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Published in:
Livestock Science

DOI:
10.1016/j.livsci.2018.03.013

First published: 29/03/2018

Document Version
Peer reviewed version

A study of associations between gastric ulcers and the behaviour of finisher pigs

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Abstract

Gastric ulcers are a common condition in finisher pigs. A study was conducted to investigate the hypothesis that gastric ulceration alters the behaviour of finisher pigs. Two one-hour observations (from video recordings) of home pen behaviour were conducted in finisher pigs, at two farms (one in Denmark and one in Scotland), in the days immediately prior to slaughter. Stomach condition was assessed post mortem according to a pre-established ulcer score index. The behaviour of pigs with healthy stomachs (n=36) was compared with the behaviour of pigs with deep ulceration of the pars oesophagea (n=26). Assessment of various predefined postures and behaviours was made by an observer blind to the gastric ulcer status of the observed pigs. Behavioural data from the two sites were combined in a single analysis. Pigs with gastric ulcers tended to spend less time idle (P=0.081) and less time lying on their left side (P=0.064), and significantly more time standing (P=0.009), or walking (P=0.038) compared to healthy pigs. Pigs with ulcers also showed an increased frequency of posture changes (P=0.02). A decrease in time spent lying on the left and an increase in standing/walking could both be interpreted as attempts to avoid liquid gastric contents pooling in the cranial region of the stomach. This along with the higher level of posture changes observed may indicate some degree of pain/discomfort associated with the presence of gastric ulcers in pigs. This study is the first to identify apparent behavioural differences between finisher pigs with or without gastric ulcers, and further work is needed to establish to what extent the apparent behavioural differences are a consequence of pain or discomfort for the animals concerned. Since gastro-oesophageal ulceration of pigs is associated with pelleting and fine grinding of feed which in turn is linked to increased growth efficiency there may be a dilemma

between on one hand concern for preventing gastric ulcers and on the other hand concern for the efficiency and sustainability of pig production.

Keywords: Gastric ulcer; Pigs; Behaviour; Welfare

1. Introduction

The occurrence of gastric ulcers in pigs is an on-going concern in relation to animal health and production. Erosion and ulceration of the lining of the stomach is a common condition in intensively managed pigs (Thomson and Friendship, 2012). It occurs around the area where the oesophagus enters the stomach (called the pars oesophagea). In the early stages of the disease, the pars oesophagea becomes roughened and gradually changes as the surface becomes eroded and can get deeply ulcerated (Doster, 2000). These changes may lead to intermittent haemorrhage followed by anaemia, or massive haemorrhage resulting in death.

The prevalence of gastric lesions in pigs is a major cause for concern in many pig producing countries (and has been for many decades: Baustad and Nafstad, 1969). A recent abattoir study in the UK (Swaby and Gregory, 2012) found that four out of every five slaughter pigs had some signs of ulceration or pre-ulcerative damage, and 6% of slaughter pigs had signs of severe ulceration. A study examining 1101 finisher pigs in Denmark found that 29% had signs of moderate to severe ulceration (Nielsen et al. 2012). Similarly, high gastric ulcer prevalences have been found in a number of countries over the last two decades (Thomson and Friendship, 2012). The prevalence of ulcers seen at slaughter can be highly variable between farms (Christensen and Cullinane, 1990; Guise et al. 1997), and on-farm mortality associated with bleeding from ulcers can be high on affected units (Melnichouk, 2002).

The pathogenesis of gastric ulcers appears to be highly multifactorial. The incidence and severity of the condition are associated with nutritional factors, housing

and feeding systems, some forms of stress, pig gender, other concurrent diseases and genetic effects (Doster, 2000; Thomson and Friendship, 2012). However, amongst these the physical structure of feed is the most significant risk factor; fine particle size and pelleting significantly increase the prevalence of gastric ulcers (Wondra et al. 1995; Eisemann and Argenzio, 1999b; Robertson et al. 2002; Grosse Liesner et al. 2008; Millet et al. 2012a, 2012b; Cappai et al. 2013; Mösseler et al. 2014; Overholt et al. 2016). It is thought that the more fluid gastric contents associated with these feeds allow reflux of acidic fluids to the non-glandular tissue of the pars oesophagea.

Whilst the incidence of gastric ulcers is high in commercial pigs and the pathology well recognised, there appears to be little information as to how the condition affects welfare. A small proportion of pigs with severe acute ulcers hemorrhage and either die on farm (e.g. Melnichouk, 2002) or show various acute clinical signs of pain (Taylor, 2006), and perforation of an ulcer can also lead to peritonitis (Jackson and Cockcroft, 2007). Such animals clearly suffer impairment to their welfare. However, the majority of pigs with gastric ulcers are not detected under farm conditions, and the welfare status of these sub-clinically affected animals relative to those with healthy stomachs remains uncertain. Finding out whether these ulcerated pigs suffer is important because the main risk factor for ulceration (the feeding of pelleted feed with small particle size) is used by the industry to improve feed conversion efficiency. So the clear benefits in terms of production efficiency (Doster, 2000) of this feeding strategy need to be balanced against any detrimental effect to welfare; and if there were significant effects on welfare it would seem relevant to consider changing this strategy.

