SHAM CHEWING AND SOW WELFARE AND PRODUCTIVITY

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Co-operative Research Centre for High Integrity Australian Pork

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Executive Summary

In relation to livestock production, the focus of welfare concerns by the community has been on intensive production systems. Indoor production systems are considered by some to provide barren environments for animals and barren environments have been implicated in the development of stereotypic behaviours in captive animals. Stereotypies are repetitive behaviours induced by frustration, repeated attempts to cope, and/or Central Nervous System dysfunction. They may originate from redirected behaviours (and other abnormal behaviours) if the conflict or thwarting persists. Once developed, stereotypies can become ritualized to the extent that they become part of the behavioural repertoire and persist even in the absence of the original eliciting, stimuli/conditions. In pigs, stereotypies are essentially oral activities and include vacuum chewing, head waving, chewing and licking of bars, and chewing or nosing of various available objects. Stereotypies have been reported in a range of housing systems including tethered, stall-housed and group-housed sows.

While it is believed that stereotypies develop due to suboptimal environments and indicates a welfare concern, the actual welfare implications remain poorly understood. Despite the move from stall to group-housing during gestation, stereotypies such as sham chewing are still anecdotally observed in group-housed sows. To date, the welfare implications of stereotypic behaviour in pigs, particularly sham chewing, have received little examination. The present study examined the relationships between sham chewing and the welfare and productivity of group-housed nulliparous gestating sows.

Archive video footage of 170 Large White × Landrace group-housed nulliparous sows (housed in groups of ten sows) in their first gestation was utilised. Over four time replicates, gilts were twice artificially inseminated and within seven days of insemination randomly mixed into groups of ten (floor space of 1.8 m²/gilt). Sows were marked with individually identifiable symbols prior to mixing. During gestation sows were floor fed a standard commercial gestation pelleted diet (13.1 MJ/kg DM and 12.8% protein; 31.3 kg per feeder per drop) with a daily allowance of 2.5 kg/sow/day over four feed drops per day (approximately 0730, 0900, 1100, 1500 h). Water was supplied ad libitum.
From video recordings, observations of sham chewing of individual sows were conducted using instantaneous point sampling at 30-s intervals (+/- 5 s to identify the behavioural state) from 0700 to 1600 h, at days 8 and 52 of gestation. Sham chewing was defined as repetitive jaw movement without contact with any substrate or feed, and as such the 15-min period post-feed drop was not sampled. Using this sampling method, there were 960 possible sampling points per sow, per day. At each possible observation point a sow was recorded as ‘visible’ if the sow’s snout and jaw was clearly visible or ‘not visible’ if the sow’s snout and jaw was not able to be viewed clearly. If visible, a sow was also recorded as either performing sham chewing or not performing the behaviour. Using the sham chewing data, sows were classified as showing sham chewing at < 5% of visible observations (Category 1), 5 - 10% of visible observations (Category 2), and > 10% of visible observations (Category 3), on days 8 and 52 of gestation, and overall. Sow welfare and productivity outcomes were taken from archival data; aggressive behaviour, the number of fresh skin injuries and plasma cortisol concentrations for individual sows at days 2, 9, and 51 of gestation, live weight gain from days 2 to 100 of gestation, litter size (born alive, total born, and stillborn piglets) and farrowing rate.

Sham chewing was recorded in 97% of the 170-nulliparous group-housed sows observed on day 8 of gestation, and 91% of the 150-nulliparous group-housed sows observed on day 52 of gestation. Based on the limited literature this was substantially higher than expected. Sows on average were observed in the present study performing sham chewing at 10% and 9% of the visible observation points on days 8 and 52 of gestation.

There were few significant relationships found between sham chewing and welfare and productivity variables in the present study. Sows that performed sham chewing behaviour in less than or equal to 5% of visible observations on days 8 and 52 had less still-born piglets and lower cortisol concentrations on day 8, respectively. Several studies report a relationship between the performance of stereotypic behaviour and lower levels of HPA activation. However, there has been, and still is, ongoing discussion and research on the welfare significance of stereotypies. There is a report in the literature that sows performing sham chewing give birth to fewer piglets born alive.
While the present findings provide limited evidence of relationships between sham chewing and sow welfare and productivity, a better understanding of the aetiology of the behaviour would assist in appreciating the implications of sham chewing. For example, understanding the factor(s) leading to sham chewing would provide an opportunity to manipulate this causal factor(s) in controlled experiments to examine the effects on sow welfare and productivity. Since the present study shows a high level of sham chewing in group-housed sows, research of this nature may be both pertinent from a sow welfare and productivity perspective and prudent in terms of addressing community and NGO criticisms of indoor sow group-housing.
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1. Introduction

Indoor production systems are considered by some to provide barren environments for animals (Barnett et al., 2001) and barren environments have been implicated in the development of stereotypic behaviours in captive animals. Stereotypies are repetitive behaviours induced by frustration, repeated attempts to cope, and/or Central Nervous System dysfunction (Mason, 2008). Stereotypies may originate from redirected behaviours (and other abnormal behaviours including displacement behaviours, vacuum behaviours, etc.) if the conflict or thwarting persists. Once developed, stereotypies can become ritualized to the extent that they become part of the behavioural repertoire and persist even in the absence of the original eliciting, stimuli/conditions (Mason, 1991).

