JOURNAL OF ANIMAL BEHAVIOUR AND BIOMETEOROLOGY

RESEARCH ARTICLE
Published Online: February 19, 2025
https://doi.org/10.31893/jabb.2026004

# Environmental enrichment strategies for growing pigs: Effects on welfare indicators and stress-related responses

Anna Lykhach[a] | Mykhailo Chentsov[a] | Vadym Lykhach[b] | Leonid Lenkov[b] | Rostyslav Faustov[c] | Yevhen Barkar[d] | Olena Izhboldina[e] | Roman Mylostyvyi[f]

[a]Department of Applied Biology, Animal Breeding and Genetics, Faculty of Animal Science and Water Bioresources, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukrainec
[b]Department of Technologies of Animal Husbandry, Faculty of Animal Science and Water Bioresources, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine.
[c]Laboratory of Innovative Technologies and Experimental Livestock Facilities, Institute of Pig Breeding and Agro-Industrial Production, National Academy of Agrarian Sciences of Ukraine, Poltava, Ukraine.
[d]Department of Biotechnology and Bioengineering, Faculty of Technology of Production and Processing of Livestock Products, Standardization and Biotechnology, Mykolayiv National Agrarian University, Mykolayiv, Ukraine.
[e]Department of Animal Feeding and Breeding Technology, Faculty of Biotechnology, Dnipro State Agrarian and Economic University, Dnipro, Ukraine.
[f]Department of Animal Products Processing Technology, Faculty of Biotechnology, Dnipro State Agrarian and Economic University, Dnipro, Ukraine.

**Abstract** This study investigated the impact of different environmental enrichment strategies on the welfare of growing pigs under industrial housing conditions. Four groups of piglets (n = 22 heads per group) were housed on fully slatted floors and provided with various enrichment objects: cotton rope, grain-filled plastic bottles and wrapping paper balls, whereas the control group had none. Welfare parameters, including lameness; injuries to the body, ears, carpal joints and tails; and tear staining intensity, which is a biomarker of stress, were assessed weekly via modified Pig Welfare Quality Assessment protocols. Statistical analyses were performed via the Wilcoxon signed-rank test and the Friedman rank variance test. The absence of enrichment resulted in a significant increase in the incidence of lameness, carpal joint lesions and body-side injuries ($P < 0.05$). Compared with the enriched piglets, the control piglets also presented markedly greater rates of ear and tail biting. Among the enrichment types, grain-filled bottles provided the most stable welfare outcomes, maintaining low levels of both physical injuries and tear staining intensity. In contrast, pigs exposed to transient or less interactive enrichment presented higher emotional stress indicators. Overall, the results confirmed that the type and functionality of enriched objects play a decisive role in mitigating harmful oral manipulations, improving locomotor health and reducing chronic stress. Tear staining intensity has proven to be a reliable noninvasive parameter of welfare and is sensitive to changes in environmental conditions. Implementing diversified enrichment strategies alongside regular welfare monitoring can serve as an effective tool for increasing pig welfare and production efficiency in intensive farming systems.

**Keywords:** ears and tail biting, growing pigs, oral manipulation, pen design, tear staining, type of enrichment object

## 1. Introduction

An effective platform for ensuring the sustainability of the pig industry is the implementation of the principles of pig welfare for different technological groups (Godyń et al., 2019; Vitali et al., 2020). On the basis of a review of the literature (De Jong et al., 2000; Courboulay, 2004; Bracke, 2007, 2018), pig welfare is clearly becoming an increasingly important issue for the smooth production of high-quality pork (Pietrosemoli and Tang, 2020). In industrial pig farming, animals are usually raised in pens without bedding or manipulative material (Delsart et al., 2020; Warns et al., 2021) to prevent them from fully expressing their specific natural behavior and causing mental suffering, aggressive behavior and, as a result, the development of chronic stress negatively affects their performance traits (Velarde et al., 2015). Such phenomena provoke harmful social behavior, which manifests itself in the form of biting the tail and ears, sides of the body, limbs and genitals to suppress their natural behavior (Gifford et al., 2007; Lykhach et al., 2022), or is the result of frustration. Harmful oral manipulation of pigs negatively affects their health; even increases the risk of infection, growth and welfare; and leads to significant economic losses for producers (Van de Weerd et al., 2003). According to the literature available in Ukraine, unfortunately, for various reasons, there are no statistics on the quantitative expression of harmful oral manipulations between pigs of different sexes and age groups in terms of farms, households and industrial companies.

In the European Union, the Commission and a specialized animal health and welfare agency are conducting research into the risks associated with tail biting in pigs and identifying possible ways to reduce the need for docking. This analysis, which considers various factors, housing systems and breeding methods, revealed that between 30–70% of cases of aggressive behavior (tail and ear biting) were recorded on commercial farms. Moreover, 1–5% of pigs have tail injuries that incur additional veterinary costs (EFSA, 2007; Beaudoin et al., 2019).

Harmful oral manipulations are among the most common forms of behavioral deviation in pigs under industrial conditions of detention, especially during the period of growth. This stage of development is accompanied by the active formation of a social hierarchy, adaptation to group retention and physiological changes. The occurrence of such actions as biting, chewing, licking or sucking usually indicates the presence of stress or discomfort factors. Moreover, oral activity aimed at exploring the environment (chewing objects, searching and digging the litter) is a natural form of behavior that helps reduce aggressiveness and facilitates the process of adapting to animals (Chou et al., 2019; Rabhi et al., 2020; Boyle et al., 2022; Mun et al., 2023).

The manifestation of oral manipulation in pigs is significantly influenced by factors such as pen density, microclimate parameters, the level of feed and water supply and the availability of objects for research (Lykhach et al., 2022). The absence of elements for environmental enrichment, violation of feeding or the influence of stress factors can increase the frequency of undesirable forms of oral behavior (Schmitt et al., 2020).

Modern studies by scientists from different countries have shown that enrichment objects for pigs can be classified into separate groups (Beaudoin et al., 2019; Bracke and Koene, 2019; Buijs and Muns, 2019). The categories of objects for gnawing and chewing include rubber or wooden toys without toxic coatings; pressed straw and hay in bales or briquettes; strong ropes, cords and chains suspended indoors; rattan or jute balls suitable for chewing; and special rubber or plastic rodents that make it possible to realize the natural need to chew, reduce the level of aggression, prevent harmful oral manipulations and stimulate social interaction between piglets (Elkmann and Hoy, 2009; Averós et al., 2010; Beaudoin et al., 2019; Fàbrega et al., 2019; Lykhach et al., 2020). Moreover, as noted by Lykhach et al. (2022), the widespread use of slatted floors on pig farms complicates the use of straw and hay, as they can interfere with the operation of self-draining sewage systems.

The group of objects that stimulate digging in pigs includes bulk materials (straw, wood shavings, peat, sand, coconut chips), which provide the opportunity to realize the natural instinct of digging. In addition, this category includes massive plastic or rubber containers filled with feed or sensory substrates, as well as modular platforms with a variety of textures that activate olfactory and tactile sensations. The use of such objects allows piglets to satisfy their natural need to dig, which reduces the level of stress and manifestations of stereotypical behavior (Smith and Pierdon, 2024).

The group of interactive feeders and feeding stimulation devices includes automated systems with dosed feed, which activate the locomotor activity of piglets; the “scatter feeding” method, which encourages the search for and research behavior of animals; and bunker feeders with regulated access, which reduce manifestations of apathy and aggression and can monitor the application of cameras in precision pig farming (Arulmozhi et al., 2021). The group of dynamic environments includes variable objects and their rotation: regular movement of toys or replacement of materials (once every two days), alternate introduction of new objects to maintain interest, and use of suspended or moving elements (balls, barrels, plastic pipes). This approach prevents habituation to the same type of stimuli and reduces the level of stress and aggression between piglets (Beaudoin et al., 2019; Lykhach et al., 2020, 2022; Yang et al., 2024). The categories of water and cooling devices, especially those relevant to hot periods or arid regions, include water spray systems and shower installations; wet bedding (peat, shavings, sawdust), which reduces overheating; and cooling mats or floor systems, which maintain an optimal microclimate and prevent heat stress (Godyń et al., 2020; Costantino et al., 2022). A separate group of audio and light enrichment is distinguished: the use of variable lighting modes with imitation of the daily cycle, dimmed light before rest, and the reproduction of calm music or natural sounds. These effects have positive effects on the physiological state of piglets, reduce stress levels, and improve the quality of rest and overall welfare of the animals (Li et al., 2020; Ciborowska et al., 2021; Lippi et al., 2022).