To date no scientific appraisals have been made of the welfare significance of gastric ulcers in pigs. Whilst it might be presumed that ulcers, at least beyond a

certain level of severity, have a negative effect on welfare, the extent of this effect has not been quantified. Since behavioural indicators are widely used in the study of pain in pigs (Ison et al. 2016a) and as a first step towards understanding the welfare impact of gastric ulcers, the aim of the present study was to conduct a controlled study of the behaviour of pigs with and without ulcers.

2. Materials and Methods

Video footage was collected and analysed from pigs at two different research farms: Grønhøj (GR) farm in Denmark and EasterHowgate (EH) farm in Scotland. Video recordings were taken from all study pigs, and healthy or ulcerated pigs were retrospectively chosen for detailed behavioural analysis based on post mortem appraisal of stomach condition. The experiments at both farms were conducted in accordance with EU Directive 2010/63/EU and following ethical review by SRUC's Animal Welfare and Ethical Review Body, and the Scottish study was conducted under UK Home office licence.

2.1 Grønhøj farm, Denmark

The pigs used in this study were part of a larger study, which aimed to investigate the performance and health implications of gastric ulcers in pigs. In each replicate (batch) of the study, pigs (Dam: DanAvl landrace + DanAvl Yorkshire; Sire: DanAvl Duroc) were housed, from 30kg, in 10 pens (4.33m x 2.75m; two thirds slatted flooring), with 12 pigs (females and barrows) in each pen. Before the trial started, weaners to be included in the trial were fed medium-coarse meal feed. During the trial period pigs were *ad libitum* fed a pelleted feed from a single electronic feeder (NEDAP, The Netherlands) in each pen. Each pen also had a single drinker and an

enrichment device (a vertical wooden log attached to the side of the pen). The pigs were tagged with electronic ear tags (for identification by the feeding system) and were spray marked with an identification system based on stripes, which allowed individual pigs in each group to be identified on video. Lights were on in the experimental building from 0500 to 2100.

Video recordings were made from single cameras positioned above each pen. Footage was recorded onto a digital system (AnnoxNext). The pigs selected for observation came from four separate batches of a larger trial. On the day of slaughter, pigs were transported (for ~1 hour) to a commercial abattoir, and kept in lairage for ~1 hour before slaughter. Feed continued to be available to the pigs until shortly before moving for transport. Stomachs were collected, marked with pig identification and transported to the Danish Laboratory for Pig Diseases for assessment.

2.2 EasterHowgate Farm, Scotland

Seventy-eight pigs (Dam: Large White x Landrace, Sire: Hampshire) were used in two separate batches of 39 pigs. Pigs were housed (from ~ 2 weeks prior to slaughter) in small (2.85m x 3.7m for a single pen) straw bedded pens, with *ad libitum* access to a pelleted feed in a trough (90cm long) and a single drinker in the pen. Each pen held between 3 and 6 pigs (pens with 4, 5 or 6 pigs were provided with twice as much space as the groups of 3). Lighting was on between 0600 and 1800.

Video recordings were made from single cameras positioned above each pen. Footage was recorded onto a digital system (GeoVision). Prior to moving to the experimental building, pigs had been housed from weaning onwards in larger pens with straw bedding in groups of between 10 and 20 pigs. Pigs were euthanized on-site at EH. On the day of euthanasia, pigs were moved in their whole groups to a different pen. Feed was provided in the home pen until each group was moved for euthanasia.

Individual pigs were then sedated before being given an overdose of barbiturates (Euthatal) via injection to the heart. Following confirmation of death, stomachs were dissected out whole and transferred to the SAC Consulting Veterinary Services (SACCVS) for gastric ulcer scoring.