Stereotypies have been thought to indicate that an animal’s environment is suboptimal (Hediger, 1950; Luescher and Hurnik, 1987; Odberg, 1987), and that the animal is suffering from a welfare problem (Broom, 1983; Wiepkema, 1983; Fraser and Broom, 1990). Mason (1991) reports that stereotypies often develop in situations of low stimulus input, physical restraint/restriction, and inescapable fear or frustration; and that these are situations that behavioural and physiological data have indicated are aversive and stressful. The origins and mechanisms of stereotypic behaviour are poorly understood and a range of theories have been discussed in the literature (Terlouw et al., 1991). It has been suggested that stereotypies of pigs are a response to restraint and subsequent loss of control over the environment (Cronin 1985), or the frustration of motivated behaviour, including feeding (Rushen 1984; Appleby and Lawrence 1987; Terlouw et al., 1991) or nesting behaviour (Jensen, 1988). These hypotheses however, do not provide a complete explanation for the observed properties of stereotypic behaviour in different species (Terlouw et al., 1991).

The increased incidence of stereotypic behaviour in confinement has been used to suggest that such housing systems may be detrimental to the welfare of animals, with the hypothesis that animal welfare could be assessed by their presence and/or frequency (Olberg, 1978; Dawkins, 1980; Duncan, 1980; Broom, 1983; Fraser and
Broom, 1990; Wiepkema, 1993; Vieuille-Thomas et al., 1995). As such, attempts have been made to define the levels of stereotypy that may be indicative of a serious welfare concern, based on the assumption that the more inadequate the environment the more frequent of long lasting the performance of the stereotypy will be (Fox, 1984; Dawkins, 1990; Mason, 1991). Broom (1983) suggested that stereotypies should be considered a welfare concern if they take up more that 10% of an animal’s time, while Wiepkema (1983) proposed that welfare is unacceptable if stereotypies occur in more than 5% of the population. The level of abnormal behaviour at which welfare is deemed to be poor is yet to be determined (Mason, 1991). In most animal species including pigs, the welfare implications of stereotypic behaviour have received little examination and remain largely unknown.

Sows housed in modern intensive pig production systems exhibit a large range of stereotypic behaviour (Stolba et al., 1983; Rushen, 1984; Appleby and Lawrence, 1987) that are reported to occur primarily just before and after feeding (Vieuille-Thomas et al., 1995). They are essentially oral activities that can be easily identified and described (Vieuille-Thomas et al., 1995); they include vacuum chewing ('sham-chewing'), head waving, chewing of bars, licking, chewing or nosing of various available objects (Fraser, 1975; Stolba et al., 1983; Terlouw et al., 1991a). Stereotypies are reported in a range of housing systems including tethered, stall-housed and group-housed sows (Vestergaard and Hansen, 1984; Barnett et al., 1984; Schouten and Rushen, 1992). They are reportedly less frequent in gilts and increase in frequency with parity (Cariolet and Dantzer, 1984; Rushen, 1985).

Sham-chewing is often classified as an abnormal behaviour, and as such conveys a negative image. Despite the move from stall to group-housing during gestation, stereotypies such as sham-chewing are still anecdotally observed in Australian sow herds. Although previous data (Vieuille-Thomas et al., 1995) suggests the proportion of group-housed sows (66%) performing stereotypic behaviour is lower than stall-housed sows (93%), however stereotypies were still displayed by more than half of the herd. Vieuille-Thomas et al. (1995) also report the most frequent forms of stereotypy observed in group-housed sows were repeated vacuum chewing (sham-chewing) and licking of concrete walls.
Currently, the welfare implications of sham-chewing in Australian (and international) pig production systems are poorly understood. Research in several species suggests that in some situations animals may develop stereotypic behaviours as a means to successfully cope with their environment (Mason and Rushen, 2008). Consequently, the impact of sham-chewing on pig welfare and productivity needs to be investigated and better understood.

The present study examined the relationships between sham chewing behaviour and the welfare and productivity of group-housed gestating sows.

2. Methodology

2.1 Materials and methods

2.1.1 Ethical note

The present study used archive video footage from a Pork CRC study (Pork CRC Project number 1C-102) to investigate the relationships between sham chewing and the welfare and productivity of group-housed gestating sows. Consequently, ethical approval was not required for this project. For the Pork CRC Project 1C-102 all animal procedures were conducted with prior institutional ethical approval under the requirement of the New South Wales Prevention of Cruelty to Animals Act (1979) in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organization/Australian Animal Commission Australian Code of Practice for the Care and Use of Animals for Scientific Purposes (NHMRC, 2013).

2.1.2 Facilities

Archive video footage from this earlier Pork CRC research (Pork CRC Project number 1C-102) conducted between October 2010 and February 2012 in a gestation unit of a large commercial piggery in southern NSW was utilised in this study. The 6-m-long and 19-m-wide building was equipped with adjustable blinds. Overhead water sprinklers covered 50% of the slatted floor area of the pens and were activated (3
min on and 15 min off) when the internal temperature exceeded 26°C. The maximum and minimum mean daily ambient temperatures for spring, summer, autumn, and winter of 2011 were 21.3 and 8.5°C, 29.2 and 15.2°C, 21.3 and 7.9°C, and 15.6 and 3.9°C, respectively. Within the unit, 12 pens (3.7 by 4.8 m) were used. Each pen had partially slatted floors (50%) with a solid cement lying/feeding area and a slatted dunging area and was fitted with two overhead feed droppers and one nipple drinker. One video camera with built-in infrared lights was positioned above each pen and recorded from 0700 to 1700 h on days 8 and 52 after mixing. The camera covered most of the pen floor area (14 m²); however, some area in the corners of the pens could not be observed.