Therefore, the use of enrichment objects in the housing of growing piglets not only reduces stress levels but also significantly reduces the manifestations of undesirable oral manipulations (tail and ears biting), which is one of the main problems of modern pig farming. Properly selected and combined environmental enrichment strategies minimize cases of aggression and cannibalism while contributing to harmonious growth and development and improved animal welfare. This topic is of particular value from a practical point of view: it opens the way to the implementation of new approaches in production conditions that meet EU requirements for animal welfare. For this reason, the authors focused on comparative research of enrichment strategies for growing piglets and assessing pig welfare experimentally. The results obtained can become not only a theoretical basis but also a real tool for farmers, consultants and researchers who seek to combine pig productivity with high standards of welfare.

## 2. Materials and Methods

### *2.1. Ethics*

The animal treatments used in the experiments fully complied with the requirements. Conditions for feeding, watering, housing, care, prevention and treatment following European legislation on the protection of animals and their comfort (Council Directive 2008/120/EU) and the Order of the Ministry of Economy of Ukraine «On approval of the requirements for the welfare of farm animals during their housing» of February 18, 2021, were organized. The Bioethics Commission of the National University of Life and Environmental Sciences of Ukraine approved the experimental protocol (November 30, 2023 (008)).

*2.2. Experimental design*

Experimental studies were carried out during the period of 2023, at the farm of Ukraine – the private rental enterprise "Victoria" of the Bashtanka district, Mykolayiv region. The experiment used four groups of piglets – a 1st control group (1CON), 2nd (2EXP), 3rd (3EXP), and 4th (4EXP) – and – experimental groups of 22 heads each.

The growing piglets were kept in pens on a fully slatted polymer floor with an area of 0.4 m² per head. Transportation of feed by cable–pulley conveyors to automatic feeders. Two adjacent pens are equipped with one automatic feeder, each of which has two cup-type automatic drinkers installed. The diets of the piglets in all the experimental groups were identical according to specific feeding standards, taking into account the physiological characteristics of the animals and the type of feeding. Until the 42nd day of life, the piglets were fed ad libitum with complete prestarter compound feed from the company "Cehavekorm", and from the 42nd to the 49th day, they were gradually transferred from prestarter to starter feed produced in our own feed mill based on cereal crops, "Cehavit pig concentrate starter", from the company "Cehavekorm". The nutritional value was as follows: a crude protein content of 182.700 g/kg and metabolic energy of 3164.800 kcal/kg. The compound feed contained the following ingredients (%): wheat (45.000), barley (25.000), and Cehavit pig concentrate starter (30.000) (the certificate of quality according to the Technical Conditions of the State Standard of Ukraine 4508:2005).

The ventilation system in the negative pressure room was implemented with exhaust fans and supply valves. Air was fed into the room through the valves, mixed with the existing air, and extracted by the fan. The microclimate was regulated via computer equipment. Microclimate parameters during the maintenance of growing piglets corresponded to the Departmental Norms for Technological Design - Agro-Industrial Complex - 02.05 «Pig-breeding enterprises (complexes, farms, small farms) », 2005. During the experimental period, the average indoor air temperature ranged from 22.0 to 24.0°C, the relative humidity ranged from 60 to 80%, and the air velocity ranged from 0.20 to 0.60 m $s^{-1}$, in accordance with national design standards. These conditions are continuously regulated by an automated ventilation system, which minimizes heat stress while still reflecting typical summer biometeorological challenges that may influence exploratory and oral behaviors in growing pigs. Piglets were heated during the early stages of growth via UV heaters that were suspended at a height of 1.2 m. Houses were heated via a 100-kW pyrolysis boiler and a twin-pipe system.

Manure removal from the housing involved vacuum self-flow. Manure removal was carried out as the samples were filled under slatted tubs but at least once every two weeks via a vacuum self-flowing system.

The piglets were brought to the section every Thursday, immediately after weaning from the sows, weighed and maintained there for 7 weeks until they reached 77 days of age, after which they were weighed individually and sent for fattening.

*2.3. Enrichment objects*

The age of the piglets at the beginning of the experiment was 28 days. The Piglets in the 1CON group were not enriched; the 2EXP group was maintained with a cotton rope twisted with a diameter of 16 mm (Figure 1) to hang on the pen fence; the 3EXP group was maintained with plastic bottles with a volume of 1 liter, 50% filled with grain (Figure 2), with 4 units per pen rotated weekly; and the 4EXP group, with a density of 80 g/m2 (Figure 3), was rolled into a ball and changed twice a day.

The enrichment objects were provided to the experimental groups of piglets during the day before the start of video monitoring (day 0) to ensure that all pigs were accustomed to the objects by the following morning. The objects (Figure 2) and (Figure 3) were placed on the floor in the cleanest part of the pen, far enough from the walls to ensure all-round access. The suspended object (Figure 1) was placed on the pen so that the pigs could manipulate it from all sides.

All enrichment materials used in the study were soft or destructible (cotton rope, wrapping paper) or combined destructible with sensory stimulation (grain-filled plastic bottles). No hardwood materials were used. This ensured that differences in pig interactions were not limited by excessive material hardness.

*2.4. Pig welfare assessment*

The welfare assessment of growing piglets was determined by the health status of each animal, and possible injuries to the piglets' body parts were assessed by the same observer each week in the pen via the Pig Welfare Quality Assessment (Welfare Quality, 2009), modified (Warns et al., 2021) and included lameness, injuries to the ears, carpal joints and sides of the body. The assessment of possible tail lesions was carried out according to the German pig scoring system (Friedrich Loeffler Institute, 2017), modified (Warns et al., 2021). Tear staining was conducted following the DeBoer–Marchant–Forde scale as described by DeBoer et al. (2015) with a 5-point scale. At a score of 0, there are no signs of staining. At a score of 1, the stain does not extend below the eyelid. At a score of 2, the stain is approximately 50% of the eye area, whereas at a score of 3, the stain is 50–100% of the eye area. At a score of 4, the stain is >100% of the eye area but does not extend below the mouth line, whereas at a score of 5, it does reach below the mouth line.

**Figure 1** Cotton twisted rope suspended on the fence of the pen.
*Note:* the orange oval highlights the enrichment object for piglets 2nd experimental group (2EXP).

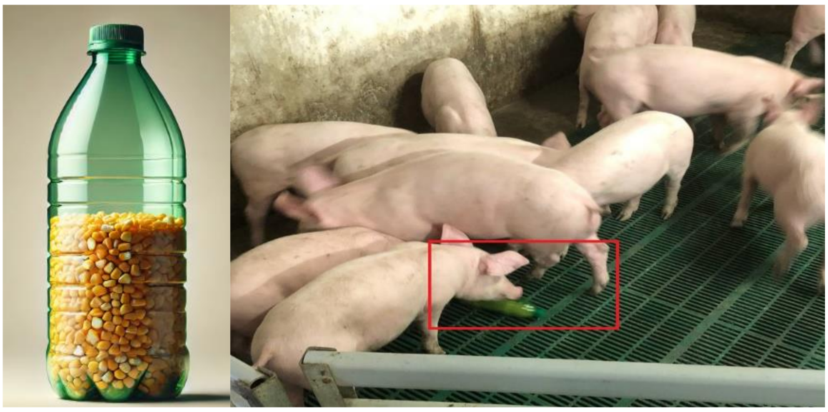

**Figure 2** Plastic bottles with a volume of 1 liter, 50% filled with grain.
*Note:* the red rectangle highlights the enrichment object for piglets 3rd experimental group (3EXP).