2.3 Ulcer scoring and selection of pigs for observation

Stomachs were scored according to a pre-existing gastric ulcer scoring system (Jensen et al. 2017; **Table 1**) at the Danish Laboratory for Pig Diseases or at SACCVS by experienced veterinary pathologists. The non-glandular pars oesophagea ('white part') of each stomach was scored for the presence of hyperkeratosis (where the mucosa of the pars oesophagea has become thickened and keratinized), erosion (superficial tissue erosion where layers of the epithelium have disappeared but the basement membrane is intact), ulceration (where the submucosa, nerves and blood vessels are exposed and potentially damaged) and scarring or stenosis of the oesophageal opening. The final ulcer score (ranging from 0 to 10) for any individual stomach is based on the severity of the most severe sign seen (e.g. an erosion score of 1 produces a stomach index score of 4, irrespective of how much hyperkeratosis is present). Based on the stomach score, individual pigs were retrospectively chosen for behavioural analysis (healthy: score 0 or 1; gastric ulcer: score 7 or 8, i.e. 'deep' rather than 'superficial' (score 6) lesions). In the scoring system a stomach can be given a score of 6, 7, or 8 based on the presence and extent of an ulcer, or based on the presence of scar tissue. All selected ulcerated GR pigs had an ulcer (i.e. any pigs which were scored 7 or 8 due to scarring alone were not considered for selection) but all also had signs of scarring from healing or healed ulcers. All ulcerated EH pigs only had ulcers without any distinguishable scar tissue. Pigs recorded with other health problems (at slaughter or earlier in the trial) were excluded from selection, and

selection of pigs for observation was done blind to pig sex or weight. One experimenter identified a complete list of possible observation pigs, and this list (blinded to gastric ulcer status) was passed onto another experimenter who conducted preliminary observations of the relevant recordings to identify and rule out pigs that were not visible for the majority of the required observation time. This meant that some healthy or ulcerated pigs in the trial could not be observed. Under these criteria, observations were conducted on 40 pigs at GR (mean ±SE weight: 85.2kg±1.36; 22 females, 18 castrated males; 13 pigs (healthy: 7, gastric ulcer: 6) from batch one, 21 (healthy: 12, gastric ulcer: 9) from batch two, three (healthy: 1, gastric ulcer: 2) from batch three, three (healthy: 1, gastric ulcer: 2) from batch four) and 22 pigs at EH (mean ±SE weight: 114.6kg±2.8; 16 females, 6 males; 12 (healthy: 7, gastric ulcer: 5) from batch one and 10 (healthy: 8, gastric ulcer: 2) from batch two).

2.4 Behavioural analysis

Quantification of different behavioural states and events was conducted using Observer Software (Noldus, Version 12.5). Two one-hour long continuous focal observations were conducted on video recordings of 36 healthy pigs and 26 pigs with gastric ulcers (GR: n=21 healthy, 19 ulcerated; EH: n=15 healthy, 7 ulcerated). All behavioural observations were conducted by a researcher who was blind to the gastric ulcer status of individual observed pigs. Intra-observer testing was conducted at the mid-point of the observations to ensure reliability. The timing of the two one-hour long observations differed between EH and GR. For the GR pigs observations were conducted on video footage recorded between 0800 and 0900 and between 1600 and 1700 on the day prior to slaughter. EH observations were conducted on footage recorded either one or two days prior to slaughter. The first observation was the last

hour before farm staff entered the room to check pigs and muck out pens (approximately between 0600 and 0700). The second observation started between 0930 and 1030 for different pens. The ethogram (**Table 2**) was developed based on previous work (D'Eath, 2002; Rutherford et al. 2006; Camerlink and Turner, 2013; Hintze et al. 2013; Ison et al. 2016b) and on preliminary viewings of a selection of recordings.

2.5 Statistical analysis

All analysis was conducted in Genstat (16th Edition) using the REML procedure. Initial models (analysing the two sites separately) fitted gastric ulcer status (scores 7 or 8 = yes; scores 0 or 1 = no), time (first or second observation) and sex as fixed effects, and pig weight as a covariate. Observation time did not prove significant alone or in interaction with treatment so subsequent analysis were conducted on datasets which combined the two one-hour observations. For initial models the random effect was pig nested within batch/pen (a single variable produced from each unique combination of batch and pen), and for the subsequent analyses it was batch/pen. Initial models examined interaction effects. Where effects of sex or weight were not found, these parameters were removed from the model. Data were transformed where necessary to achieve normality of residuals. Final models were run which included data from both sites and followed the same process as that described here for the single site analyses (but with site fitted as a fixed effect). Many of the behavioural states did not occur often enough to analyse; only four states were included in statistical analysis: idle, nosing other pigs, feeding (GR: being in the feeder; EH: with the head in the feed trough) and rooting/exploring the pen. For the behavioural events, individual events, with the exception of Ease Quarters Hind,

occurred too infrequently to analyse, so the behavioural events were summed either according to whether they were front leg events, rear leg events, or as a total of all recorded events.

3. Results

3.1 GH pigs

The prevalence of gastric ulcers was low in batch 1 but increased in subsequent batches (**Table 3**). Gastric ulcer status did not significantly affect any of the posture variables, apart from a trend towards increased time spent kneeling/sitting in pigs with ulcers (**Table 4**). For the four behavioural states recorded, there were also no significant effects, apart from a trend for increased time spent nosing other pigs in pigs with ulcers (**Table 5**). There were no differences between pigs with and without ulcer in the recorded behavioural events (**Table 5**).

