Title – A longitudinal study of the effects of providing straw at different stages of life on tail-biting and other behaviour in commercially-housed pigs

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Abstract

Tail-biting (TB) is a welfare concern. Recent studies indicate that early provision of straw may help prevent TB, however, many of these studies were carried out on small groups of pigs and may have limited applicability to commercial farms. The effect of providing straw at different stages of life was studied in large groups of pigs (21-39) on a commercial farm. Six replicates of four treatments were used (No Straw (NS), Straw in Finishing (12 weeks of age onwards) (SF), Straw from Weaning (SW), Straw Throughout Life (ST)). Based on previous studies, it was predicted that levels of TB would be lowest in ST and highest in NS. A total of 706 pigs were followed from birth to slaughter, however one replicate (all four groups) was excluded due to circumstances beyond our control. All pigs were housed on solid floors, and shavings were provided in pens without straw. Fresh bedding was provided twice per week. Behaviours were recorded at regular intervals and all tail-biting outbreaks were recorded.

The timing of straw provision had limited effect on pigs' behaviour. Before weaning there was no difference in the time spent exploring the substrate between groups with straw and those without. After weaning, the time spent rooting was significantly different between treatments ($F_{(13,16)}$=3.796, $p<0.05$) with post-hoc testing indicating that levels were significantly higher in SW than NS but that there was no difference between ST and the other treatments. Of the 20 groups, fourteen had tail-biting outbreaks (NS=3, SF=2, SW=4, ST=5), eight of these were classed as severe (NS=2, SF=0, SW=1, ST=3). Provision of straw did not have a significant effect on the distribution of tail-biting outbreaks ($p = 0.336$).

This unexpected finding was not explained by other variables (e.g. stocking density). It may have been related to the finding that straw provision did not increase the amount of rooting as expected, perhaps because the provision of solid floors and shavings allowed rooting in non-straw treatments. Most TB was seen in the finishing pigs where straw levels increased for SF but declined for ST and SW relative to earlier in life due to the farm's management practice. The levels of tail-biting were higher than expected in ST / SW and lower than expected in SF, suggesting that the novelty of straw for SF might have decreased the risk of TB whilst the decline in straw provision for ST/SW might have increased the risk.

Keywords

Tail-biting, pigs, behaviour, welfare, straw, environmental enrichment

1 Introduction

Tail-biting is a damaging social behaviour that leads to reduced production, profitability and welfare (Edwards, 2006). Prevention of tail-biting on farms is therefore beneficial to both pig and producer. In a UK survey carried out in 2001 it was estimated that 83.5% of pigs were tail-docked (Hunter et al., 2001) a technique that farmers and many vets believe is the most effective means of preventing tail-biting (Paul et al., 2007). Although this procedure may reduce the number of mild lesions seen on tails, it does not reduce moderate or severe lesions (Hunter et al., 2001) and it may simply be a case of reducing the size of the area on which lesions can occur (Webster and Day, 1998). Indeed in an epidemiological study in the UK, tail docking was related to a three-fold increase in the risk of tail-biting (Moinard et al., 2003). This is likely to be a result of farms with a persistent history of tail-biting deciding to tail-dock (Schrøder-Petersen and Simonsen, 2001). However, what is clear is that tail docking did not eliminate tail-biting on farms practising this procedure in the Moinard et al. (2003) study. This, combined with the evidence of acute pain caused to piglets when tail-docked (Noonan et al., 1994; Prunier et al., 2005; Sutherland et al., 2008), makes a clear case as to why alternative preventions should be sought.

One of the reasons for the lack of faith in alternatives to tail-docking is that the causes of tail-biting are multi-factorial and therefore solutions which work on one farm might have no effect on another (e.g. Taylor et al., 2010). The strategy which offers the most hope in preventing tail-biting without the need to tail-dock is straw provision. Tail-biting can be considered as a redirected behaviour, following the theory that in the absence of rooting material manipulative behaviours are redirected to pen-mates and may develop into harmful social behaviours. This has been supported by a number of studies which have shown that providing straw can reduce the levels of tail-biting (Beattie et al., 1995; Day et al., 2002a; Zonderland et al., 2004; Van de Weerd et al., 2005; Van De Weerd et al., 2006; Scott et al., 2007a) and other harmful social behaviour such as aggression (Ruiterkamp, 1985; Beattie et al., 1996; O'Connell and Beattie, 1999; Beattie et al., 2000b), bellynosing (Petersen et al.,

1995) and nosing, chewing or biting pen-mates (Fraser et al., 1991b; Beattie et al., 1995; Simonsen, 1995; Beattie et al., 2000b). Straw also provides a pig with roughage and thermoregulatory control at cold temperatures.

The stage of life at which straw is provided appears to be important in minimising tail-biting behaviour. Moinard et al's (2003) study of tail-biting on farms in the UK suggested that straw provision pre-weaning might be important in reducing the risk of tail-biting after weaning. There is some evidence that early rearing environment impacts on behaviour later in life, with pigs from a "barren" environment subsequently performing more nibbling on pen mates (Simonsen, 1995) and more aggression (Munsterhjelm et al., 2009). There is no solid evidence that levels of tail-biting are affected by early straw provision and it is possible that in the epidemiological study by Moinard et al. (2003), early straw provision may have been confounded with straw provision later in life. It is thus possible that the cumulative experience of straw over a longer period of life, perhaps through a combination of early and current experience, is more beneficial than simply receiving straw after weaning or later in life. A better understanding of how the effects of straw are influenced by the stage of life at which it is presented is required.

Whilst there has been considerable research into the relationship between tail-biting and straw provision, it seems to fall into one of two categories. The first category is research carried out on small groups of pigs, e.g. groups of six (Beattie et al., 1995; Beattie et al., 1996) or ten pigs (McGlone et al., 1990; O'Connell and Beattie, 1999; Day et al., 2002a; Day et al., 2002b; Zonderland et al., 2008). This type of research is usually carried out in a controlled environment in a research establishment and typically involves straw provision on a daily basis. This means that whilst the findings are likely to be reliable they may have limited applicability to commercial farms in the UK where group sizes tend to be larger, many extraneous factors vary from day to day and, due to economic and time constraints, straw provision is typically weekly or bi-weekly if it is used at all. The second category is research carried out on commercial farms but where the presence of straw has been confounded with other factors such as higher stocking density in the non-straw

treatment (Simonsen, 1995) or both higher stocking density and the presence of slats in the non-straw treatment groups (Beattie et al., 1995; O'Connell and Beattie, 1999; Beattie et al., 2000b; Guy et al., 2002; Van de Weerd et al., 2005; Scott et al., 2007a). Whilst these are commercially relevant comparisons it means that it is unclear whether the provision of straw, the presence of a solid floor or decreased stocking density was most influential in reducing tail-biting.

