (2013) reported that intact tail pigs were the most common receptors for tail directed behaviour under conventional production. In a study performed to investigate the effect of tail docking in the weaner and finishing phase in heavy pigs, undocked animals showed a higher prevalence for mild tail lesions (di Martino *et al.*, 2015). Li *et al.* (2017) found that tail docked swine had fewer victimised animals with severe tail damage when compared to intact tails group. Recently, Thodberg *et al.* (2018) also demonstrated that docking length affected the probability for a tail biting outbreak and the occurrence of tail-directed behaviour between pen mates, where only the short-docked animals presented a reduced tail biting risk, even with outbreak occurrence.

Although the European council directive requires the progressive reduction of tail docking as a practice detrimental to the welfare of swine (Council of the European Union, 2008), it appears to be very difficult to achieve this reduction without occasional outbreaks of tail biting, especially in conventional production where docking was widely adopted as a preventive measure (EFSA, 2007). Even when production conditions are more favourable, as in the organic production system, tail lesions may be observed.

No significant differences were observed between docked at mid-length or fully docked carcasses regarding the occurrence of tail lesions (Table 9). According to Marchant-Forde *et al.* (2009), tail docking is known to cause pain, discomfort, and distress to piglets who have the freedom to express their normal behaviour denied since, based on Nannoni *et al.* (2014), the missing tail is a tool of communication and interaction among them.

Herskin *et al.* (2016) demonstrated that tail docking caused behavioural changes, such as sudden movements, escape attempts and vocalisation up to 5 hours following treatment. When local anaesthesia was used (e.g., lidocaine), the piglet's reaction to acute pain seemed to diminish. Morrison & Hemsworth (2020) stated that tail docking in 2-day old piglets using either clippers or a cauteriser, increased the piglets' cortisol concentrations at 15- and 30-minutes post-treatment, compared to the control group. Tail docked animals also exhibited increased behaviours characteristic of pain both during the procedure and in the first 60 minutes after, spending more time standing with their heads lowered. Piglets subjected to tail docking vocalised longer and showed additional escape responses during the procedure than piglets in the control treatment, clearly showing signs of distress. After 24 hours, the behavioural responses in the tail docking and control group were similar, which intends that pain had diminished by this time.

Neuroma formation can be a consequence of this procedure, being that its development can occur up to 4 months after docking (Sandercock *et al.*, 2016). They have been associated with diminished nociceptive thresholds (Wall & Gutnick, 1974) and non-evoked pain (Devor *et al.*, 1992). In human medicine, neuromas have been linked to a significant cause of pain. (di Giminiani *et al.*, 2017 a). These have also been described in other animal species (dogs and lambs) as a repercussion of the docking procedure. (French & Morgan, 1992; Gross & Carr, 1990). Herskin *et al.* (2015) suggested that the amputated parts of the tail during docking procedure led to long-term neuroanatomical and morphological consequences, having found neuromas throughout all docking lengths. However, the neuroma's extent was not affected by the tail's size. Different results were found later by Di Giminiani *et al.* (2017 a), showing long docked animals had a lower mean mechanical nociceptive threshold, and therefore, presented a higher sensitivity to mechanical stimuli when compared to intact or short docked pigs, contradicting the previous human literature.

Other consequences of docking can include the risk of infections, mostly if the procedure is performed under poor hygienic conditions (Valros & Heinonen, 2015). In 2020, researchers proved that animals with a larger part of the tail missing presented a higher probability of developing secondary infections (Valros *et al.*, 2020). Therefore, the amount of condemned meat was also higher in carcasses with a large proportion of the tail resected. The animal's growth rate can also be affected (Marchant-Forde *et al.*, 2009).

According to our results, since the odds of developing tail lesions between fully docked and docked at mid-length showed no statistical significance, if we considered the literature stated above allied with animal welfare and economic concerns, it could be beneficial to amputate the tail as little as possible, as an alternative to a shorter resection.

Regarding husbandry systems, conventional production presented the highest prevalence for severe tail lesions and severe scarring (2.1% and 3.1%, respectively; Table 8). In contrast, the organic batches registered the lowest prevalence for severe lesions (0.5%; Table 8) when compared to the other systems. However, these values did not reveal significant differences between the various types of production (Table 9).

The advantages and disadvantages of conventional/organic systems concerning tail biting are controversial among researchers. Tail biting is often seen in conventional indoor husbandry systems (Valros *et al.*, 2004). Hansson *et al.* (2000) proved that conventionally raised pigs had a higher prevalence of tail biting when compared to organic free-range pigs and that these findings were statistically significant. However, recent studies indicate that organic free-range pigs had a higher prevalence of tail lesions when compared to conventional indoor (Alban *et al.*, 2015; Kongsted & Sørensen, 2017). Considering that the organically raised animals were not free-range in our study, we cannot directly compare them with the aforementioned studies. The only asset we can confirm is that organic production does not entirely prevent tail biting behaviour.