**Figure 3** Wrapping paper rolled into a ball.
*Note:* the yellow circles highlight the enrichment object for piglets 4th experimental group (4EXP).

### *2.5. Statistical analysis*

To compare piglet welfare assessment parameters at the beginning and at the end of the growing period, the Wilcoxon signed-rank test was used. To assess the independence of the manifestation of welfare parameters at weaning and at the end of the growing period, Friedman's rank analysis of variance was applied. The pen was considered the experimental unit, as enrichment was applied at the pen level, whereas individual piglets were used for welfare scoring as repeated observations within pens. Because each treatment corresponded to one pen per group, the pen effect was addressed via nonparametric paired and rank-based tests, which are appropriate for pen-level comparisons with repeated measurements. All the statistical analyses were performed according to generally accepted methods (Shebanina et al., 2008) via PAST software (Hammer et al., 2001).

## 3. Results and Discussion

A comparison of the results of the welfare assessment of each piglet at weaning and at the end of the growing period, depending on the type of enrichment, revealed significant differences in lameness only among the animals in the 1CON group (Wilcoxon signed-rank test: W = 2.31; P = 0.021) (Figure 4). The results indicate that in the absence of enrichment objects, the housing environment exerts additional stress, which in turn affects the state of the musculoskeletal system.

In particular, a significant change was recorded in the assessment of welfare throughout the growing period. Of the eighteen piglets that showed no signs of lameness (score of 0) at weaning, six demonstrated lameness at the end of the growing period, with four pigs having a score of 1 and two pigs having a score of 2. Furthermore, of the four piglets with a lameness score of 1 at weaning, two progressed to a score of 2 by the end of the growing period (Figure 5). These data demonstrate the progression of limb pathologies in the absence of adequate environmental enrichment, which may be indirectly associated with increased levels of aggressive or stereotypic behaviors.

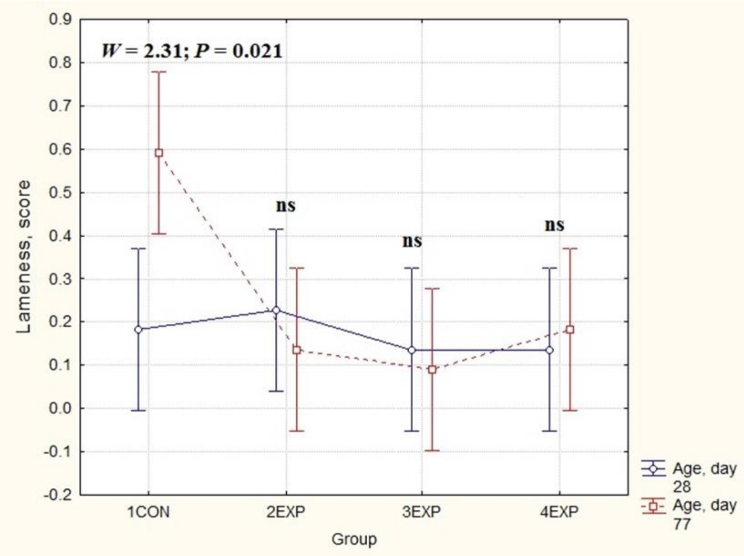


**Figure 4** Estimates of arithmetic mean (± 95% CI) lameness of piglets depending on group and age.

**Figure 5** Lameness of growing pig 1CON group.

Assessing limb condition is an important parameter of pig welfare during growth, as damage often leads to impaired natural locomotion, lameness and consequently premature culling (Mustonen et al., 2011). A comparison of our results with data from other authors confirms the importance of constructive solutions to housing design. As noted by Yang et al. (2024), pigs kept in pens with elevated platforms had lower limb injury scores than did the control group throughout the entire fattening period. This is clearly explained by the presence of thick bedding, which reduces pressure on the joints and hooves, creating more comfortable conditions for movement.

Similar patterns have been reported in other studies (Jørgensen, 2003; Scott et al., 2006), where the use of straw bedding significantly reduced the incidence of hoof and limb injuries in pigs. These findings indicate that even minor modifications to the microenvironment can have a significant effect on the physical welfare of animals.

Yang et al. (2024) reported that as the animals grew, the level of limb damage increased in both experimental groups. This observation is consistent with the hypothesis that floor type is a critical factor in the development of limb injuries. In this study, concrete flooring may have contributed to bursitis, calluses and mechanical damage, which corresponds with the findings of KilBride et al. (2008), who reported a greater risk of limb injuries on concrete floors than on metal or plastic floors.

A similar tendency was observed in the analysis of injuries to carpal joints. A comparison of the welfare assessment of each piglet at weaning and at the end of the growing period revealed significant differences in carpal joints only among the animals in the control group (Wilcoxon signed-rank test: $W = 3.64$; $P < 0.001$) (Figure 6). The results once again confirm that the absence of objects for behavioral activity creates conditions for microtrauma to supportive structures. Among the sixteen piglets without carpal joint lesions at weaning (score of 0), ten had a score of 1 or 2 at the end of the growing period. Of the six animals with an initial injury score of 1, four progressed to a score of 2 at the end of the growing period. It can be assumed that the intensity of motor activity without the possibility of implementing natural manipulative actions (rooting, chewing, researching) potentially increases the load on joints and limbs.

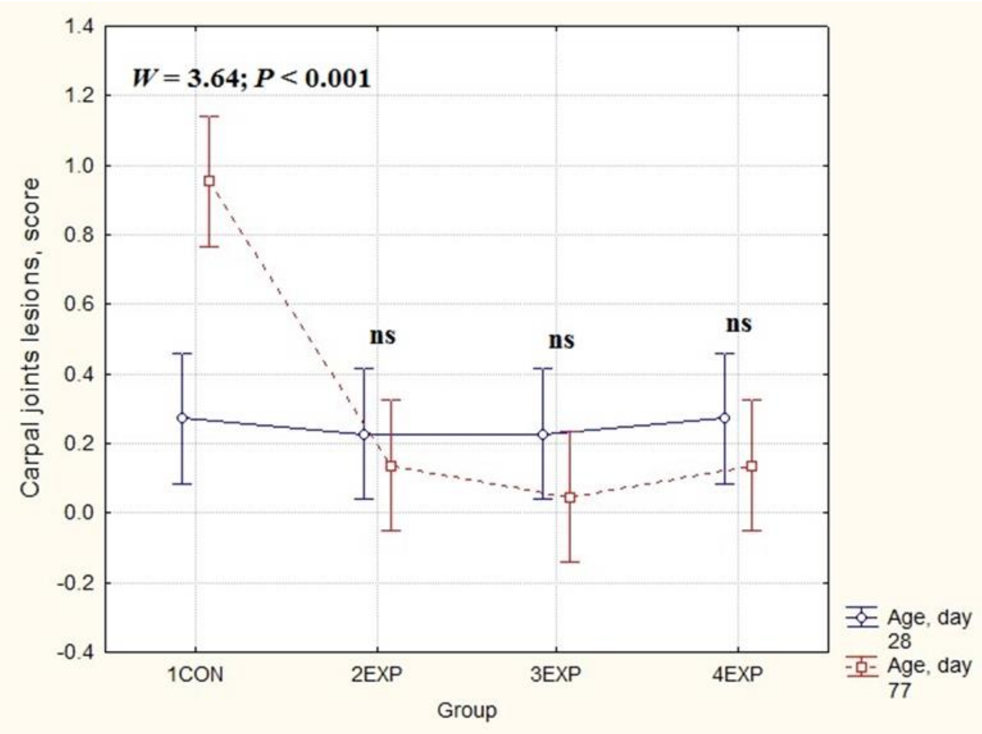


**Figure 6** Estimates of arithmetic means (± 95% CI) carpal joints lesions of piglets depending on group and age.

The results of previous studies (van Staaveren et al., 2019) demonstrated that the prevalence of both mild and severe body-side lesions in fattening pigs was not significantly correlated with the type of enrichment objects used ($F_{2,25} = 0.80$; $p = 0.4616$; $F_{2,25} = 0.82$; $p = 0.4515$; $F_{2,25} = 0.60$; $p = 0.5556$). In addition, the number of enrichment elements per pig did not correlate with the level of damage to the sides of the body ($F_{1,\ 25} = 0.02$; $p = 0.8888$). These results indicate that enrichment alone is not always the determining factor in preventing mechanical injuries and that additional behavioral or technological factors can be involved.

