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REVIEW ARTICLE

Tail Biting in Pigs: Behavioral Signs, Welfare Impact, Risk Factors, and Prevention Strategies

Ishaya UG[1*], Vanessa AM[2], Yolanda D[3], Rutendo PM[3], Methun CD[4], Abdullateef AI[5], Chidiebere NA[6], Michael Idowu B[6] and Samuel UE[7]

[1]School of Agriculture and Food Sustainability, University of Queensland, Gatton, QLD 4343, Australia
[2]Department of Livestock Sciences, University of Zimbabwe, Churchill Ave, Harare 630, Zimbabwe
[3]Department of Livestock Sciences, Faculty of Agriculture, Environment and Food Systems, University of Zimbabwe, Mount Pleasant, Harare, 263, Zimbabwe
[4]Institute of Livestock Science and Technology, Netrokona 2400, Bangladesh
[5]Department of Animal Production, Faculty of Agriculture, University of Jos, Plateau State 930001, Nigeria
[6]Department of Animal Science, University of Ibadan, Ibadan, Oyo State 200005, Nigeria
[7]Department of Animal Production and Health, Federal University of Agriculture, Abeokuta, Ogun State 111101, Nigeria

Abstract

Tail biting in pigs remains a persistent welfare and economic challenge in commercial pig production, despite decades of research. This harmful behavior is driven by a combination of genetic, environmental, and management factors, resulting in injuries, infections, and reduced growth performance. Tail-bitten pigs showed 10-21 g/day lower average daily gain compared to non-bitten pigs. Additionally, tail-bitten pigs exhibited poorer feed efficiency, resulting in increased production costs. Farmers have traditionally relied on tail docking to prevent tail biting. However, this practice causes pain and fails to fully address the issue, as studies show that 96% of docked pigs still exhibit minor tail damage. To combat tail biting effectively, a holistic approach is necessary. Providing manipulable substrates, such as straw, ropes, or wood, reduces tail biting by 65-88%. Ensuring adequate feeder space and improving ventilation are also key environmental interventions. Enhanced human-animal interaction during rearing has also been shown to reduce tail biting in piglets. Beyond housing adjustments, Precision Livestock Farming (PLF) technologies, including automated monitoring systems, enable early detection of stress and behavioral changes by monitoring tail posture (e.g., 3D cameras, RFID sensors), allowing timely intervention. Nutritional strategies, such as balanced protein/amino acid levels, further support pig health and reduce aggression. Genetic selection offers long-term potential by breeding for resilience traits (h² = 25-36%) and pigs less prone to tail biting, while improved husbandry practices strengthen overall herd resilience. When outbreaks occur, rapid response protocols such as isolating affected pigs and increasing enrichment help minimize damage. Farmer education is critical to ensure these strategies are properly implemented. By integrating environmental, technological, nutritional, and genetic solutions, the pig industry can move away from tail docking while improving welfare and productivity.

Introduction

Tail biting in pigs has long been recognised as a formidable challenge in commercial pig production, persisting for at least 50 years with an apparent increase in frequency over time [1,2]. This abnormal behavior is globally recognized as a significant concern, impacting both animal

welfare and economic viability within the swine industry [3-5]. The genesis of tail biting is complex and multifactorial, stemming from a variety of internal and external factors including genetics, nutrition, environment, and management [6]. Key environmental risk factors frequently identified include the absence or insufficiency of manipulable enrichment materials, the presence of fully slatted floors, overcrowding at feeders, high stocking densities, and inadequate housing climate conditions [7]. Health problems, such as respiratory disease and feeding issues, also contribute to outbreaks [5,8]. The consequences of tail biting extend far beyond mere superficial damage, inflicting severe pain and stress upon affected pigs [9]. Injuries commonly lead to systemic infections, abscesses, and arthritis, severely compromising the animals' health [10]. Pigs subjected to tail biting may also suffer from respiratory diseases and gastric ulcers, further exacerbating their suffering [11]. Nutritional elements, such as dietary fiber, protein, feed form, and competition at the feeder, as well as the intricate relationship between gut health and behavior via the microbiota-gut-brain axis, also play a role [12,13]. Health problems, including respiratory diseases and a generalized activation of the immune system, further contribute to outbreaks [14-16].

From an economic standpoint, tail biting results in substantial losses for producers, manifested as reduced weight gain, diminished carcass weights, and partial or total carcass condemnations due to secondary bacterial infections [9,17]. In fact, osteomyelitis, a bone infection, is frequently caused by the entry of pathogens through open wounds, such as those resulting from tail biting, and it represents a significant cause of total carcass condemnation in abattoirs [11]. Decisions regarding condemnation are often influenced by traditional perceptions of pyaemia risk, highlighting the need for more explicit criteria [18].

Historically, tail docking, a procedure involving the removal of part of a pig's tail, has been a widespread preventive measure, proven to reduce the occurrence and severity of tail biting [13,19]. However, this practice is inherently painful for pigs and can lead to long-term chronic pain and nerve damage (neuromas) [20]. Crucially, tail docking fails to address the underlying welfare issues that precipitate tail biting behaviour [1,20,21]. Consequently, routine tail docking has been prohibited by European Union law, with exceptions granted only when other preventative measures prove insufficient [22,23]. Despite this legislation, a significant proportion, approximately 90 to 95%, of pigs in the EU continue to undergo tail docking due to farmers' reluctance to cease the practice, driven by fears of failure, economic repercussions, and the complex multifactorial nature of tail biting outbreaks [2].

To reduce dependence on tail docking, research has increasingly focused on developing and implementing alternative strategies. Environmental enrichment, such as providing straw, wood, or ropes, is not only mandated by EU law but has also shown considerable efficacy in reducing tail damage [24-30]. However, the results can be inconsistent, and practical challenges like the risk of slurry system blockages, increased labor, and biosecurity concerns often limit the widespread adoption of certain materials like straw in commercial settings [13]. Early detection is crucial for timely and effective interventions to mitigate tail-biting outbreaks [31-34]. Indicators such as subtle changes in tail posture (e.g., lowered or tucked tails), increased restlessness, altered body posture, or changes in feeding or drinking behaviour can serve as early warnings [34]. The development of automated systems for early warning, leveraging technologies like 3D cameras to detect changes in tail posture, represents a promising area of advancement in precision livestock farming [31,32,35,36]. When outbreaks occur, interventions often involve removing affected pigs or suspected biters from the pen or adding more enrichment material [6,37]. Studies suggest that the success of these interventions depends more on the proportion of biters and victims in a pen than on the specific method used, emphasizing the need for prompt action [7,22]. Other management adjustments, like lowering stocking density and ensuring adequate feeding space, are also vital [4,7].

Interestingly, farmers' perceptions of effective preventive measures may differ from those of scientists, often reflecting a more holistic, experience-based view of the farm environment [13,18,38]. Additionally, the potential health risks associated with mycotoxin contamination in certain organic enrichment materials, particularly maize products, should be taken into consideration [12,18].

Furthermore, slaughterhouse monitoring plays a crucial role in assessing the prevalence of tail lesions and overall animal welfare at a farm level [9,11,39-41]. Tail lesions are often more visible on carcasses

than on live animals. However, challenges exist due to varying scoring systems and the potential for underestimation if severely affected pigs die on-farm or lesions heal before slaughter [9,11,18,39-41]). The inclusion of scarring scores in monitoring programs has been suggested to provide a more detailed classification of lesions [19,22,26,38,42-44]. Understanding the risk factors of tail biting and behavioral signs, and their impact on animal welfare, as well as strategies for prevention and management, is crucial for addressing this multifactorial problem [4,18,19,23,42, 43,45,46]. Therefore, the main aim of this study is to comprehensively review existing research on the impact of tail biting on pig growth performance, welfare and health, and to investigate the intricate dietary and physiological links. In addition, this study seeks to identify effective on-farm management and intervention strategies that reduce the need for painful tail docking while improving overall pig health and welfare. This concerted effort is of paramount importance, not only for ethical reasons related to animal well-being, but also for ensuring the sustainable economic viability of modern pig production systems.

Classifications of Tail Biting in Pigs

Tail biting is defined as injury to the tail of different degrees of severity through manipulations with the mouth [47]. Differences exist in the manner of how the behavior is expressed, as well as in the underlying causes [47], which could be influenced by behavioral, environmental, genetic, and welfare-related factors. Understanding these factors is crucial for developing effective prevention and intervention strategies to mitigate their occurrence in pig production [4].

Behavioral factors

Tail biting is broadly classified into four distinct forms, including: 'two-stage,' 'sudden-forceful,' 'obsessive,' and 'suddenly occurring, epidemic' [48] (Figure 1). The 'two-stage' type, which initiates with a pre-injury phase followed by visible tail damage, is often attributed to a lack of rooting substrate or biologically relevant environmental enrichment [4,14,33,49]. Another form is 'sudden-forceful' tail biting, characterized by an acute clinical onset of injury without a discernible pre-injury stage, believed to be precipitated by animal frustration due to insufficient environmental resources and physical discomfort [50]. The third type is 'obsessive' tail biting, where a pig becomes fixated on manipulating the tails of pen mates, with no clear motivation, though a genetic component has been hypothesized[2, 14, 51]. The human-animal relationship can influence behavior and performance, and intensified human-animal interaction during rearing can reduce tail biting in weaned piglets [7]. Pigs categorized as tail-biters, tail-bite victims, and control pigs showed differences in behavioral and physiological responses, suggesting dysfunctional autonomic regulation, which may indicate psychological disturbance in both victims and biters [52]. The ability to cope with stressful situations may vary between individuals, and behavioral responses could be consistent across different fear-eliciting situations, potentially impacting the likelihood of being a tail-biter or victim [53].