A German study conducted in tail docked weaner pigs recorded a higher tail biting prevalence when there was a superior stocking density per pen and in farms with a higher number of animals (Grümpel *et al.*, 2018). Moinard *et al.* (2003) showed that a stocking density of 100kg/m^2 or more also increased the probability of tail biting by 3 times. The percentage of slatted floors, which are used for their economic benefits, is also positively associated with tail biting (Hevia, 2012; Kallio *et al.*, 2018; Moinard *et al.*, 2003). One of the most typical behaviours for pigs is the exploratory, which was a necessary conduct to search for food in the natural environment, where the rooting allowed them to explore their surroundings (Taylor *et al.*, 2010). When the floor is slatted or in concrete, the animals redirect this behaviour to other objects or animals (Hevia, 2012). Van de Weerd *et al.* (2005) found that pigs housed on slatted floors spent more time displaying tail-directed activity towards other pen mates when compared to pigs housed in straw bedding parks. Moinard *et al.* (2003) stated that the risk for biting behaviour increase 2 to 3 times more in total or partially slatted floor systems when compared to solid/concrete floor.

If we consider that conventionally raised pigs presented in this research are housed in fully slatted floors with bedding and a stocked density of 0.65 m^2 per head, we can corroborate this information into confirming the tendency for conventional production to display a higher tail biting occurrence.

1.2 Relationship between *post mortem* findings, tail scores, production system and tail length

Prevalence of *post mortem* findings by tail lesion and tail scarring scores on the pigs examined individually at the slaughterhouse is reported in Table 10. Table 11 expresses a mixed logistic regression model exploring individual-level variation in the probability of observing *post mortem* findings in pigs at the slaughterhouse.

The most common scenario was having a carcass with 1 or 2 findings (80.8%), being the presence of more than 2 findings the rarest event (6.8%) (Table 10). The same result was obtained by Brocke *et al.* (2019) being more than 2 findings the rarer situation. The most common *post mortem* lesions were pneumonia (85%) and pleurisy (32.7%) (Table 10). It was also registered that higher the percentage of mild tail lesions (77.8%), mild and severe scarring (13.7% and 3.6%, respectively), higher the number of *post mortem* findings (Table 10).

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Table 10 - Prevalence of *post mortem* findings by tail lesion and tail scarring scores on the pigs examined individually at the slaughterhouse (N=3636). Unless otherwise specified, 95% confidence intervals (CI) of the prevalence are reported within brackets.

		Tail lesions			Tail scarring		
	N (%)	0	Mild (1,2)	Severe (3,4)	C0	C1	C2
Pigs with no findings	451 (12.4)	37.9% (33.4 – 42.4)	61.6% (57.1 – 66.1)	0.4% (0 – 1.1)	91.3% (88.7 – 93.9)	7.3% (4.9 – 9.7)	1.3% (0.3 – 2.4)
Pigs with 1-2 findings	2937 (80.8)	29.2% (27.6 – 30.8)	68.9% (67.2 – 70.6)	1.9% (1.4 – 2.4)	85.7% (84.5 – 87.0)	11.4% (10.2 – 12.6)	2.9% (2.3 – 3.5)
Pigs with >2 findings	248 (6.8)	20.6% (15.5 – 25.6)	77.8% (72.6 – 83.0)	1.6% (0.1 – 3.2)	82.7% (77.9 – 87.4)	13.7% (9.4 – 18.0)	3.6% (1.3 – 6.0)
Type of finding							
Pleurisy	1189 (32.7)	25.4% (22.9 – 27.9)	72.7% (70.2 – 75.3)	1.8% (1.1 – 2.6)	85.1% (83.0 – 87.1)	11.6% (9.8 – 13.4)	3.4% (2.3 – 4.4)
Pneumonia	3092 (85.0)	28.8% (27.2 – 30.4)	69.5% (67.8 – 71.1)	1.7% (1.3 – 2.2)	85.9% (84.7 – 87.1)	11.3% (10.2 – 12.4)	2.8% (2.2 – 3.4)
Abscess pneumonia	53 (1.4)	20.7% (9.5 – 32.0)	71.7% (59.2 – 84.2)	7.5% (0 – 14.9)	71.7% (59.2 – 84.2)	22.6% (11.0 – 34.3)	5.7% (0 – 12.1)
Purulent pneumonia	19 (0.5)	15.8% (0 – 33.8)	84.2% (66.1 – 100)	–	63.1% (39.3 – 87.0)	21.0% (0.9 – 41.2)	15.8% (0 – 33.8)
Pericarditis	275 (7.6)	21.4% (16.6 – 26.3)	77.4% (72.5 – 82.4)	1.1% (0 – 2.3)	83.3% (78.8 – 87.7)	14.9% (10.7 – 19.1)	0.8% (0.2 – 3.4)
Milk spots	193 (5.3)	25.9% (19.7 – 32.1)	73.0% (66.7 – 79.4)	1.0% (0 – 2.5)	87.0% (82.3 – 91.8)	9.8% (5.6 – 14.1)	3.1% (0.6 – 5.6)

Tail lesion score was positively associated with all the examined findings (all $p<0.05$, see Table 11), while scarring score was associated with all but pneumonia.