3.2 EH pigs

The distribution of gastric ulcer scores seen in the EH pigs is shown in **Table 3**. The total frequency of posture changes or duration spent lying on the right hand side, ventral lying, mixed lying, kneeling/sitting or walking did not differ between pigs with and without ulcers (**Table 4**). The duration of time spent lying on the left side was significantly lower in pigs with ulcers (**Table 4**). Pigs with ulcers also spent significantly more time standing (**Table 4**). There were no significant differences between pigs with and without ulcers in any of the four behavioural states or in the behavioural events (**Table 5**).

3.3. Combined analysis

When data from both sites were combined in a single analysis, three posture variables showed significant differences between pigs with and without gastric ulcers. Pigs with ulcers spent longer standing or walking, and showed a higher frequency of posture changes than pigs without ulcers (**Table 4**). There was also a trend for pigs with ulcers to spend less time lying on their left side. The only significant effect of site was on duration of rooting/exploring; this behaviour was much more common at EH compared to GR (Duration in seconds, Predicted Mean ± SE: EH=832.6 ± 112.7; GR = 30.8 ±106.9). The four behavioural states did not differ significantly according to ulcer status, though there was a trend for less time spent idle in pigs with an ulcer compared to those without (**Table 5**). There was no effect of ulcer status on the individual behavioural events recorded or on the total number of events seen (**Table 5**).

4. Discussion

Gastric ulcers, in finisher pigs and sows, occur at high prevalence in many countries with an intensive pig industry (e.g. Swaby and Gregory, 2012). The main risk factors for gastric ulcers are well known but many are an inherent part of modern efficient pig production. There is potentially a relationship between increased feed efficiency (by using pelleted feed with a small particle size; e.g. <700µm: Cappai et al. 2013) and increased ulceration that may give rise to a dilemma between sustainability and prevention of gastric ulcers. However, the welfare implications of gastric ulcers are unclear. Studies on growth rates in ulcerated pigs have produced variable findings (Thomson and Friendship, 2012), and no detailed attempts have been made to assess behavioural or physiological measures, which might reflect the welfare status of affected animals. Given this, it is not clear to what extent the pig

industry or the public should be concerned about stomach ulcers. As a first step to understand the link between gastric ulcers and animal welfare this study aimed to compare the behaviour of pigs with and without deep gastric ulcers.

No association was found between the presence of gastric ulcers and various specific pig behaviours recorded at the two sites. However, at EH, pigs with ulcers were found to spend more time standing and less time lying on their left side compared to pigs with healthy stomachs. The same pattern (decreased left lateral lying and increased standing) was seen in the GR pigs, but the difference between pigs with and without gastric ulcers did not reach statistical significance. When data from EH and GR were combined into a single analysis the duration of standing and walking were found to be higher in pigs with ulcers, and these pigs also showed a higher overall frequency of posture changes. There was a trend for pigs with ulcers to spend less time lying on their left side.

It is worth considering, provided the direction of causality is that gastric ulcers cause the change in behaviour, why that might be the case. Within the abdominal cavity the stomach sits largely to the left of the medial line, though the pars oesophagea and the nonglandular mucosa, which is the site of ulceration when it occurs, sit more centrally. It is possible to speculate that lying on the left may either: i) increase exposure of the pars oesophagea to gastric fluids, or ii) increase physical pressure on the damaged tissue (for instance, from the pressure of the liver now being above it). Lying on the left makes the ingesta (if liquid) go into the cardiac portion of the stomach, so is likely to keep the ingesta in contact with the oesophageal area. Lying on the right makes the ingesta go into the fundic and pyloric areas of the stomach, away from the oesophageal area. A tendency for decreased time lying on the left side in pigs with ulcers might therefore imply that having acidic material in

298 contact with ulcerated tissue is painful. The other behavioural differences – increased
299 time standing and increased restlessness (as indicated by the frequency of postural
300 changes) – also tentatively suggest the presence of some pain or discomfort associated
301 with gastric ulceration. A study of shoulder ulcers in pigs (Larsen et al. 2015)
302 similarly found an increased standing time in pigs with shoulder ulcers, as well as
303 other changes such as increased frequency of overall posture changes, and concluded
304 these were pain related.

