Animal 18 (2024) 101045

Contents lists available at ScienceDirect

Animal

The international journal of animal biosciences

Inclusion of silage in diets to fattening pigs: effect on gastric ulcers and skin lesions

J. Friman [a,*], E. Verbeek [b], A. Sannö [c], M. Presto Åkerfeldt [a]

[a] Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Ulls väg 26, 756 51 Uppsala, Sweden
[b] Department of Animal Environment and Health, Swedish University of Agricultural Sciences, Ulls väg 26, 756 51 Uppsala, Sweden
[c] Department of Clinical Sciences, Swedish University of Agricultural Sciences, Ulls väg 26, 756 51 Uppsala, Sweden

ARTICLE INFO

Article history:
Received 24 April 2023
Revised 19 November 2023
Accepted 21 November 2023
Available online 28 November 2023

Keywords:
Finishing pig
Gastric lesions
Roughage
Social interactions
Welfare

ABSTRACT

Limited access to high-quality feed protein for pigs has made it necessary to evaluate new protein sources that both promote sustainable pig production and meet the nutritional requirements of pigs. Providing pigs with roughage has positive effects on their behaviour and gut health. However, roughage is seldom given as a part of the pigs' diet and often has a long straw length. Knowledge is lacking on the effect of feeding silage with smaller particle size and as a part of the pigs' diet on pig behaviour and welfare. This study evaluated the influence of feeding fattening pigs silage with different particle sizes on aggressive encounters, measured as the number of skin lesions, and on the occurrence of gastric lesions and ulcers. In total, 128 Swedish Yorkshire × Hampshire pigs were fed either a commercial control feed without silage (**Pellet-C**), or silage mixed with commercial feed, either in a pellet (**Pellet-S**) or in a total mixed ration (**TMR**) with chopped (**TMR-Ch**) or intensively treated silage (**TMR-Ex**). Skin lesions were assessed twice in the study according to the Welfare Quality® protocol. The first assessment was performed when the pigs were 105 days old and the second assessment at 132 days of age. Gastric lesions were examined in both the *pars oesophagea* and the *pars glandularis* region of the stomach. Stomachs were collected after slaughter, and gastric lesions were scored based on established scoring criteria. There was a treatment × assessment interaction on the number of skin lesions on the ear ($P = 0.049$). Apart from this interaction, no other effect of treatment on the number of skin lesions could be observed between the treatments or the assessment occasions. Treatment had a clear effect on the occurrence of gastric lesions and pigs fed the fresh silage (TMR-Ch and TMR-Ex) had a lower occurrence of gastric lesions and ulcers compared to the pelleted treatments (Pellet-C and Pellet-S) ($P = 0.001$). This study could not show any clear reduction effect of dietary silage inclusion on skin lesions. However, feeding silage in TMR significantly reduced the occurrence of stomach ulcers.

Implications

Interest is increasing to use silage as an alternative feed source for fattening pigs. Providing silage to pigs reduces negative behaviours and potentially also the prevalence of gastric lesions. Previous studies have shown that pelleted silage can improve pig performance and may be easier to implement in practice than fresh silage. This study compared the effects of feeding pelleted silage to fresh silage on pig behaviour and gastric health. While the number of skin lesions did not differ between treatments, pigs fed fresh silage had significantly reduced gastric lesions. This suggests that feeding silage could promote pig health and welfare.

Introduction

Pigs are explorative animals with a high motivation to perform feed-related behaviours such as rooting and foraging. Raised in barren environments, pigs often redirect oral activities towards the interior and pen mates, which could lead to injuries and reduced welfare (Olsen, 2001; Studnitz et al., 2007). To reduce the occurrence of harmful interactions, pigs should be provided with straw (or similar) to enrich the housing environment (SJVFS, 2019). To increase animal welfare, additional provision of *ad libitum* access to roughage is required in organic production (EC, 2018). Providing pigs with straw as rooting and bedding material increased activity levels, feed-related behaviours (e.g., rooting, nosing the floor) and reduced manipulative oral behaviours towards pen mates (Beattie et al., 2000; Olsen, 2001; van de Weerd and Day, 2009).

* Corresponding author.
E-mail address: johanna.friman@slu.se (J. Friman).

https://doi.org/10.1016/j.animal.2023.101045
1751-7311/

In addition to the positive influence on pigs' behaviour, fibrous feedstuff affects intestinal health and may prevent the development of gastric ulcers, which is a prevalent problem in pig production (Thomson & Friendship, 2012; Mößeler et al., 2014; Rutherford et al., 2018). Gastric lesions and ulcers predominantly develop in the non-glandular region of the gastric mucosa, the *pars oesophagea*, at the oesophageal entry. Gastric ulcers are problematic because they result in reduced growth performance, cause pain and are an indicator of stress and deprived welfare (Ayles et al., 1996; Amory et al., 2006; Rutherford et al., 2018). Risk factors for the development of gastric ulcers are, among others, excessive stress, barren environments and finely ground or pelleted feed (Amory et al., 2006; Mößeler et al., 2014; Holinger et al., 2018).