It has been documented that carcass findings are associated with tail lesions (vom Brocke *et al.*, 2019). In a Finnish study, major acute wounds were also associated with almost all MI findings (Valros *et al.*, 2020). Findings such as lung lesions or abscesses were also previously documented as associated with tail biting lesions (Huey, 1996; Kritas & Morrison, 2007; Marques *et al.*, 2012). In recent research, most MI findings were commonly recorded in carcasses with lesioned tails when compared to healthy ones. They stated that even though tails appear healed, there might still be an underlying ongoing infection (Valros *et al.*, 2020).

Table 11 - Mixed logistic regression models exploring individual-level variation in the probability of observing *post mortem* findings in pigs (N=3636) at the slaughterhouse. The batch was included as a random intercept. For significant variables, odds ratio estimates (OR) and their 95% confidence interval (CI) are presented. Significant p-values and ORs are highlighted in bold.

Response variable	Explanatory variable	Statistic	p-value	Odds Ratios		
					Estimate	95%CI
Pleurisy	Tail lesion score	χ^2_2=39.68	**<0.0001**	Severe vs no lesions	**2.37**	**1.28 – 4.41**
				Mild vs no lesions	**1.83**	**1.51 – 2.22**
				Severe vs mild lesions	1.30	0.71 - 2.36
	Scarring score	χ^2_2=14.02	**0.0009**	Severe vs no lesions	**1.98**	**1.23 – 3.18**
				Mild vs no lesions	**1.45**	**1.11 – 1.89**
				Severe vs mild lesions	1.36	0.81 – 2.29
	Production system	χ^2_2=3.19	0.20			
	Tail length	χ^2_2=0.45	0.80			
Pneumonia	Tail lesion score	χ^2_2=6.69	**0.035**	Severe vs no lesions	1.36	0.58 – 3.21
				Mild vs no lesions	**1.34**	**1.07 – 1.66**
				Severe vs mild lesions	1.02	0.44 – 2.37
	Scarring score	χ^2_2=2.65	0.27			
	Production system	χ^2_2=2.24	0.33			
	Tail length	χ^2_2=1.21	0.54			
Abscess and purulent pneumonia	Tail lesion score	χ^2_2=14.58	**0.0007**	Severe vs no lesions	**10.68**	**2.97 – 38.5**
				Mild vs no lesions	**2.42**	**1.26 – 4.64**
				Severe vs mild lesions	**4.41**	**1.39– 14.00**
	Scarring score	χ^2_2=23.18	**<0.0001**	Severe vs no lesions	**4.27**	**1.61 – 11.30**
				Mild vs no lesions	**4.22**	**2.20 – 8.07**
				Severe vs mild lesions	1.01	0.35 – 2.91
	Production system	χ^2_2=0.24	0.89			
	Tail length	χ^2_2=5.91	0.055			
Pericarditis	Tail lesion score	χ^2_2=15.64	**0.0004**	Severe vs no lesions	1.07	0.32 – 3.61
				Mild vs no lesions	**1.88**	**1.37 – 2.59**
				Severe vs mild lesions	0.57	0.17 – 1.86
	Scarring score	χ^2_2=10.95	**0.0042**	Severe vs no lesions	0.73	0.28 – 1.86
				Mild vs no lesions	**1.85**	**1.27 – 2.69**
				Severe vs mild lesions	0.40	0.15 – 1.06
	Production system	χ^2_2=1.09	0.58			
	Tail length	χ^2_2=1.87	0.39			

The most common *post mortem* lesions were pneumonia (85%) and pleurisy (32.7%; Table 10). This was also stated by Brocke *et al.* (2019), stressing out the importance of respiratory diseases in swine production. In detail, pigs with severe and mild tail damage (p<0.0001 with OR=2.37 and 1.83, respectively) and tail scarring (p=0.009 with OR=1.98 and OR=1.45, namely) had a higher probability of showing pleurisy than pigs with no lesions (Table 11). Valros *et al.* (2020) also proved that healed tail lesions (which, in these results, reflects scarred lesions) in combination with bite marks or bruises were significantly associated with pleuritis. Pigs presenting mild tail lesions had a higher chance of showing pneumonia (p=0.035, OR=1.34; Table 11) than pigs with no lesions. Abscess pneumonia prevalence for animals with severe tail lesions was higher when compared to other findings (7.5%; Table 10). Although purulent pneumonia was not observed in carcasses presenting severe tail lesions, the percentage of occurrence was higher when the scarring score was C2 (15.8%; Table 10). Pigs with severe and mild tail lesions (p=0.0007) and tail scarring (p<0.0001) had a higher probability of showing these mentioned findings (Table 11).

In a study conducted in 2019, lung findings and pleurisy were more common in animals with severe tail damage (vom Brocke *et al.*, 2019). Kritas & Morrison (2007) discovered an association between the severity of tail biting and the presence of lung abscessation and pleurisy, stating that severe and mild tail lesions reflected a higher odd for the carcass to be trimmed, supporting the theory that tail biting leads to systemic infections that causes abscessiform lesions or infections. According to Marques *et al.* (2012) the lung is one of the most affected organs due to the abundance of small capillaries, supporting the hypothesis that the infectious agents that causes these lesions may spread through blood circulation from the tail to the lung area or others, justifying the sighting of possible embolic pneumonia, pleuritis and lung abscesses.