305 In comparison to somatic pain, visceral pain has a number of distinctive defining
306 features. It is diffuse and poorly localised within the body (Cervero and Laird, 1999),
307 which means that behavioural responses tend to be less specific and whole-body
308 responses are more common (Sikandar and Dickenson, 2012). Visceral pain is also
309 given higher affective-motivational pain ratings by human patients (i.e. visceral pain
310 is more emotionally distressing) (Sikandar and Dickenson, 2012) and commonly
311 induces increased anxiety/fear in animal models (e.g. Zhang et al 2014). With
312 reference to pigs, the diffuse nature of visceral pain could explain the general (i.e. not
313 focused on a particular body region) behavioural differences seen in pigs with gastric
314 ulcers. In addition to spontaneous pain, visceral pain can also alter somatic sensitivity
315 causing referred hyperalgesia (Traub and Wang, 2004; Yarushkina et al. 2006). For
316 instance, rats with induced gastric ulcers were found to have a lower nociceptive
317 response threshold to thermal stimulation of the tail (Yarushkina et al. 2006). Indeed,
318 Taylor (2006) reports that pigs with acute gastric ulcers are more sensitive to pressure
319 applied to the xiphoid process. Farmers rate gastrointestinal disease as being similarly
320 painful as lameness and shoulder ulcers; gastrointestinal disease was given a mean
321 rating of 5.6 out of 10 for painfulness by pig farmers, compared to a score of 6.3 for

lameness (a pig with minimal ability to bear weight) and 5.6 for shoulder sores (Ison and Rutherford, 2014).

It is of course possible that the link between lesion status and behaviour could causally occur in either direction. For instance, it is not possible to rule out the possibility that pig behaviour can be a risk factor for gastric ulcer formation (and therefore that the differences in behaviour between pigs with and without ulcers were pre-existing and in some sense relate to why ulcers subsequently formed; e.g. that restless pigs could be more likely to get ulcers). Indeed, previous studies have found that coping style can affect the susceptibility of pigs to develop ulcers (Hessing et al. 1994; Bolhuis et al. 2006) so behavioural risk factors are plausible.

The issue of feeding and gastric ulceration in pigs is an interesting example where there may be trade-offs between different desirable and undesirable aspects of production. Pelleting and fine grinding of feed (the principal risk factors for ulceration) have various apparent positive effects: increased performance (Eisemann and Argenzio, 1999a; Mikkelsen et al. 2004; Millet et al. 2012b; Ball et al. 2015; Nemechek et al. 2015; Overholt et al. 2016); reduced nitrogen excretion (Wondra et al. 1995; Ball et al. 2015); reduced greenhouse gas emissions (Dammgen et al. 2016); reduced feed wastage (Ball et al. 2015). These effects are linked to increased efficiency and increased sustainability (smaller negative effects on the environment and the climate per kg pork produced). There are also likely negative effects: poor environmental conditions for pigs and stock workers (e.g. increased particulate matter in pig houses: Ulens et al. 2015); negative alterations to gut health (Eisemann and Argenzio, 1999b; Sander et al. 2012; Longpré et al. 2016) and increased food safety risk (Mikkelsen et al. 2004; Hedemann et al. 2005; Visscher et al. 2009). Gastric ulceration also raises animal welfare concerns; certainly for animals that haemorrhage

and die, and perhaps, as suggested here, an effect of ulceration on pig discomfort. However, further studies are needed to properly investigate the full animal welfare significance of gastric ulcers before the issue of how to deal with competing concerns can fully be addressed. These studies should attempt to confirm the behavioural associations identified here and should expand the behavioural assessment to consider the motivational significance of pain putatively associated with ulcers. They should also investigate the effects of pain relief provision and add assessment of physiological variables in order to fully understand the welfare relevance of gastric ulceration.

Conclusion

The study demonstrated behavioural differences – alterations to postural time budgets and an increased frequency of posture changes – between pigs with and without gastric ulcers. The most plausible explanation for these effects is that sub-clinical ulceration may cause pigs to experience some degree of discomfort. However, other explanations are possible, and the failure to fully replicate findings across the two studies does indicate that a note of caution is warranted. The behavioural differences between pigs with and without ulcers are also difficult to classify in terms of the severity of any welfare impact associated with them.

Acknowledgements

Funding from SEGES, Danish Pig Research Centre supported this study. This funding is mainly from pig industry sources, and three of the authors of the paper also work for, or have worked for, this organisation, resulting in a potential or perceived conflict

of interest. However, the contract for this research with two of the independent academic partners (SRUC and University of Copenhagen) explicitly endorses that the work is at 'arm's length' from commercial interests, and the first and senior author, who work with the two academic partners, have led the process, and are satisfied that the framing of the study and the interpretation of the findings have not been unduly influenced by commercial interests.