The aim of this study was therefore to carry out a detailed investigation of the effects of providing straw at different stages of life on the behaviour of pigs. The focus was on comparing the effects of cumulative cross-life experience of straw compared to straw presented after weaning or later in life only, as often is the case on commercial farms. A controlled experimental study was carried out on a commercial farm in which the only manipulation was the presence and timing of straw provision. Measures of growth rate, tail-biting outbreaks, and other behaviours enabled many of the potential effects of straw to be monitored. It was predicted that the lowest levels of tail-biting would be in groups where straw was provided throughout life and that the highest levels would be where no straw was provided at all.

2 Methods

2.1 Animals and housing

The study was carried out on a 130-sow commercial farm in the UK. A total of 706 Large White x Landrace x Pietrain pigs were studied. Sows farrowed in loose pens with an uncovered yard (1.52m x 2.35m), a kennel (1.52m x 2.5m) and a creep (1.52m x 0.6m) with a heat lamp, there was a solid concrete floor throughout. The piglets remained in this pen with the sow until weaning at 25 ± 3 days. At weaning three litters were mixed together in a weaner pen, giving group sizes of 30 ± 9 pigs. Weaner pens had a solid concrete floor throughout and consisted of an open area (2.2m x 4.46m) and a kennel area (2.2m x 4.35m) with heat lamps, a manipulable object (a wellington boot), and a feeder 168cm in length with 8 feeder spaces. At approximately 12 weeks of age each group of

pigs was moved, without mixing, into a finisher building where they remained for the last 9 weeks of the study. Finisher pens also had solid concrete floors and consisted of a kennel area (3.52m x 3.83m) and an open area (3.52m x 4.4m) with a manipulable object (a plastic barrel suspended from the kennel), and a feeder with three spaces. Creep feed was added daily from 2 weeks of age and after weaning the pigs were fed ad-lib on a commercial pellet.

2.2 Straw provision

Since all the pens in the study had solid concrete floors without insulation, they were designed for use with bedding. There were four treatment groups with pigs provided with *Straw Throughout life* (ST), *Straw from Weaning* (SW), *Straw in Finishing* (i.e. from 12 weeks) (SF) and *No Straw* (NS) (see Fig. 1). Ideally fresh straw would have been provided daily as this is associated with decreased levels of tail-biting (Moinard et al., 2003), however this study was conducted on a commercial farm and therefore a balance had to be struck between commercial and experimental practices. Thus for the purposes of the study, straw provision was standardised and increased in frequency wherever possible. In all of the farrowing pens around 2kg of wood shavings was added to the pen around farrowing to give some insulation and help dry the newborn piglets. The pens were cleaned each day and 0.5kg of fresh wood shavings was added to the pens in treatment groups SW, SF and NS twice a week. For the pigs allocated to ST treatment approximately 1kg of straw was added to the pen shortly after farrowing and twice a week from then on.

Prior to weaning the weaner pens were bedded up with either a bale of shavings (around 22kg) or the start of a deep bed of straw (around 45kg). The dunging passage of the weaner pens was cleaned out daily for all groups, in SF and NS treatment groups the lying area was cleaned out weekly and around 11 kg of wood shavings was added at this time. In ST and SW groups the lying area was not cleaned, however fresh straw (around 25kg) was added into the lying area once a week. In the finisher pens the dunging passage was scraped out daily and the lying areas cleaned once a week. Fresh straw (around 5kg)

was added to ST, SW and SF groups twice a week, no bedding was provided for the NS groups.

Six replicates of each treatment were carried out, three in 2005 and three in 2006, with each replicate containing one of each treatment group (Fig. 1). Since there were four treatment groups, each made up from 3 litters, but only 6 litters born each week, each replicate (12 litters total) comprised litters born across a two-week period. Thus the first two treatment groups were weaned in the first week and the second two a week later, the order being balanced between replicates. Of the 24 groups in the study, one full replicate of 4 groups had to be excluded due to circumstances beyond our control.

2.3 Non-behavioural procedures

Each pig was individually identified with a tattoo at birth and with an ear tag at weaning. At birth piglets' teeth were clipped and an iron injection administered; males were not castrated and tails were not docked. Each pig was weighed at birth, weaning, 11 weeks of age and at the end of the study. The tails of the pigs were formally examined twice, the first examination at approximately 11 weeks of age and the second at 19 weeks. During each formal examination, the tails were thoroughly cleaned, measured and details of all damage indicative of tail-biting was noted. This involved recording the type of damage (scrapes from teeth, bite marks, chewing damage or severe damage where tail length is reduced) and the position on the tail where it occurred. As well as these checks, tails were informally inspected (without cleaning) each week when the pig's identification was re-marked. If any tail damage was noted during a weekly tail examination then an additional formal tail examination was carried out on every pig in the pen.

2.4 Pre-weaning behavioural observations

Pre-weaning behavioural observations were made during one day when piglets were 18 ± 3 days. Since it was not possible to identify individual piglets, observations were carried out at litter level. Due to this limitation and time restrictions, pre-weaning behaviours were recorded only for ST and the other treatment group to be weaned that

week (which had no straw), in other words for 6 of the 12 litters in each replicate. This gave a total sample of 18 litters with straw and 18 without, but two of the litters in the non-straw treatment had to be excluded. On the behavioural observation day each litter was scan sampled 36 times and in each scan the number of piglets performing each behaviour listed in Table 1 was recorded. Each litter was observed in turn by the same person and thus the observations were evenly spread between 9am and 5pm.

2.5 Post-weaning behavioural observations

Direct behavioural observations of each group were also made at approximately 7, 11, 15 and 19 weeks of age. Since two treatment groups were weaned in one week and the other two were weaned a week later, behavioural observations were also spread over a two week period to ensure that the pigs were at the same age when observations were done. So on one full working day (8am to 6pm) observations were made on two groups of pigs. The observer scan sampled both groups at the start of the day, then carried out 10 minutes of behaviour sampling on each group of pigs in turn. This was then repeated throughout the day, with each type of sampling completed at least ten times per group.