2.1.3 Animals and Experimental Design

A total of 200 pregnant Large White × Landrace sows (Sus scrofa) were used in this study so that 200 gilts (50 gilts per replicate) in 4 replicates were studied in their first gestation. Gilts detected in oestrus from 32 weeks of age were transferred from groups of 30 gilts to stalls for insemination. Gilts were twice artificially inseminated (morning/afternoon insemination routine) and, within 7 d of insemination, were randomly mixed into groups of 10 (space allowance of 1.8 m²/gilt) between 0800 and 1300 h. Before mixing, symbols were sprayed on the backs of gilts allowing for individual identification. One week before farrowing, gilts were moved to farrowing stalls where they remained until piglets were weaned at 25 d of age. For convenience, in the remainder of this paper, gestating gilts will be referred to as sows. During gestation, sows were fed a standard commercial gestation pelleted diet (13.1 MJ/kg DM and 12.8% protein; 31.3 kg per feeder per drop and 2.5 kg per sow per d). Feed was delivered onto the floor in four feed drops (at approximately 0730, 0930, 1100, and 1500 h). Water was supplied ad libitum.

2.1.4 Measures recorded

2.1.4.1 Preliminary study: examination of sham chewing in group-housed nulliparous sows

It was initially proposed that the sham chewing would be assessed using instantaneous point sampling at 5 min intervals from 0700 and 1700 h on two days (days 8 and 52 of gestation). However, given that the characteristics of sham
chewing are currently poorly understood, the first step was to characterise sham chewing in a small sample of group-housed gestating sows in order to develop a valid and effective measure of sham chewing.

This preliminary study aimed to characterise sham chewing in group-housed gestating sows with regard to average bout duration, bout frequency and the persistence of sham chewing, and to develop a valid method of sampling this stereotypy. Archive video footage of 20 group-housed nulliparous sows (two groups of ten sows) in their first gestation was utilised (Pork CRC Project number 1C-102). One video camera with built-in infra-red lights was positioned above each pen during gestation and video recordings were conducted from 0700 to 1600 h on days 3 and 8 post-mixing. An ethogram was developed (Table 1); a sow was deemed visible if the observer could clearly view the snout and jaw, and sham chewing was defined as repetitive (more than one) jaw movement without contact with any substrate. The performance of sham chewing was assessed using continuous sampling, instantaneous point sampling at 2-min intervals (2-min IPS), and instantaneous point-sampling at 5-min intervals (5-min IPS). Wilcoxon signed-rank tests (Z) were used to compare continuous sampling with the two instantaneous point sampling methods. Wilcoxon signed-rank tests were used to compare sham-chewing characteristics on day 3 and day 8.

2.1.4.2 Behaviour sampling methodology: developing an appropriate method to sample sham chewing in group-housed nulliparous sows

The findings from the preliminary study found average sham chewing bout duration of 54-78 s, and that both 2-min and 5-min instantaneous point sampling methods failed to identify sham chewing in some sows (approximately 20% of sows identified as performing sham chewing using continuous sampling were not identified by 2-min and 5-min instantaneous point sampling). As a result, 30-s instantaneous point sampling method was deemed the most appropriate method of sampling sham chewing behaviour in group-housed gestating nulliparous sows.

Therefore, the performance of sham chewing was measured in 30 animals using continuous sampling and instantaneous point sampling at 30-s intervals from 0700
to 1700 h on day 52, in order to validate 30-s instantaneous point sampling as an effective sampling method.

The 30-s instantaneous point sampling method and the study’s ethogram (i.e. sham chewing sampling method) needs to be consistent or reliable when being applied repeatedly by the same assessor (intra-observer) or independently by different assessors (inter-observer). As such, the inter- and intra-observer reliability of the sampling method were investigated using a test-retest assessment (Whitham and Wielebnowski, 2009), which examines the similarity between measures collected on an animal at two different time points (intra-observer) or the agreement between measures taken on an animal by multiple assessors (inter-observer). Kappa statistics (κ) were used to examine the inter- and intra-observer reliability of the sham chewing sampling method.

2.1.4.3 Main study: sham chewing and sow welfare and productivity

The relationships between sham chewing and the welfare and reproductive outcomes in 170 group-housed Large White × Landrace nulliparous gestating sows was examined.

*Sham chewing behaviour*

The sham chewing of individual sows was recorded using instantaneous point sampling (Martin and Bateson, 2009) at 30-s intervals (+/- 5 s to identify the behavioural state) from 0700 to 1600hr, at days 8 and 52 post-mixing. Sham chewing (outlined in the ethogram in Table 1) was defined as repetitive jaw movement without contact with any substrate or feed, and as such, the 15-min period post-feed drop was not sampled. The results from Pork CRC project number 1C-102 suggest that when fed their daily allocation over four drops per day, sows consume the majority of feed within 5-10 minutes of delivery. While sows may continue to display appetitive feeding/foraging behaviours (e.g. rooting the ground) from approximately 10 minutes post-feed delivery, all feed appears to have been consumed 15 minutes following the feed drop. Thus, sampling of sham chewing ceased at the delivery of feed and did not recommence until 15 minutes post-feed
drop when all feed had been consumed. Using this sampling method, there were 960 possible sampling points per sow, per day.

Video recordings were observed using the developed ethogram (Table 1). At each possible sampling point a sow was recorded as ‘visible’ if the sow’s snout/jaw was clearly visible or ‘not visible’ if the sow’s snout/jaw was not clearly visible. If visible, a sow was also recorded as either performing sham chewing or not performing the behaviour. A sow was recorded as performing sham chewing (a behavioural state, i.e. of appreciable duration) if there was visible jaw movement with no contact with substrate or feed.

Table 1. Ethogram for sham chewing behaviour.