Thanks to Per Mark Hagelskjær and the Grønhøj farm staff for animal care and organisation of marking pigs and collection of video footage at Grønhøj. Thanks to Jo Donbavand and Mhairi Jack for animal care at EasterHowgate and for assistance with pig euthanasia and tissue collection. Agnieszka Futro and Marianne Farish also provided help with pig euthanasia and tissue collection. Thanks also to the EasterHowgate farm staff (Peter Finnie, Phil O'Neil) for animal care during the pilot trial. Thanks to Calum Wilson at SACCVS and to Jens-Ove Hansen (JOH Consult) for assistance with stomach tissue collection and processing for ulcer scoring. Thanks to Kenneth Damholt Kristensen (Denmark) and Tomasz Krzyzelewski (Scotland) for assistance with transfer of the video files.

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Table 1

Description of gastric ulcer score system[#]

Gastric score:	**Description**	*Keratosis score*	*Erosion score*	*Ulcer score*	*Scar score*
0	Normal stomach with a white and shiny pars oesophagea without visible lesions				
1	Finely granulated parakeratosis in pars oesophagea, less than 1 mm thick	1			
2	Coarse parakeratosis in pars oesophagea, 1-3 mm thick	2			
3	Coarse, laciniated or papillomatous parakeratosis in pars oesophagea, more than 3 mm thick	3			
4	Erosion (superficial tissue erosion without damage of nerves and blood vessels) with a diameter less than 0.5 cm in pars oesophagea		1		
5	Erosion with a diameter on 0.5 cm or more in pars oesophagea		2/3		
6	Superficial ulceration (nerves and blood vessels exposed and potentially damaged) with a diameter of less than 0.5 cm in pars oesophagea **OR** palpable scar tissue in pars oesophagea consisting of one or more peripheral fibrous strands			1	1
7	Deep ulcers with a diameter of less than 0.5cm or more superficial ulceration with a diameter			2	2

	on 0.5-2.0 cm in pars oesophagea **OR** palpable scar tissue in pars oesophagea with fibrous strands producing an almost complete circular structure that may be slightly flexible		
8	Deep ulcers with a diameter of at least 0.5 cm or more superficial ulceration with a diameter of more than 2 cm in pars oesophagea **OR** palpable scar tissue in pars oesophagea with fibrous strands producing a circular, rigid structure	3	3
9 /10	Scar tissue constricting the oesophageal opening, leaving it inflexible with a diameter between 6 and 15 mm (score 9) or with a diameter of maximum 5.9 mm (score 10)		

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Table 2

Ethogram of recorded behaviours

Category *Behaviour*	**Definition**
Postures [mutually exclusive states]	
Ventral	Sternum in contact with floor and belly partially or completely concealed. Body axis vertical (±45°).
Lateral (right)	Recumbent, shoulder and pelvis in contact with the ground, with legs extended, body axis is >45° away from vertical, belly exposed. Lying on right side.
Lateral (left)	Recumbent, shoulder and pelvis in contact with the ground, with legs extended, body axis is >45° away from vertical, belly exposed. Lying on left side.
Mixed	Mixed posture between ventral and lateral: i.e. both rear legs have been pushed out from under the body and are presented as lateral, with hip in contact with the floor. Front legs are presented as ventral.
Sit	Rump in contact with the ground, front of body raised up by extension of front legs.
Kneel	Rump raised off ground by rear legs, front legs flexed, head close to the ground. [Posture must be maintained for at least 3 seconds – i.e. not recorded during transition from lying to standing].

Stand	Body is raised off the ground on all four legs.
Walk	Pig takes more than one step forward or back.
Behaviours [mutually exclusive states]	
Idle	No active behaviours. Includes putative sleeping.
Root ground / pen	Pig makes contact (nosing, touching, rooting) with snout to pen fixtures or the ground for >2 seconds.
Alert	Pig stands alert with ears pricked.
Nose other pig	Pig makes contact (touching, gently rubbing or licking) with snout to another pig (anywhere but the belly) for >2 seconds.
Belly nosing	Repetitive up and down snout movement on the belly of a pen mate.
Rub rear	Pig rubs back third of body against a pen fixture or against another pig.
Rub head	Pig rubs front third of body against a pen fixture or against another pig.
Rub flank	Pig rubs middle third of body against a pen fixture or against another pig.
Reciprocal Aggression	Mutual ramming or pushing, with or without aggressive biting. Pigs are in continuous social contact with one another, pushing and circling (separations of under 5 s were ignored). At intervals, bouts of vigorous biting and head-knocking occur. Both pigs engage with the other, each apparently trying to injure the other.