2.5.1 Instantaneous scan sampling

An ethogram was created by taking elements from various studies of tail-biting and enrichment (e.g. Fraser et al., 1991b; Beattie et al., 2000a; McIntyre, 2003). Observations of tail-biting during a pilot study led to the addition of a category of *Tail Interest* to the ethogram (see Table 2). Instantaneous scan observations of each pig in the group were made, recording their posture (*Lying*, *Sitting* or *Standing*) and behaviour.

2.5.2 Behaviour sampling

All the pigs within each group were observed simultaneously for 10 minutes and the occurrence of the following behaviours was recorded: *Aggression*, *Belly-nosing*, *Tail Interest*, *Tail Interest/Chewing*, *Tail Chewing* and *Tail Biting* (definitions as per Table 2).

The frequency and duration of these behaviours in seconds was noted, together with which individual pig was performing and receiving the behaviour.

2.6 Analysis

2.6.1 Classification of the level of tail-biting in a group

Each group of pigs was classified as having No Outbreak (no confirmed signs of tail-biting), an Underlying Outbreak (signs of tail-biting only detected during formal tail examinations) or a Severe Outbreak ('clinical' tail-biting problem with blood seen in the pen and severe damage, i.e. damage causing a reduction in tail length, on at least two pigs). These three levels of severity were used because it was important to distinguish between those outbreaks that would be readily detected and classified as a 'clinical problem' and those that were likely to be undetected on commercial farms. Intervention was applied as soon as a severe outbreak was detected; both tail-biters and severely bitten pigs were removed from the trial pen and enrichment objects were added.

2.6.2 Pre-weaning behavioural observations

In order to examine any differences in pre-weaning behaviours, the average proportion of piglets performing each behaviour over all of the scan observations was calculated for each litter. Comparisons between litters with and without straw were made using either T-tests or Mann-Whitney U-tests depending upon the outcome of normality and homogeneity of variance tests.

2.6.3 Post-weaning behavioural observations

Since the pens were not entirely balanced with respect to group size and sex ratio, one-way ANOVAs were used to check that there was not an imbalance between treatments. These confirmed that there was no significant difference in the stocking densities at any age: 7 weeks ($F_{3,16}$ = 0.999, p = 0.419), 11 weeks ($F_{3,16}$ = 0.864, p = 0.480), 15 weeks ($F_{3,16}$ = 0.864, p = 0.480) and 19 weeks of age ($F_{3,16}$ = 0.611, p = 0.618). There was also no significant difference in sex ratio ($F_{3,16}$ = 2.111, p = 0.139) between treatments.

From the Behaviour Sampling data the frequency and duration of each of the behaviours during each observation day was calculated for each group of pigs. These were summed and converted to rates of seconds per pig per hour. From the scan observations all behaviour categories that were not included in the behaviour sampling were analysed. The total occurrence of each of these was summed for each group on each observation day and then converted to a proportion of the total number of scans made that day. For all of these measures, differences over time and between treatments were examined. Parametric tests (repeated measure GLMs with a between-subjects factor of treatment) were used if the assumptions of normality and homogeneity of variance were satisfied. When assumptions were not met, changes over time and between treatments were examined using Friedman tests. Where significant overall effects of age or treatment were found, Wilcoxon tests were then used to see which age or treatment groups were significantly different from each other.

2.6.3 Outbreaks of tail-biting

The effect of housing treatments on the occurrence of outbreaks was analysed. The use of survival analysis was considered, but there were a number of problems identified relating to the variation in risk. Firstly the risk of being bitten changes once one event has occurred in a pen, secondly the interventions which we applied when a severe outbreak occurred would have affected the risk for those pigs remaining in the pen, and finally the risk was greatly increased on tail examination days since underlying outbreaks were highly likely to be discovered on that day. All of this meant that survival analysis was not possible and since individuals in the same pen could not be considered independent, data analyses had to be carried out on a group level.

With each group of pigs having been classified as having no tail-biting, an underlying problem or a severe problem, the occurrence within each treatment group was compared using Fisher exact tests. Since it was not possible to fully control the stocking density or

sex ratio of groups in the study, analyses of these factors on the number of outbreaks of tail-biting were carried out using one-way ANOVA's.

3 Results

3.1 Pre-weaning behaviours

The presence of straw had little influence on the pigs' behaviour pre-weaning. There was no significant difference in the proportion of pigs performing any of the behaviour categories in the ethogram, including Substrate Explore with 13.1% of pigs performing this behaviour in each treatment (t_{32} = 0.000, p = 1.000). There was a tendency for more Other Social behaviours to be seen in the groups without straw (3.5%) when compared with straw (2.5%) (t_{32} = 1.897, p = 0.067). The only incidents of Tail Chewing were observed in pens without straw; however this only occurred twice and therefore was not a significant difference.

3.2 Tail-biting

There were no significant effects of treatment group on the levels of any of the tail-orientated behaviours recorded in the direct behavioural observations, nor any interactions between treatment and age (see Figure 2). Levels of Tail Chewing and Tail Interest significantly increased with age.

Of the 20 groups of pigs in this stage of the analysis, 14 groups had outbreaks of tail-biting of one type or another. The levels of tail-biting within each treatment are shown in Table 3. The overall distribution of outbreaks over treatment groups was not significantly different (p = 0.336), nor was the number of severe outbreaks (p = 0.381).

In a comparison between the Severe, Underlying and No Outbreak groups, there were no significant differences in stocking density at any age (7 weeks ($F_{2,17}$ = 1.348, p = 0.286), 11 weeks ($F_{2,17}$ = 2.330, p = 0.128), 15 weeks ($F_{2,17}$ = 2.330, p = 0.128) and 19 weeks ($F_{2,17}$ = 0.357, p = 0.705) or sex ratios ($F_{2,17}$ = 0.095, p = 0.910), suggesting that these variables did not readily explain the distribution of outbreaks.