The same authors (van Staaveren et al., 2019) also concluded that body-side lesions can represent an independent welfare issue that is not directly related to the type of environmental enrichment. Moreover, their high prevalence on commercial farms highlights the importance of a comprehensive assessment of housing conditions, considering that stocking density, behavioral interactions and microclimate parameters can indirectly contribute to injury occurrence. In general, our results are consistent with these conclusions (van de Weerd & Ison, 2019), who highlighted that even when effective enrichment objects are available, pigs actively interact with them, but this does not always lead to the complete elimination of harmful behavior or mechanical injuries.

A comparison of the results of the welfare assessment of each piglet at weaning and at the end of the growing period revealed that, depending on the type of enrichment, significant differences in body-side lesions were found only among the animals in the control group (Wilcoxon signed-rank test: 2.89; P = 0.004) (Figure 7, Figure 8). These findings indicate that in the absence of environmental enrichment, the risk of microtrauma and mechanical damage increases significantly throughout the growing period. A detailed analysis revealed that out of seventeen piglets had no damage to their body side lesions at weaning (score of 0), seven piglets had body side lesions by the end of growth: six animals were scored as 1, and one animal was scored as 2. Among the five animals with an initial damage score of 1, two had already reached a score of 2 by the end of the period. This dynamic confirms the tendency for lesions to accumulate in animals deprived of behavioral stimuli for natural activity.

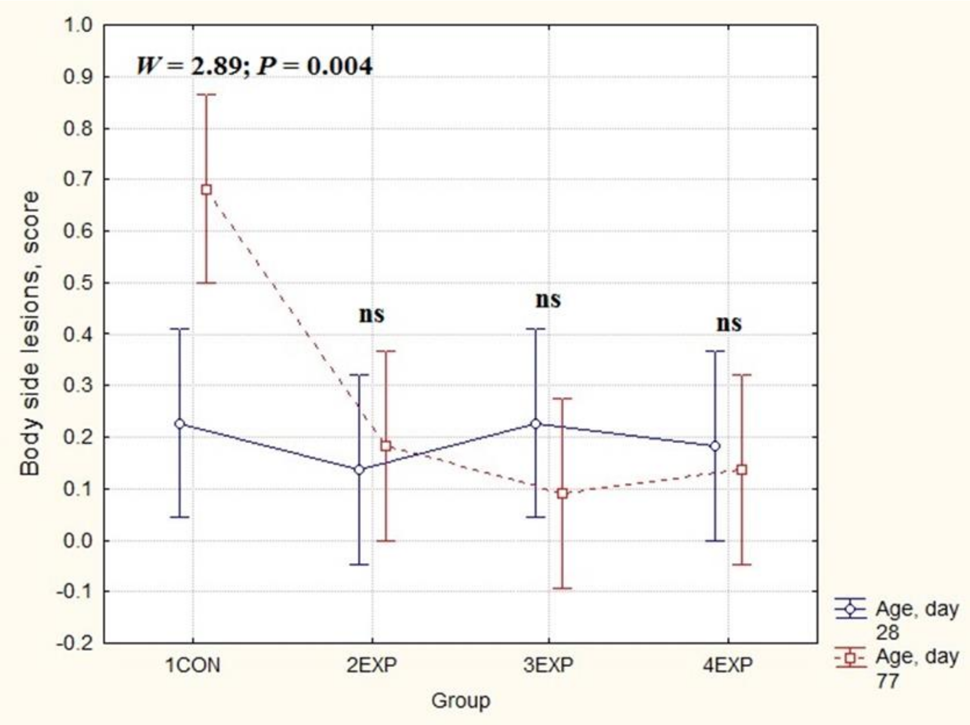


**Figure 7** Estimates of arithmetic means (± 95% CI) body side lesions of piglets depending on group and age.

**Figure 8** Body side lesions of growing pig 1CON group.

On the basis of the data presented here, it can be assumed that body-side lesions in pigs are multifactorial in nature, with social behavior, stress, and spatial constraints playing a leading role rather than just the characteristics of enrichment materials. Our results are consistent with the hypothesis that a balanced environment that provides both physical comfort and social stability within the group is a key factor in preventing injuries and improving the welfare of pigs.

Tail docking of piglets was practiced at the experimental farm – a procedure that, despite numerous warnings, remains common both in Ukraine and in several other countries. This approach is traditionally considered a preventive measure against tail biting, but it does not eliminate the behavioral causes of this phenomenon. As noted by Goossens et al. (2008), ear biting occurs more frequently on farms where tail docking is performed, significantly because the shortened tail ceases to be an attractive object for oral manipulation.

Even under tail docking conditions, the natural behavior of pigs remains unsatisfactory, leading to the redirection of oral manipulation toward other body parts of pen mates. This finding is consistent with the data from Camerlink et al. (2015), who reported that pigs with intack or half-docked tails were more likely to bite ears and engage in other forms of body manipulation than to bite tails. Moreover, the animals performed oral actions much more often in the direction of their neighbors in the pen than in the direction of the enrichment objects offered. This is probably explained by two main factors. On the one hand, the body parts of other pigs can better satisfy the natural need for chewing and rooting activity, making them more attractive objects for oral manipulation (Van de Weerd et al., 2003). On the other hand, an imbalance between the number of animals in the pen and the available enrichment objects creates competition for resources, increasing frustration and stimulating aggressive or displacement behavior.

A comparison of the welfare assessment of each piglet at weaning and at the end of the growing period, depending on the type of enrichment, revealed significant differences in ear biting among only the animals in the control group (Wilcoxon signed-rank test: 3.47; P < 0.001) (Figure 9, Figure 10). These findings indicate a significant impact of the absence of environmental enrichment on the dynamics of ear biting during the growing period.