<table>
<thead>
<tr>
<th>Sham chewing behaviour: visible jaw movement with no contact with substrate or feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>• substrate defined as floor or pen fittings</td>
</tr>
<tr>
<td>• contact defined as snout contact with substrate</td>
</tr>
<tr>
<td>• sow considered <strong>visible</strong> if majority of snout (Figure 1) is in view with jaw clearly visible</td>
</tr>
<tr>
<td>• if the sow’s snout/jaw is not in view the animal is considered <strong>non-visible</strong></td>
</tr>
</tbody>
</table>

Inclusions:

• standing with no substrate contact and visible jaw movement
• lying down with no substrate contact and visible jaw movement
• lying down with substrate contact and visible jaw movement
  - whilst the sow is lying down it is in a rest position, its snout may come into contact with substrate but it is not in motion therefore the animal is unlikely to be foraging

Exclusions:

• standing with substrate contact and visible jaw movement
  - can indicate foraging or feeding behaviours as animal is often in motion
Measures of aggressive behaviour, cortisol, skin injuries, weight gain and reproductive performance were provided from the findings of Pork CRC project number 1C-102. Details of these measurements are as follows:

**Aggressive behaviour at feeding**

Aggressive behaviour of individuals was observed using continuous sampling for 30 min after each of 4 daily feed drops on the day after mixing (Day 2) and Days 9 and 51. Aggressive behaviour was defined as bites, presses, and knocks (Samarakone and Gonyou, 2009) and included fights, which were defined as aggressive interactions involving the same pair of animals and that continued for at least a 5-s duration. The numbers of aggressive acts delivered and received by each individual sow during the observation period were recorded. During fights, a bout criterion interval of 5 s was chosen to separate one bout of aggressive behaviour from another bout (Hemsworth et al., 2013). Only when the full head of the attacking animal and the identifying symbol of the animals delivering and receiving aggression were clearly in the field of view were aggressive interactions recorded. From the observations of aggressive behaviour at feeding at Day 2, sows were classified as “dominant” if they delivered more aggression than they received at Day 2, “subdominant” if they received more aggression than they delivered at Day 2, and “submissive” if they delivered very little or no aggression relative to aggression received at Day 2 (that is, the ratio of aggression delivered to aggression delivered + aggression received ≤ 0.05). Aggressive behaviour at Day 2 was used because aggression between group-housed sows that are restrictively fed is most pronounced early after grouping (Barnett et al., 2001). This aggression classification is similar to that developed by
Mendl et al. (1992) and used later by Zanella et al. (1998), but these studies used displacements rather than aggression.

**Cortisol concentrations**

Blood samples were taken by a single team at Days 2, 9, and 51 by venipuncture of the jugular vein while animals were restrained with a snout snare. Sampling commenced at approximately 1200 h and it took an average of 37 min to sample all sows in the replicate (average 7.5 min per pen). A 6-mL sample was taken in a heparinized tube (BD Vacutainer; Becton, Dickinson and Company, Belliver Industrial Estate, Plymouth, UK). For each animal, a maximum of 2 min from snaring could obtain the blood sample. This was so that an acute stress response associated with handling and blood sampling could be avoided, which would influence concentrations of plasma cortisol (Broom and Johnson, 1993). Karlen et al. (2007) found no effects of repeatedly sampling different animals within groups on salivary cortisol concentrations. The individual samples were centrifuged for 10 min at 1,912-× g at 4°C, and the plasma was poured off into individual microtubes and stored at -20°C until analysed. During this study, the laboratory that analysed the plasma samples for gestation 1 and for the majority of gestation 2 ceased to operate (Monash University, Melbourne, Australia). Consequently, 92 of 177 samples collected at Day 51 of gestation 2 (replicates 3 and 4) were analysed elsewhere (The University of Western Australia, Perth, Australia). The first laboratory measured plasma cortisol with an extracted RIA (Bocking et al., 1986), using hydrocortisone (H-4001; Sigma Chemical Co., St. Louis, MO) as the standard. The assay used [3H]-cortisol (Amersham Pharmacia Biotech, UK, Buckinghamshire, England) as tracer and a dicholoromethane extraction procedure. The second laboratory measured plasma cortisol using a commercial RIA kit (Cortisol GammaCoat RIA kit CA-1549; DiaSorin Inc., Stillwater, MN). The intra- and inter-assay CV of the first and second laboratories were 7.81 and 12.06% and 5.13 and 4.85%, respectively.

**Skin injuries**

The same assessment as described by Karlen et al. (2007) was used to assess skin injuries for individual sows in the morning of each of Days 2, 9, and 51 after mixing. Only skin injuries categorized as being fresh (scratches, abrasions, and cuts) were
recorded. Each side of the sow’s body was divided into 21 areas for injury data collection (see Karlen et al., 2007). The number and the type of skin injuries were recorded, and, from these records, the number of fresh injuries was collated for each sow on each observation day.

**Live weight gain**

Sows were individually weighed at Days 2 and 100. From this, live weight gain for the gestation was calculated.

**Reproductive performance**

The reproductive performance data collected allowed for the farrowing rate percent of inseminated sows that farrowed (excluding those removed for injury, illness, or death) to be calculated. Litter size data (number of piglets that were born alive, total number born and stillborn) as well as non-reproductive removals were also collected. Stillborn piglets were judged on the basis that they were fully formed at farrowing, covered in foetal membrane, had fully formed eponychia on their hooves, and were located behind the sow.

2.2 Statistical analysis

The number of sows and pens observed at each day are reported in Table 2. A technical malfunction meant there were no day 52 behavioural data for replicate 3. Operational errors meant that the fourth feed drop was not delivered at day 8 of replicate 1, and video recordings were not taken of three pens at day 8 of replicate 3.