3.3. Other post-weaning behaviours

Many of the behaviours recorded varied with age, but not with straw provision. There were no significant effects of treatment group on the levels of other harmful social behaviours such as bellynosing or aggression, or other social behaviours, and no age x treatment interactions (see Figure 3). The data for all of the exploratory behaviours are represented in Figure 4. The level of Pen Explore varied with age but not with treatment. For the behaviour Rooting there was also a significant difference between age groups, however there was also a difference between treatments ($F_{(3,16)}$=3.796, $p<0.05$). Post-hoc Bonferroni tests showed that levels of Rooting were higher in SW than in NS ($p<0.05$) (Figure 4b). Finally the proportion of pigs Chewing Other changed significantly with age and there was an interaction between treatment and age ($F_{(9,48)}$=2.143, $p<0.05$) but no treatment effect. Post-hoc LSD tests indicated that at 11 weeks of age the levels of Chewing Other were higher in ST and SW than in SF, whilst at 15 weeks levels were higher in SF and ST than in NS and at 19 weeks levels were higher in SW than in NS. The presence of straw did not affect the occurrence of any of the other recorded behaviours or postures.

4 Discussion

The main aim of this study was to carry out a detailed investigation of the effect of providing straw at different stages of life on the behaviour of pigs. Of particular interest was the impact that straw had on tail-biting and specifically whether providing straw pre-weaning (ST group) had a beneficial protective effect against tail-biting later in life compared to providing it from weaning onwards (SW group).

Pre-weaning behaviour was recorded to see if the provision of straw would result in any detectable differences in the behaviour of the pigs at this stage. We did not detect any of the differences in behaviour of the sort observed in other similar studies of pre-weaning pigs (Petersen et al., 1995; Cox and Cooper, 2001). This may be because these studies used treatment groups which were more differentiated than ours, with the enriched group

being outdoors (Cox and Cooper, 2001) or provided with straw, logs and branches in the pen (Petersen et al., 1995). Neither of these studies found a significant difference in the amount of tail-orientated behaviour pre-weaning. However our study and that of Petersen et al (1995) only ever observed tail-orientated behaviours in the barren or straw-free environment The low levels of tail-orientated behaviours seen pre-weaning may be both statistically and biologically insignificant and are unlikely to be predictive of tail-biting (Statham et al., 2009), but it remains possible that they were influenced by straw presence or absence.

For the post-weaning behaviours it was predicted that the levels of tail-biting and other harmful social behaviours would be lowest in Straw Throughout and that they would increase with decreasing straw provision, culminating in the highest levels occurring in No Straw groups. However this was not observed. Treatment did not significantly affect the levels of aggression, belly-nosing, other social behaviours, tail-orientated behaviours or indeed the number of outbreaks of tail-biting. Our sample size was slightly diminished as we had to exclude one replicate (4 groups) from the study (see section 2.6.1). However, on the basis of the data, it seems unlikely that increasing the sample size would yield our hypothesised findings, since all of the five groups in Straw Throughout treatment (which we hypothesised would show low levels of tail-biting) had tail-biting outbreaks. Therefore we have to conclude that in these circumstances providing straw pre-weaning did not have a protective effect against tail-biting and that overall in this study straw did not reduce tail-biting levels.

There are a number of reasons which may explain why our results did not match our hypothesis. The first is that another factor, such as the group sex ratio or stocking density which could not be controlled in this experiment, was over-riding the effects of straw provision. Stocking density has often been confounded with the presence of straw in previous work and has been shown to affect the amount of time spent manipulating substrate (Jensen et al., 2010). However in this instance our analysis suggested that neither sex ratios nor stocking density were significantly related to the level of tail-biting seen in

the study. It remains a possibility that another factor influenced the occurrence of tail-biting more strongly than the provision of straw. For example, some aspect of nutrition or temperature fluctuation (which would have applied equally to all treatment groups) may have over-ridden the effects of straw provision. If so, our findings suggest that the differences in straw provision used here did not have a strong enough effect to counteract the influence of factors that may vary naturally (and uncontrollably) under commercial conditions.

Another possibility is that straw provided twice a week at commercially viable levels was simply not having the desired effect. If tail-biting is indeed a redirected behaviour then we would expect decreased levels of tail-biting in conditions which induced increased levels of rooting. Previous studies which have found that provision of straw reduced the amount of tail-biting seen have involved adding straw to the pen every day (Fraser et al., 1991a; Day et al., 2002b; Scott et al., 2006; Van De Weerd et al., 2006; Scott et al., 2007a; Scott et al., 2007b; Zonderland et al., 2008), and also noted increased time spent interacting with substrate (Day et al., 2002a; Guy et al., 2002; Van De Weerd et al., 2006). Providing straw frequently has been linked to increased interactions with the straw due to the novelty factor (Moinard et al., 2003). As described in the methodology, for this study we had to strike a balance between commercial and experimental practices. It may therefore be that the expected differences in rooting and tail-biting were not seen because providing straw bi-weekly was not effective in increasing interactions with the substrate and preventing outbreaks of tail-biting.

There may also be other reasons for why providing straw did not increase the time spent rooting or indeed why the non-straw treatments did not have lower levels. As mentioned earlier, much of the previous research has compared groups with straw provided on solid floors and no bedding on slatted floors (Beattie et al., 1995; O'Connell and Beattie, 1999; Beattie et al., 2000b; Guy et al., 2002; Van de Weerd et al., 2005; Scott et al., 2007a). A slatted system confounds the lack of bedding with a reduced opportunity to root as all substrates pass through the slats. This study was different because all the pigs

were housed on solid floors and shavings were provided in the early stages, both of which could have increased the level of rooting seen in the non-straw treatments relative to previous work. Direct comparisons have not been made between straw and wood shavings as enrichment for pigs. Other research has suggested however that wood shavings were considerably less favoured than compost (Studnitz et al., 2004) which is ranked similarly to straw in a systematic comparison of enrichments for pigs (Van de Weerd et al., 2003). It thus seems unlikely that shavings are as effective an enrichment as straw and therefore we could expect to have seen differences between these conditions in our study. Also because no shavings were provided in the finisher buildings and there was still no difference between treatments at this stage, making it improbable that the provision of shavings explains the lack of difference. It is possible however that the presence of solid floors instead of slats may have contributed to the lack of difference between treatment groups in this study.

Another factor which may help to explain the lack of difference between our treatment groups is the frequency and amount of bedding provided at different stages. As described in the methodology, due to the pen design, the weaner pens had larger amounts of straw added than the finisher pens. This combination of bedding provision may well have influenced the outcome of our study, since those pigs in Straw Throughout or Straw from Weaning treatments almost certainly experienced a decline in straw provision when moving into the finisher building. For the groups in the No Straw treatment there may have been a minor decline in bedding provision since they no longer had shavings provided, whilst the pigs in Straw from Finishing had an increase in bedding provision at this stage.