Respecting pericarditis, pigs with mild tail lesions (p=0.0004, OR=1.88) and tail scarring (p=0.0042, OR=1.85) had higher odds of showing these findings than pigs with no lesions (Table 11). A study conducted in Finland also found a significant association between pericarditis and carcasses with major acute wounds or carcasses with healed tail lesions and no additional bite marks or bruises (Valros *et al.*, 2020).

2 Batch-level analysis

2.1 Relationship between tail scores, production system and tail length

Overall, batch-level scores had a mean value of 0.85 for lesions and 0.17 for scarring. A detailed breakdown of mean scores by production system and tail length is reported in Table 12.

Table 12 - Values (mean ± Standard Error and range) of batch-level (N=73) tail lesions and scarring scores by production system and tail-docking practices in pigs' batches examined at the slaughterhouse.

		Batch tail lesion score		Batch scarring score	
	N	Mean ± SE	Range (min – max)	Mean ± SE	Range (min – max)
All batches	73	0.85 ± 0.03	0.26 – 1.74	0.17 ± 0.02	0 – 0.66
Production System					
Conventional	51	0.87 ± 0.04	0.37 – 1.74	0.18 ± 0.02	0 – 0.66
Conventional without AM	12	0.82 ± 0.06	0.55 – 1.22	0.14 ± 0.03	0 – 0.34
Organic	10	0.75 ± 0.10	0.26 – 1.12	0.13 ± 0.03	0 – 0.31
Tail-docking					
Fully docked	57	0.80 ± 0.03	0.26 – 1.39	0.16 ± 0.02	0 – 0.66
Docked at mid-length	7	0.88 ± 0.07	0.64 – 1.12	0.16 ± 0.03	0.06 – 0.31
Undocked	9	1.10 ± 0.10	0.76 – 1.74	0.19 ± 0.04	0.04 – 0.42

AM - antimicrobials

Regarding tail length, undocked animals had a higher mean value for both tail scores (1.10 and 0.19, respectively) compared to the other categories (Table 12). These findings corroborate what was previously stated relating to tail resection and the possibility of reducing tail biting behaviour and therefore would explain why undocked animals are more prone to develop tail damage (di Martino *et al.*, 2015; Hunter *et al.*, 2001; Lahrmann *et al.*, 2017; Li *et al.*, 2017; Scollo *et al.*, 2013; Sutherland & Tucker, 2011; Thodberg *et al.*, 2018).

In terms of husbandry systems, conventional production presented the highest mean value of all productions regarding tail lesion score (0.87) and tail scarring score (0.18). In contrast, the organic batches had the lowest mean value for both scores at batch-level values (0.75 and 0.13, respectively; Table 12). These results reinforce what was previously mentioned relating to the tendency for conventional production to own a higher tail biting prevalence.

2.2 Relationship between total condemnations and tail scores, production system and tail length

Table 13 presents the batch- and all population-level prevalence of total condemnations (and respective causes) and its distribution over the various production types. Table 14 presents the results regarding the logistic regression model exploring batch-level variation in the occurrence of total condemnations.

Table 13 - Batch-level (% of batches with at least one condemnation/no. of examined batches) and all population-level (% of pigs/no. of examined pigs) prevalence of total condemnations (and respective cause) and its distribution over the various production types. Unless otherwise specified, 95% confidence intervals (CI) of the prevalence are reported within brackets.

	Batch-level (N=73)	All population (N=9189)	Conventional (N=7201)	Conventional without AM (N=1348)	Organic (N=640)
Total condemnations (TC)	52.1 %, 48 (40.59 – 63.52)	0.8%, 70 (0.6 – 0.9)	0.8%, 58 (0.6 – 1.0)	0.3%, 4 (0.01 – 0.6)	1.3%, 8 (1 – 1.5)
Causes for total condemnation					
Pyemia	38.4%, 28 (27.2 – 49.5)	0.5%, 49 (0.4 – 0.7)	0.6%, 42 (0.4 – 0.8)	0.2%, 3 (0 – 0.5)	0.6%, 4 (0.01 – 1.2)
Peritonitis	13.7%, 10 (5.81 – 21.6)	0.1%, 10 (0.04 – 0.2)	0.1%, 7 (0.03 – 0.2)	0.1%, 1 (0 – 0.2)	0.3%, 2 (0 – 0.7)
Jaundice	2.7%, 2 (0 – 6.5)	0.02%, 2 (0 – 0.05)	0.03%, 2 (0 – 0.07)	0	0
Organoleptic alterations	4.1%, 3 (0 – 8.7)	0.03%, 3 (0 – 0.07)	0.04%, 3 (0 – 0.1)	0	0
Inflammation	4.1%, 3 (0 – 8.7)	0.03%,3 (0 – 0.07)	0.04%, 3 (0 – 0.1)	0	0
Trauma	1.4%, 1 (0 – 4.0)	0.01%, 1 (0 – 0.03)	0.01%, 1 (0 – 0.04)	0	0
Erysipelas	1.4%, 1 (0 – 4.0)	0.02%, 2 (0 – 0.05)	0	0	0.3%, 2 (0 – 0.7)
AM - antimicrobials					

The number for total condemnations (N=9189 animals) was 0.8% (n=70), with 52.1% (n=48 of 73) of the batches having at least one condemnation accounted for (Table 13). In a Portuguese study conducted on 211159 finisher pigs, 240 carcasses (0.11%) were entirely condemned (Vieira-Pinto *et al.*, 2020). Valros *et al.* (2004) conducted a survey where 0.6% of 10852 animals were entirely condemned, so these current results are similar.