Fibrous feeds have a high water-holding capacity that slows down the passage rate in the stomach. It also reduces the fluidity of the stomach content, and these factors together can protect the *pars oesophagea* from erosion (Regina et al., 1999; Bindelle et al., 2008; Mößeler et al., 2014). With endoscopic assessment, it has been shown that pigs with developed gastric ulcers, resulting from a finely ground diet, can heal from the severity of ulcers when given a coarse diet (Ayles et al., 1996). Moreover, when comparing diets with a fine particle size towards a more coarsely ground diet, it was shown that coarser grinding (e.g., bigger particle size) reduced the prevalence of gastric lesions (Regina et al., 1999; Nielsen and Ingvartsen, 2000; Mößeler et al., 2014). Adding straw to the diet also reduced the prevalence of severe ulceration (Herskin et al., 2016) and when pigs were provided with straw bedding, the occurrence of gastric lesions was decreased compared to pigs housed without straw provision (Bolhuis et al., 2005; Herskin et al., 2016). This is most likely caused by the ingestion of straw, which would have added more structure to the gastric content. A recent study by Holinger et al. (2018) concluded that the provision of grass silage decreased gastric ulceration even more than if only straw was provided. In a study by Presto Åkerfeldt et al. (2019), pigs fed silage had higher activity levels and spent more time nosing/rooting compared to commercially fed pigs. In addition, Høøk Presto et al. (2009) concluded that extra provision of roughage in addition to straw was important from a welfare perspective.

Silage is currently mainly used as an enrichment material, but within the pig industry, there is a growing interest to include ley crop silage as an ingredient in feed rations, since it can be used as a locally grown and sustainable feed source (Damborg et al., 2018; Stødkilde et al., 2021). Consumption and utilisation of the silage are affected by factors such as fibre content, stem length and particle size of the silage (Wallenbeck et al., 2014; Presto Åkerfeldt et al., 2018). Feeding silage with small particle size, mixed with a cereal-based feed in a total mixed ration (**TMR**), showed promising results because the silage intake was improved and the growth performance of the pigs could be maintained (Wüstholz et al., 2017; Presto Åkerfeldt et al., 2018; Friman et al., 2021). Furthermore, pig performance was also improved when silage was dried and mixed with cereal-based feed and fed as a pellet (Wallenbeck et al., 2014; Friman et al., 2021). Feeding pelleted silage is potentially easier to implement in practice compared to fresh silage. However, pelleted feed does not provide foraging opportunities and does not increase the activity levels to the same extent that fresh silage does (Presto et al., 2013). It is therefore of interest to determine how the feeding strategy (pelleted or fresh) and the particle size of the silage influences the pig in terms of behaviour and health and to evaluate how different particle sizes of the silage can prevent gastric lesions and reduce skin lesions (as a proxy of the number of negative social interactions).

Consequently, the objective of this study was to investigate the effects of including silage in the diet of growing/finishing pigs, either as a pellet or fresh with two different particle sizes, on the prevalence of skin lesions and gastric ulcerations. It was hypothesised that including silage in the diet would reduce the number of skin lesions and gastric ulcers compared to a standard commercial diet without silage. Furthermore, it was expected that feeding fresh silage, regardless of particle size, would be more effective in reducing skin lesions resulting from negative social interactions compared to feeding pelleted silage. Likewise, we expected that fresh silage would be better at preventing gastric ulcers than pelleted silage.

Material and methods

The current study was conducted in parallel with another study by Friman et al. (2021), where the same animal material and dietary treatments were used to evaluate pig performance concerning daily weight gain and carcass traits. Brief descriptions of feed intake and pig performance are included in this paper, whereas detailed data are presented in another paper by Friman et al. (2021).

Animals, housing and management

The trial was conducted between January and May, 2020 at the Swedish Livestock Research Centre, Funbo Lövsta (Uppsala, Sweden). The experiment was performed in a batch-wise production system, with 128 growing/finishing pigs (Swedish Yorkshire × Hampshire) from two production batches (1 and 2), raised 2 weeks apart, and included 64 pigs each. Each batch included eight pens (thus, in total sixteen pens for the whole trial), with eight pigs in each pen. The pens were allocated to one of the four dietary treatments (see section 'dietary treatments' below) so the treatments were evenly distributed in the stable. Pigs were kept in their litter group from weaning until 9 weeks of age and were then fed in accordance with the standard routines of the pig facility. They were fed *ad libitum* in automatic feeders and received a standard commercial complete feed for piglets (Tjuvstart, Svenska Foder AB, Sweden) from weaning until 6 weeks of age. From 6 weeks of age, they were fed *ad libitum* with a standard commercial complete feed optimised for growing pigs (Smågris Syra Express, Svenska Foder AB, Sweden) until the start of the study at 10 weeks of age. At 9 weeks of age, pigs were allocated to one of the eight pens. First, a new pig group was assigned and thereafter allocated to a pen using the Microsoft Excel random number generator (Microsoft Corporation (2016) available at https://office.microsoft.com/excel). The pigs were assigned to the pen based on birth litter (to represent each sow in all treatments), weaning weight and sex to receive balanced groups. Each pen included four gilts and four male pigs (later immunocastrated), and the pigs originated from different litters so that no siblings were included in the same pen. After an acclimatisation period of 1 week to the new groups and at 66 days of age (±1 d), pigs were fed their first ratio of the experimental diets (see section 'dietary treatments' below) in the afternoon, which marked the start of the study. The pigs then had an average BW of 32.5 kg (±4.2 kg). The pen had a 4.5 m long feeding trough along the front of the pen and two water nipples placed over the slatted dunging area in the back of the pen. The lying and feeding area had solid concrete flooring. The total pen area was 11.12 m^2 giving 1.39 m^2 per pig. All pens were provided with approximately 1 kg of wood shavings per pen daily.

All male pigs were immunocastrated with Improvac™, receiving the first injection at 66 days of age and the second injection at 92 days of age. Weighing occurred at the start of the experimental period at 10 weeks of age, then every 2nd week until they reached approximately 90 kg of BW and thereafter every week until slaughter. In each batch, there were three slaughter occasions. A pig was assigned for slaughter when it reached a BW of 107.7 kg (±5.5 kg) and was sent to the slaughter facility the following week.