Environmental factors

Possible risk factors for tail biting include environmental factors such as insufficient enrichment, improper weaning management,
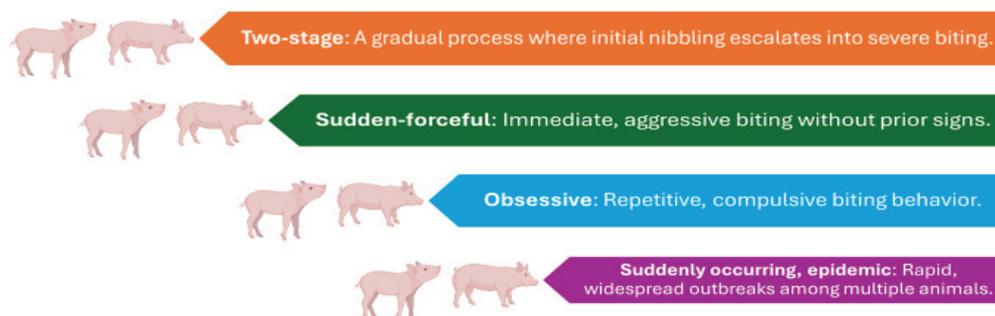

Figure 1 Types of tail biting in pigs.

inadequate climate and ventilation, improper feeding, excessive stocking density, and large group sizes, as well as animal-specific factors, including health status, genetic predisposition, and gender [47] (Figure 2). The development of tail damage over time may provide more accurate information on external and internal factors affecting tail biting than end-point observation [54]. The presence of manipulable materials is essential to control the risk of tail biting and avoid tail-docking, and the absence of such materials can increase the risk of tail biting in weaners and rearing pigs [2,51,55].

Genetic factors

The multi-factorial nature of tail biting suggests analyses should consider breeding, husbandry, and feeding aspects simultaneously, including genotype × environment or genotype × feeding interactions [56]. Pigs housed in control pens performed a wider variety of pig-directed abnormal behavior compared to neutral pigs, suggesting that neutral pigs have a genetic and behavioral profile that makes them resistant to performing or receiving pig-directed abnormal behavior, such as tail biting [57].

Welfare implications

Tail biting is a significant welfare issue in the swine industry, causing distress to victims and negatively impacting farm profitability [3]. The suffering associated with tail damage and the expression of tail-biting behaviors are influenced by pig-specific factors, and continuous recording of animal and environmental data is essential to reduce its prevalence [58]. Detecting early indicators of tail biting would allow farmers to implement intervention measures and minimize negative consequences. The Bite-o-Mat, a device to automatically detect enrichment manipulation behavior, shows potential for early detection of tail lesions due to tail biting across multiple production periods [32].

Effects of Tail Biting on the Growth Performance of Pigs

Tail biting is a pervasive issue in pig production, with detrimental effects on growth performance, welfare, and economic outcomes (Figure 3). Research indicates that tail biting has a negative impact on key
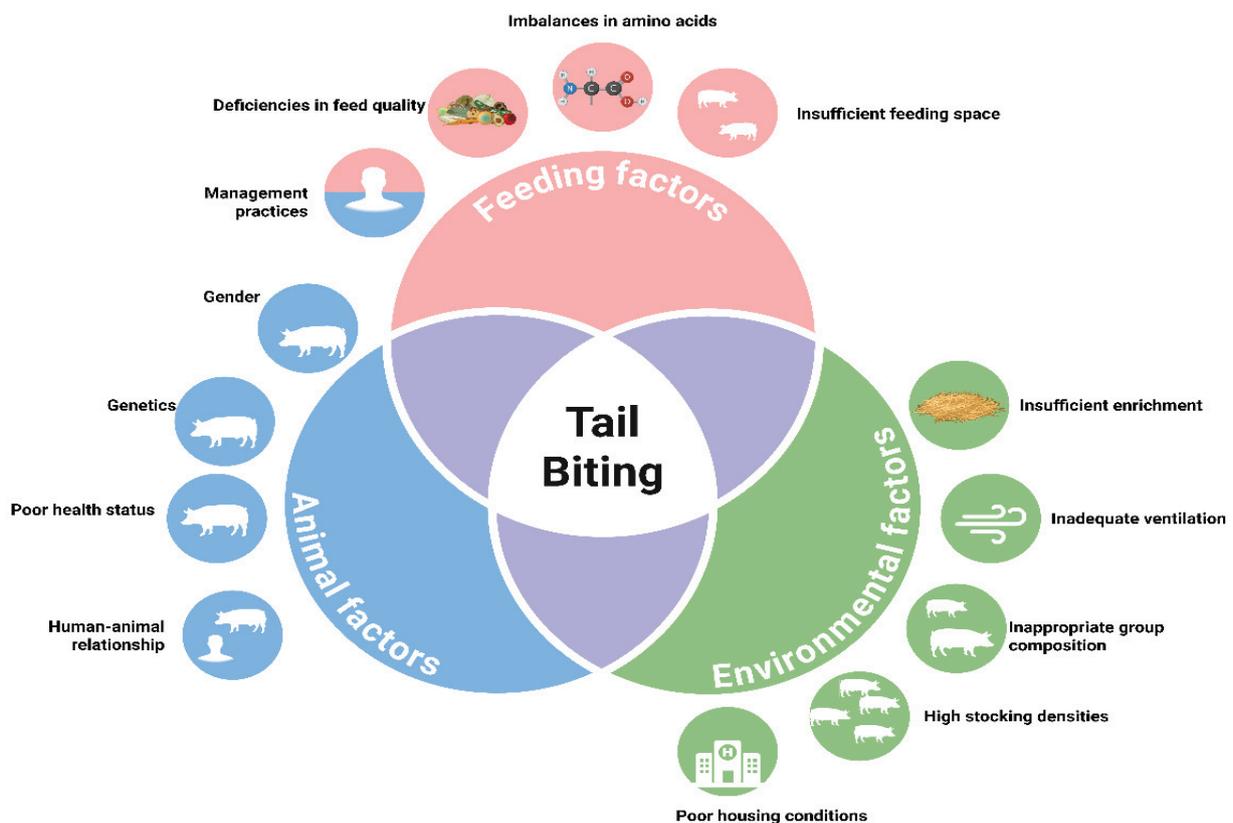
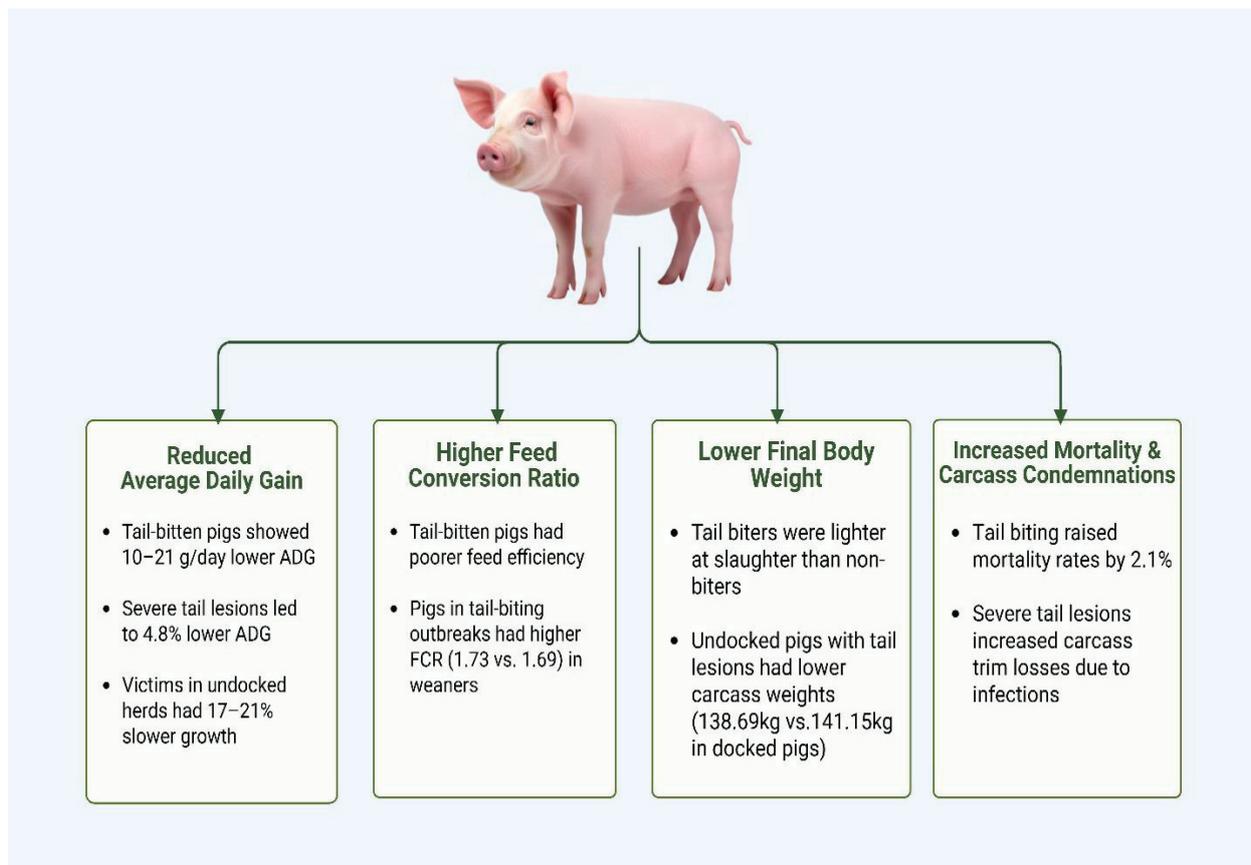**Figure 2** Risk factors associated with tail biting in pig farming.

Figure 3 Negative effects of tail biting on growth performance of pigs.

growth metrics, including Average Daily Gain (ADG) and feed efficiency, although findings vary depending on breed, age, and management practices. Studies showed that biters exhibited reduced exploration and lower weight gain during suckling, suggesting that early behavioral differences may predispose pigs to tail biting later in life [15,59]. Similarly, Håkansson F, et al. [60] reported that high-biters had significantly lower weaning weights and ADG compared to non-biters, reinforcing the link between tail biting and impaired growth.

Moreover, severe tail lesions have been associated with substantial reductions in growth performance. Van Staaveren VN, et al. [61] observed that pigs with severe tail lesions (≥ 0.86%) experienced a 4.8% reduction in ADG, requiring an additional seven days to reach slaughter weight. This aligns with findings by Li YZ, et al. [62], who observed that victimized pigs had lower ADG, higher carcass trim loss, and elevated inflammatory markers, further compromising productivity. However, not all studies report consistent effects; Archer CA, et al. [59] found no differences in ADG or final weight between biters and non-biters in pigs with intact tails, suggesting that management and genetic factors may modulate the impact of tail biting.

The Feed Conversion Ratio (FCR) appears less consistently affected by tail biting. D'Alessio RM, et al. [18] demonstrated that double-feeder space improved FCR compared to single-space feeding, implying that competition for feed may exacerbate tail biting without necessarily altering FCR in victimized pigs. On the other hand, Minussi I, et al. [12] found that low-protein diets reduced growth and feed intake, but amino acid supplementation restored performance, indicating that nutritional strategies may mitigate some effects of tail biting.