Pyemia was the most common cause of condemnation in all productions (0.5%), followed by peritonitis (0.1%; Table 13). Pyemia can be defined as a systemic infection due to the generalised hematogenous spread of pyogenic bacteria (Vieira-Pinto *et al.*, 2020). According to several surveys performed in Portugal, vertebral osteomyelitis, defined as a possible consequence of pyemia, is an inflammation with medullar cavity involvement and was also the most recurrent cause of *post mortem* carcass condemnation (Garcia-Diez & Coelho, 2014; Vieira-Pinto *et al.*, 2020). Since we included osteomyelitis and the presence of multiple abscesses in the same category (pyemia) without distinction, we cannot perform a direct comparison.

The only two condemnations by Erysipelas were registered in organic production (Table 13), which was expected if we consider the fact that the pigs from this type of production have exterior access and can be exposed to infected water or infected mammals' urine or faeces (e.g. birds and rodents), which are a form of transmission for this disease (Jackson & Cockcroft, 2007). Jaundice, organoleptic alterations of the carcass, inflammation and trauma existed only in conventional production in percentages lower than 0.1% (Table 13). We can relate this to sample size discrepancy (being conventional pigs 71.4% of the observed animals; Table 7), and therefore as the number of animals increases, the probability of observing uncommon lesions increases as well.

Table 14 - Logistic regression model exploring batch-level variation in the occurrence of total condemnations in pigs' batches (N=73) at the slaughterhouse. For significant variables, odds ratio estimates (OR) and their 95% confident intervals (CI) are presented, with estimates for continuous scores calculated for a 0.5 unit increase. Significant p-values and ORs are highlighted in bold.

Response variable	Explanatory variable	Statistic	p-value	Odds Ratios		
					Estimate	95%CI
Total condemnations	Batch tail lesion score	χ^2_1=5.98	**0.0145**		**1.81**	**1.12 – 2.91**
	Batch scarring score	χ^2_1=13.81	**0.0002**		**3.24**	**1.74 – 6.02**
	Production system	χ^2_2=7.27	**0.0263**	Organic vs conventional	**2.27**	**1.07 – 4.81**
				Organic vs conventional without AM	**4.36**	**1.38 – 13.7**
				Conventional without AM vs conventional	0.52	0.19 – 1.40
	Tail length	χ^2_2=0.06	0.97			

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As it is possible to observe in Table 14, batches with higher tail lesion scores presented a significant (p=0.014) higher probability (OR=1.81) of observing total condemnations. This result highlights the financial impact of tail lesions due to total condemnations, following the results presented by Valros *et al.* (2020) and Marques *et al.*

(2012), who proved that animals with higher tail lesion scores had higher odds for carcass condemnation. Similarly, the probability for total condemnations in a batch was strongly associated (p=0.0002) with tail scarring scores, with an increase of 0.5 units in the score leading to more than a 3-fold increase in the odds of having a total condemnation (Table 14). In 2004, (Valros *et al.*, 2004) showed that healed tail damage also significantly increased the risk of condemnation. This underlines scar evaluation as a valuable parameter to be included in any tail lesion score scheme used at the abattoir level.

In this study, besides evaluating bite lesions through a classical system, another classification system was included to assess the presence of healed lesions through scars. This was decided since although tail lesions can be absent at the time of slaughter, it does not exclude the possibility that they have not occurred during the animal's life. They could be already healed locally at the time of slaughter and therefore would not be detected during PMI (Kruse *et al.*, 2015; Marques *et al.*, 2012) or could even be hard to distinguish from docked tails during *post mortem* evaluation (Taylor *et al.*, 2010). In these cases, a scar may be seen with or without a reduction in the size of the tail.

The probability of observing total condemnations varied depending on the production system (p=0.03), with organic farms showing a higher probability of total condemnation occurrence than conventional and conventional without AM productions (OR=2.27 and OR=4.36, respectively; Table 14). Indeed, 1.3% of organic batches registered at least one total condemnation and only 0.8% and 0.3% of conventional and conventional without AM, respectively (Table 13). Some researchers supported this finding, stating that the prevalence of animals rejected *post mortem* was higher in organic production than conventional (Kongsted & Sørensen, 2017). According to Lis Alban *et al.* (2015), a higher number of lesions in organic production (which in this case could reflect in total condemnations) might be linked to the prohibition to use AM where the absence of correct treatment leads to generalised bacterial infection and causes these condemnations rates. However, although AM restrictions are also applied to the conventional without the administration of AM production system, this prohibition is only applicable from the 65^{th} day of the pig's life. This fact, associated with better batch health management and prophylactic measures, might justify why this production system had the lowest number of condemnations rates in this study. However, a direct comparison cannot be performed since the finisher pigs considered in this study are not free-range.