Diets and feeding

Dietary treatments

The four dietary treatments used in this study are described in detail in Friman et al. (2021). The control treatment group was fed a commercial pelleted complete feed without silage (**Pellet-C**), optimised to meet the nutritional recommendations for growing/finishing pigs and produced at a commercial feed plant (Swedish Agro, Kalmar, Sweden). The three experimental diets included silage that was either dried, milled and mixed with commercial feed and fed as a pellet (**Pellet-S**) or was fed fresh and mixed with commercial pelleted feed as part of a TMR with chopped (**TMR-Ch**) or intensively treated (**TMR-Ex**) silage. Silage was included to replace 20% of the dietary CP (g/kg).

The silage used in the study was from the second harvest of a first-year grass ley and cut at harvest to approximately 4–15 mm with a forage harvester. The crop was ensiled in a silage bun directly after harvesting.

To produce the silage pellet for the Pellet-S diet, the same silage as used in the TMR-Ch and TMR-Ex diets was heat-dried and pelleted into a pure silage pellet by a dry feed producer (Genevads Grönfodertork, Laholm, Sweden). The silage pellet was sent to a feed production facility (Swedish Agro, Kalmar, Sweden) and included as an ingredient in the Pellet-S diet. The commercial pelleted feed for the TMR mixtures (**TMR concentrate**) was optimised to meet the nutritional requirements of finishing pigs when mixed with fresh silage at a 60:40 ratio.

Both the Pellet-C, Pellet-S and the TMR concentrate for the TMR-Ch and TMR-Ex diets were produced at the same feed production facility (Swedish Agro, Kalmar, Sweden). The chemical composition and energy value of the chopped and intensively treated silage and of the Pellet-C feed, Pellet-S feed, TMR concentrate and TMR as fed are presented in Table 1. Chemical analysis of feed samples is emphasised in Supplementary material SA.

Preparations of total mixed ration diets

Once a week, the daily rations for TMR-Ch and TMR-Ex diets were prepared. The silage for TMR-Ch was left intact with a particle size of approximately 4–15 mm. The silage for the TMR-Ex diet was intensively treated into a smaller particle size (1–3 mm) in a bio-extruder (Bio-extruder MSZ-B15e, LEHMANN Maschinenbau GmbH), equipped with rotating double-screws and set at 60% rotation speed (Lehmann, 2018). Silage rations were prepared for each pen and feeding event and stored in a chilled container at approximately +4 °C until feeding (Cooltainer, Isolett Panelbyggen AB, Uppsala, Sweden). Before every feeding event, the silage was mixed with TMR concentrate into a TMR, on a 40:60 ratio, in a mixer (Syntesi 140, Epox Maskin AB).

Feeding

Pigs were fed twice daily (in the morning and afternoon) according to the Swedish norm and nutrient recommendations for growing/finishing pigs, based on the average pen BW (Andersson et al., 1997). Pigs were fed above maintenance level until an average BW of 65.7 (±7.9) kg and were then given a restricted ration of a maximum of 25.9 MJ net energy (**NE**) per pig and day until slaughter. Restricted feeding in the second phase of the fattening period is common practice in Swedish pig production to avoid fat carcasses and increase the lean meat content. The Pellet-C feed and the Pellet-S feed were fed by an automatic computerised feeding system whereas the pigs that received the TMR-Ch and TMR-Ex treatment were fed by hand. Fig. 1 displays the four different treatments and illustrates the varying structures of the pelleted and TMR diets, as well as the different particle sizes of the chopped and extruded silages (TMR-Ch and TMR-Ex).

Data recordings

Pig performance

Feed intake was measured at pen level and presented as mean values per pig. During the study, the pigs consumed all the feed that was provided, and no feed residuals could be collected. Pigs were weighed every 2 weeks until they reached approximately 90 kg of BW, and thereafter, weighing was done once per week. When the pigs weighed an average of 108 kg, they were registered for slaughter and sent to the abattoir 1 week later. Detailed descriptions of the methods for measuring performance data were previously published by Friman et al. (2021).

Study design

Fig. 2 shows a schematic overview of the study design and the time points of each data recording. The two batches (batch 1 and batch 2) ran parallel to each other, and batch 2 started 2 weeks after batch 1.

Gastric ulcers

At slaughter, stomachs from 41 of the animals, randomly chosen within each treatment and balanced regarding sex, were collected (Lövsta slaughterhouse, Uppsala, Sweden).

Table 1
Chemical composition (g kg^{-1} DM) and energy content (MJ kg^{-1} DM) of the experimental feeds, silages, and the total mixed ration (TMR) as fed to fattening pigs.

Item	Pellet-C[1]	Pellet-S[2]	TMR concentrate[3]	Chopped silage	Intensively treated silage	TMR as fed TMR-Ch[4]	TMR as fed TMR-Ex[4]
DM, %	88	89	88	34	35	66	67
GE	18.3	18.9	19.5	16.7	17.2	18.4	18.6
NE[5]	11.0	11.0	11.8	8.1	8.9	10.3	10.6
CP	191	202	205	183	178	196	194
Crude fat	36	51	69	-	-	41	41
Ash	51	59	42	95	97	63	64
NDF	126	157	117	384	361	224	215

Abbreviations: GE = gross energy, NE = net energy, dE = energy digestibility, TMR = total mixed ration.
Source: Friman et al. (2021).
[1] Pellet-C = commercial feed for fattening pigs fed as control.
[2] Pellet-S = commercial feed + ground silage, mixed and pelleted.
[3] TMR concentrate = concentrate feed optimised for mixing with silage in TMR at a 60:40 ratio.
[4] TMR as fed; TMR-Ch = chopped silage mixed with TMR concentrate in a 60:40 ratio, TMR-Ex = intensively treated silage mixed with TMR concentrate in a 60:40 ratio.
[5] Estimated according to Lindberg and Andersson (1998), where dE % = 94.8 + (−0.93 × NDF %). Digestible energy = dE × GE, Metabolisable energy = 0.95 × Digestible energy and NE = 0.75 × Metabolisable energy.