Snap	In response to physical contact, usually in the form of nosing, rubbing or biting of tail, ears, flank or feet, from another pig, (may also be directed at a pig who is just walking by), focal pig reacts with a sharp movement of its head towards the head/neck of other pig.
Being snapped at	Pig is snapped by other pig.
Being belly nosed	Pig is belly nosed by another pig.
Nosing rear	Pig makes contact (touching, gently rubbing or licking) with snout to another pig's rear (anywhere but the belly) for >2 seconds.
Ear biting	Taking the ear of a pen mate into the mouth or nibbling, sucking or chewing the ear.
Mounting	Pig lifts its two front legs and puts the two legs or its breast on any part of the body or head of another pig.
*In feeder**	GR: At least head and front two legs are over the threshold of the automatic feeder. EH: Head in feed trough.
Behavioural Events	
Ease quarters hind limbs	One or both rear legs gently shifted in position (tensed and relaxed) in a less forceful manner than kicking.
Ease quarters front	One or both front legs gently shifted in position (tensed and relaxed) in a less forceful manner than kicking.

limbs	
Back leg forward	One or both rear legs brought rapidly forward towards abdomen and then returned to original position.
Kick	One or both rear legs rapidly pushed out and away from body.
Leg twitch	One or both rear legs shows brief sharp movement, but doesn't change position.
Draw in back leg	In a lateral lying position, the back leg is pulled in towards the body in a lower less forceful manner than kicking.
Paw	In a lateral lying position, one or both front legs moved forward and away from the body and dragged back.
Back arch	In a lateral lying position, one or both sets of legs become tense and are pushed away from the body and/or inwards towards the centre, forming an arch in the back.
Whole body movement (shudder)	Whole body movement (when lying) that does not result in a shift to a new posture.

520 * Due to the different feeder set-ups at the two farms, the definition for being in the feeder varied.

Table 3

Frequency (and percentage) of pigs with different gastric ulcer scores across different experimental batches at research farms in Denmark (GR) and Scotland (EH).

	Grønhøj					EasterHowgate		
Ulcer Score	**Batch 1 (n=111)**	**Batch 2 (n=109)**	**Batch 3 (n=115)**	**Batch 4 (n=112)**	**All GR (n=447)**	**Batch 1 (n=39)**	**Batch 2 (n=39)**	**All EH (n=78)**
0	20 (18.0%)	1 (0.9%)	2 (1.7%)	0 (0.0%)	23 (5.1%)	8 (20.5%)	8 (20.5%)	16 (20.5%)
1	39 (35.1%)	18 (16.5%)	14 (12.2%)	3 (2.7%)	74 (16.6%)	8 (20.5%)	7 (18.0%)	15 (19.2%)
2	19 (17.1%)	8 (7.3%)	4 (12.2%)	5 (4.5%)	36 (8.1%)	9 (23.1%)	8 (20.5%)	17 (21.8%)
3	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (7.7%)	1 (2.6%)	4 (5.1%)
4	7 (6.3%)	6 (5.5%)	0 (0.0%)	6 (5.4%)	19 (4.3%)	2 (5.1%)	10 (26.5%)	12 (15.4%)
5	2 (1.8%)	0 (0.0%)	1 (0.9%)	3 (2.7%)	6 (1.3%)	2 (5.1%)	2 (5.1%)	4 (15.4%)
6	14 (12.6%)	27 (24.8%)	21 (18.3%)	25 (22.3%)	87 (19.5%)	2 (5.1%)	1 (2.6%)	3 (3.9%)
7	2 (1.8%)	26 (23.9%)	39 (33.9%)	35 (31.3%)	102 (22.8%)	3 (7.7%)	1 (2.6%)	4 (5.1%)
8	7 (6.3%)	16 (14.7%)	21 (18.3%)	28 (25.0%)	72 (16.1%)	2 (5.1%)	1 (2.6%)	3 (3.9%)

9	1 (0.9%)	6 (5.5%)	13 (11.3%)	6 (5.4%)	26 (5.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
10	0 (0.0%)	1 (0.9%)	0 (0.0%)	1 (0.9%)	2 (0.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

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Table 4

Predicted means and statistical analysis for postures of pigs observed at research farms in Denmark (Grønhøj) and Scotland (EasterHowgate) and for a combined data set. Significant findings (P<0.05) are highlighted in bold.

	Grønhøj			**EasterHowgate**			**Combined**				
	Ulcer (n=19)	**Healthy (n=21)**	**Ulcer Status**	**Ulcer (n=7)**	**Healthy (n=15)**	**Ulcer Status**				**Ulcer Status**	**Site by Status**
Category	Mean	Mean	P value	Mean	Mean	P value	Mean	Mean	P value	P value	P value
Variable	(SE)	(SE)	(F value)	(SE)	(SE)	(F value)	(SE)	(SE)	(F value)	(F value)	(F value)
Postures *(duration, secs)*											
Lateral left	1389	1946	0.217	1187	2442	**0.044**	1416	2132	0.492	0.064	0.489
	(343)	(220)	(1.52)	(425)	(302)	**(5.18)**	(303)	(216)	(0.49)	(3.76)	(0.48)
Lateral right)[*]	1712	1736	0.960	1671	1660	0.981	2010	1958	0.252	0.895	0.773
	(372)	(380)	(0.00)	(262)	(359)	(0.00)	(319)	(273)	(1.37)	(0.02)	(0.08)
Ventral	1525	1110	0.162	1135	1501	0.374	1461	1308	0.553	0.541	0.080
	(218)	(219)	(2.03)	(317)	(220)	(0.84)	(198)	(164)	(0.36)	(0.38)	(3.19)