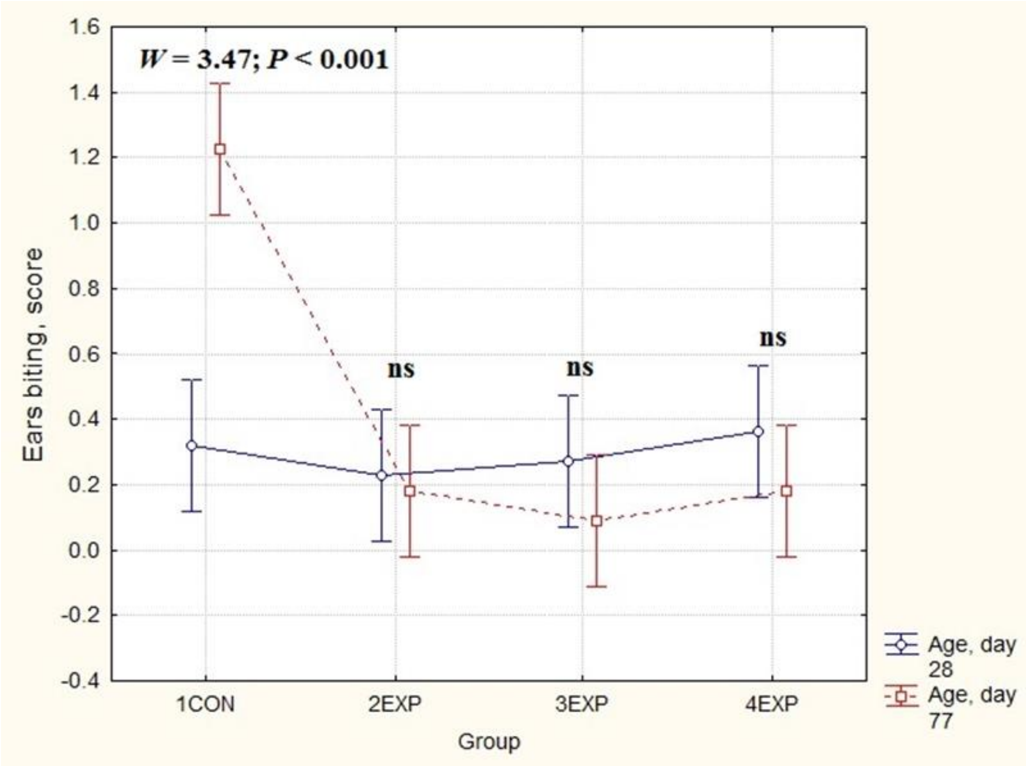


**Figure 9** Estimates of arithmetic means (± 95% CI) ears biting of piglets depending on group and age.

A detailed analysis revealed that, out of the fifteen piglets that did not bite ears at weaning (score of 0), twelve piglets bites ears by the end of growth: six animals were scored as 1, and five animals were scored as 2. Among the seven animals that had a score of 1 at the beginning of the experiment, four received a score of 2 at the end of the period. The absence of opportunities to express natural research behavior likely led to the redirection of activity toward social partners, resulting in an increase in the incidence of ear biting.

Similar tendencies were described by van Staaveren et al. (2019), who concluded that the frequency of ear biting in fattening pigs did not depend on the type of enrichment ($F_{2,25} = 1.35$; $p = 0.2778$) and that the number of enrichment objects per pig had no significant relationship with the level of the corresponding behavior ($F_{1,25} = 0.57$; $p = 0.4578$). Our results are consistent with the scientific data, confirming that not only enrichment objects but also their availability, social interactions and pen density play key roles in the formation of damage. In summary, effective reduction of ear biting is possible only with a comprehensive approach to the housing environment, combining optimal space, social compatibility of animals, sufficient stimulating objects and avoidance of stress factors.

**Figure 10** Injures of ears of growing pig 1CON group.

Despite the active development of animal welfare standards, such as those in Ukraine, as in some European Union countries, the practice of tail docking in pigs remains widespread. This procedure, involving partial or complete amputation of the tail at a young age, is traditionally used to reduce the risk of further damage in adult animals (Sutherland and Tucker, 2011). However, numerous studies have shown that tail docking does not eliminate the main behavioral cause of the problem – the pig's tendency to engage in oral manipulation. As a result, injuries and inflammation in the tail area remain common, even on farms where this procedure is standard practice (Valros and Heinonen, 2015).

The results of the experiment by Meer et al. (2017) additionally confirmed this trend: almost all of the experimental animals showed signs of biting, and approximately 39% of pigs had noticeable or significant wounds on their tails during the production cycle. This finding indicates that tail docking does not guarantee the prevention of biting but only masks its consequences. The data also revealed that the percentage of pigs with tail injuries was greater than that with ear biting, suggesting that, despite its lower frequency, tail biting is more serious and traumatic and is associated with more intense forms of aggression or stress (Scollo et al., 2013).

Similar conclusions were reached by van Staaveren et al. (2019), who noted that the frequency of tail behavior significantly depends on the type of enrichment object; in particular, a statistically significant difference was found between chain and plastic devices ($F_{2,25}$ = 3.41; p = 0.0488; $t_{25}$ = 2.22; p = 0.0869). This metric can indicate different levels of sensory stimulation that animals receive from enrichment materials. The quality and properties of enrichment objects, rather than their quantity, are likely needed to determine their effectiveness in preventing harmful oral behavior.

A comparison of the welfare assessment of each piglet at weaning and at the end of the growing period revealed that, depending on the type of enrichment, significant differences in tail biting were found only among the animals in the control group (Wilcoxon signed-rank test: 2.98; P = 0.003) (Figure 11). These findings indicate that the absence of objects for the implementation of natural behavior increases the risk of developing injuries and inflammation in the tail area during growth.

A detailed analysis revealed that out of the twelve piglets that did not bite the tail at weaning (score of 0), nine piglets bit the tail by the end of growth: six animals were scored as 1, and three animals were scored as 2. Among the ten animals that had a score of 1 at the beginning of the experiment, five received a score of 2 at the end of the period. Therefore, it can be assumed that with age and increased pen density, the intensity of contact between animals and the absence of adequate environmental enrichment contribute to the development of stereotypical or aggressive forms of behavior. Our results suggest that reducing tail biting is only possible through a combination of behavioral and technological solutions.

To assess the level of animal welfare, a noninvasive method for determining the intensity of tear color in the eye area of pigs to reflect the level of porphyrin secretion, a natural pigment secreted by the Harderian gland, was used (Santillo et al., 2020). As noted by Telkänranta et al. (2016), tear staining is a promising biomarker of pig welfare, as tear intensity is positively correlated with the degree of tail and ear damage in the same animal. The authors emphasize that this indicator can be used as a rapid tool for monitoring the emotional state of animals without the need for stressful manipulations.

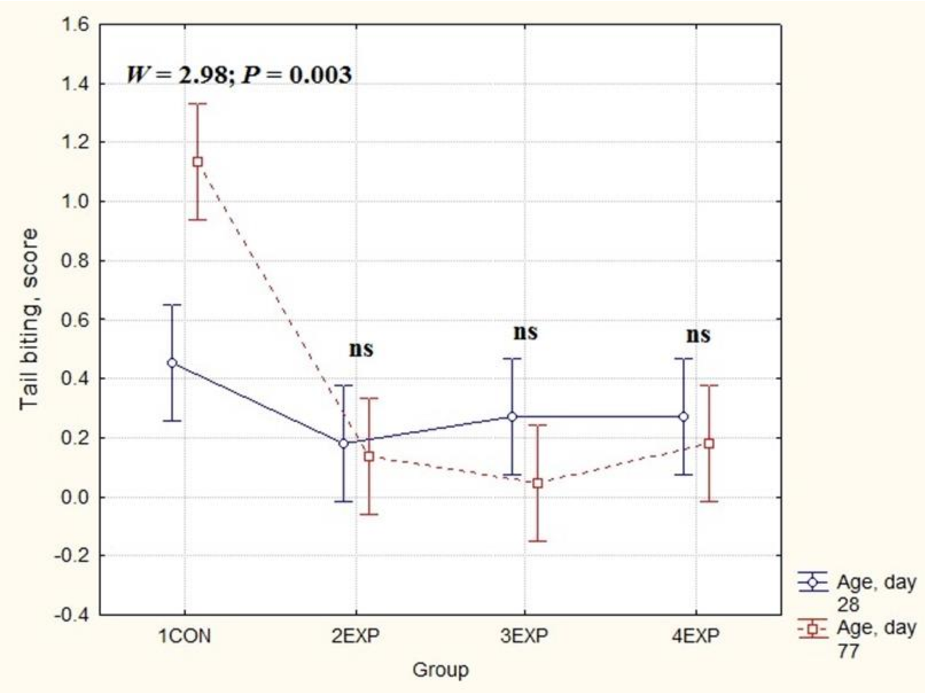


**Figure 11** Estimates of arithmetic means (± 95% CI) tail biting of piglets depending on group and age.

Similar conclusions were reached by DeBoer et al. (2015), who reported that tear staining is a sensitive marker of stress levels and that its reduction is observed under conditions of an enriched environment and social interaction. Larsen et al. (2019) noted that tear staining can reflect age, physiological and behavioral changes, and the influence of housing conditions and the microclimate. The results of Lagoda et al. (2023) confirmed that tear staining is reduced in animals with better housing conditions, which correlates with reduced levels of aggression and improved social stability in groups. Recently, Vacušková et al. (2025) confirmed via thermographic analysis that the intensity of porphyrin spots is accompanied by an increase in temperature around the eyes, indicating physiological stress responses.