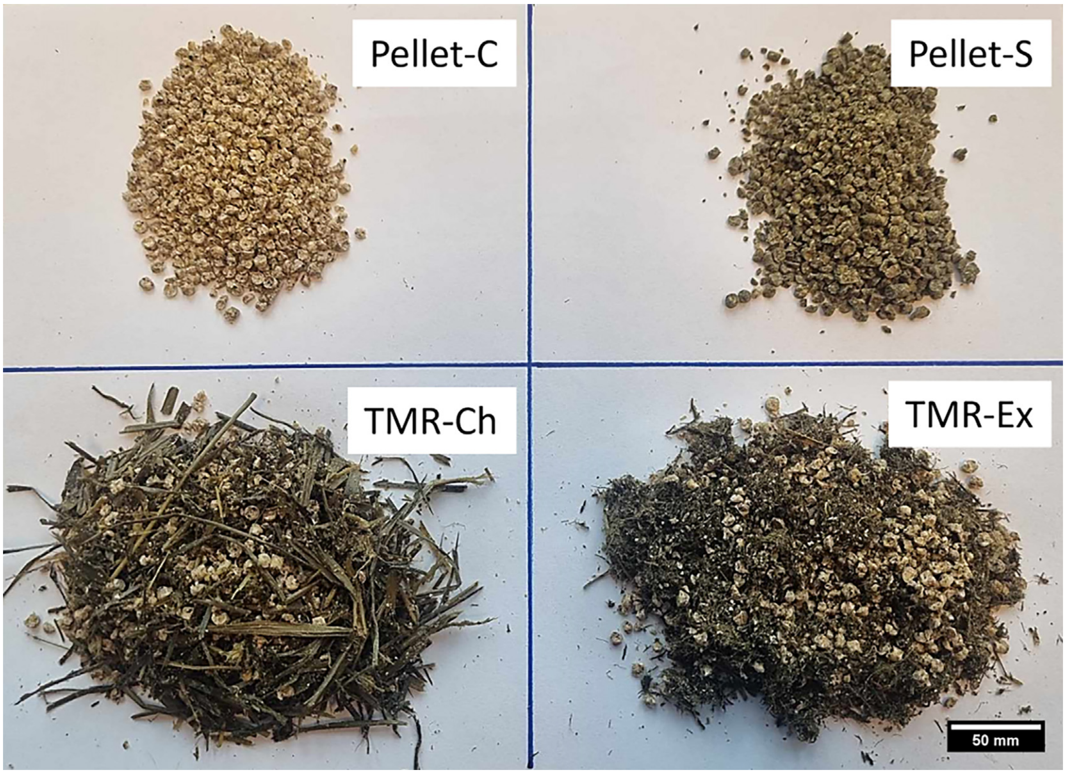

Fig. 1. A visual presentation of the study's four different dietary treatments[1] fed to fattening pigs (scale bar, 50 mm). Abbreviations: TMR = total mixed ration. [1]Dietary treatments: Pellet-C = commercial feed for fattening pigs fed as control; Pellet-S = commercial feed + ground silage, mixed and pelleted; TMR-Ch = chopped silage mixed with TMR concentrate in a 60:40 ratio; TMR-Ex = intensively treated silage mixed with TMR concentrate in a 60:40 ratio.

The stomachs were collected at the slaughter line and immediately stored on ice and transported to the research lab (SLU, Uppsala, Sweden) for examination. The stomachs were opened along the major curvature, emptied, and carefully rinsed with water. Two experienced examiners performed the examination and photo documentation of the mucosa of all stomachs. The examiners were both veterinarians, one of which was specialised in pathology, and they were blinded to which treatment the pigs belonged to. Gross lesions in both the *pars oesophagea* and the *pars glandularis* were scored based on established scoring criteria (Blackshaw et al., 1980; Carstensen et al., 2006; Jensen et al., 2017) using a graded scale, ranging from 0 for normal mucosa and increased score with severity of lesions. The grading criteria are presented in Table 2. Pictures with examples of different ulceration scores are shown in Fig. 3.

Table 2
Description of the scoring criteria that were used during the visual inspections of pigs' stomach mucosa for gastric ulcers in the *pars oesophagea* and *pars glandularis* regions.

Score	Description
0	Intact mucosa
1	Mild hyperkeratosis[1] (<50% of surface area)
2	Severe hyperkeratosis[1] (>50% of surface area)
3	Hyperkeratosis[1] and a few small erosions (fewer than five and shorter than 2.5 cm)
4	Hyperkeratosis[1] and extensive erosions (more than five erosions and/or longer than 2.5 cm)
5	Hyperkeratosis[1] and very large erosions (more than 10 erosions or longer than 5 cm) and/or ulcers

[1] Hyperkeratosis is the yellowing and roughening of the skin as a response to prolonged exposure to acidic stomach content in the *pars oesophagea* region (Hewetson and Tallon, 2021).