<table>
<thead>
<tr>
<th></th>
<th>Number of pens recorded</th>
<th>Number of sows recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FD 1</td>
<td>FD 2</td>
</tr>
<tr>
<td>Day 8</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Day 52</td>
<td>5</td>
<td>5</td>
</tr>
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</table>

Table 2. Number of pens recorded per day, and total sows recorded per day.
Data on the sham chewing of sows on days 8 and 52 of gestation represented a count of occurrences (i.e. the number of visible observations points in which sows were performing sham chewing) over a 9 h period each day (i.e. 960 possible sampling points per sow, per day). These count data were then converted into a proportion of occurrences (i.e. the proportion of visible observation points where sows were performing sham chewing) by dividing the number of observation points where sows were performing sham chewing by the number of visible observation points (observation points in which the sow’s snout/jaw was clearly visible), per day (observation points where sow was sham chewing/visible observation points). Based on the distribution, sham chewing was classified as showing sham chewing at < 5% of visible observations (Category 1), 5 - 10% of visible observations (Category 2), and > 10% of visible observations (Category 3).

The statistical package used for all analysis was SPSS 24.0 (SPSS Inc., Chicago, IL) and the unit of analysis was always the individual sow. Wilcoxon signed-rank tests (Z) were used to compare continuous sampling with 30-s instantaneous point sampling. Kappa statistic was used to examine the intra- and inter-observer reliability of the sham chewing sampling method. Several variables did not conform to a normal distribution when examined by visual methods (quantile-quantile plots and histograms); aggression, injury and death data were square root transformed, while cortisol and stillborn data were log10(x + 1) transformed before analysis. The relationship between sham chewing and sow behaviour, welfare and reproductive variables were examined using Pearson Product Moment correlations. Chi-Squared Rank tests examined relationship between aggression class and sham chewing classification (on day 8, day 52 and overall). Paired sample t-tests were used to examine the differences in sham chewing of individual sows at days 8 and 52 of gestation. Data on aggressive behaviour (delivered and received), skin injuries, cortisol, reproductive success and sham chewing were analysed separately using a general linear mixed model that included replicate, group/pen (nested within replicate), sham chewing classification, and their interaction as fixed effects. Where there were significant main or interactive effects (P<0.05) the LSD test determined where estimated marginal means differed.
2.3 Results

2.3.1 Preliminary study: examination of sham chewing in group-housed nulliparous sows

The average duration of sham chewing bouts was 54 s on day 3 (SD = 47) and 78 s on day 8 (SD = 173), and the difference in average bout duration between the two days was not significant (Z = -1.11, P = 0.27). The average frequency of sham chewing bouts was 8 bouts/sow/d on day 3 and 5 bouts/sow/d on day 8, and the difference in average frequency of bouts between the two days was significant (Z = -2.16, P = 0.03). 85% of sows were identified as performing sham chewing on day 3 and 70% of sows on day 8, however the difference between the days was not significant (Z = -1.34, P = 0.18). Sham chewing was observed across the day, both pre- and post-feed drops. The proportion of sows identified as performing sham chewing behaviour with continuous sampling was significantly different to 5-min IPS on both day 3 (Z = -2.45, P = 0.01) and day 8 (Z = -2.65, P = 0.01), and 2-min IPS on day 3 (Z = -2.00, P = 0.05) but not day 8 (Z = -1.73, P = 0.08). When comparing the two instantaneous sampling methods, the proportion of sows identified as performing sham chewing behaviour was significantly different on day 8 (Z = -2.00, P = 0.04) but not day 3 (Z = -0.82, P = 0.41). Using 5-min IPS, 65% of sows were identified as performing sham chewing behaviour on day 3 and 35% of sows on day 8. While for 2-min IPS, 55% of sows were identified as performing sham chewing behaviour on day 3 and 55% of sows on day 8. Thus, while 2-min IPS was more accurate in identifying sows sham chewing than 5-min IPS, both instantaneous point sampling methods failed to identify some sows that continuous sampling identified. These findings suggest that a point sampling frequency of 30 s is likely to be an effective method of sampling sham chewing.

2.3.2 Behaviour sampling methodology: developing an appropriate method of sampling sham chewing in group-housed nulliparous sows

All 30 sows were identified as performing sham chewing on day 52 of gestation, and sham chewing was observed across the day, both pre- and post-feed drops. All sows identified as performing sham chewing using continuous sampling were also identified performing sham chewing when using 30-s instantaneous point sampling.
The 30-s instantaneous point sampling method and the study’s ethogram (i.e. sham chewing sampling method) need to be consistent or reliable when being applied repeatedly by the same assessor (intra-observer) or independently by different assessors (inter-observer). As such, the inter- and intra-observer reliability of the sampling method were investigated using a test-retest assessment (Whitham and Wielebnowski, 2009), which examines the similarity between measures collected on an animal at two different time points (intra-observer) or the agreement between measures taken on an animal by multiple assessors (inter-observer). Kappa statistics (κ) demonstrated substantial agreement between the observer’s assessments (κ = 0.80, p = 0.001) and between the multiple observers’ measures (κ = 0.79, p = 0.001). These findings suggest 30-s instantaneous point sampling is an effective sampling method for sham chewing in group-housed sows.

2.3.3 Main study: sham chewing and sow welfare and productivity

Prevalence and Incidence of Sham Chewing

The mean proportion of visible observation points (observation points in which the sow’s mouth was clearly visible) on days 8 and 52 of gestation were 0.29 and 0.22, respectively. Of the 170 sows observed on day 8 and 150 sows on day 52, 97% and 91% of the sows, respectively, were observed performing sham chewing behaviour. The mean proportion of visible observation points where sows were performing sham chewing behaviour on days 8 and 52 were 0.10 (SD) and 0.09 (SD), respectively. There was no difference in the proportion of visible observation points in which sham chewing was shown by sows at days 8 and 52 (t_{149} = 1.02, P = 0.31). Histograms of the distribution of the frequency of sham chewing shown by sows on days 8 and 52 and in total are reported in Figure 2.
Figure 2. Histograms of the distribution of the frequency of sham chewing shown by sows on day 8 (a), day 52 (b) and overall (c).