A comparison of the welfare assessment of each piglet at weaning and at the end of the growing period revealed significant differences in the intensity of tear staining color among the three groups: 1CON (Wilcoxon signed-rank test: = 4.14; $P < 0.001$), 2nd EXP (Wilcoxon signed-rank test: = 2.71; $P = 0.007$) and 4th EXP (Wilcoxon signed-rank test: = 3.81; $P < 0.001$) (Figure 12).

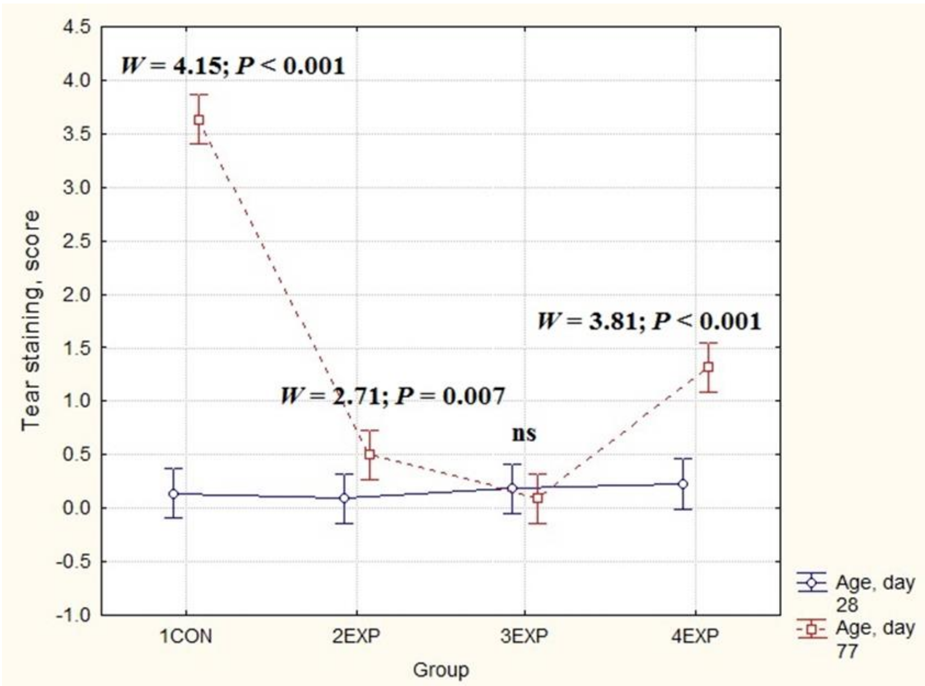


**Figure 12** Estimates of arithmetic means (± 95% CI) tear staining of piglets depending on group and age.

Changes in the intensity of the porphyrin stains during growth were observed in most groups, except for group 3rd E, where the parameters remained stable. Thus, an increase in the intensity of tear staining at the end of growth was noted in nineteen animals in the 1 CON group (86.3%), eight animals in the 2nd EXP group (36.4%) and nineteen animals in the 4th EXP group (86.3%). The assessment results revealed that, in pigs in the 1CON group.

The level of tear staining according to the scale was 4–5 points (Figure 13), 2EXP and 4EXP were 1–2 points (Figure 14), and 3EXP was 0–1 point (Figure 15).

**Figure 13** Tear staining of growing pigs 1 CON group.

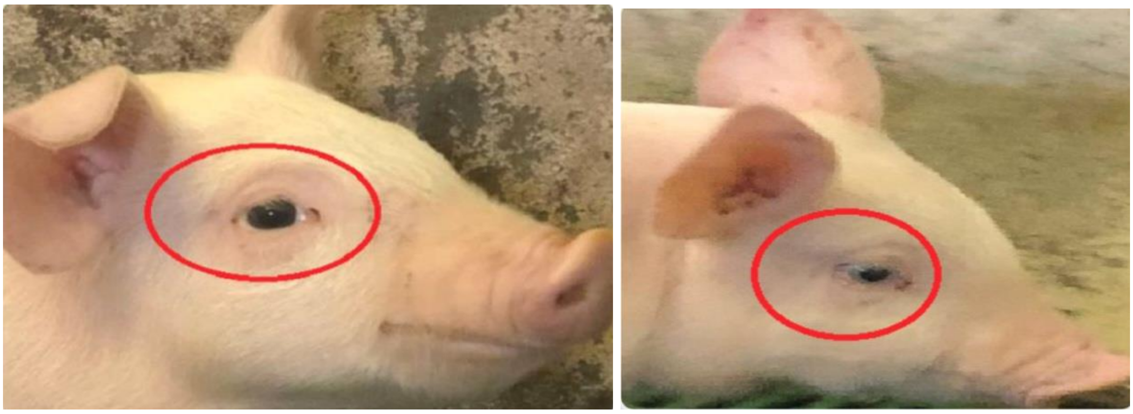

**Figure 14** Tear staining of growing pigs 2EXP and 4 EXP groups.

These results are consistent with the findings of Telkänranta et al. (2016), Larsen et al. (2019) and Lagoda et al. (2023), who reported that the absence of enriched objects and sensory deprivation increase the manifestations of tear staining, reflecting emotional stress and behavioral frustration. Thus, the results obtained confirm that the intensity of tear staining can be a reliable integral indicator of the mental health of pigs to respond sensitively to changes in housing conditions depending on the enrichment object. Its use in combination with behavioral, physiological and clinical criteria allows the formation of a comprehensive system for assessing animal welfare, which is the key not only to ethical housing but also to the successful management of modern pig farming.

**Figure 15** Tear staining of growing pigs 3EXP group.

## 4. Conclusions

The findings of this study demonstrate that the welfare status of growing piglets is strongly influenced by the quality and type of environmental enrichment provided. The absence of suitable enrichment objects increases the risk of tail injury and inflammation, as does the intensity of tear staining, indicating increased emotional tension and chronic stress. In contrast, the inclusion of enrichment materials that stimulate research and chewing behaviors contributes to a reduction in oral manipulative activity, stabilization of emotional responses and, in general, improvement in animal welfare.

Tear staining intensity has proven to be an effective noninvasive bioindicator of stress in piglets and is sensitive to changes in housing conditions and enrichment type. When combined with behavioral, clinical and physiological parameters, this indicator can serve as a valuable component of an integrative welfare assessment system for pigs in commercial production.

From a practical standpoint, implementing balanced environmental enrichment strategies alongside routine monitoring of tear staining can provide an early warning system for stress detection and prevention of damaging behaviors. This approach not only promotes higher ethical standards of pig husbandry but also increases production efficiency by reducing losses associated with injuries, stress and premature culling.

## 5. Declarations

### 5.1. Ethical considerations

The experimental procedures were approved by the Bioethics Commission of the National University of Life and Environmental Sciences of Ukraine (Protocol No. 008, November 30, 2023). All procedures complied with Directive 2008/120/EC and Directive 2010/63/EU, as well as national Ukrainian legislation on animal welfare.

### 5.2. Use of artificial intelligence (AI)

The authors declare that no generative artificial intelligence (AI) tools were used in the preparation, analysis, or writing of this manuscript.

### 5.3. Conflicts of interest

The authors declare that they have no conflicts of interest.

### 5.4. Funding

This research did not receive any financial support.