Mixed	354	690	0.108	481	201	0.186	322	455	0.133	0.395	0.062
	(152)	(151)	(2.72)	(170)	(116)	(1.88)	(124)	(105)	(2.36)	(0.73)	(3.64)
Kneel/Sit)[#]	185	72	0.07	128	119	0.902	233	172	0.05	0.374	0.511
	(60)	(26)	(3.51)	(59)	(41)	(0.02)	(55)	(46)	(4.18)	(0.80)	(0.44)
Stand	1630	1143	0.147	1399	728	**0.009**	155	925	0.281	**0.009**	0.423
	(242)	(240)	(2.20)	(205)	(157)	**(10.65)**	(188)	(158)	(1.20)	**(7.24)**	(0.65)
Walking	71	47	0.133	67	39	0.221	70	43	0.749	**0.038**	0.864
	(13)	(13)	(2.35)	(19)	(13)	(1.61)	(11)	(10)	(0.10)	**(4.52)**	(0.03)
Total Posture changes	66	54	0.323	61	41	0.189	67	45	0.688	**0.022**	0.523
(number)	(8)	(8)	(1.00)	(13)	(9)	(1.88)	(8)	(7)	(0.16)	**(5.57)**	(0.41)

[*] EH: data back transformed (log10)

[#] GR: data back transformed (log10)

Table 5

Predicted means and statistical analysis for behavioural states and events of pigs observed at research farms in Denmark (Grønhøj) and Scotland (EasterHowgate) and for a combined data set. Significant findings (P<0.05) are highlighted in bold.

	Grønhøj			**EasterHowgate**			**Combined**				
	Ulcer (n=19)	**Healthy (n=21)**	**Ulcer Status**	**Ulcer (n=7)**	**Healthy (n=15)**	**Ulcer Status**	**Ulcer**	**Healthy**	**Site**	**Ulcer Status**	**Site by Status**
Category	Mean	Mean	P value	Mean	Mean	P value	Mean	Mean	P value	P value	P value
Variable	(SE)	(SE)	(F value)	(SE)	(SE)	(F value)	(SE)	(SE)	(F value)	(F value)	(F value)
States *(duration, secs)*											
Feeder	753	532	0.341	358	257	0.416	587	394	0.069	0.223	0.790
	(165)	(154)	(0.94)	(104)	(71)	(0.69)	(124)	(100)	(3.54)	(1.52)	(0.07)
Idle	5500	5902	0.284	5528	6005	0.217	5434	5945	0.805	0.081	0.739
	(268)	(220)	(1.20)	(337)	(243)	(1.66)	(227)	(181)	(0.06)	(3.18)	(0.11)
Nose	339	43	0.097	49	61	0.73	240	54	0.452	0.114	0.321
	(136)	(134)	(2.9)	(33)	(24)	(0.12)	(93)	(79)	(0.58)	(2.57)	(1.00)

Root/Explore	37	38.8	0.971	1130	682	0.179	507	356	**<0.001**	0.161	0.052
	(28)	(25.9)	(0.00)	(273)	(188)	(1.94)	(98.7)	(89.0)	**(26.5)**	(2.02)	(3.94)
Events *(freq. /2hrs)*											
BACK LEG	95.6	88.4	0.732	80.3	66.8	0.417	86.7	77.4	0.225	0.522	0.861
	(16.3)	(16.6)	(0.12)	(12.9)	(10.0)	(0.68)	(11.5)	(10.2)	(1.53)	(0.42)	(0.03)
FRONT LEG[#]	11.1	10.6	0.912	9.7	6.7	0.395	10.3	8.5	0.374	0.556	0.581
	(3.7)	(3.5)	(0.01)	(3.2)	(1.7)	(0.76)	(2.6)	(1.8)	(0.82)	(0.35)	(0.31)
TOTAL	127.4	124.8	0.926	99.6	87.1	0.488	112.2	105.4	0.104	0.712	0.812
	(21.2)	(21.7)	(0.01)	(13.9)	(10.8)	(0.50)	(14.5)	(12.9)	(2.82)	(0.14)	(0.06)

534 [#] EH, GR and combined: data back transformed (log10)