Based on this distribution of sham chewing, sows were classified as showing sham chewing at < 5% of visible observations (Category 1), 5 - 10% of visible observations (Category 2), and > 10% of visible observations (Category 3) and the distributions on day 2, day 8 and overall are reported in Figure 3.
Figure 3. Histograms of number of sows observed performing sham chewing at < 5% of visible observations (Category 1), 5 - 10% of visible observations (Category 2), and > 10% of visible observations (Category 3) on day 8 (a), day 52 (b) and overall (c).

Relationship between sham chewing behaviour and welfare and productive variables

Pearson Product Moment correlations between sham chewing behaviour and welfare and productive variables are presented in Table 3. There were few significant correlations. The proportion of observation points in which sham chewing on day 8 was observed was positively correlated ($P<0.05$) with piglet deaths and aggression delivered on day 8 (as well as overall). Similar findings were apparent when the relationships between sham chewing classification and the welfare and productivity variables were examined using a Univariate General Linear Model (SPSS 24.0, SPSS
Inc., Chicago, Illinois, USA) was used (Table 4). Sows that overall performed sham chewing behaviour in less than or equal to 5% of visible observations (classification 1) delivered less (P<0.05) aggression on day 8 than those that performed sham chewing behaviour in more than 10% of visible observations (classification 3). Sows that performed sham chewing behaviour in less than or equal to 5% of visible observations (classification 1) on day 52 had lower (P<0.05) cortisol concentrations on day 8 than those that performed sham chewing behaviour in more than 10% of visible observations (classification 3). Finally, sows that performed sham chewing behaviour in less than or equal to 5% of visible observations (classification 1) on day 8 had less (P<0.05) stillborn piglets than those that performed sham chewing behaviour in 5-10% of visible observations (classification 2).

Table 3. Pearson Product Moment correlations of sham chewing behaviour (proportion of visible observations in which sows were performing sham chewing behaviour) and factors relating to sow welfare and productivity, for day 8, day 52 and in total.

<table>
<thead>
<tr>
<th></th>
<th>Sham chewing prop. D8</th>
<th>Sham chewing prop. D52</th>
<th>Sham chewing prop. Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight gain</td>
<td>141 -0.01</td>
<td>127 0.03</td>
<td>127 0.01</td>
</tr>
<tr>
<td>Piglets born alive</td>
<td>138 -0.02</td>
<td>122 0.04</td>
<td>150 -0.06</td>
</tr>
<tr>
<td>Piglets still born</td>
<td>138 0.03</td>
<td>122 -0.06</td>
<td>122 -0.02</td>
</tr>
<tr>
<td>Piglets weaned</td>
<td>135 -0.07</td>
<td>119 -0.02</td>
<td>119 -0.06</td>
</tr>
<tr>
<td>Piglet deaths</td>
<td>135 <strong>0.18</strong></td>
<td>119 0.08</td>
<td>119 0.17</td>
</tr>
<tr>
<td><strong>Behaviour and Welfare</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggression classification</td>
<td>170 -0.06</td>
<td>150 -0.11</td>
<td>150 -0.12</td>
</tr>
<tr>
<td>Aggression delivered (D2)</td>
<td>170 0.01</td>
<td>150 -0.00</td>
<td>150 0.03</td>
</tr>
<tr>
<td>Aggression delivered (D8)</td>
<td>167 0.09</td>
<td>148 <strong>0.21</strong></td>
<td>148 <strong>0.20</strong></td>
</tr>
<tr>
<td>Aggression delivered (D51)</td>
<td>127 -0.01</td>
<td>127 0.06</td>
<td>127 0.03</td>
</tr>
<tr>
<td>Aggression received (D2)</td>
<td>170 0.01</td>
<td>150 -0.01</td>
<td>150 0.03</td>
</tr>
<tr>
<td>Aggression received (D8)</td>
<td>165 -0.00</td>
<td>146 -0.01</td>
<td>146 -0.03</td>
</tr>
<tr>
<td>Aggression received (D51)</td>
<td>134 -0.14</td>
<td>134 -0.12</td>
<td>134 -0.16</td>
</tr>
<tr>
<td>Skin injury (D8)</td>
<td>167 0.03</td>
<td>148 -0.03</td>
<td>148 -0.00</td>
</tr>
<tr>
<td>Skin injury (D51)</td>
<td>152 -0.02</td>
<td>135 -0.01</td>
<td>135 -0.10</td>
</tr>
<tr>
<td>Stress (cortisol D8)</td>
<td>166 0.05</td>
<td>147 0.08</td>
<td>147 0.09</td>
</tr>
<tr>
<td>Stress (cortisol D51)</td>
<td>144 0.09</td>
<td>127 -0.05</td>
<td>127 0.03</td>
</tr>
</tbody>
</table>