## References

Arulmozhi, E., Bhujel, A., Moon, B.-E., & Kim, H.-T. (2021). The application of cameras in precision pig farming: An overview for swine-keeping professionals. *Animals, 11*(8), 2343. https://doi.org/10.3390/ani11082343

Averós, X., Brossard, L., Dourmad, J.-Y., de Greef, K. H., Edge, H. L., Edwards, S. A., & Meunier-Salaün, M.-C. (2010). A meta-analysis of the combined effect of housing and environmental enrichment characteristics on the behaviour and performance of pigs. *Applied Animal Behaviour Science, 127*, 73–85. https://doi.org/10.1016/j.applanim.2010.09.010

Beaudoin, J.-M., Bergeron, R., Devillers, N., & Laforest, J.-P. (2019). Growing pigs' interest in enrichment objects with different characteristics and cleanliness. *Animals, 9*(3), 85. https://doi.org/10.3390/ani9030085

Boyle, L. A., Edwards, S. A., Bolhuis, J. E., Pol, F., Šemrov, M. Z., Schütze, S., Nordgreen, J., Bozakova, N., Sossidou, E. N., & Valros, A. (2022). The evidence for a causal link between disease and damaging behavior in pigs. *Frontiers in Veterinary Science, 8*, 771682. https://doi.org/10.3389/fvets.2021.771682

Bracke, M. B. M. (2007). Multifactorial testing of enrichment criteria: Pigs 'demand' hygiene and destructibility more than sound. *Applied Animal Behaviour Science, 107*(3–4), 218–232. https://doi.org/10.1016/j.applanim.2006.10.001

Bracke, M. B. M. (2018). Chains as proper enrichment for intensively-farmed pigs? In M. Špinka (Ed.), *Advances in pig welfare* (pp. 167–197). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-101012-9.00005-8

Bracke, M. B. M., & Koene, P. (2019). Expert opinion on metal chains and other indestructible objects as proper enrichment for intensively-farmed pigs. *PLoS ONE, 14*, e0212610. https://doi.org/10.1371/journal.pone.0212610

Buijs, S., & Muns, R. (2019). A review of the effects of non-straw enrichment on tail biting in pigs. *Animals, 9*(10), 824. https://doi.org/10.3390/ani9100824

Camerlink, I., Ursinus, W. W., Bijma, P., Kemp, B., & Bolhuis, J. E. (2015). Indirect genetic effects for growth rate in domestic pigs alter aggressive and manipulative biting behaviour. *Behavior Genetics, 45*, 117–126. https://doi.org/10.1007/s10519-014-9671-9

Chou, J.-Y., O'Driscoll, K., D'Eath, R. B., Sandercock, D. A., & Camerlink, I. (2019). Multi-step tail biting outbreak intervention protocols for pigs housed on slatted floors. *Animals, 9*, 582. https://doi.org/10.3390/ani9080582

Ciborowska, P., Michalczuk, M., & Bień, D. (2021). The effect of music on livestock: Cattle, poultry and pigs. *Animals, 11*(12), 3572. https://doi.org/10.3390/ani11123572

Costantino, A., Comba, L., Cornale, P., & Fabrizio, E. (2022). Energy impact of climate control in pig farming: Dynamic simulation and experimental validation. *Applied Energy, 309*, 118457. https://doi.org/10.1016/j.apenergy.2021.118457

Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (codified version). (2009). *Official Journal of the European Union, L 47*, 5–13.

Council Directive 2010/63/EC of 22 September 2010 on the protection of animals used for scientific purposes. (2010). *Official Journal of the European Union, L 276*, 33–79.

Courboulay, V. (2004). Comment l'apport d'objets manipulables en hauteur et au sol influence-t-il l'activité des porcs charcutiers logés sur caillebotis intégral. *Journées de la Recherche Porcine, 36*, 389–394.

De Jong, I. C., Prelle, I. T., Van de Burgwal, J. A., Lambooij, E., Korte, S. M., Blokhuis, H. J., & Koolhaas, J. M. (2000). Effect of environmental enrichment on behavioral responses to novelty, learning and memory and the circadian rhythm in cortisol in growing pigs. *Physiology & Behavior, 68*(4), 571–578. https://doi.org/10.1016/S0031-9384(99)00212-7

DeBoer, S., Garner, J., McCain, R., Lay, D., Eicher, S., & Marchant-Forde, J. (2015). An initial investigation into the effects of isolation and enrichment on the welfare of laboratory pigs housed in the PigTurn system, assessed using tear staining, behaviour, physiology and haematology. *Animal Welfare, 24*(1), 15–27. https://doi.org/10.7120/09627286.24.1.015

Delsart, M., Pol, F., Dufour, B., Rose, N., & Fablet, C. (2020). Pig farming in alternative systems: Strengths and challenges in terms of animal welfare, biosecurity, animal health and pork safety. *Agriculture, 10*(7), 261. https://doi.org/10.3390/agriculture10070261

Departmental Norms for Technological Design—Agro-Industrial Complex—02.05 "Pig-breeding enterprises (complexes, farms, small farms)." (2005). Ministry of Agrarian Policy of Ukraine.

EFSA. (2007). Scientific report on the risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. *EFSA Journal, 611*, 1–13. https://doi.org/10.2903/j.efsa.2007.611

Elkmann, A., & Hoy, S. (2009). Frequency of occupation with different simultaneously offered devices by fattening pigs kept in pens with or without straw. *Livestock Science, 124*, 330–334. https://doi.org/10.1016/j.livsci.2008.12.008

Fàbrega, E., Marcet-Rius, M., Vidal, R., Escribano, D., Cerón, J. J., Manteca, X., & Velarde, A. (2019). The effects of environmental enrichment on the physiology, behaviour, productivity and meat quality of pigs raised in a hot climate. *Animals, 9*(5), 235. https://doi.org/10.3390/ani9050235

Friedrich-Loeffler-Institut. (2017). *Deutscher Schweine Bonitur Schlüssel*. Friedrich-Loeffler-Institut.

Gifford, A. K., Cloutier, S., & Newberry, R. C. (2007). Objects as enrichment: Effects of object exposure time and delay interval on object recognition memory of the domestic pig. *Applied Animal Behaviour Science, 107*, 206–217. https://doi.org/10.1016/j.applanim.2006.10.019

Godyń, D., Herbut, P., Angrecka, S., & Corrêa Vieira, F. M. (2020). Use of different cooling methods in pig facilities to alleviate the effects of heat stress: A review. *Animals, 10*(9), 1459. https://doi.org/10.3390/ani10091459

Godyń, D., Nowicki, J., & Herbut, P. (2019). Effects of environmental enrichment on pig welfare: A review. *Animals, 9*(6), 383. https://doi.org/10.3390/ani9060383

Goossens, X., Sobry, L., Ödberg, F., Tuyttens, F., Maes, D., De Smet, S., Nevens, F., Opsomer, G., Lommelen, F., & Geers, R. (2008). A population-based on-farm evaluation protocol for comparing the welfare of pigs between farms. *Animal Welfare, 17*(1), 35–41. https://doi.org/10.1017/S0962728600031961

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica, 4*(1), 1–9.

Jørgensen, B. (2003). Influence of floor type and stocking density on leg weakness, osteochondrosis and claw disorders in slaughter pigs. *Animal Science, 77*(3), 439–449. https://doi.org/10.1017/S1357729800054382

KilBride, A. L. (2008). *An epidemiological study of foot, limb and body lesions and lameness in pigs* (Doctoral dissertation, University of Warwick). University of Warwick.