Environmental and housing conditions also play a crucial role. Wei, et al. (2019) reported no differences in final body weight or feed efficiency between deep litter and playground housing systems. In contrast, Andersen IL, et al. [63] observed that liquid feeding reduced aggression, but paradoxically lowered weight gain compared to dry feed. These contrasting results highlight the complexity of tail biting's impact,

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where management interventions may have trade-offs between behavior and growth. Early detection of tail biting remains critical for mitigation. D'Eath RB, et al. [31] and Drexl V, et al. [64] identified low tail postures as a reliable early indicator of tail biting, allowing for preemptive interventions. Additionally, genetic resilience traits have been linked to tail-biting susceptibility [65], suggesting that selective breeding could complement management strategies.

Impact of Tail Biting on Pig Welfare

Tail biting is a complex welfare issue in pig production with significant consequences for animal health, productivity, and farm economics (Figure 4). Early detection and prevention strategies are critical in mitigating this problem. Drexl V, et al. [64] found that changes in tail posture can be detected up to a week before lesions develop, suggesting that daily monitoring and environmental enrichment (such as straw or ropes) can help prevent outbreaks. Moreover, automated systems like the Bite-o-Mat [32] and scream detection algorithms [66] have demonstrated high accuracy in identifying tail-biting events, enabling early intervention. These technological advancements, combined with improved housing conditions, could significantly reduce the incidence of tail biting.

The risks and consequences of tail lesions are severe, as chronic injuries often lead to infections, osteomyelitis, and neuromas, indicating long-term pain [67]. Munsterhjelm C, et al. [68] reported that 27.6% of early tail lesions heal undetectably by slaughter, emphasizing the need for early prevention in the nursery phase—furthermore, Gomes-Neves et al. [10] observed higher tail lesion prevalence in undocked pigs (24.4%) compared to docked pigs (11.5%), reinforcing the debate over tail docking as a preventive measure. However, tail docking alone does not resolve welfare concerns, as biters and victims still exhibit reduced immunity and growth performance [62].

Genetic and health factors also play a crucial role in tail biting. Archer CA, et al. [59] found that tail biters had elevated TNF-α levels, suggesting a link between inflammation and abnormal behavior. Furthermore, Gorssen W, et al. [65] found that tail lesions and lameness correlate with body weight deviations, indicating that breeding for resilience could improve welfare. Certain breeds, such as Yorkshire pigs, are more prone to tail biting than Finnish Landrace pigs [17], highlighting the need for genetic selection strategies.

Environmental and management strategies are

Physical Health Impacts

- Causes pain, infection, and inflammation (e.g., osteomyelitis, abscesses).
- Leads to chronic wounds, neuromas (nerve damage), and necrosis.
- Increases mortality rates (up to 14.4% in undocked pigs).
- Reduces growth performance (↓ average daily gain by 10.8 g/day).
- Raises carcass condemnation rates due to lesions and secondary infections

Behavioral and Psychological Effects

- Increased aggression and stress (higher cortisol levels in victims).
- Redirected exploratory behavior (pigs bite tails when deprived of enrichment).
- Victims show more fear (e.g., lowered tail posture, avoidance behaviors).
- Biters may have compromised immunity (lower IgG and serum protein levels).

Impacts on Pig

Economic and Production Consequences

Higher veterinary costs

Longer time to slaughter
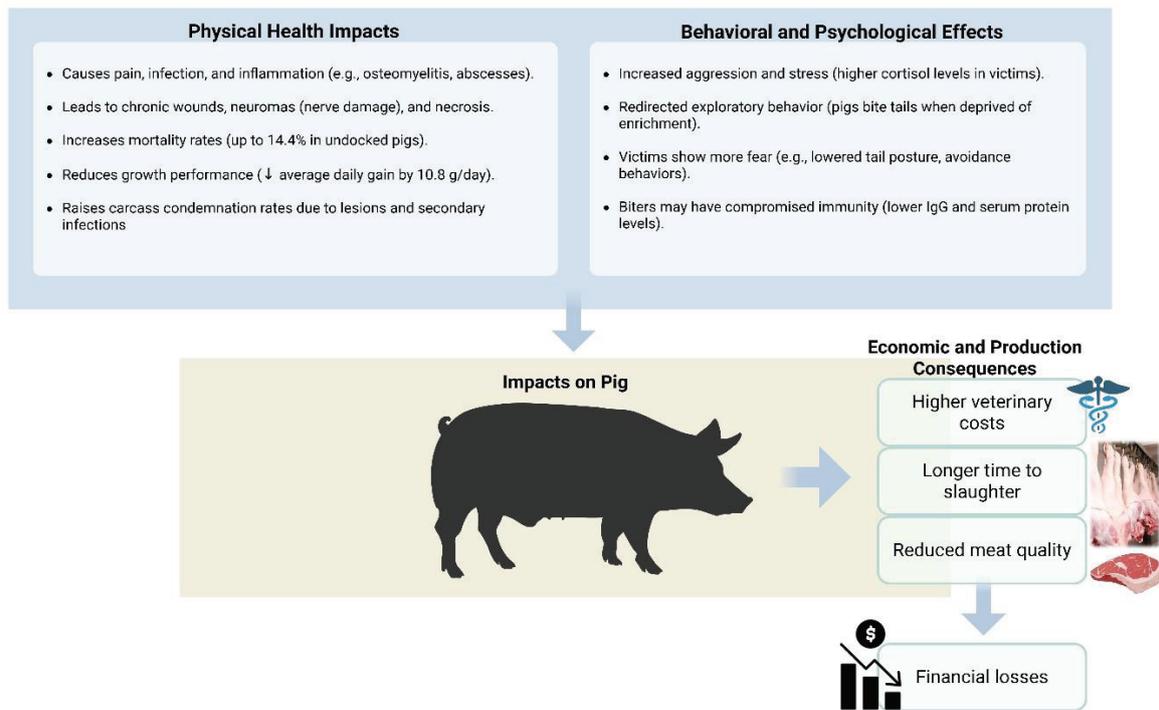
Reduced meat quality

Financial losses

Figure 4 Effects of tail biting on pig welfare.

essential in reducing tail biting. Providing straw [54] and increasing feeder space[18] have been shown to reduce aggression and tail lesions. Deep litter housing has also proven effective in minimizing abnormal behaviors compared to conventional systems [45,59,69,70]. Furthermore, liquid feeding and lower stocking densities improve welfare, though they may affect growth rates [63].

Nutritional influences are another critical factor. Hewett E, et al. [71] found that low-lysine diets increased ear biting, while adequate lysine levels reduced lesions. Similarly, magnesium supplementation has been shown to lower aggression and cortisol levels [72]. These findings suggest that balanced diets can mitigate tail biting by reducing stress and competition.

Regional and policy considerations further shape tail-biting management. Despite the EU ban on routine tail docking, compliance remains low [18]. However, Swiss farms, where 99% of pigs are undocked, report better welfare outcomes than Spanish farms with high docking rates [73], emphasizing the importance of structural improvements and policy enforcement.

Impact of Tail Biting Carcass Traits and Meat Quality

Tail biting in livestock, particularly in pig production, has significant implications for animal welfare, economic profitability, and carcass traits. It is considered a serious animal welfare problem, compromising the well-being of the animals and causing considerable economic losses [1,74]. Tail biting has been shown to have a serious impact on both the welfare and health status of pigs, as well as on the economic profitability of the farm [32,36]. The multifactorial origin of tail biting occurs mainly in fattening pigs, with high stocking densities, poor environment, and bad air quality seen as important factors [48]. Early indicators of tail biting include increased restlessness, biting activities, manipulative behavior, increased foraging, and avoidance behavior toward the feed trough [34]. Behaviorally, tail biting influences production performance in fattening pigs, with non-victims having greater average daily gain than victims [17].

Tail lesions due to biting decrease animal welfare and health, as well as production efficiency and carcass quality [9]. These lesions are associated with several meat inspection findings, with more severe lesions and shorter tails increasing the risk for meat inspection findings to a higher degree [9]. Severe tail biting can lead to a high rate of partial or full carcass condemnations [9]. Tail-bitten pigs tend to have lower carcass weights and produce less lean meat compared to control pigs, likely due to prolonged or repeated stress from tail biting, which can lead to a blunted stress response [9]. Amatucci L, et al. [38] found that docked pigs had higher carcass weights (141.15 kg vs. 138.69 kg) but lower lean meat percentages (52.16% vs. 53.36%) compared to undocked pigs, suggesting that while docking may mitigate some tail-biting effects, it does not fully compensate for production losses.

In terms of meat quality, chronic stress from tail biting has been linked to altered cortisol responses, which may influence muscle metabolism and meat characteristics [9] tail-bitten pigs show a lower cortisol response to transport-induced stress and lower serum cortisol concentration after stunning, indicating a possible state of hypocortisolism due to chronic stress [9]. While Fàbrega E, et al. [75] found no significant differences in meat quality between pigs provided with different enrichment materials, they emphasized that straw remains the most effective for welfare, albeit requiring improved rack designs to prevent slurry blockage.

Economically, tail damage, in all its forms, causes lowered welfare for the animals and has significant economic implications for production [20]. The costs of tail-biting lesions can be as high as €2.3 per slaughtered pig, which is approximately 1.6% of the carcass value [22]. Menegon F, et al. [2] reported that pigs raised under suboptimal conditions exhibited higher mortality rates and increased feed conversion ratios in weaners (1.73 vs. 1.69), leading to elevated production costs. These findings align with previous research indicating that tail biting is associated with prolonged stress, which can impair growth performance and carcass yield [9].

Implementing a detailed lesion scoring system at slaughterhouses can help identify carcasses at risk for condemnations and provide valuable data for on-farm welfare assessments [9,19,44]. Reducing stressors and improving living conditions for pigs can help mitigate the incidence of tail biting, with environmental enrichment and better management practices being essential [76]. In summary, tail biting has a negative impact on both carcass traits and meat quality, resulting in economic losses and welfare concerns. Effective monitoring and preventive

measures are necessary to improve outcomes in pig production, prioritizing holistic management strategies over tail docking to ensure both animal welfare and economic sustainability.

Tail Lesion Detection in Pigs

Tail lesion detection and prevention in pigs involve various methods, each with distinct advantages and limitations. Effective tail lesion management requires a combination of manual and automated methods, with early detection being crucial for intervention. Visual inspection remains practical for severe lesions, while handling detects subtler damage. Automated systems, RFID tracking, and machine learning enhance early warning capabilities, while social network analysis helps identify high-risk individuals. Integrating these approaches can enhance pig welfare and reduce economic losses from tail biting and secondary infections, such as osteomyelitis [22,77-79].