2.3 Relationship between total condemnations by pyemia, tail scores, production system and tail length

Pyemia was the most common cause of condemnation found in this study. Since several researchers support a close relation between tail biting and abscess formation or pyemia (Huey, 1996; Kritas & Morrison, 2007; Marques *et al.*, 2012; Valros *et al.*, 2004, 2020), it was the only evaluated parameter by the statistical model.

Table 15 presents the results regarding the logistic regression model exploring batch-level variation in the occurrence of total condemnation by pyemia (the leading cause of condemnation) in pigs' batches (N=73) at the slaughterhouse.

Table 15 - Logistic regression model exploring batch-level variation in the occurrence of total condemnations by pyemia in pigs' batches (N=73) at the slaughterhouse. For significant variables, odds ratio estimates (OR) and their 95% confidence interval (CI) are presented, with estimates for continuous scores calculated for a 0.5 unit increase. Significant p-values and ORs are highlighted in bold.

Response variable	Explanatory variable	Statistic	p-value	Odds Ratios	
				Estimate	95%CI
Total condemnations by pyemia	Batch tail lesion score	χ^2_1=6.22	**0.0126**	**2.06**	**1.16 – 3.63**
	Batch scarring score	χ^2_1=13.79	**0.0002**	**3.86**	**1.89 – 7.88**
	Production system	χ^2_2=2.30	0.32		
	Tail length	χ^2_2=0.45	0.80		

As it is possible to observe in Table 15, pyemia showed significative and highly significative association with tail lesion (p=0.013) and scarring (p=0,0002) scores, respectively, with the batches with the higher score for tail scarring having 3 times more probability of total condemnation. These results stress out the importance of tail lesions as an important source of secondary infection leading to generalised condition like pyemia (Marques *et al.*, 2012; Martínez *et al.*, 2007) and highlight once again the importance of using the scar lesion score during the classification of tails at the abattoir.

2.4 Relationship between local condemnations of carcass anatomical regions and tail scores, production system and tail length

Batch-level (percentage of batches with at least one condemnation/no. of examined batches) and population-level (percentage of pigs/no. of examined pigs) prevalence of local condemnations and their distribution over the various production types are presented in Table 16. Breakdown of prevalence by parts condemned is also reported. Table 17 represents a logistic regression model exploring batch-level variation in local condemnation probability and parts condemned within pigs' batches at the slaughterhouse.

Table 16 - Batch-level (% of batches with at least one condemnation/no. of examined batches) and all population-level (% of pigs/no. of examined pigs) prevalence of local condemnations and its distribution over the various production types. Unless otherwise specified, 95% confidence intervals (CI) of the prevalence are reported within brackets.

	Batch- level (N=73)	All pigs (N=9189)	Conventional (N=7201)	Organic (N=640)	Conventional without AM (N=1348)
Local condemnations (LC) – N, %	69, 94.5% (89.3 – 99.8)	692, 7.5% (7.0 – 8.1)	565, 7.9% (7.2 – 8.5)	48, 7.5% (5.5 – 9.5)	79, 5.9% (4.6 – 7.1)
Parts condemned					
Anterior third	26, 35.6% (24.6 – 46.6)	62, 0.7% (0.5 – 0.8)	56, 0.8% (0.6 – 1.0)	1, 0.2% (0 – 0.5)	5, 0.4% (0.05 – 0.7)
Posterior third	12, 16.4% (7.9 – 24.9)	14, 0.15% (0.1 – 0.2)	13, 0.2% (0.1 – 0.3)	0	1, 0.1% (0 – 0.2)
Head	35, 48% (36.5 – 59.4)	48, 0.5% (0.4 – 0.7)	39, 0.5% (0.4 – 0.7)	3, 0.5% (0 – 1.0)	6, 0.5% (0.1 – 0.8)
Ribs	56, 76.7% (67.0 – 86.4)	450, 4.9% (4.5 – 5.3)	375, 5.2% (4.7 – 5.7)	33, 5.2% (3.4 – 6.9)	42, 3.1% (2.2 – 4.04)
Rabada	23, 31.5% (20.9 – 42.2)	84, 0.9% (0.7 – 1.1)	59, 0.8% (0.6 – 1.0)	11, 1.8% (0.7 – 2.7)	14, 1.04% (0.5 – 1.6)
Hock	17, 23.3% (13.6 – 33)	28, 0.3% (0.2 – 0.4)	21, 0.3% (0.2 – 0.4)	0	7, 0.5% (0.1 – 0.9)
Shoulder	2, 2.7% (0 – 6.5)	2, 0.02% (0 – 0.05)	1, 0.01% (0 – 0.04)	0	1, 0.1% (0 – 0.2)
Ham	1, 1.4% (0 – 4.0)	1, 0.01% (0 – 0.03)	1, 0.01% (0 – 0.04)	0	0

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Regarding local condemnations, 692 out of 9189 (7.5%) pigs' carcasses were locally condemned, with 94.5% (69/73) of the batches having at least one accounted (Table 16). This prevalence is similar when compared to a study performed in Finland in 2004, where 7.0% of the observed pigs were locally condemned (Valros *et al.*, 2004).