Significance levels: **, P<0.01; *, P<0.05.
Table 4. Probability and main effects of sow sham chewing classification on behaviour, welfare and productivity variables for sows on days 8 and 52, and in total.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sham chewing classification</th>
<th>&lt; 5% SC</th>
<th>5 - 10 % SC</th>
<th>&gt; 10% SC</th>
<th>F-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggression class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>1.93 ± 0.12</td>
<td>1.73 ± 0.12</td>
<td>1.86 ± 0.11</td>
<td>0.71</td>
<td>0.49</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>1.88 ± 0.12</td>
<td>1.91 ± 0.12</td>
<td>1.74 ± 0.12</td>
<td>0.64</td>
<td>0.53</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.97 ± 0.14</td>
<td>1.79 ± 0.12</td>
<td>1.73 ± 0.11</td>
<td>1.21</td>
<td>0.30</td>
</tr>
<tr>
<td>Aggression delivered D2, frequency per sow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>3.56 ± 0.41</td>
<td>3.82 ± 0.40</td>
<td>3.50 ± 0.37</td>
<td>0.14</td>
<td>0.87</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>3.64 ± 0.40</td>
<td>3.45 ± 0.41</td>
<td>3.50 ± 0.41</td>
<td>0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3.19 ± 0.47</td>
<td>3.61 ± 0.40</td>
<td>3.74 ± 0.40</td>
<td>0.26</td>
<td>0.77</td>
</tr>
<tr>
<td>Aggression delivered D8, frequency per sow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>3.29 ± 0.41</td>
<td>3.76 ± 0.39</td>
<td>3.41 ± 0.36</td>
<td>0.61</td>
<td>0.55</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>3.07 ± 0.38</td>
<td>3.58 ± 0.39</td>
<td>4.02 ± 0.39</td>
<td>2.22</td>
<td>0.11</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3.16 ± 0.42</td>
<td>3.47 ± 0.36</td>
<td>4.10 ± 0.35</td>
<td>3.10</td>
<td>0.05*</td>
</tr>
<tr>
<td>Aggression delivered DS2, frequency per sow per day</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>2.61 ± 0.32</td>
<td>2.60 ± 0.28</td>
<td>2.92 ± 0.26</td>
<td>0.80</td>
<td>0.45</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>2.49 ± 0.33</td>
<td>2.74 ± 0.28</td>
<td>2.93 ± 0.28</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2.67 ± 0.34</td>
<td>2.85 ± 0.26</td>
<td>2.80 ± 0.24</td>
<td>0.40</td>
<td>0.67</td>
</tr>
<tr>
<td>Skin injuries D8, frequency per sow</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>3.85 ± 0.21</td>
<td>3.86 ± 0.20</td>
<td>4.21 ± 0.18</td>
<td>0.74</td>
<td>0.48</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>3.89 ± 0.20</td>
<td>3.96 ± 0.21</td>
<td>3.93 ± 0.21</td>
<td>0.12</td>
<td>0.88</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3.70 ± 0.22</td>
<td>4.15 ± 0.19</td>
<td>3.95 ± 0.19</td>
<td>0.55</td>
<td>0.58</td>
</tr>
<tr>
<td>Skin injuries DS2, frequency per sow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>3.95 ± 0.23</td>
<td>3.98 ± 0.22</td>
<td>4.22 ± 0.20</td>
<td>0.62</td>
<td>0.54</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>3.88 ± 0.21</td>
<td>3.82 ± 0.21</td>
<td>4.10 ± 0.21</td>
<td>0.61</td>
<td>0.55</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3.95 ± 0.23</td>
<td>3.90 ± 0.19</td>
<td>3.93 ± 0.19</td>
<td>0.05</td>
<td>0.95</td>
</tr>
<tr>
<td>Plasma cortisol day 8, ng/ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>1.18 ± 0.04</td>
<td>1.22 ± 0.04</td>
<td>1.22 ± 0.03</td>
<td>0.65</td>
<td>0.52</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>1.10 ± 0.04</td>
<td>1.27 ± 0.04</td>
<td>1.22 ± 0.04</td>
<td>4.15</td>
<td>0.02*</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.24 ± 0.05</td>
<td>1.15 ± 0.04</td>
<td>0.04 ± 0.04</td>
<td>1.91</td>
<td>0.15</td>
</tr>
<tr>
<td>Plasma cortisol day 52, ng/ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>1.23 ± 0.04</td>
<td>1.31 ± 0.04</td>
<td>1.33 ± 0.04</td>
<td>1.56</td>
<td>0.21</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>1.20 ± 0.05</td>
<td>1.32 ± 0.04</td>
<td>1.31 ± 0.04</td>
<td>1.96</td>
<td>0.15</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.24 ± 0.05</td>
<td>1.28 ± 0.04</td>
<td>1.35 ± 0.04</td>
<td>1.06</td>
<td>0.35</td>
</tr>
<tr>
<td>Weight gain, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>70.33 ± 2.80</td>
<td>70.90 ± 2.75</td>
<td>75.23 ± 2.42</td>
<td>0.79</td>
<td>0.46</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>68.14 ± 3.45</td>
<td>72.93 ± 2.91</td>
<td>72.70 ± 3.03</td>
<td>0.84</td>
<td>0.43</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>67.92 ± 3.57</td>
<td>70.86 ± 2.91</td>
<td>74.15 ± 2.65</td>
<td>0.55</td>
<td>0.58</td>
</tr>
<tr>
<td>Piglets born alive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>10.58 ± 0.48</td>
<td>9.38 ± 0.48</td>
<td>9.73 ± 0.46</td>
<td>1.65</td>
<td>0.20</td>
</tr>
<tr>
<td>Day 52</td>
<td></td>
<td>9.60 ± 0.62</td>
<td>10.30 ± 0.51</td>
<td>9.20 ± 0.50</td>
<td>1.22</td>
<td>0.30</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>10.20 ± 0.64</td>
<td>9.98 ± 0.52</td>
<td>9.34 ± 0.50</td>
<td>0.75</td>
<td>0.48</td>
</tr>
<tr>
<td>Piglets still born</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 8</td>
<td></td>
<td>0.07 ± 0.03</td>
<td>0.17 ± 0.03</td>
<td>0.12 ± 0.03</td>
<td>3.91</td>
<td>0.02*</td>
</tr>
</tbody>
</table>
### 2.4 Discussion

Indoor production systems are considered by some to provide barren environments for animals (Barnett et al., 2001) and barren environments have been implicated in the development of stereotypies in captive animals. Stereotypies are repetitive behaviours induced by frustration, repeated attempts to cope, and/or Central Nervous System dysfunction (Mason, 2008). Stereotypies may originate from redirected behaviours (and other abnormal behaviours including displacement behaviours, vacuum behaviours, etc.) if the conflict or thwarting persists. Once developed, stereotypies can become ritualized to the extent that they become part of the behavioural repertoire and persist even in the absence of the original eliciting stimuli/conditions (Mason, 1991). In pigs, stereotypies are essentially oral activities and include vacuum chewing ('sham chewing'), head waving, chewing of bars, and licking, chewing or nosing of various available objects (Fraser, 1975; Stolba et al., 1983; Terlouw et al., 1991). Stereotypies have been reported in a range of housing systems including tethered, stall-housed and group-housed sows (Barnett et al., 2001; Schouten and Rushen, 1992).