D'Alessio RM, et al. [80] compared Visual Inspection (VIS) and handling (HAND) for assessing tail damage in docked pigs and found that while VIS was highly specific (99.98%) for severe lesions, HAND detected more mild lesions and bruises, suggesting that HAND may be more sensitive for early-stage tail biting. However, the strong correlation between the two methods indicates that VIS remains a practical alternative for large-scale assessments where handling is impractical. The authors recommended separate bruise scoring to improve early detection, as bruises often precede severe tail damage. Interventions such as improvements in straw provision, housing ventilation, genetics, stocking density, herd health, provision of point-source enrichment objects, and adoption of early warning systems have been identified to affect the risk of tail-biting lesions [22].

Precision Livestock Farming and AI for Early Detection of Tail Biting in Pigs

Beyond manual inspection, automated systems have shown promise in detecting early tail-biting. The integration of Artificial Intelligence (AI) and Precision Livestock Farming (PLF) technologies has revolutionized the monitoring and management of pig welfare, particularly in addressing critical issues such as tail biting. Recent advancements in AI-driven behavior monitoring have demonstrated significant potential in enhancing real-time welfare assessments by analyzing animal-based responses [81,82]. These technologies leverage computer vision and deep learning models to detect subtle behavioral changes, such as altered locomotion or reduced activity, which may indicate poor environmental conditions or emerging health issues [83-85]. Eisermann J, et al. [32] demonstrated that automated enrichment manipulation monitoring could predict tail lesions up to 14 days in advance, allowing for timely interventions such as additional enrichment or removing aggressive pigs. Similarly, Heseker P, et al. [33,66,86]) found that audio-based detection identified tail biters 1-9 days earlier than visual observation, highlighting the potential of integrating automated sensors with environmental enrichment (e.g., sisal ropes and alfalfa pellets) for early warning. RFID technology has also helped track individual pig behavior, with Kauselmann K, et al. [87] reporting that tail biters often had lower weaning weights, suggesting weight monitoring could help identify at-risk pigs before lesions develop. Therefore, by automating these assessments, farmers can intervene promptly, minimizing stress and improving overall herd health [4, 88].

One of the most promising applications of AI in pig farming is the early detection of tail biting. Research has shown that tail posture serves as a reliable early indicator, with low tail carriage often preceding outbreaks [89,90]). Automated systems utilizing 3D cameras and machine vision algorithms have achieved notable success in classifying tail postures, enabling preemptive measures [31] (Figure 5). Furthermore, deep learning models such as YOLOv5 and EfficientNetV2 have been employed to monitor pig interactions, including head-to-rear contacts, which are strongly associated with tail biting behavior [77,91]. These technologies provide continuous, non-invasive monitoring, reducing reliance on labor-intensive manual inspections [92].

Machine learning approaches further enhance the accuracy of detection. Håkansson F, et al. [78] found that a CNN-LSTM (Convolutional Neural Network-Long Short-Term Memory) model outperformed CNN-CNN in detecting tail-biting behavior (71.3% vs. 64.7% accuracy), demonstrating the value of temporal data analysis in behavioral monitoring. Drexl V, et al. [94] applied Nonlinear AutoRegressive with eXogenous inputs (NARX) neural networks to predict tail lesions with high precision (recall: 0.63–0.97), emphasizing the role of predictive modeling
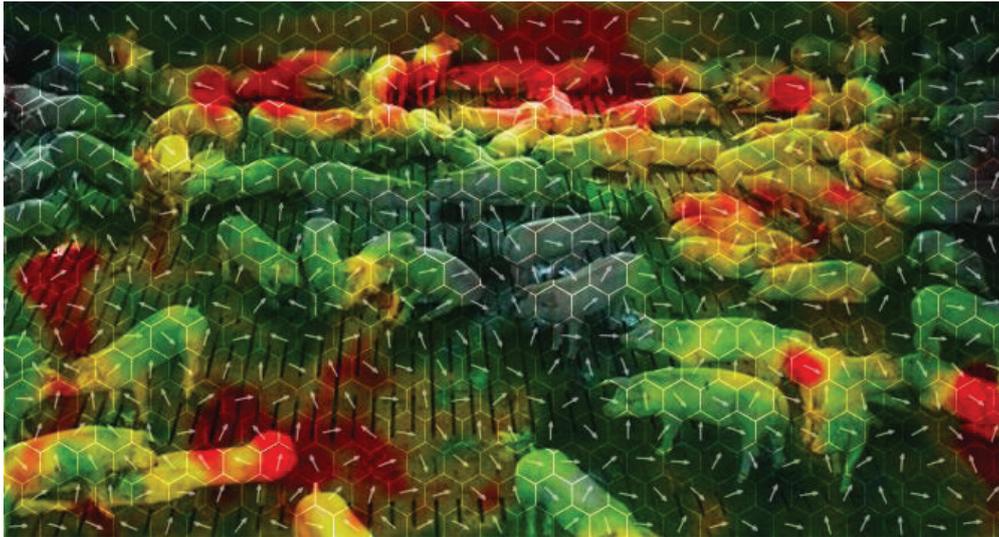
Figure 5 Automated monitoring system using computer vision and deep learning to detect disturbances in pig husbandry. Adapted from [93].

in preemptive management. Additionally, social network analysis [95] revealed that pigs receiving more tail bites had higher odds of severe injury, suggesting that mixed-litter grouping and social dynamics monitoring could mitigate tail biting.

Despite these advancements, challenges remain in the widespread adoption of AI-driven systems. The multifactorial nature of tail biting necessitates the integration of diverse data streams, including environmental parameters such as feed intake, temperature, and air quality [94]. While devices like the Bite-o-Mat have shown high accuracy in detecting early signs of tail biting through changes in enrichment manipulation behavior [32], broader implementation is hindered by cost, data management complexities, and the need for farmer-friendly interfaces [96]. Additionally, ethical concerns regarding data privacy and the potential objectification of animals must be addressed to ensure responsible deployment [97].

The CuRly Pig TAIL project represents a significant step forward in overcoming these limitations by developing an automated resilience monitoring system (Figure 6). This initiative integrates interdisciplinary knowledge of pig physiology, ethology, and machine learning to detect early signs of declining resilience, such as changes in tail posture and group dynamics [93]. By combining computer vision with deep learning, the system aims to provide farmers with actionable insights, enabling timely interventions that enhance welfare while reducing economic losses associated with tail biting and disease [98]. Moreover, this approach aligns with

societal concerns over routine tail docking, offering a more ethical and sustainable alternative [99].

Looking ahead, the continued refinement of AI and PLF technologies holds immense potential for improving pig welfare and farm productivity. Machine learning models such as Nonlinear Autoregressive Neural Networks with Exogenous Inputs (NARX) have demonstrated high predictive accuracy for tail biting outbreaks by analyzing diverse datasets [94]. Future research should focus on enhancing the scalability and affordability of these systems while ensuring seamless integration into existing farm operations [100]. By fostering collaboration between researchers, farmers, and technology developers, the agricultural sector can harness the full potential of AI to create resilient, high-welfare pig production systems.

Strategies to Mitigate Tail Biting in Pigs

Environmental enrichment

Tail biting in pigs remains a significant welfare and economic challenge in pig production, prompting extensive research into diverse mitigation strategies. Environmental enrichment has long been considered a primary preventive measure (Figure 7). Early work established that providing manipulable materials, particularly ample straw, effectively reduces tail biting behaviour and lesion severity [4,47]. Subsequent studies confirmed straw's high efficacy, reporting that it prevented escalation in 75% of cases (Figure 7), significantly outperforming other objects,
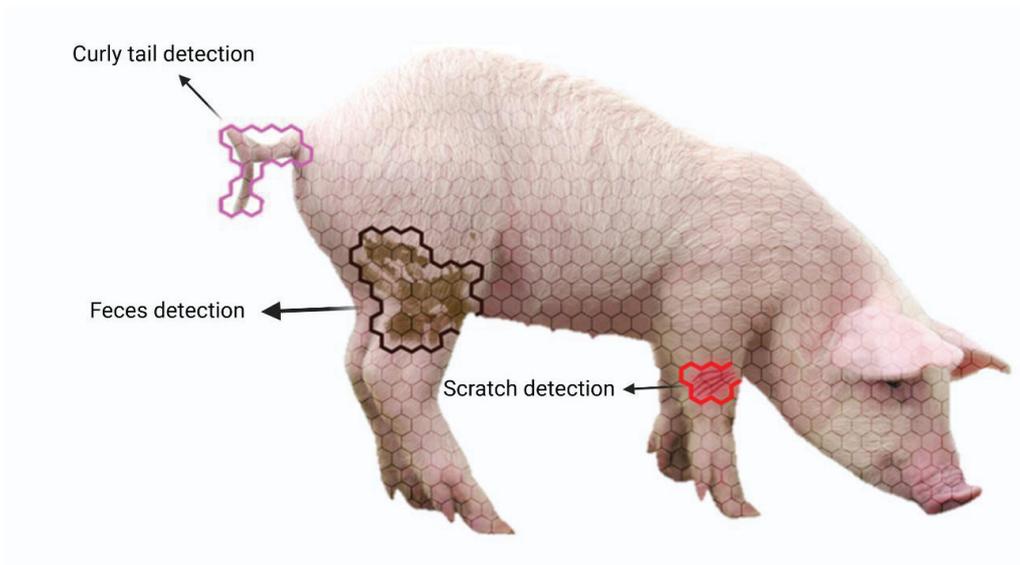
Figure 6 Monitoring pig tail posture and intactness for early resilience detection. Adapted from [93].

Figure 7 Providing sufficient environmental enrichment, including straw, ropes, balls, toys, and other manipulable materials, can alleviate frustration and stress, thereby reducing the risk of tail biting in pigs.

such as ropes (65% effective) or Bite-Rite devices (35% effective), during outbreaks [24]. Furthermore, other non-straw enrichment materials, including roughage, hessian sacks, compost, fresh wood, and space dividers, have also demonstrated moderate effectiveness, although their sustained benefit often relies on regular changes to maintain pigs' interest [25,101]. However, a major limitation hindering widespread adoption of substrates like straw in commercial settings is their poor compatibility with slatted flooring systems, coupled with concerns regarding cost and biosecurity [6,47].