Lagoda, M. E., O'Driscoll, K., Galli, M. C., Marchewka, J., & Boyle, L. A. (2023). Indicators of improved gestation housing of sows. Part I: Effects on behaviour, skin lesions, locomotion, and tear staining. *Animal Welfare, 32*(1), e51. https://doi.org/10.1017/awf.2023.47

Larsen, M. L. V., Gustafsson, A., Marchant-Forde, J. N., & Valros, A. (2019). Tear staining in finisher pigs and its relation to age, growth, sex, and potential pen-level stressors. *Animal, 13*(10), 2134–2141. https://doi.org/10.1017/S1751731118003646

Li, J., Han, Q., Zhang, R., Liu, H., Li, X., & Bao, J. (2020). PSV-7 Effects of music stimulus on behavior response, cortisol level and immunity horizontal of growing pigs. *Journal of Animal Science, 98*, 224–225. https://doi.org/10.1093/jas/skaa278.412

Lippi, I. C. C., Caldara, F. R., Almeida-Paz, I. C. L., Morais, H. B., Odakura, A. M., Konkiewitz, E. C., Ferreira, W. S., Fraga, T. L., Burbarelli, M. F. C., Felix, G. A., Garcia, R. G., & Santos, L. S. (2022). Effects of music therapy on neuroplasticity, welfare, and performance of piglets exposed to music therapy in the intra- and extra-uterine phases. *Animals, 12*(17), 2211. https://doi.org/10.3390/ani12172211

Lykhach, A. V., Lykhach, V. Y., Shpetny, M. B., Mykhalko, O. H., & Zhyzhka, S. V. (2020). Influence of toys on behavioural patterns of pigs and their association with the concentration of serotonin in blood plasma. *Regulatory Mechanisms in Biosystems, 11*(1), 146–150. https://doi.org/10.15421/022022

Lykhach, A., Lykhach, V., Faustov, R., Getya, A., & Lesik, I. (2022). Influence of enrichment materials on the behaviour and productive traits of fattening pigs. *Acta Fytotechnica et Zootechnica, 25*(2), 77–84. https://doi.org/10.15414/afz.2022.25.02.77-84

Meer, Y., Gerrits, W. J. J., Jansman, A. J. M., Gerritsen, R., Lambert, W., Zonderland, J. J., & Bolhuis, J. E. (2017). A link between damaging behaviour in pigs, sanitary conditions, and dietary amino acid profile. *PLoS ONE, 12*(4), e0174688. https://doi.org/10.1371/journal.pone.0174688

Mun, H.-S., Lagua, E., Ampode, K. M. B., Chem, V., Park, H.-R., Kim, Y.-H., & Yang, C.-J. (2023). Interactions of environmental conditions, day-night cycles, and growing periods on postural behavior of pigs. *Journal of Animal Behaviour and Biometeorology, 11*(4), 2023035. https://doi.org/10.31893/jabb.23035

Mustonen, K., Ala-Kurikka, E., Orro, T., Peltoniemi, O., Raekallio, M., Vainio, O., & Heinonen, M. (2011). Oral ketoprofen is effective in the treatment of non-infectious lameness in sows. *The Veterinary Journal, 190*(1), 55–59. https://doi.org/10.1016/j.tvjl.2010.09.017

Order of the Ministry for Development of Economy, Trade and Agriculture of Ukraine No. 224 dated 08.02.2021 «On approval of requirements for the welfare of farm animals during their keeping». (2021). *Official Bulletin of Ukraine*. https://zakon.rada.gov.ua/laws/show/z0206-21#Text

Pietrosemoli, S., & Tang, C. (2020). Animal welfare and production challenges associated with pasture pig systems: A review. *Agriculture, 10*(6), 223. https://doi.org/10.3390/agriculture10060223

Rabhi, N., Thibodeau, A., Côté, J.-C., Devillers, N., Laplante, B., Fravalo, P., Larivière-Gauthier, G., Thériault, W. P., Faucitano, L., Beauchamp, G., & Quessy, S. (2020). Association between tail-biting and intestinal microbiota composition in pigs. *Frontiers in Veterinary Science, 7*, 563762. https://doi.org/10.3389/fvets.2020.563762

Santillo, A., Chieffi Baccari, G., Minucci, S., Falvo, S., Venditti, M., & Di Matteo, L. (2020). The Harderian gland: Endocrine function and hormonal control. *General and Comparative Endocrinology, 297*, 113548. https://doi.org/10.1016/j.ygcen.2020.113548

Schmitt, O., Poidevin, A., & O'Driscoll, K. (2020). Does diversity matter? Behavioural differences between piglets given diverse or similar forms of enrichment pre-weaning. *Animals, 10*, 1837. https://doi.org/10.3390/ani10101837

Scollo, A., Martino, G. D., Bonfanti, L., Stefani, A. L., Schiavon, E., Marangon, S., & Gottardo, F. (2013). Tail docking and the rearing of heavy pigs: The role played by gender and the presence of straw in the control of tail biting, blood parameters, behaviour and skin lesions. *Research in Veterinary Science, 95*(2), 825–830. https://doi.org/10.1016/j.rvsc.2013.06.019

Scott, K., Chennells, D. J., Campbell, F. M., Hunt, B., Armstrong, D., Taylor, L., Gill, B. P., & Edwards, S. A. (2006). The welfare of finishing pigs in two contrasting housing systems: Fully-slatted versus straw-bedded accommodation. *Livestock Science, 103*(1–2), 104–115. https://doi.org/10.1016/j.livsci.2006.01.008

Shebanina, O. V., Kramarenko, S. S., & Ganganov, V. M. (2008). *Practical work on biometrics: Methods of nonparametric statistics*. Mykolaiv State Agrarian University.

Smith, K. C., & Pierdon, M. K. (2024). Utilization of enrichment objects by growing pigs in a commercial facility and the impact on behavior and skin lesions. *Applied Animal Behaviour Science, 272*, 106181. https://doi.org/10.1016/j.applanim.2024.106181

Sutherland, M. A., & Tucker, C. B. (2011). The long and short of it: A review of tail docking in farm animals. *Applied Animal Behaviour Science, 135*(3), 179–191. https://doi.org/10.1016/j.applanim.2011.10.015

Telkänranta, H., Marchant-Forde, J. N., & Valros, A. (2016). Tear staining in pigs: A potential tool for welfare assessment on commercial farms. *Animal, 10*(2), 318–325. https://doi.org/10.1017/S175173111500172X

Vacušková, Z., Šárová, R., & Šárová, M. (2025). Infrared thermography of different tear staining scores in pigs. *Journal of Thermal Biology, 105*, 103321. https://doi.org/10.1016/j.jtherbio.2024.103321

Valros, A., & Heinonen, M. (2015). Save the pig tail. *Porcine Health Management, 1*, Article 2. https://doi.org/10.1186/2055-5660-1-2

Van de Weerd, H. A., & Ison, S. H. (2019). Providing effective environmental enrichment to pigs: How far have we come? *Animals, 9*(5), 254. https://doi.org/10.3390/ani9050254

Van de Weerd, H. A., Docking, C. M., Day, J. E. L., Avery, P. J., & Edwards, S. A. (2003). A systematic approach towards developing environmental enrichment for pigs. *Applied Animal Behaviour Science, 84*, 101–118. https://doi.org/10.1016/S0168-1591(03)00150-3

Van Staaveren, N., Calderón Díaz, J. A., Garcia Manzanilla, E., Hanlon, A., & Boyle, L. A. (2019). Prevalence of lesions on the carcasses of finisher pigs reared in Ireland and risk factors associated with their occurrence. *Porcine Health Management, 5*, Article 11. https://doi.org/10.1186/s13620-018-0121-5

Velarde, A., Fàbrega, E., Blanco-Penedo, I., & Dalmau, A. (2015). Animal welfare towards sustainability in pork meat production. *Meat Science, 109*, 13–17. https://doi.org/10.1016/j.meatsci.2015.05.010

Vitali, M., Santacroce, E., Correa, F., Salvarani, C., Maramotti, F. P., Padalino, B., & Trevisi, P. (2020). On-farm welfare assessment protocol for suckling piglets: A pilot study. *Animals, 10*(6), 1016. https://doi.org/10.3390/ani10061016

Warns, F. K., Gültas, M., van Asten, A. L., Scholz, T., & Gerken, M. (2021). Is there a link between suckling and manipulation behavior during rearing in pigs? *Animals, 11*(4), 1175. https://doi.org/10.3390/ani11041175

Welfare Quality®. (2009). *Welfare Quality® assessment protocol for pigs (sows and piglets, growing and finishing pigs)*. Welfare Quality® Consortium.

Yang, Y., Zhou, S., Li, X., Fu, Q., Zhang, X., Ji, W., & Liu, H. (2024). Effect of an enriched elevated platform rearing system on the welfare and bone quality of fattening pigs. *Agriculture, 14*(6), 943. https://doi.org/10.3390/agriculture14060943