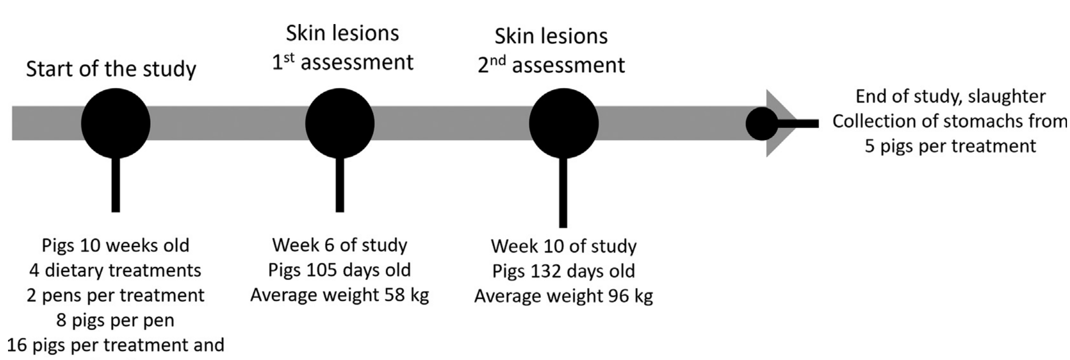

Fig. 2. A schematic overview of the study's timeline. The study had two batches with pigs, where batch 2 started 2 weeks after batch 1. The figure shows an overview of the process in each pig batch, e.g., the process was repeated twice.

Skin lesions

All pigs were individually marked with ear tags at birth and could therefore easily be identified on every measuring occasion. Skin lesions were assessed twice according to the standardised Welfare Quality® protocol (Welfare Quality®, 2009) for growing and finishing pigs by the same observer. However, before the observations were performed in the trial, one pilot round was performed with the observer and an experienced assessor to practice the counting of skin lesions and ensure high inter-observer reliability of the observations. Lesions were measured twice in each batch; the first assessment was done at an approximate BW of 58 kg (±7.0 kg) and 105 days of age (±2.6 d), and the second assessment was performed at an approximate BW of 96 kg (±9.1 kg) and 132 days of age (±1.3 d). For registrations, the body of each pig was divided into five regions (front, middle, hindquarters, legs, and ear) and the number of lesions was counted on the pig's left side as described by the protocol (Table 3). In this study, the lesions were not divided into scores as described by the protocol, but the total number of lesions was used for the statistical analysis. Detailed descriptions of the division of the body regions are presented in Supplementary material SB, Supplementary Fig. S1. The pigs were raised with intact tails, as tail docking is forbidden by law in Sweden. To evaluate differences in tail biting, tail lesions were recorded at each assessment separately. Tail-bitten pigs were treated with tar to prevent further tail biting. In addition, lameness was also recorded.

Statistical analyses

Data were analysed with the Statistical Analysis System, version 9.4 (SAS, 2020). During the study, four pigs were culled or died. Two pigs had reduced general condition and did not respond to treatment and were therefore culled. One pig was culled due to a severe rectal prolapse and a fourth pig died from a ruptured stomach. This pig was autopsied, and the damage to the stomach was determined to be unrelated to the dietary treatments. These pigs were excluded from the statistical analysis considering the skin lesions. Hence, the results are based on 124 pigs. In addition, lesions on the legs of the pigs were rarely found and were therefore excluded from the analysis.

The number of skin lesions was analysed with Proc Glimmix, using a Poisson distribution, and multiple comparisons were analysed and adjusted with Bonferroni's method. All pigs were marked and individually scored for skin lesions at both assessments and the model included treatment, batch, sex, time, and treatment $\times$ time as fixed effects, while sow and pen were regarded as random effects. The time structure in the data was accounted for by adding an estimate for the unstructured variance–covariance matrix on the error term. To account for overdispersion, an observation-level random effect was also included in the model. For the analyses on ulcer scores, data were based on stomachs from 41 pigs, with the individual pig as experimental unit. Normal probability QQ plots were used to examine the residuals of the ulcer score variable, and they were found to be normally distributed. The effect of treatment on the ulcer scores was tested using Proc Glimmix with a Gaussian distribution, and multiple comparisons were analysed using Tukey-Kramer's method. The model included the fixed effects of treatment (Pellet-C, Pellet-S, TMR-Ch and TMR-Ex), batches (1 and 2) and sex (male and female) and random effects of sow and pen.

Feed intake and feed efficiency were analysed with pen as the experimental unit. The model included (Pellet-C, Pellet-S, TMR-Ch and TMR-Ex), batches (1 and 2) as the fixed effects. Daily weight gain was analysed with pig as the experimental unit and the model included (Pellet-C, Pellet-S, TMR-Ch and TMR-Ex), batch (1 and 2) and sex (male and female) as fixed effects. Pen nested within batch and birth litter nested within batch were included as random effects. The feed efficiency was calculated as: Energy intake per kg weight gain = (Mean total energy intake/(Sum of final BW − Sum of initial BW)). Detailed descriptions of statistical models used for analysing pig performance are described in Friman et al. (2021). Statistical codes for analysing skin lesions and gastric ulcers are presented in Supplementary material SC, including validations of methods. Calculations of Bonferroni adjusted *P*-values are presented in Supplementary Material SC (Supplementary Table S1).

Results

Pig performance

Effects of treatment on pig performance and carcass traits were evaluated in another study and detailed results regarding feed intake and performance are presented by Friman et al. (2021). All diets were completely consumed by the pigs, and no feed residuals could be collected during the study. The pigs in the TMR-Ch and