Management strategies

When prevention falls short, effective intervention protocols are crucial. Research demonstrates that promptly removing identified biters and victims from affected pens is a highly effective measure to halt

ongoing outbreaks [37,99]. Moreover, combining this removal strategy with the immediate provision of accessible enrichment, such as ropes, results in rapid reductions in biting incidents, controlling outbreaks in approximately 80% of cases within three interventions [37]. This multi-step approach has proven highly effective, specifically for pigs housed on challenging slatted floors [37]. Beyond environmental and management considerations, nutritional strategies have been explored, albeit with mixed results. Contrary to initial hypotheses, providing a high-fiber diet within a relatively barren environment was found to increase tail biting behaviour and tail lesion severity, rather than reduce it [37,102].

Nutritional strategies to mitigate tail biting in pigs

Among nutritional interventions, protein balance is critical, as McAuley M, et al. [103] found that reduced dietary protein levels increase harmful social behaviors, including tail biting. Boyle LA, et al. [104] further highlights that deficiencies in energy, protein, or micronutrients can induce metabolic hunger, leading to redirected foraging behaviors such as tail biting.

Amino acid imbalances may also contribute to tail biting by disrupting neurotransmitter synthesis, which regulates mood and feeding behavior [104]. Furthermore, high genetic lean growth potential or gut inflammation can elevate amino acid requirements, intensifying nutritional deficiencies and subsequent behavioral issues. Stress-induced sodium imbalances and gut microbiome dysbiosis, mediated through the gut-brain axis, are additional mechanisms by which diet influences the risk of tail biting [104].

Dietary fiber has been explored as a potential mitigation strategy, though results are inconsistent. Chou JY, et al. [102] reported that high-fiber diets
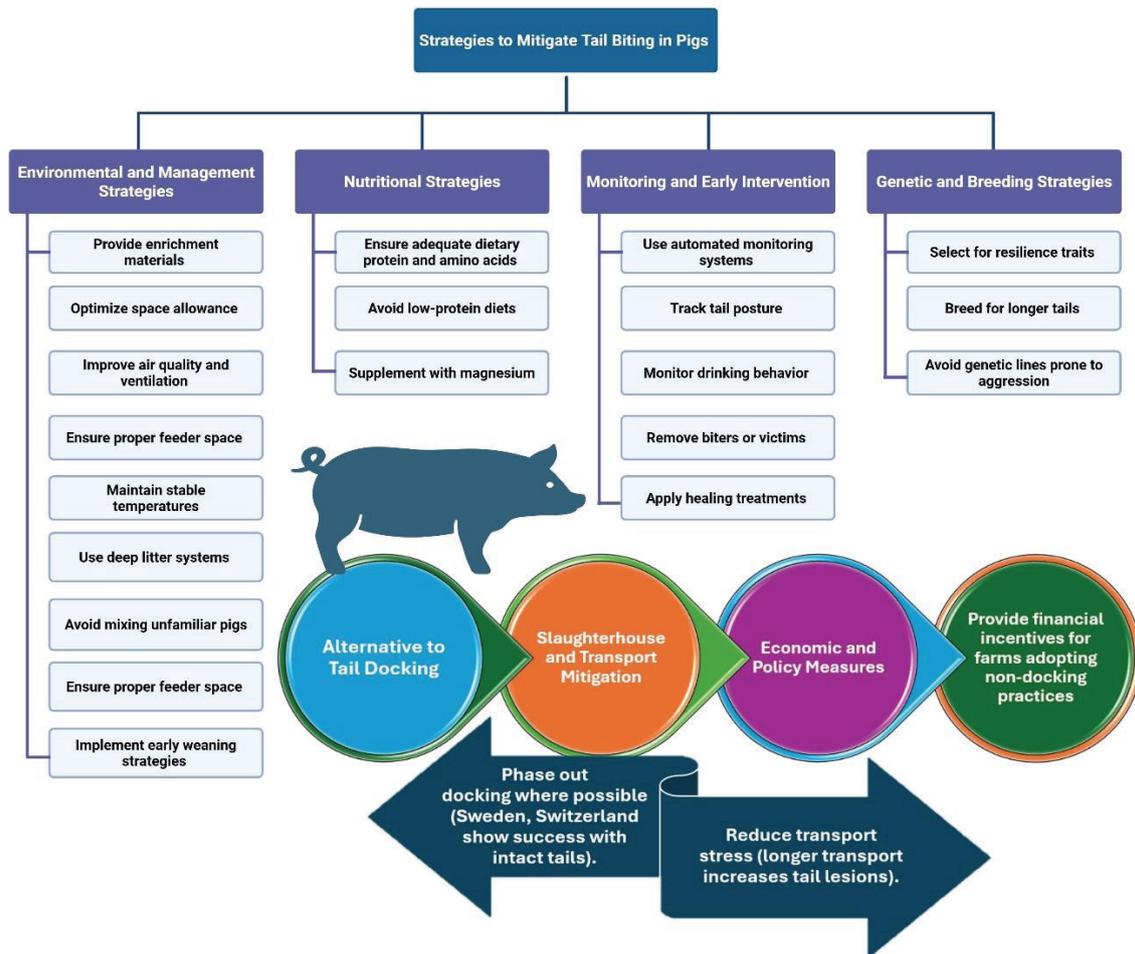

Figure 8 Strategies for mitigating tail biting in pigs.

(11.6% crude fiber) worsened tail biting compared to standard-fiber diets (5.9% crude fiber), possibly due to impaired nutrient absorption. Conversely, Boyle LA, et al. [104] suggests that certain fiber types may reduce foraging-related tail biting by promoting satiety. Supplementation with stress-reducing additives, such as Passiflora incarnata extract, has shown promise, as Pastorelli G, et al. [105] observed a reduction in aggression and cortisol levels in supplemented pigs.

Environmental enrichment, including manipulable substrates like straw, ropes, or wood, can also reduce tail biting when provided in sufficient quantities and refreshed regularly [24,25] (Figure 8). However, Buijs S, et al. [101]caution that enrichment alone may not suffice without proper feeding management. Inadequate feeder space or irregular feed delivery heightens competition and frustration, thereby increasing the risk of tail biting [104]. Additionally, high-energy diets may induce endotoxin stress, necessitating careful formulation of the diet for young pigs [102,106,107].

Emerging research suggests gut microbiota modulation as a potential strategy, as Rabhi N, et al. [108] found that non-biting pigs had higher Lactobacillus levels, indicating a possible link between gut health and behavior. Integrating balanced nutrition with proper feeding practices and enrichment offers the most effective approach to mitigating tail biting, though further research is needed to refine dietary interventions [103,104].

Genetic selection

Genetic selection offers another potential long-term avenue (Figure 8). Some breeding companies are actively investigating options to reduce the genetic propensity for tail biting, although this strategy is still under development and requires further validation through research [20,22,65]. Underpinning all these strategies is the critical importance of fundamental good husbandry. Optimizing stocking density, ensuring adequate ventilation, maintaining good health, and managing stable social groups are consistently identified as essential factors in reducing the overall risk of tail biting outbreaks [6,48]. Finally, effectively translating research into practice necessitates farmer engagement and training. Behaviour changes interventions for farmers, focusing on recognizing early signs and implementing appropriate mitigation strategies, are essential for the successful practical application of these research findings on commercial farms [109].

Conclusion

Tail biting in pigs is a complicated problem that affects both the pigs' well-being and farm productivity. It occurs due to a combination of factors, including genetics, environment, diet, and farm management. Issues like a lack of toys, poor air quality, overcrowding, and health problems contribute to this behaviour. Severe tail injuries can cause long-lasting pain, infections, and slower growth, leading to higher costs due to increased mortality, rejected carcasses, and additional veterinary care. Even though the EU has banned routine tail docking, farmers still do it because they worry about losing money and find it hard to fix the underlying issues. However, tail docking does not address the primary causes of tail biting, so additional preventive measures are necessary.

Effective ways to reduce tail biting include providing environmental enrichment, such as straw or ropes, to keep pigs busy and less stressed. Early detection of early signs of tail biting, such as changes in tail position, can help catch the problem early. Using automated systems like the Bite-o-Mat can also aid in detection. Improving pigs' diet with balanced nutrients can boost their gut health and reduce stress-related behaviors. Additionally, ensuring pigs have sufficient space, access to proper feeding areas, and adequate ventilation can help lower the risk. While genetic selection for resilience shows promise, further research is needed to validate its long-term efficacy. Educating farmers and using advanced farming technologies (precision livestock farming) are key to successfully applying these strategies.

Ultimately, a comprehensive approach that incorporates a healthier environment, improved nutrition, and effective management is essential to mitigate tail biting without resorting to tail docking. Solving this issue not only improves pig welfare but also makes pig farming more economically sustainable. Ongoing research, policy enforcement, and cooperation within the industry are necessary to develop and implement effective, ethical solutions that strike a balance between animal well-being and farm profitability.

Author Contributions

I.U.G.: Conceptualization, data extraction, table visualization, writing—original draft, project

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References

1. Valros A, Heinonen M. Save the pig tail. Porcine Health Manag. 2015 Apr 16;1:2. doi: 10.1186/2055-5660-1-2. PMID: 28405411; PMCID: PMC5375127.

2. Menegon F, Scollo A, Trestini S, Urbani R, Ru G, Di Martino G. The Economic Implications of Phasing Out Pig Tail Docking: A Pilot Study in Italy. Animals (Basel). 2025 Apr 29;15(9):1250. doi: 10.3390/ani15091250. PMID: 40362067; PMCID: PMC12070853.

3. Kakanis M, Sossidou EN, Kritas SK, Tzika ED. Update on Tail biting in pigs: An undesirable damaging behavior. 2021;72(1):2629-2646. doi: 10.12681/jhvms.26745.

4. Gadzama IU. Pig Welfare: From Tail Biting to Resilience and Precision Farming. Wikifarmer. 2025.

5. Rego Ribas JC, Grajales-Cedeño JK, Gianeis I, Sobral VS, Paranhos da Costa MJ. Implications of No Tail Docking on Performance, Health, and Behavior of Pigs Raised Under Commercial Conditions in Brazil. Animals. 2025;15(9). doi: 10.3390/ani15091308.

6. D'Eath RB, Arnott G, Turner SP, Jensen T, Lahrmann HP, Busch ME, Niemi JK, Lawrence AB, Sandøe P. Injurious tail biting in pigs: how can it be controlled in existing systems without tail docking? Animal. 2014 Sep;8(9):1479-97. doi: 10.1017/S1751731114001359. PMID: 25130712.