It was suggested by Day *et al.*(2002a) that a change in straw provision may be more important than the straw *per se* in altering pigs' behaviour. Other research has shown the removal of straw (Ruiterkamp, 1985) or enrichment (Munsterhjelm et al., 2009) increases the amount of tail-biting observed. Since most of the outbreaks were observed in the finisher building, it is therefore possible that changes to the amount of straw provided were

affecting the amount of tail-biting seen in this study. Our data also suggests that the decline in straw provision may have had an effect, since there was a significant overall decline in the amount of rooting between 11 and 15 weeks of age. This is also supported by studying Figure 4b, where it can be seen that the decline was much less pronounced in the Straw from Finishing treatment, where straw had been encountered for the first time. Non-significant differences in the number of outbreaks between treatments should also be considered in light of the fact that most of the outbreaks occurred in the finisher stage of the study. Whilst there were no significant differences between treatments, there were only two underlying outbreaks in the Straw in Finishing treatment groups and in contrast there were outbreaks in all five of the groups in Straw Throughout. It is possible that the pigs in Straw Throughout may have perceived a decline in straw provision when moving into the finisher building and that this may have been a trigger for outbreaks. If this was the case then it is important that recommendations take into consideration the system being used on each farm and not only whether straw can be provided at each stage but also how much. The sequence and amount of straw provision should therefore be considered an important area for further research.

In conclusion, on this particular commercial unit with solid floors throughout, providing straw twice a week (as opposed to shavings or no bedding) did not significantly increase the time pigs spent interacting with the substrate or decrease the amount of tail-biting within the four treatments. This means that both the amount and frequency of straw provided at each stage of housing should be considered as an important part of advice given to farmers regarding the use of straw to reduce tail-biting.

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Tables:

Table 1. Ethogram for pre-weaning behavioural observations

Table 2. Ethogram for post-weaning behavioural observations.

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Figure 1. Diagram showing the housing systems the study pigs moved through and the conditions in the four different treatments used in the study; Straw Throughout Life (ST), No Straw (NS), Straw from Weaning (SW) and Straw in Finishing (SF).

Figure 2. Means and SE for time spent in tail-orientated behaviours at different ages and in the four treatments. Symbols indicate treatment groups. —▲— = No Straw, —■— = Straw in Finishing, —△— = Straw Throughout, —⊟— = Straw from Weaning. Significance levels for changes across age are represented by * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$. Figure 2a is for Tail Biting behaviour, 2b Tail Chewing, 2c Tail Interest, 2d Tail Interest / Chewing.

Figure 3. Means and SE for time spent in other social behaviours at different ages and in the four treatments. Symbols indicate treatment groups. —▲— = No Straw, —■— = Straw in Finishing, —△— = Straw Throughout, —⊟— = Straw from Weaning. Significance levels for changes across age are represented by * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$. Figure 3a is for Aggression, 3b Bellynosing, 3c Other Social.

Figure 4. Means and SE for time spent exploratory behaviours at different ages and in the four treatments. Symbols indicate treatment groups. —▲— = No Straw, —■— = Straw in Finishing, —△— = Straw Throughout, —⊟— = Straw from Weaning. Significance levels for changes across age are represented by * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$. Figure 4a is for Pen Explore, 4b Rooting and 4c. Chewing Other

Table 1. Ethogram for pre-weaning behavioural observations.

Behaviour	Description
Out of view	The pig cannot be seen
Lying Inactive	Lying and not performing any other behaviour
Sitting Inactive	Sitting and not performing any other behaviour
Standing Inactive	Standing and not performing and other behaviour
Locomotion	Any movement including walking, running, scampering and rolling, provided that the pig is not investigating the pen or substrate or interacting with another pig at the same time
Substrate Explore	Sniffing, nosing or rooting in the straw or shavings
Pen Explore	Sniffing, touching, sucking or chewing any object which is part of the pen including the bare floor
Elimination	Excreting or urinating
Feeding	Eating creep feed or sow pellets
Drinking	Manipulating drinker with or without ingestion of water or drinking water from the floor beneath the drinker
Suckling	Being active at the sows' udder when at least half the litter are present and the sow is in nursing position
Manipulate Udder	Being active at the sows' udder when the sow is not in the nursing position or when less than half the litter is present at the udder
Agonistic	Head-thrusting, ramming, biting or pushing a littermate, it may be mutual or one-way
Tail Chewing	Having the tail of a littermate in its' mouth
Chewing Other	Chewing on something (not another pig) with its' head raised and away from the feeder
Other Social	All other social interactions including mounting, head rubbing and nosing parts of the body other than the belly
Other	All other behaviours not listed

Table 2. Ethogram for post-weaning behavioural observations. All behaviours were recorded in the scan sampling, those marked with an asterisk were also recorded in the behaviour sampling.

Behaviour	Description
Out of view	The pig cannot be seen
Inactive	Not performing any behaviour
Chewing Other	Chewing (not another pig) with its head raised and away from the feeder
Locomotion	Any movement including walking, running, scampering and rolling, provided that the pig is not investigating the pen or substrate or interacting with another pig at the same time
Rooting	Nosing or rooting in the straw, shavings or muck on the pen floor
Pen Explore	Sniffing, touching, sucking or chewing any object which is part of the pen including the bare floor and the enrichment object
Drinking	Manipulating drinker with or without ingestion of water or drinking water from the floor beneath the drinker
Feeding	Head positioned in the feeder or chewing food having just been displaced from the feeder
Elimination	Defaecating or urinating
*Tail Biting**	Having the tail of another pig in its mouth and biting or pulling hard enough to cause a reaction from the other pig
*Tail Chewing**	Having the tail of another pig in its mouth without biting or pulling hard enough to cause a reaction in the other pig
*Tail Interest **	Sniffing, nosing or manipulating the tail of another pig without taking the tail into its mouth
*Tail Interest / Chewing **	Alternating between the two behaviours described above rapidly enough that it was not possible to distinguish which was being performed.
*Belly-nosing **	Repeatedly thrusting snout into the belly of another pig
*Agonistic **	Head-thrusting, ramming, biting or pushing another pig. This may be mutual or one-way
Other Social	All other social interactions including mounting, head rubbing and nosing parts of the body other than the belly
Other	All other behaviours not listed