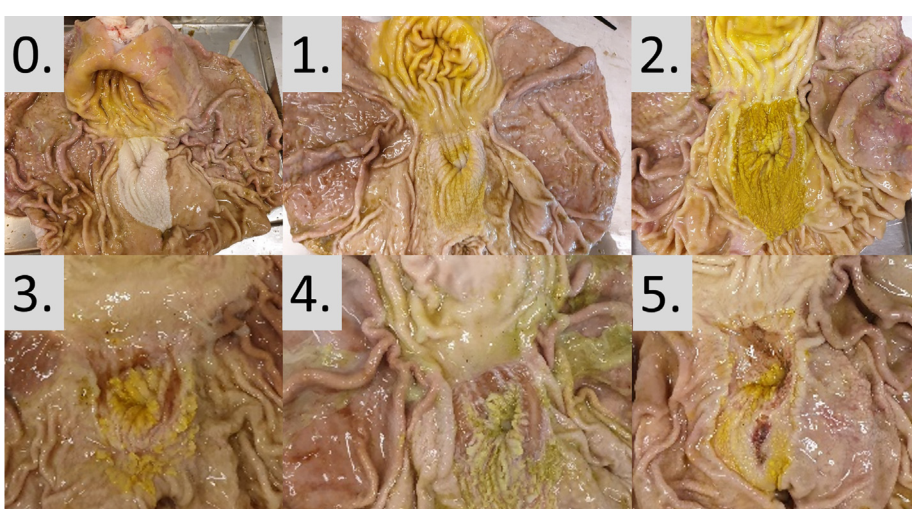

Fig. 3. Gastric ulceration score used to assess lesions in the *pars oesophagea* region of the stomach in fattening pigs. Scoring according to Table 2. The images are cropped to provide a visual representation of the ulcer scores and the damage caused to the gastric mucosa. The original images of the stomachs and their ulcer scores can be found in Supplementary Material SD (Supplementary Figs. S2–S7).

Table 3
Skin lesions on the pig's ear, front, middle, hindquarters, and legs were counted and classified according to the Welfare Quality® protocol (2009).

Wounds on the pig's body
Any scratch longer than 2 cm = 1 lesion
2 parallel scratches with ≤0.5 cm in-between = 1 lesion
Any wound ≤2 cm and not bleeding = 1 lesion
Any bleeding wound 2–5 cm, or any healed wound ≥5 cm = 5 lesions
Deep, open and bleeding wound ≥5 cm = 16 lesions

TMR-Ex treatments consumed in total more feed than the pigs in the Pellet-S and Pellet-C treatments (P < 0.001). The pigs in the Pellet-C treatment consumed an average of 2.4 kg of feed per day, while those in the Pellet-S treatment consumed an average of 2.6 kg per day. Pigs fed the TMR diets (TMR-Ch and TMR-Ex) consumed an average of 3.2 kg of feed per day (1.9 kg TMR concentrate and 1.3 kg silage). The feed efficiency (MJ NE/kg weight gain) did not differ significantly between treatments and was 23.0, 23.6, 23.6 and 23.1 for the Pellet-C, Pellet-S, TMR-Ch and TMR-EX treatments, respectively.

Pigs in the Pellet-S treatment had the highest daily weight gain (1084 g/day) (P = 0.001), while pigs in the TMR-Ch treatment had the lowest daily weight gain (951 g/d) compared to the other treatments (P = 0.001). Total daily weight gain was similar between pigs in the TMR-Ex (996 g/d) and Pellet-C (1023 g/d) treatments.

Gastric ulcers

Occurrence of gastric lesions and ulcers was affected by treatment ($F_{(2, 23)}$ = [17.43], P < 0.001). The pigs that were fed TMR with fresh silage (TMR-Ch and TMR-Ex) had a lower prevalence of gastric lesions and received a lower ulcer score compared to pigs in the Pellet-S and Pellet-C treatment (P = 0.001). The number of pigs within each score is presented in Fig. 4.

Skin lesions

The total number of skin lesions in the different body regions is presented in Table 4. There was an assessment (time of observation) × treatment interaction on the skin lesions on the ear ($F_{(3, 122)}$ = [2.69], P = 0.049). However, even though the interaction term was significant, multiple comparisons adjusted with Bonferroni's method did not show any significant differences between treatments at any of the two assessments or between assessments. Apart from this assessment × treatment interaction, no other significant differences in the number of skin lesions could be found between the treatments or the assessments.

Only nine pigs showed signs of lameness and tail biting was detected only in three pigs in the Pellet-C treatment and two pigs in the Pellet-S treatment. These numbers were too low to be analysed statistically.

Discussion

The present study aimed to evaluate the effect of feeding silage either as a pellet, or fresh with different particle sizes, and how the strategies influenced the occurrence of skin lesions and the development of gastric ulcers in pigs. In agreement with the hypothesis, feeding fresh silage reduced the development of gastric ulcers considerably. Pigs in the TMR-Ch and TMR-Ex treatment had no or very little changes in the gastric mucosa and pigs fed the two pelleted feeds (Pellet-C and Pellet-S) showed more visual damage to the mucosa. Several factors influence the development of gastric ulcers, such as particle size and pelleting of the feed, hunger, stress, and non-management factors such as gastric microbiota composition and infectious agents (Amory et al., 2006; Mößeler et al., 2014; Holinger et al., 2018). Despite the multifactorial origin of the development of gastric ulcers, the structure and particle size of the feed have a great impact (Mößeler et al., 2014; Rutherford et al., 2018). Studies have shown that finely ground and pelleted diets, that lack sufficient structural characteristics, can result in fluid stomach content and rapid emptying of digesta, thereby increasing the risk of gastric ulcers as pepsin (secreted in the pyloric region) can enter from the distal stomach to the proximal region that lacks protective mucus. (Regina et al., 1999; Mößeler et al., 2014; Peralvo-Vidal et al., 2021). Fibre can contribute to the reduction of gastric lesions in different ways, such as slowing down the emptying of the stomach due to its water-holding capacity (Bindelle et al., 2008; Herskin et al., 2016), and acting as a protective layer that impedes the mixing of stomach contents between the proximal and distal stomach (Regina et al., 1999; Jensen et al., 2017; Peralvo-Vidal et al., 2021).