7. Büttner K, Czycholl I, Basler H, Krieter J. Effects of an intensified human-animal interaction on tail biting in pigs during the rearing period. 2018;156(8):1039-1046. doi: 10.1017/S002185961800103X.

8. Nyachoti CM, Jayaraman B, Lee J. Intersecting husbandry practices and piglet gut health and function. Environmental effects on gut health in production animals. 2024;40-72. doi: 10.3920/9789004695467_004.

9. Valros A, Munsterhjelm C, Puolanne E, Ruusunen M, Heinonen M, Peltoniemi OA, Pösö AR. Physiological indicators of stress and meat and carcass characteristics in tail bitten slaughter pigs. Acta Vet Scand. 2013 Oct 30;55(1):75. doi: 10.1186/1751-0147-55-75. PMID: 24172255; PMCID: PMC4176994.

10. Gomes-Neves E, Teixeira MF, Cardoso MF. Occurrence of tail docking and tail biting in weaner pigs—A preliminary study in Portuguese abattoirs. Livestock Science. 2024;287:105533. doi: 10.1016/j.livsci.2024.105533.

11. Teiga-Teixeira P, Alves Rodrigues M, Moura D, Teiga-Teixeira E, Esteves A. Osteomyelitis in Pig Carcasses at a Portuguese Slaughterhouse: Association with Tail-Biting and Teeth Resection. Animals (Basel). 2024 Jun 15;14(12):1794. doi: 10.3390/ani14121794. PMID: 38929413; PMCID: PMC11200971.

12. Minussi I, Gerrits WJJ, Jansman AJM, Gerritsen R, Lambert W, Zonderland JJ, Bolhuis JE. Amino acid supplementation counteracts negative effects of low protein diets on tail biting in pigs more than extra environmental enrichment. Sci Rep. 2023 Nov 7;13(1):19268. doi: 10.1038/s41598-023-45704-0. Erratum in: Sci Rep. 2024 Jun 25;14(1):14632. doi: 10.1038/s41598-024-65126-w. PMID: 37935708; PMCID: PMC10630283.

13. Wallgren P, Johansson M, Wallgren T, Susic Z, Sigfridson K, Johansson SE. Impact of feed, light and access to manipulable material on tail biting in pigs with intact tails. Acta Vet Scand. 2024 Jan 9;66(1):2. doi: 10.1186/s13028-023-00716-8. PMID: 38195502; PMCID: PMC10777577.

14. Czycholl I, Büttner K, Becker D, Schwennen C, Baumgärtner W, Otten W, Wendt M, Puff C, Krieter J. Are biters sick? Health status of tail biters in comparison to control pigs. Porcine Health Manag. 2023 May 9;9(1):19. doi: 10.1186/s40813-023-00314-0. PMID: 37161469; PMCID: PMC10170755.

15. Dumas G, Lo Verso L, Guay F. Effect of creep and post-weaning feeding composition on piglets' intestinal health and post-weaning growth according to their creep feed consumption status. Canadian Journal of Animal Science. 2025;105:1-15. doi: 10.1139/cjas-2024-0140.

TOPIC(S): TOPIC(S): VETERINARY SCIENCE | BIOLOGY

16. Mluba HS, Atif O, Lee J, Park D, Chung Y. Pattern Mining-Based Pig Behavior Analysis for Health and Welfare Monitoring. Sensors (Basel). 2024 Mar 28;24(7):2185. doi: 10.3390/s24072185. PMID: 38610396; PMCID: PMC11013991.

17. Sinisalo A, Niemi JK, Heinonen M, Valros A. Tail biting and production performance in fattening pigs. Livestock Science. 2012;143(2-3):220-225. doi: 10.1016/j.livsci.2011.09.019.

18. D'Alessio RM, Mc Aloon CG, Correia-Gomes C, Hanlon A, O'Driscoll K. Evaluation of a scheme to identify risks for tail biting in pigs. Plos one. 2024;19(8):e0305960. doi: 10.1371/journal.pone.0305960.

19. Valros A. Managing tail biting in pigs: Preventing risk factors or docking tails? 2023;261-287. doi: 10.1016/B978-0-323-85676-8.00002-X.

20. D'Eath RB, Arnott G, Turner SP, Jensen T, Lahrmann HP, Busch ME, Niemi JK, Lawrence AB, Sandøe P. Injurious tail biting in pigs: how can it be controlled in existing systems without tail docking? Animal. 2014 Sep;8(9):1479-97. doi: 10.1017/S1751731114001359. PMID: 25130712.

21. Valros A, Munsterhjelm C, Hänninen L, Kauppinen T, Heinonen M. Managing undocked pigs - on-farm prevention of tail biting and attitudes towards tail biting and docking. Porcine Health Manag. 2016 Feb 1;2:2. doi: 10.1186/s40813-016-0020-7. PMID: 28405428; PMCID: PMC5382372.

22. Niemi JK, Edwards SA, Papanastasiou DK, Piette D, Stygar AH, Wallenbeck A, Valros A. Cost-Effectiveness Analysis of Seven Measures to Reduce Tail Biting Lesions in Fattening Pigs. Front Vet Sci. 2021 Sep 7;8:682330. doi: 10.3389/fvets.2021.682330. PMID: 34557537; PMCID: PMC8452948.

23. Dippel S. Risk assessment. 2024;249-278. doi: 10.3920/9789004694989_012.

24. Pelant Lahrmann H, Faustrup JF, Hansen CF, D'Eath RB, Nielsen JP, Forkman B. The Effect of Straw, Rope, and Bite-Rite Treatment in Weaner Pens with a Tail Biting Outbreak. Animals (Basel). 2019 Jun 17;9(6):365. doi: 10.3390/ani9060365. PMID: 31212960; PMCID: PMC6617339.

25. Buijs S, Chou JY, van de Weerd H. Environmental enrichment. 2024;195-219. doi: 10.3920/9789004694989_010.

26. Heseker P, Probst J, Ammer S, Hartmann U, Hasler M, Kemper N, Traulsen I. Use of organic material provided by an automatic enrichment device by weaner pigs and its influence on tail lesions. PLoS One. 2024 Nov 1;19(11):e0309244. doi: 10.1371/journal.pone.0309244. PMID: 39485808; PMCID: PMC11530003.

27. Kuri N, Skok J, Škorjanc D, Prevolnik Povše M. Enrichments Adjusted to the Number of Litters: Simple Approach to Improve the Welfare of Weaned Piglets under Farm Conditions. Animals (Basel). 2024 Oct 15;14(20):2972. doi: 10.3390/ani14202972. PMID: 39457902; PMCID: PMC11506118.

28. Lee J, Oh S, Kim M. Impact of environmental enrichment on growth, behavior, and welfare of weanling piglets from pre-weaning to 6 weeks of age. J Anim Sci Technol. 2025 Jan;67(1):152-163. doi: 10.5187/jast.2024.e1. Epub 2025 Jan 31. PMID: 39974793; PMCID: PMC11833199.

29. Van de Perre V, Driessen B, Van Thielen J, Verbeke G, Geers R. Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. Animal Welfare. 2011;20(4):641-9. doi: 10.1017/s0962728600003286.

30. Van de Weerd HA, Docking CM, Day JE, Edwards SA. The development of harmful social behaviour in pigs with intact tails and different enrichment backgrounds in two housing systems. Animal Science. 2005;80(3):289-98. doi: 10.1079/ASC40450289.

31. D'Eath RB, Jack M, Futro A, Talbot D, Zhu Q, Barclay D, Baxter EM. Automatic early warning of tail biting in pigs: 3D cameras can detect lowered tail posture before an outbreak. PLoS One. 2018 Apr 4;13(4):e0194524. doi: 10.1371/journal.pone.0194524. PMID: 29617403; PMCID: PMC5884497.

32. Eisermann J, Schomburg H, Diers S, Janssen H, Küstner L, van Asten AL, Schrader L, Patt A. Bite-o-Mat: a device for the early detection of tail biting in pigs. Smart Agricultural Technology. 2025;11:101010. doi: 10.1016/j.atech.2025.101010.

33. Heseker P, Bergmann T, Scheumann M, Traulsen I, Kemper N, Probst J. Detecting tail biters by monitoring pig screams in weaning pigs. Sci Rep. 2024 Feb 24;14(1):4523. doi: 10.1038/s41598-024-55336-7. PMID: 38402339; PMCID: PMC10894255.

34. Schukat S, Heise H. Indicators for the early detection of tail biting in pigs - A literature review. 2019;97(3).

35. D'Eath RB, Jack M, Futro A, Talbot D, Zhu Q, Barclay D, Baxter EM. Automatic early warning of tail biting in pigs: 3D cameras can detect lowered tail posture before an outbreak. PLoS One. 2018 Apr 4;13(4):e0194524. doi: 10.1371/journal.pone.0194524. PMID: 29617403; PMCID: PMC5884497.

36. Eisermann J, Schomburg H, Diers S, Janssen H, Küstner L, van Asten AL, et al., editors. Pulling the rope - predicting tail biting in pigs with the Bite-o-Mat. 2024;136-143.

37. Chou JY, O'Driscoll K, D'Eath RB, Sandercock DA, Camerlink I. Multi-Step Tail Biting Outbreak Intervention Protocols for Pigs Housed on Slatted Floors. Animals (Basel). 2019 Aug 20;9(8):582. doi: 10.3390/ani9080582. PMID: 31434257; PMCID: PMC6720717.

38. Amatucci L, Luise D, Luppi A, Virdis S, Prosperi A, Cirelli A, Bosco C, Trevisi P. Evaluation of carcass quality, body and pulmonary lesions detected at the abattoir in heavy pigs subjected or not to tail docking. Porcine Health Manag. 2023 Feb 15;9(1):4. doi: 10.1186/s40813-022-00297-4. PMID: 36788627; PMCID: PMC9930331.

39. Svoboda M, Hodkovicova N, Siwicki A, Szweda W. The importance of slaughterhouses in monitoring the occurrence of tail biting in pigs - Review. Vet Med (Praha). 2023 Sep 28;68(9):349-358. doi: 10.17221/85/2023-VETMED. PMID: 37981944; PMCID: PMC10646543.

40. D'Eath RB, O'Driscoll K, Fàbrega E. Editorial: Holistic prevention

TOPIC(S): TOPIC(S): VETERINARY SCIENCE | BIOLOGY

strategies for tail biting in pigs; from farm to slaughterhouse. Front Vet Sci. 2023 Nov 9;10:1296461. doi: 10.3389/fvets.2023.1296461. PMID: 38026673; PMCID: PMC10666616.