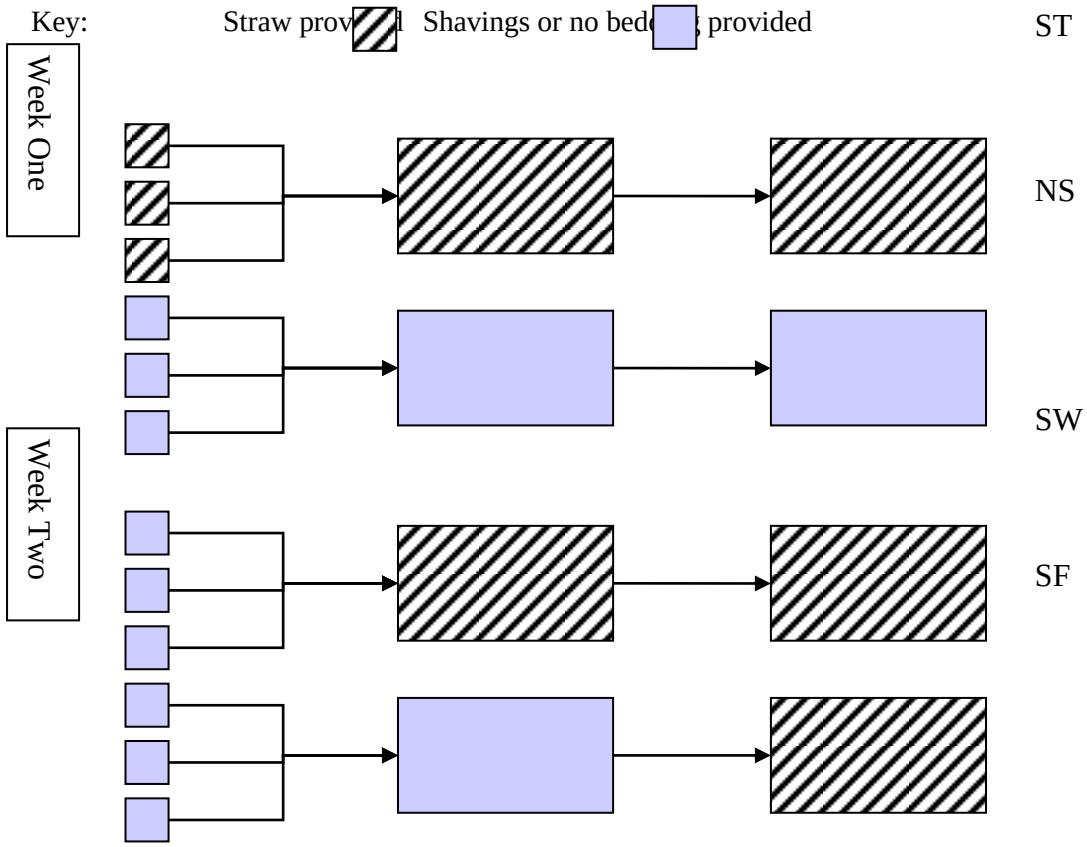
Table 3. Occurrence and type of tail-biting in each treatment group

Treatment	Severe	Underlying	Total
No Straw (NS)	2	1	3 / 5
Straw from Finishing (SF)	0	2	2 / 5
Straw from Weaning (SW)	1	3	4 / 5
Straw Throughout Life (ST)	3	2	5 / 5

Farrowing pens Weaner pens Finishing pens

SW

Figure 1. Diagram showing the housing systems the study pigs moved t
and the conditions in the four different treatments used in the study; Straw Throughout Life (ST), No Straw (NS), Straw from Weaning (SW) and Straw in Finishing (SF).



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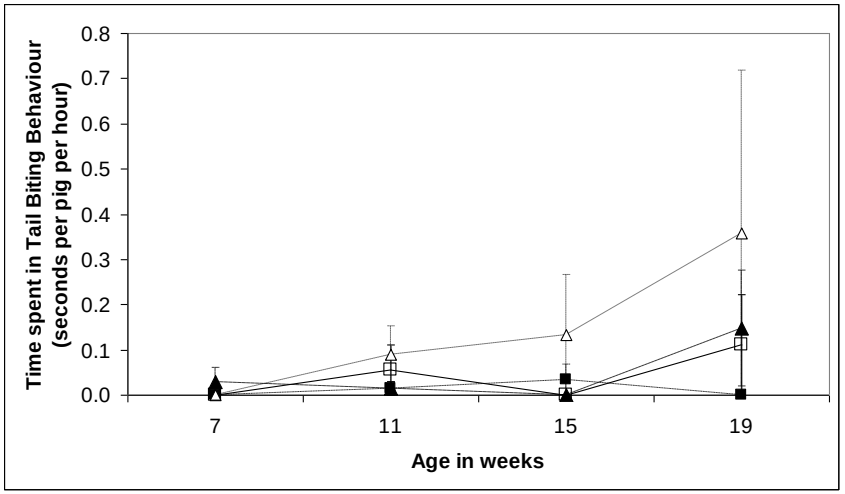
a.



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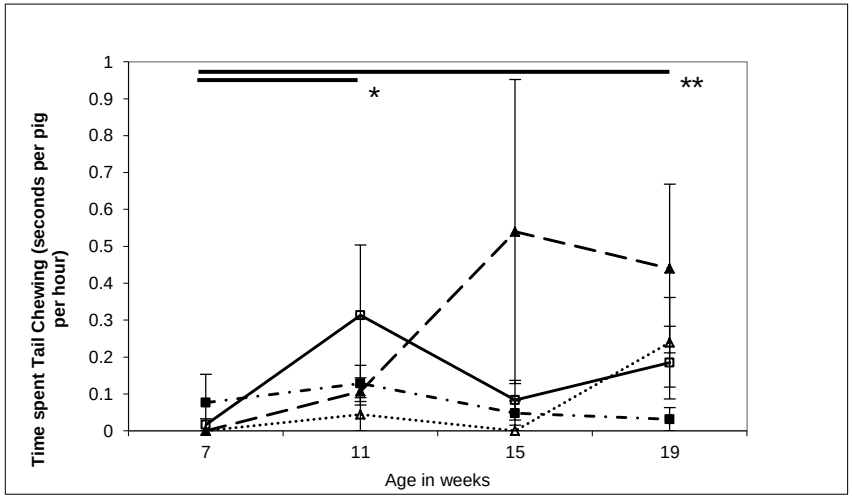