In all production systems, ribs were the most condemned area (76.7%), followed by head (48%), anterior third (35.6%), rabada (31.5%), hock (23.3%), posterior third (16.4%), shoulder (2.7%) and ham (1.4%) (Table 16). Similar results were previously found by Harley *et al.* (2014) and Valros *et al.* (2004). Condemnation of ribs was related to pleurisy, where the adherence made it impossible to remove the pleura from the ribs. This result reflects the importance of respiratory diseases as a common finding in swine productions worldwide and its economic impact during MI.

Table 17 - Logistic regression model exploring batch-level variation in local condemnation probability and parts condemned within pigs' batches (N=73) at the slaughterhouse. For significant variables, odds ratio estimates (OR) and their 95% confidence interval (CI) are presented, with estimates for continuous scores calculated for a 0.5-unit increase. Significant p-values and ORs are highlighted in bold.

Response variable	Explanatory variable	Statistic	p-value	Odds Ratios		
					Estimate	95%CI
Local condemnations	Batch tail lesion score	χ^2_1=1.33	0.50			
	Batch scarring score	χ^2_1=57.7	**<0.0001**		**6.28**	**3.9 – 10.09**
	Production system	χ^2_2=3.22	0.20			
	Tail length	χ^2_2=4.07	0.13			
Anterior third	Batch tail lesion score	χ^2_1=1.33	0.25			
	Batch scarring score	χ^2_1=4.54	**0.033**		**2.13**	**1.06 – 4.26**
	Production system	χ^2_2=3.21	0.20			
	Tail length	χ^2_2=1.29	0.52			
Head	Batch tail lesion score	χ^2_1=0.15	0.69			
	Batch scarring score	χ^2_1=1.95	0.16			
	Production system	χ^2_2=0.57	0.75			
	Tail length	χ^2_2=4.16	0.12			
Ribs	Batch tail lesion score	χ^2_1=1.19	0.28			
	Batch scarring score	χ^2_1=26.3	**<0.0001**		**2.18**	**1.59 – 2.84**
	Production system	χ^2_2=4.04	0.13			
	Tail length	χ^2_2=9.44	**0.0089**	Fully docked vs undocked	**1.85**	**0.36 - 0.83**
				Undocked vs docked at mid-length	0.72	0.43 – 1.20
				Fully docked at mid-length vs docked	0.76	0.53 – 1.10
Rabada	Batch tail lesion score	χ^2_1=0.13	0.72			
	Batch scarring score	χ^2_1=40.29	**<0.0001**		**7.61**	**4.07 – 14.25**
	Production system	χ^2_2=15.0	**0.0006**	Organic vs conventional	**3.99**	**1.98 – 8.04**
				Organic vs conventional without AM	**2.97**	**1.32 – 6.67**
				Conventional without AM vs conventional	1.34	0.72 – 2.48
	Tail length	χ^2_2=44.47	**<0.0001**	Undocked vs fully docked	1.56	0.77 – 3.13
				Docked at mid-length vs undocked	**3.84**	**0.12 – 0.55**
				Docked at mid-length vs fully docked	**6.07**	**3.57 – 10.33**

AM - antimicrobials

The second most condemned region was the head (Table 16). These condemnations, which included the neck region, were mainly related to the presence of abscesses. Since it is one of the most common inoculation areas for intramuscular and subcutaneous injections, it allows us to equate the hypothesis that these rejections may be associated with poor practice in this procedure (Coelho *et al.*, 2019). Heads condemnations were also not associated with any of the examined variables (Table 17), which supports that head abscesses are potentially related to incorrect practices rather than tail lesions (King *et al.*, 2010).

For overall numbers, the within-batches probability for local condemnations increased significantly with higher scarring scores (all $p<0.05$, Table 17), while it was not affected by tail lesion scores, highlighting the importance of scarring over the classical tail lesion classification. This result follows the ones found by Valros *et al.* (2020) in Finland, which demonstrated that healed lesions, in combination with bite marks or bruises, were associated with partial carcass condemnations and abscesses.

Ribs and *rabada* condemnations association with tail length showed to be significant ($p=0.009$ and $p<0.0001$, respectively), with the former (ribs) showing higher odds of being condemned in fully docked than undocked pigs (OR=1.85) and the latter (*rabada*) showing the highest odds in pigs with tail docked at mid-length when compared to fully docked or undocked (OR=6.07 and OR=3.84, respectively; Table 17). These contradictory results can be attributed to the low occurrence of some events and sample discrepancy, since fully docked animals represented about 78.3% of the total sample, while docked at mid-length represented only 9.8% (Table 7).

Conventional pigs had a higher percentage for rejected parts when compared to the rest of the batches (7.9%). Condemnations of posterior thirds, hock and shoulder were not observed in organic production, which could be attributed to sampling discrepancy (Table 7). Regarding hock condemnation, Alban *et al.* (2015) stated that scar/hock lesions were more prone to occur in conventional production than in organic, which would explain why it would not be recorded in organic production.

Additionally, *rabada* was more likely to be condemned in organic systems compared to both conventional (OR=3.99) and conventional without AM (OR=2.97) (Table 17). Hence *rabada* is a specific cut, and we cannot find current studies that directly evaluate this parameter. Due to its anatomical location, it can be hypothesised that *rabada* condemnations may be related to tail abscessation. If we take into consideration Lis Alban's research, tail lesion, tail infections and abscesses in hindquarters were all more frequent in organic production when compared to conventional being that difference highly significant, which support the thesis that these lesions in the *rabada* area can, in fact, be linked to the production system (Alban *et al.*, 2015).