41. González-Solé F, Camp Montoro J, Solà-Oriol D, Pérez JF, Lawlor PG, Boyle LA, Garcia Manzanilla E. Effect of mixing at weaning and nutrient density of the weaner diet on growth performance and welfare of pigs to slaughter. Porcine Health Manag. 2023 Aug 28;9(1):38. doi: 10.1186/s40813-023-00334-w. PMID: 37641119; PMCID: PMC10464064.

42. Grümpel A, Krieter J, Veit C, Dippel S. Factors influencing the risk for tail lesions in weaner pigs (Sus scrofa). Livestock Science. 2018;216:219-226. doi: 10.1016/j.livsci.2018.09.001.

43. Scollo A, Contiero B, Gottardo F. Frequency of tail lesions and risk factors for tail biting in heavy pig production from weaning to 170 kg live weight. Vet J. 2016 Jan;207:92-98. doi: 10.1016/j.tvjl.2015.10.056. Epub 2015 Nov 9. PMID: 26626091.

44. Valros A, Boyle L. The evidence of tail biting: Where, when and how to measure tail lesions. 2024:279-304. doi: 10.3920/9789004694989_013.

45. Hakansson F, Houe H. Risk factors associated with tail damage in conventional non-docked pigs throughout the lactation and rearing period. Prev Vet Med. 2020 Nov;184:105160. doi: 10.1016/j.prevetmed.2020.105160. Epub 2020 Sep 25. PMID: 33011560.

46. Scollo A, Gottardo F, Contiero B, Edwards SA. A cross-sectional study for predicting tail biting risk in pig farms using classification and regression tree analysis. Prev Vet Med. 2017 Oct 1;146:114-120. doi: 10.1016/j.prevetmed.2017.08.001. Epub 2017 Aug 2. PMID: 28992915.

47. Veit C, Beilage EG, Krieter J. Review of the behavioural disorder tail biting in pigs. 2016;97(3):232-241.

48. Sonoda LT, Fels M, Oczak M, Vranken E, Ismayilova G, Guarino M, Viazzi S, Bahr C, Berckmans D, Hartung J. Tail biting in pigs--causes and management intervention strategies to reduce the behavioural disorder. A review. Berl Munch Tierarztl Wochenschr. 2013 Mar-Apr;126(3-4):104-12. PMID: 23540192.

49. Bagaria M, Kuiper L, Meijer E, Sterck EHM. Individual behavioral correlates of tail biting in pre-finishing piglets. Front Vet Sci. 2022 Dec 5;9:1033463. doi: 10.3389/fvets.2022.1033463. PMID: 36544555; PMCID: PMC9760930.

50. Bracke MBM. Rope test may indicate efficacy of tail-biting treatments in growing pigs. Animal Welfare. 2009;18(3):263-266. doi: 10.1017/s0962728600000518.

51. Egerer C, Gerhards K, Becker S, Engel P, König S, Reiner G. Pig tail length is associated with the prevalence of tail malformations but not with inflammation of the tail. BMC Vet Res. 2025 Feb 26;21(1):111. doi: 10.1186/s12917-025-04598-y. PMID: 40011910; PMCID: PMC11863879.

52. Zupan M, Janczak AM, Framstad T, Zanella AJ. The effect of biting tails and having tails bitten in pigs. Physiol Behav. 2012 Jul 16;106(5):638-44. doi: 10.1016/j.physbeh.2012.04.025. Epub 2012 May 3. PMID: 22579933.

53. Haigh A, Chou JY, O'Driscoll K. Variations in the Behavior of Pigs During an Open Field and Novel Object Test. Front Vet Sci. 2020 Sep 3;7:607. doi: 10.3389/fvets.2020.00607. PMID: 33102553; PMCID: PMC7494949.

54. Zonderland JJ, Bracke MB, den Hartog LA, Kemp B, Spoolder HA. Gender effects on tail damage development in single-or mixed-sex groups of weaned piglets. Livestock Science. 2010;129(1-3):151-8. doi: 10.1016/j.livsci.2010.01.018.

55. Nielsen B, Horndrup LV, Turner SP, Christensen OF, Nielsen HM, Ask B. Selection for social genetic effects in purebred pigs improves behaviour and handling of their crossbred progeny. Genet Sel Evol. 2023 Jul 25;55(1):54. doi: 10.1186/s12711-023-00828-9. PMID: 37491205; PMCID: PMC10367277.

56. König S, Halli K. Tail Biting in Pigs. 2024:517-530. doi: 10.1007/978-3-031-51788-4_22.

57. Brunberg E, Jensen P, Isaksson A, Keeling LJ. Behavioural and Brain Gene Expression Profiling in Pigs during Tail Biting Outbreaks - Evidence of a Tail Biting Resistant Phenotype. PLoS One. 2013 Jun 18;8(6):e66513. doi: 10.1371/journal.pone.0066513. PMID: 23824700; PMCID: PMC3688911.

58. Canario L, Larzul C. Individual pig-related factors. 2024:83-111. doi: 10.3920/9789004694989_006.

59. Archer CA, Forster SL, Mote BE, Schmidt TB, Anderson J, Johnston LJ, Li Y. 213 Differences in growth, tail injury, and immune markers among tail-biting, non-biting, and control pigs with intact tails. Journal of Animal Science. 2025;103(Supplement_1):40-41. doi: 10.1093/jas/skaf102.044.

60. Hakansson F, Bolhuis JE. Tail-biting behaviour pre-weaning: Association between other pig-directed and general behaviour in piglets. Applied Animal Behaviour Science. 2021;241:105385. doi: 10.1016/j.applanim.2021.105385.

61. van Staaveren N, Boyle LA, Manzanilla EG, O'Driscoll K, Shalloo L, Díaz JAC. Severe tail lesions in finisher pigs are associated with reduction in annual profit in farrow-to-finish pig farms. Vet Rec. 2021 Apr;188(8):e13. doi: 10.1002/vetr.13. Epub 2021 Jan 16. PMID: 33891723.

62. Li YZ, Zhang HF, Johnston LJ, Martin W, Peterson JD, Coetzee JF. Effects of tail docking and tail biting on performance and welfare of growing-finishing pigs in a confinement housing system. J Anim Sci. 2017 Nov;95(11):4835-4845. doi: 10.2527/jas2017.1571. PMID: 29293713; PMCID: PMC6292262.

63. Andersen IL, Ocepek M, Thingnes SL, Newberry RC. Welfare and performance of finishing pigs on commercial farms: Associations with group size, floor space per pig and feed type. Applied Animal Behaviour Science. 2023;265:105979. doi: 10.1016/j.applanim.2023.105979.

64. Drexl V, Dittrich I, Haase A, Klingelhöller H, Diers S, Krieter J. Tail posture as an early indicator of tail biting-a comparison of animal

and pen level in weaner pigs. Applied Animal Behaviour Science. 2022;252:105654. doi: 10.1016/j.applanim.2022.105654.

65. Gorssen W, Winters C, Meyermans R, Chapard L, Hooyberghs K, Depuydt J, Janssens S, Mulder H, Buys N. Breeding for resilience in finishing pigs can decrease tail biting, lameness and mortality. Genet Sel Evol. 2024 Jun 20;56(1):48. doi: 10.1186/s12711-024-00919-1. PMID: 38902596; PMCID: PMC11191330.

66. Heseker P, Bergmann T, Lieboldt MA, Traulsen I, Kemper N, Probst J, Scheumann M. Exposing tail biters by automatic scream detection. Smart Agricultural Technology. 2024;9:100582. doi: 10.1016/j.atech.2024.100582.

67. Flyger CK, Becker CB, Jørgensen BM, Jensen HE. Forensic evaluation of tail-bite wounds in pigs in Denmark. J Comp Pathol. 2025 May;219:102-107. doi: 10.1016/j.jcpa.2025.05.002. Epub 2025 May 26. PMID: 40424868.

68. Munsterhjelm C, Tuominen-Brinkas M, Koskikallio H, Heinonen M, Ahlqvist K, Valros A. Tail status at both individual and pen level affects tail biting victimisation in pigs over the finishing period. Animal. 2025 Mar;19(3):101428. doi: 10.1016/j.animal.2025.101428. Epub 2025 Jan 20. PMID: 39954334.

69. Gavaud S, Haurogné K, Buchet A, Garcia Vinado I, Allard M, Lehébel A, Leblanc-Maridor M, Bach JM, Belloc C, Lieubeau B, Hervé J. Effects of improved early-life conditions on health, welfare, and performance of pigs raised on a conventional farm. Animal. 2023 Jun;17(6):100810. doi: 10.1016/j.animal.2023.100810. Epub 2023 Apr 14. PMID: 37172358.

70. Ursinus WW, Van Reenen CG, Kemp B, Bolhuis JE. Tail biting behaviour and tail damage in pigs and the relationship with general behaviour: Predicting the inevitable?. Applied Animal Behaviour Science. 2014;156:22-36. doi: 10.1016/j.applanim.2014.04.001.

71. Hewett E, Zaragoza L, Lewis C, Houdijk J, Wilson A, Turner S. Exploring the effects of dietary lysine and tryptophan on the social behavior of pigs. J Anim Sci. 2025 Jan 4;103:skaf030. doi: 10.1093/jas/skaf030. PMID: 39910971; PMCID: PMC11912881.

72. O'Driscoll K, O'Gorman DM, Taylor S, Boyle LA. The influence of a magnesium-rich marine extract on behaviour, salivary cortisol levels and skin lesions in growing pigs. Animal. 2013 Jun;7(6):1017-27. doi: 10.1017/S1751731112002431. Epub 2012 Dec 20. PMID: 23253104.

73. Knörr A, Zhou X, Bearth A, Garcia-Morante B, Correia-Gomes C, Segalés J, Echtermann T, Siegrist M. Industry stakeholders attitudes and beliefs about tail biting and docking in pigs - A case study in Switzerland and Spain. Prev Vet Med. 2025 Apr;237:106444. doi: 10.1016/j.prevetmed.2025.106444. Epub 2025 Jan 31. PMID: 39904136.

74. Valros A, Palander P, Heinonen M, Munsterhjelm C, Brunberg E, Keeling L, Piepponen P. Evidence for a link between tail biting and central monoamine metabolism in pigs (Sus scrofa domestica). Physiol Behav. 2015 May 1;143:151-7. doi: 10.1016/j.physbeh.2015.02.049. Epub 2015 Feb 26. PMID: 25728243.