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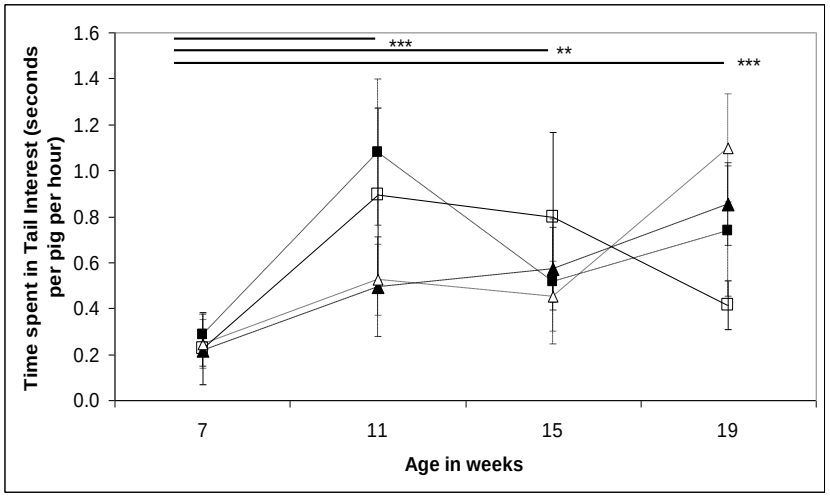

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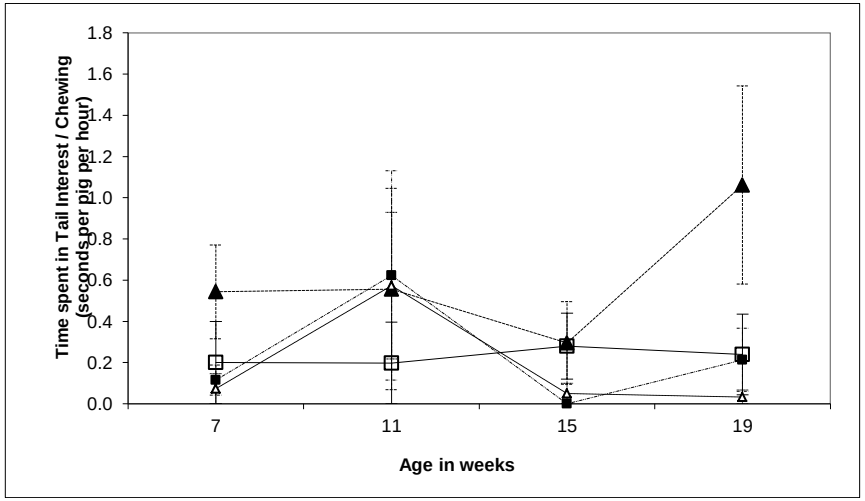

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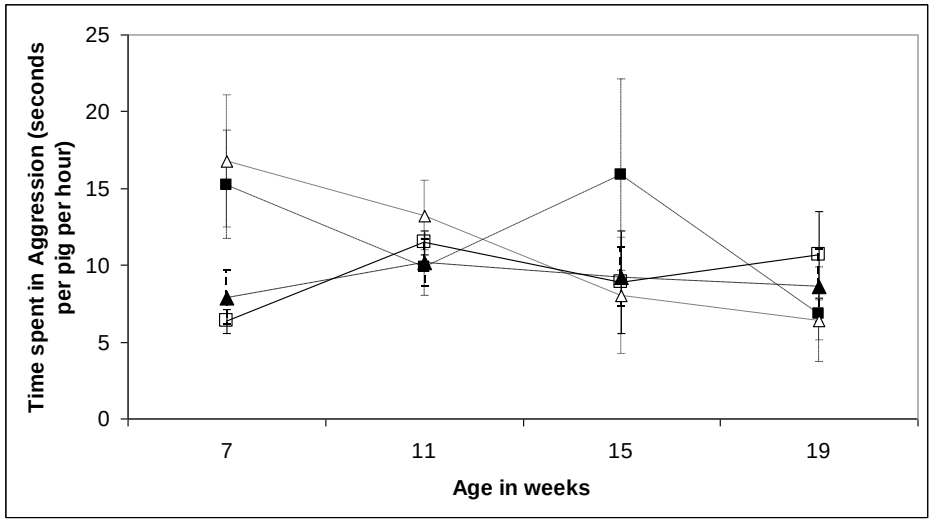
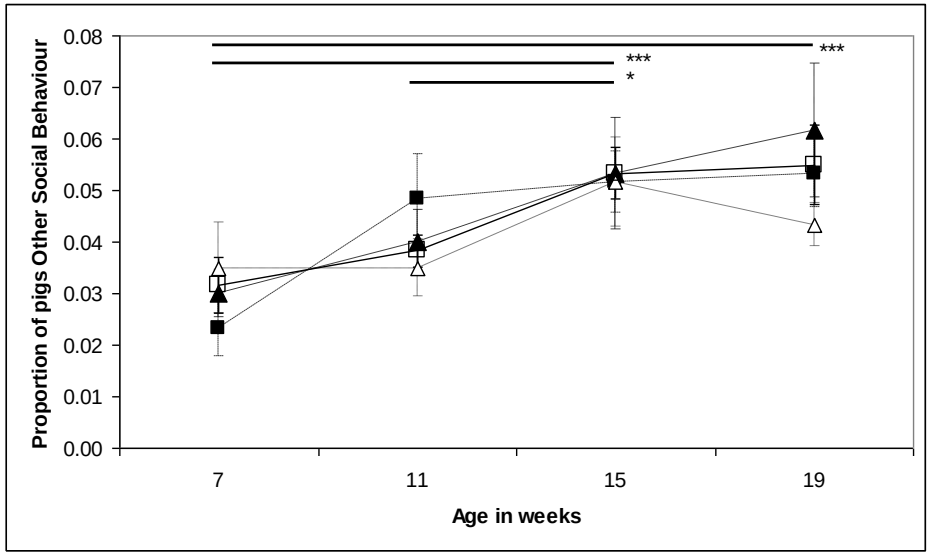
a.