2.5 <u>Relationship between local condemnations of carcass anatomical regions by abscess and tail scores, production system and tail length</u>

Table 18 represents a logistic regression model exploring batch-level variation for local condemnation by abscesses probability within pigs' batches at the slaughterhouse.

Table 18 - Logistic regression model exploring batch-level variation in local condemnation by abscesses probability within pigs' batches (N=73) at the slaughterhouse. For significant variables, odds ratio estimates (OR) and their 95% confidence interval (CI) are presented, with estimates for continuous scores calculated for a 0.5 unit increase. Significant p-values and ORs are highlighted in bold.

Response variable	Explanatory variable	Statistic	p-value	Odds Ratios		
					Estimate	95%CI
Local condemnations by abscess	Batch tail lesion score	$\chi^2_1=0.50$	0.48			
	Batch scarring score	$\chi^2_1=44.69$	**<0.0001**		**3.65**	**2.50 – 5.34**
	Production system	$\chi^2_2=2.01$	0.37			
	Tail length	$\chi^2_2=17.24$	**0.0002**	Undocked vs fully docked	**1.70**	**1.13 – 2.57**
				Undocked vs docked at mid-length	0.81	0.49 – 1.33
				Docked at mid-length vs fully docked	**2.10**	**1.43 – 3.10**

Concerning specific condemnations by abscesses, once again, they increased significantly with higher scarring scores ($p<0.0001$, OR=3.65). Tail length was also significant ($p=0.0002$), with docked at mid-length and undocked carcasses having more odds to show abscess condemnations than fully docked (OR=2.10 and OR=1.70, namely) (Table 18).

As previously mentioned, undocked pigs present a higher risk for tail biting behaviour (di Martino *et al.*, 2015; Sutherland & Tucker, 2011; Wallgren *et al.*, 2016). This assumption was later proved by a research where undocked pigs presented more tail lesions than docked (Lahrmann *et al.*, 2017). It is known that undocked pigs experience severe tail damage more frequently and are more likely subjected to carcass trim when compared to pigs without tail lesions. Pigs with undocked tails also have more probability of being treated with AM and being moved to hospital pens when compared with tail docked pigs (Lahrmann *et al.*, 2017). This indirectly supports our finding if we associate the need to administer AM with a current bacterial infection.

Tail lesions act as a point of entry for infection agents serving three separate routes for its dissemination: venous, lymphatic and cerebro-spinal drainage (Huey, 1996). Therefore, an association between tail lesions and abscessation can be established (Huey, 1996; Kritas & Morrison, 2007; Marques *et al.*, 2012; Valros *et al.*, 2004, 2020).

V. Conclusions

This study evaluated the association of tail scores with production system, tail length, *post mortem* findings, and carcass condemnations in Spanish pigs.

Tail docking is widely used to prevent tail biting and associated complications, although the practice causes great stress to piglets. This research proved that undocked pigs were associated with severe tail lesions and abscess condemnations. However, the negative impact of the docking procedure should be weighted, mainly on the pigs' welfare. Therefore, according to our results, it can be beneficial to resect a smaller proportion of the tail, in the impossibility of leaving the tails intact.

Tail lesion score was only influenced by tail length, while the scarring score was not affected by any of the variables, supporting that the second could provide a more solid data analysis. By analysing the *post mortem* findings, an association between all the findings and tail lesion score was found, which proved it could be beneficial to use tail condition as a possible prediction tool for these types of findings.

As both tail scores increased, the probability of observing total condemnation in a batch was higher, having the scarring score a more substantial effect. When it was narrowed down to condemnations by abscess regarding local condemnation, only the scarring score remained a constant indicator, presenting a more relevant role when compared to tail lesion score. This strongly supports the importance of developing more studies featuring tail scarring assessment in slaughterhouse meat inspection.

Organic farms showed a higher probability for total condemnation, probably because these animals are deprived of AM, and therefore are more prone to develop systemic infections, which leads to condemnations. Regarding tail condition, we cannot exclude the presence of tail biting behaviour just because the animals were organically raised. Although there was not a statistical significance regarding tail scores and production system, there was a higher prevalence of tail lesions in conventional herds, creating a theory that the housing conditions, stocking density, inability to perform natural behaviour and augmented stress which the pigs are subjected can lead express abnormal behaviour such as tail biting. Therefore, we can only affirm with certainty that organically raised pigs are not exempt from developing tail biting.

It is well known that tail biting can lead to tremendous economic losses due to augmented condemnation rates. There is an emergent need to surveillance this type of lesion both at the slaughterhouse and farm-level. It would be highly beneficial to create a communication channel between these organisations, where the farm could have a better perception of the batch's health and welfare from the evaluations communicated by the abattoir, and the latest could estimate a batch's economic value according to farm records, vice-versa.

This research concludes that the tail scarring score presented a close relationship with total and local condemnations and *post mortem* findings, showing that more studies should be performed in order to include scarred lesions in the tail surveillance program.

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