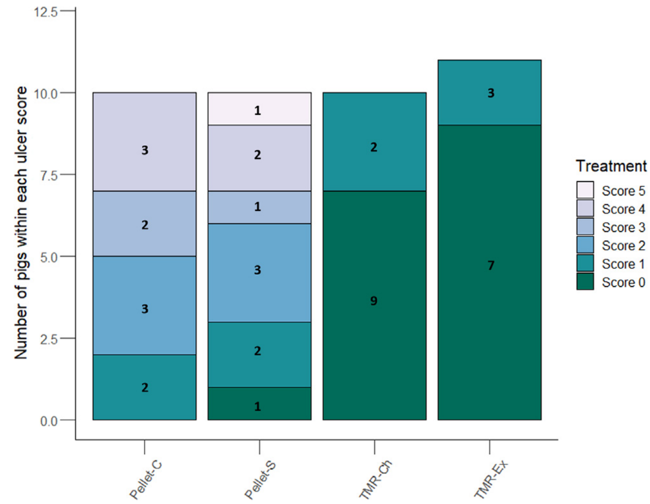

Fig. 4. The number of pigs within each ulcer score 0–5 (definition of ulcer score is described in Table 2) in the four dietary treatments[1]. N = 41. Abbreviations: TMR = total mixed ration. [1]Dietary treatments: Pellet-C = commercial feed for fattening pigs fed as control; Pellet-S = commercial feed + ground silage, mixed and pelleted; TMR-Ch = chopped silage mixed with TMR concentrate in a 60:40 ratio; TMR-Ex = intensively treated silage mixed with TMR concentrate in a 60:40 ratio.

Although the study did not investigate the actual particle size, it is likely that the fresh silage in the TMR diets (TMR-Ch and TMR-Ex) added more structure to the diet compared to the pelleted diets, which might be one reason for the reduced ulceration in the TMR treatments. In future research, an interesting approach would be to feed the silage separately from the pelleted feed to further evaluate whether it is the provision of fresh silage or the particle size of the diet that influences gastric ulceration. Nevertheless, studies have confirmed that a fibre-rich diet lowers the incidence of gastric lesions by increasing the firmness of the stomach content (Nielsen and Ingvartsen, 2000; Mößeler et al., 2014). No statistical analyses on the firmness of the stomach content were performed in this study. However, when the stomachs were opened to examine gastric lesions, visual inspection showed that the stomach content was less fluid and firmer in the stomachs of the pigs that were fed fresh silage (TMR-Ch and TMR-Ex). Therefore, the firmer stomach contents could have contributed to the lower occurrence of gastric lesions in these pigs. In future studies, it would be valuable to test the hypothesis that silage-based diets may increase the firmness of the digesta, which may prevent the development of gastric lesions.

Apart from improving gastric health, the provision of silage can positively affect the pig welfare. Based on previous studies (Olsen,

Table 4
The table shows the number of skin lesions on the pig's front, middle, hindquarter, and ears, as well as the total number of lesions for each of the four dietary treatments.[1] The data were collected from two skin lesion assessments. Results are presented as least square means and pooled SEM. N = 124.

Item	Dietary treatments[1]				SEM	*P*-value
	Pellet-C	Pellet-S	TMR-Ch	TMR-Ex		
1st assessment						
Front	3.8	3.1	2.6	4.1	0.81	0.70
Middle	1.5	1.8	1.2	2.0	0.56	0.77
Hindquarter	0.4	0.7	0.5	1.3	0.31	0.71
Ear	0.7	0.7	0.4	1.9	0.34	0.51
Total	6.6	6.4	4.9	9.5	1.60	0.63
2nd assessment						
Front	4.6	3.4	3.6	4.1	1.06	0.71
Middle	2.9	0.9	1.1	1.6	0.49	0.06
Hindquarter	0.9	0.4	0.6	1.2	0.30	0.10
Ear	0.6	0.6	1.3	1.0	0.26	0.12
Total	9.5	5.4	6.8	8.1	1.74	0.10

Abbreviations: TMR = total mixed ration
[1] Dietary treatments: Pellet-C = commercial feed for fattening pigs fed as control; Pellet-S = commercial feed + ground silage, mixed and pelleted; TMR-Ch = chopped silage mixed with TMR concentrate in a 60:40 ratio; TMR-Ex = intensively treated silage mixed with TMR concentrate in a 60:40 ratio.

2001, Presto et al., 2013), the present study hypothesised that feeding silage would reduce the occurrence of skin lesions as it would provide an opportunity to root and perform explorative behaviours.

The results found in this study, however, did not show a clear effect of silage inclusion on the number of skin lesions. This agrees with the study by Holinger et al. (2018), who also found no clear effect of feeding fresh silage on the number of skin lesions. One reason could be that the increased opportunity to root and explore is mainly related to reduced tail and ear biting (Beattie et al., 1996, Bracke, 2018).

In contrast, skin lesions on the body are more likely to occur due to aggression, which is caused by for example limited space, mixing of pigs and competition around feeders (Petherick and Blackshaw, 1987, Gonyou, 2001). Chou et al. (2020) showed that a high-fibre diet reduced aggressive encounters around the feeder due to increased satiety among the pigs and reduced motivation to feed. This finding contradicts the study by Bakare et al. (2014), who reported that a high-fibre diet increased the queuing and competition around the feeder, which resulted in more skin lesions. Pigs provided with lucerne silage showed more aggressive encounters due to increased competition for the material among pen mates in a study by Nguyen et al. (2022). Presto et al. (2013) fed fresh chopped silage mixed with a commercial feed and due to rooting in the feed trough, the silage ended up on the floor. The pigs showed a higher occurrence of head knocks and biting and had more lesions in these areas, which was thought to be caused by more interactions when the pigs were rooting the material (Presto et al., 2013). Through visual inspections in the present study, it was noted that pigs in both the TMR-Ch and TMR-EX treatments rooted the TMR feed out on the floor. As a result, they might have manipulated the material on the floor, which led to more interactions and possibly more competition for desirable parts. This could be one reason why the hypothesis that fresh silage would reduce skin lesions was not fulfilled. Nevertheless, no clear effect of silage on skin lesions could be detected and therefore this would need further investigation.