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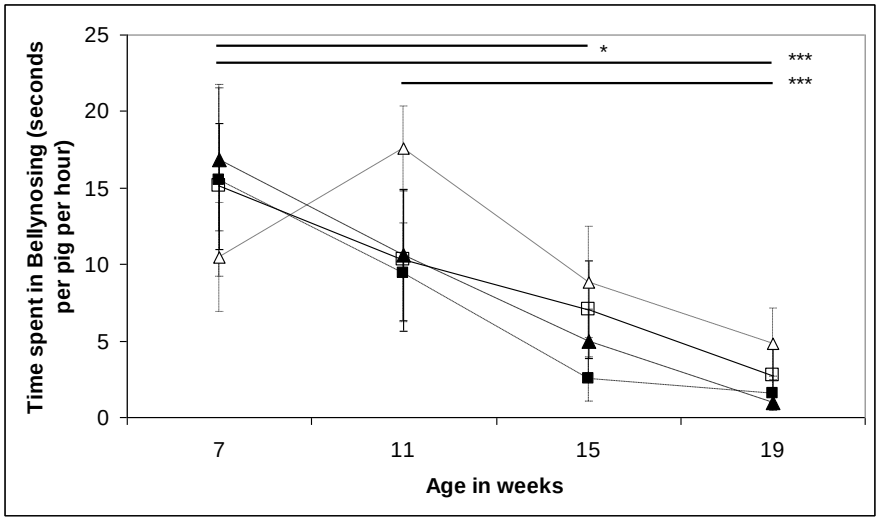

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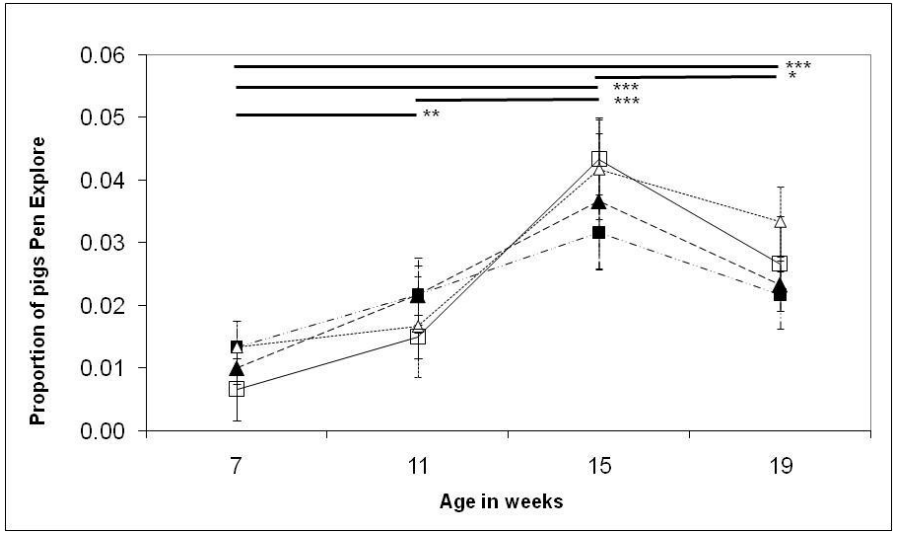
a.



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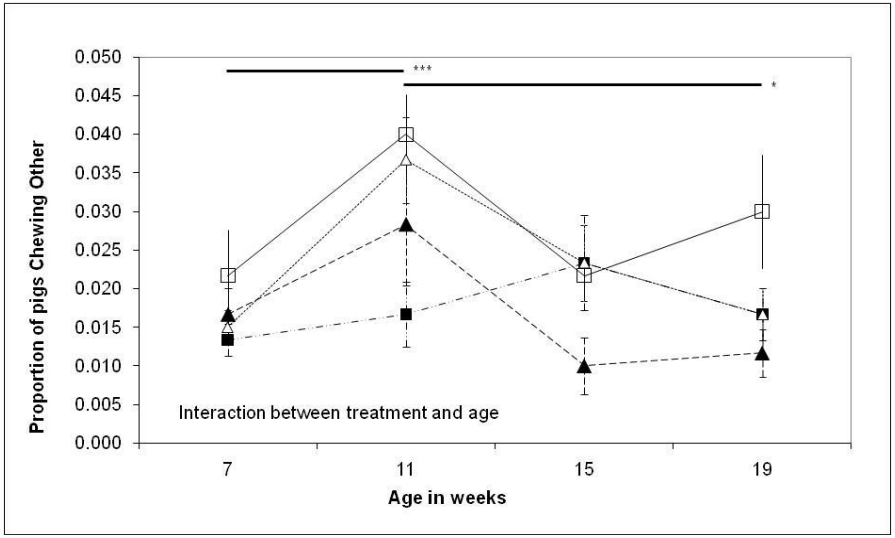

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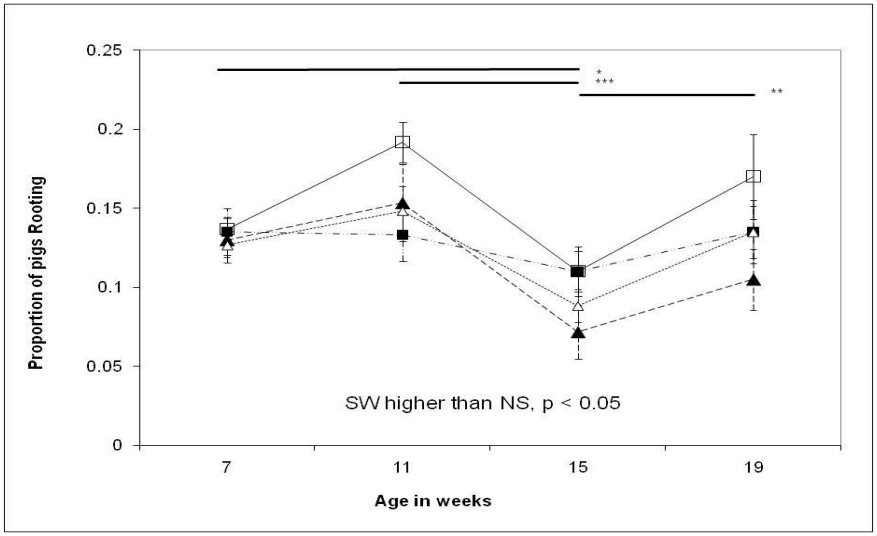

1
2