75. Fàbrega E, Marcet-Rius M, Vidal R, Escribano D, Cerón JJ, Manteca X, Velarde A. The Effects of Environmental Enrichment on the Physiology, Behaviour, Productivity and Meat Quality of Pigs Raised in a Hot Climate. Animals (Basel). 2019 May 13;9(5):235. doi: 10.3390/ani9050235. PMID: 31086082; PMCID: PMC6563062.

76. Leal DF, de Paula YH, de Sousa Faria CB, E Costa GAM, Tavares IC, de Souza Cantarelli V. The effect of different weaning strategies on piglet growth, feed intake and gut health. Trop Anim Health Prod. 2024 Sep 24;56(8):279. doi: 10.1007/s11250-024-04118-4. PMID: 39317782.

77. Alameer A, Buijs S, O'Connell N, Dalton L, Larsen M, Pedersen L, Kyriazakis I. Automated detection and quantification of contact behaviour in pigs using deep learning. Biosystems Engineering. 2022;224:118-30. doi: 10.1016/j.biosystemseng.2022.10.002.

78. Hakansson F, Jensen DB. Automatic monitoring and detection of tail-biting behavior in groups of pigs using video-based deep learning methods. Front Vet Sci. 2023 Jan 11;9:1099347. doi: 10.3389/fvets.2022.1099347. PMID: 36713870; PMCID: PMC9879576.

79. Odo A, McLaughlin N, Kyriazakis I. Automated monitoring of ear biting in pigs by tracking individuals and events. InProceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2024;7095-7103. doi: 10.1109/WACV57701.2024.00694.

80. D'Alessio RM, McAloon CG, Boyle LA, Hanlon A, O'Driscoll K. Comparison between two scoring methods to assess tail damage of docked pig carcasses during postmortem inspection in Ireland. Vet Rec Open. 2023 Aug 21;10(2):e66. doi: 10.1002/vro2.66. PMID: 37614914; PMCID: PMC10442492.

81. Bao J, Xie Q. Artificial intelligence in animal farming: A systematic literature review. Journal of Cleaner Production. 2022;331:129956. doi: 10.1016/j.jclepro.2021.129956.

82. Zhang L, Guo W, Lv C, Guo M, Yang M, Fu Q, Liu X. Advancements in artificial intelligence technology for improving animal welfare: Current applications and research progress. Animal Research and One Health. 2024;2(1):93-109. doi: 10.1002/aro2.44.

83. Li J, Green-Miller AR, Hu X, Lucic A, Mohan MM, Dilger RN, Condotta IC, Aldridge B, Hart JM, Ahuja N. Barriers to computer vision applications in pig production facilities. Computers and electronics in agriculture. 2022;200:107227. doi: 10.1016/j.compag.2022.107227.

84. Kim H, Shin H, Kim YY. Effects of different levels of dietary crude protein on growth performance, blood profiles, diarrhea incidence, nutrient digestibility, and odor emission in weaning pigs. Anim Biosci. 2023 Aug;36(8):1228-1240. doi: 10.5713/ab.22.0440. Epub 2023 Feb 27. PMID: 36915927; PMCID: PMC10330979.

85. Kim JH, Poulose A, Colaco SJ, Neethirajan S, Han DS. Enhancing animal welfare with interaction recognition: A deep dive into pig interaction using xception architecture and SSPD-PIR method. Agriculture. 2023;13(8):1522. doi: 10.3390/agriculture13081522.

TOPIC(S): TOPIC(S): VETERINARY SCIENCE | BIOLOGY

86. Heseker P. Tail biting in pigs: event and biter detection via automatic audiovisual analysis. In the 11th European conference on precision livestock farming 2024:310-317.

87. Kauselmann K, Krause ET, Schrade H, Schrader L. Retrospective exploratory evaluation of individual pigs' behaviour involved in tail biting during rearing and fattening. PLoS One. 2025 Jan 13;20(1):e0316044. doi: 10.1371/journal.pone.0316044. PMID: 39804880; PMCID: PMC11730382.

88. Benjamin M, Yik S. Precision Livestock Farming in Swine Welfare: A Review for Swine Practitioners. Animals (Basel). 2019 Mar 31;9(4):133. doi: 10.3390/ani9040133. PMID: 30935123; PMCID: PMC6523486.

89. Witte JH, Heseker P, Probst J, Kemper N, Traulsen I, Gómez JM. Tail posture as a predictor of tail biting in pigs: a camera-based monitoring system. 2024:341-348.

90. Witte JH, Heseker P, Probst J, Traulsen I, Kemper N, Marx J. Image-based Tail Posture Monitoring of Pigs. 2024:7831-7839.

91. Santos RJO, Magboo MSA, Magboo VPC. TailSafe: A pig head-to-rear contact detection system using convolutional neural networks. 2023. doi: 10.1109/INCOFT60753.2023.10425766.

92. Michielon A, Litta P, Bonelli F, Don G, Farisè S, Giannuzzi D, Milanesi M, Pietrucci D, Vezzoli A, Cecchinato A, Chillemi G, Gallo L, Mele M, Furlanello C. Mind the Step: An Artificial Intelligence-Based Monitoring Platform for Animal Welfare. Sensors (Basel). 2024 Dec 17;24(24):8042. doi: 10.3390/s24248042. PMID: 39771778; PMCID: PMC11679443.

93. WUR Research. Creating resilience in pigs through artificial intelligence (CuRly Pig TAIL). 2024.

94. Drexl V, Dittrich I, Wilder T, Diers S, Janssen H, Krieter J. Prediction of tail biting in pigs using partial least squares regression and artificial neural networks. Computers and Electronics in Agriculture. 2024;216:108477. doi: 10.1016/j.compag.2023.108477.

95. St. Charles KM, VanderWaal KL, Anderson JE, Johnston LJ, Li YZ. Evaluating social network metrics as indicators of tail injury caused by tail biting in growing-finishing pigs (Sus scrofa domesticus). Frontiers in Veterinary Science. 2024 Sep 27;11:1441813. doi: 10.3389/fvets.2024.1441813.

96. Siegford JM. Precision livestock farming and technology in pig husbandry. Advances in Pig Welfare. 2023:449-469. doi: 10.1016/B978-0-323-85676-8.00015-8.

97. Thangavelu C, Nalini S, Lalitha SD, Karthik PC, Bharathi SVS, Sivakumar A. Emerging artificial intelligence tools, advancements, and opportunities for protecting wild animals. 2025:213-245. doi: 10.4018/979-8-3693-6935-7.ch009.

98. Chen Hongyu, Yin Ling, Yang Ming, Zhang Sumin, Lin Junyong. Multimodal pig behavior recognition based on vision and sensor fusion. Transactions of the Chinese Society of Agricultural Engineering. 2025;41(8). doi: 10.11975/j.issn.1002-6819.202410206.

99. Sonoda LT, Fels M, Oczak M, Vranken E, Ismayilova G, Guarino M, Viazzi S, Bahr C, Berckmans D, Hartung J. Tail biting in pigs--causes and management intervention strategies to reduce the behavioural disorder. A review. Berl Munch Tierarztl Wochenschr. 2013 Mar-Apr;126(3-4):104-12. PMID: 23540192.

100. Larsen MLV, Pedersen LJ, Norton T. Precision livestock farming. 2024:330-347. doi: 10.3920/9789004694989_015.

101. Buijs S, Muns R. A Review of the Effects of Non-Straw Enrichment on Tail Biting in Pigs. Animals (Basel). 2019 Oct 18;9(10):824. doi: 10.3390/ani9100824. PMID: 31635339; PMCID: PMC6826462.

102. Chou JY, O'Driscoll K, Sandercock DA, D'Eath RB. Can increased dietary fibre level and a single enrichment device reduce the risk of tail biting in undocked growing-finishing pigs in fully slatted systems? PLoS One. 2020 Oct 30;15(10):e0241619. doi: 10.1371/journal.pone.0241619. PMID: 33125443; PMCID: PMC7598487.

103. McAuley M, Buijs S, Muns R, Gordon A, Palmer M, Meek K, O'Connell N. Effect of reduced dietary protein level on finishing pigs' harmful social behaviour before and after an abrupt dietary change. Applied Animal Behaviour Science. 2022;256:105762. doi: 10.1016/j.applanim.2022.105762.

104. Boyle LA, Edwards SA, Bolhuis JE, Pol F, Šemrov MZ, Schütze S, Nordgreen J, Bozakova N, Sossidou EN, Valros A. The Evidence for a causal link between disease and damaging behavior in pigs. Front Vet Sci. 2022 Jan 27;8:771682. doi: 10.3389/fvets.2021.771682. PMID: 35155642; PMCID: PMC8828939.

105. Pastorelli G, Serra V, Turin L, Redaelli V, Luzi F, Barbieri S. Tranquillizing Effect of Passiflora incarnata Extract: Outcome on Behavioral and Physiological Indicators in Weaning Pigs with Intact Tails. Animals (Basel). 2022 Jan 15;12(2):203. doi: 10.3390/ani12020203. PMID: 35049826; PMCID: PMC8773376.

106. de Greeff A, Resink JW, van Hees HM, Ruuls L, Klaassen GJ, Rouwers SM, Stockhofe-Zurwieden N. Supplementation of piglets with nutrient-dense complex milk replacer improves intestinal development and microbial fermentation. J Anim Sci. 2016 Mar;94(3):1012-9. doi: 10.2527/jas.2015-9481. PMID: 27065263.

107. Kobek-Kjeldager C, Schönherz AA, Canibe N, Pedersen LJ. Diet and microbiota-gut-brain axis in relation to tail biting in pigs: A review. Applied Animal Behaviour Science. Applied Animal Behaviour Science. 2022;246:105514. doi: 10.1016/j.applanim.2021.105514.

108. Rabhi N, Thibodeau A, Côté JC, Devillers N, Laplante B, Fravalo P, Larivière-Gauthier G, Thériault WP, Faucitano L, Beauchamp G, Quessy S. Association between tail-biting and intestinal microbiota composition in pigs. Frontiers in Veterinary Science. 2020;7:563762. doi: 10.3389/fvets.2020.563762.

109. Carroll GA, Groarke JM. The Importance of the Social Sciences in Reducing Tail Biting Prevalence in Pigs. Animals (Basel). 2019 Aug 21;9(9):591. doi: 10.3390/ani9090591. PMID: 31438625; PMCID: PMC6770512.