No further behavioural studies were performed in this study and no observations of the pigs' overall aggressive encounters were measured. Therefore, it could not be determined how the treatments influenced the pig's behaviour around feeding or the feeder. One explanation for the minimal effect of silage on pig behaviour in this study could be that the pigs were housed at a relatively low stocking density and were already kept in relatively enriched conditions (e.g., provision of wood shavings). The effect of feeding silage may be more pronounced under higher stocking densities and without additional enrichment. The role of fibre on pig aggression is complex and multifactorial, however, the addition of silage seems to reduce aggressive and manipulation behaviour towards pen mates as pigs spend more time rooting and exploring. This indicates that providing enrichment might help towards both tail and ear biting and aggression. (Olsen, 2001; Høøk Presto et al., 2009; van de Weerd and Day, 2009; Holinger et al., 2018; Presto Åkerfeldt et al., 2019).

Because the effects of treatment on the number of skin lesions could not be observed it could be questioned whether the number of skin lesions is a suitable measurement on its own to evaluate pig interaction and welfare. Previous studies have combined skin lesion assessment with continuous observations to investigate the effect of silage on pig behaviour (Olsen, 2001, Presto et al., 2013). Combining skin lesion assessments with detailed behavioural studies might therefore be a more suitable way to evaluate the effect of the feeding strategy and particle size of the silage on social interactions between pigs.

The small sample size in this study is a limitation. To improve the outcome of the statistical evaluation of both gastric lesions and skin lesions, the authors recommend using a much larger sample size in future studies. This would allow to draw a stronger conclusion regarding the effect of the treatments on gastric lesions. A larger sample size may also have resulted in a clearer effect of silage on the number of skin lesions. Moreover, it would have been beneficial to perform an assessment of skin lesions before the start of the study to determine a baseline. This would have made it possible to evaluate how the skin lesions differed over time in response to the diet. Finally, the immunocastration of boars at the start of the study might have influenced the behaviour of the pigs and therefore also the social interactions and amount of skin lesions. It has been showed that the effect of immunocastration on male pig behaviour reached the full effect only after the second injection (Rydhmer et al., 2010; Brewster and Nevel, 2013). After the first dose, immunocastrated pigs still showed more aggressive behaviours and mounting compared to surgically castrated pigs (Rydhmer et al., 2010). Only after the second booster dose did immunocastrated pigs have a reduced number of skin lesions, fewer mountings and aggressive interactions and had a similar behavioural repertoire as surgically castrated pigs (Rydhmer et al., 2010). The effect of immunocastration on social interactions was not the main research question for this study; however, it is an interesting approach and might potentially influence the outcome of the observations.

Conclusion

Feeding pigs with fresh silage considerably reduced the development of gastric ulcers compared to feeding pelleted silage. This study could not show a clear effect of silage inclusion on skin lesions. The findings in this study support the use of fresh silage fed as a TMR to fattening pigs, as it improves gastric health. More research is however necessary to obtain a better understanding of the effect of silage on behaviour and social interactions in pigs.

Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.animal.2023.101045.

Ethics approval

The study was approved by the Uppsala Ethics Committee on Animal Research (ethics approval number Dnr 5.8.18-14309/2019), which is in compliance with EC Directive 86/609/EEC on animal experiments. The conduction of the study was additionally checked towards and in compliance with the ARRIVE guidelines.

Data and model availability statement

The data were not deposited in an official repository. Upon request, the corresponding author will provide the data sets supporting the findings of this study.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors did not use any artificial intelligence-assisted technologies in the writing process.

Author ORCIDs

Johanna Friman: https://orcid.org/0000-0002-8080-7394.
Else Verbeek: https://orcid.org/0000-0002-1223-3480.
Axel Sannö: https://orcid.org/0000-0001-8381-1041.
Magdalena Presto Åkerfeldt: https://orcid.org/0000-0002-0616-7763.

Author contributions

Johanna Friman: Conceptualisation, investigation, methodology, data curation, formal analysis, writing – original draft, writing – review and following; **Else Verbeek:** Conceptualisation, methodology, formal analysis, supervision, writing - review and editing; **Axel Sannö:** Formal analysis, writing – review and editing; **Magdalena Presto Åkerfeldt:** Conceptualisation, methodology, supervision, writing - review and editing, funding acquisition and project administration. All authors have read and agreed to the published version of the manuscript.

Declaration of interest

The authors have no potential conflict of interest to disclose.

Acknowledgements

The authors are thankful to the personnel at the Lövsta pig research unit, Swedish University of Agricultural Sciences, for their assistance in caring for the pigs and the feeding during the study. They also extend their appreciation to the laboratory team at the Department of Animal Nutrition and Management, SLU, for conducting chemical analyses of all feed used in the study. The staff at Genevad Grönfodertork is also acknowledged for their assistance in manufacturing the pelleted silage, and to everyone involved at Swedish Agro for their efforts in optimising and producing the diets used in the study. This manuscript is included as part of J Friman's doctoral thesis, "Ley crop silage in diets to fattening pigs – How does it affect pig performance, nitrogen utilization, health and behaviour?" (2023) (https://doi.org/10.54612/a.557egssm04).

Financial support statement

This study was funded by the Swedish Research Council for Environment, Agricultural Science and Spatial Planning (Formas) (grant number FR-2018/0010).

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