Thus, while it is believed that stereotypic behaviour develops due to suboptimal environments and indicates a welfare concern, the actual welfare implications remain poorly understood. Despite the move from stall to group housing during gestation, stereotypies such as sham-chewing are still anecdotally observed in group-housed sows. To date, the welfare implications of stereotypic behaviour in pigs, particularly sham chewing, have received little examination. The present study examined the relationships between sham chewing and the welfare and productivity of group-housed nulliparous gestating sows.
Sham chewing in the present study was defined as visible jaw movement with no contact with substrate or feed and was recorded in 97% of the 170-nulliparous group-housed sows observed on day 8 of gestation, and 91% of the 150-nulliparous group-housed sows observed on day 52 of gestation. This is substantially higher than that reported by Vieuille-Thomas et al. (1995) who observed 66% of 71 group-housed gestating sows performing sham chewing behaviour. Furthermore, sows on average were observed performing sham chewing at 10% and 9% of the visible observation points on days 8 and 52 of gestation. The results from the main study suggest that sows are spending about 10% of their time sham chewing during our observation period of 9 h in each of the days 8 and 52 of gestation. While Wiepkema (1983) suggests that animal welfare is unacceptable if stereotypies occur in more than 5% of the population and Broom (1983) suggests that stereotypies should be considered a welfare concern if they take up more that 10% of an animal’s time, care is required in interpreting the implications of the present results. For example, sows were on average, visible for 29% of observations points on day 8 and 22% of observation points on day 52 of gestation. Sows were housed in large group pens, with one camera per pen. The method employed using archive video footage to sample sham chewing behaviour required a clear view of the sow’s snout and jaw to detect the distinct jaw movement associated with sham chewing. Sows that were out of the camera’s field of view, in the camera’s field of view but their snout and jaw was not clearly visible, drinking, or standing with substrate contact and visible jaw movement were recorded as ‘not visible’. A clear view of sow jaw movements in this study was limited by obstruction by other sows and the archive video footage in which one camera was used to provide coverage of the entire group. Nevertheless, frequent observations were made on a large number of animals over a substantial period. Furthermore, our preliminary data, which are the only data available, indicate that instantaneous point sampling at 30-s intervals should be a reliable estimate of actual duration of sham chewing. Thus, the sampling method used in the present study provided a sufficient estimation of sow sham chewing.

There were few significant relationships found between sham chewing and welfare and productivity variables in the present study. Sows that performed sham chewing behaviour in less than or equal to 5% of visible observations on days 8 and 52 had less still-born piglets and lower cortisol concentrations on day 8, respectively.
However, caution is required in interpreting these results since with 42 relationships examined in this data set (Table 4); we would expect significant statistical correlation for about one of these correlations by chance alone. Several studies report a relationship between the performance of stereotypic behaviour and lower levels of HPA activation (Weinberg et al., 1980; Dantier and Mormede, 1981; Dantzer et al., 1988; Hennessy and Foy, 1987). However, there has been, and still is, ongoing discussion and research on the welfare significance of stereotypies. Stereotypies in captive animals have been generally viewed as either an adaptive coping response to the captive environment or as the inappropriate output in a conflict or thwarting situation (Mason and Latham, 2004). It should be noted however, that sows that performed sham chewing in less than or equal to 5% of visible observations had less still-born piglets than sows that performed sham chewing in 5-10% of visible observations (but not more than 10% of visible observations). This finding is consistent with those reported by von Borell and Hurnik (1990) who reported that pregnant sows with stereotypies give birth to fewer piglets born alive.

While the present findings provide limited evidence of relationships between sham chewing and sow welfare and productivity, answering this question of the welfare and productivity implications of sham chewing relies on a well-developed understanding of the aetiology of the behaviour. Understanding the factor(s) leading to sham chewing would provide an opportunity to manipulate this causal factor(s) in controlled experiments to examine the effects on sow welfare and productivity. Since the present study shows a high level of sham chewing in group-housed sows, research of this nature may be both pertinent from a sow welfare and productivity perspective and prudent in terms of addressing community and NGO criticisms of indoor sow group-housing.

In the present study, social factors such as aggression classification and aggressive behaviour (aggression delivered and aggression received) did not appear to be related to sham chewing behaviour in group-housed nulliparous sows. We however know little about the relationships in older sows but the literature suggests that sham chewing is an advanced stage stereotypic behaviour (Mason, 1991), which reportedly increases in frequency with age (Cariolet and Dantzer, 1984; Rushen, 1985). Furthermore, sows are restrictively fed and consequently hungry.
(Terlouw et al., 1991). The time spent in stereotypies by gilts is reported to be negatively correlated to their feed allowance with high levels of stereotypy occurring at commercial levels of feed restriction (Appleby and Lawrence, 1987). Stereotypies in animals whose feed intake is restricted largely occur in the post-feeding period, and ingestion of food has specifically been shown to elicit stereotypies in sows (Rushen, 1984). These observations suggest that positive feedback from feeding produces a short-term increase in feeding motivation that at the end of the meal is directed toward alternative expressions of behaviour (Terlouw et al., 1993). The relationship between stereotypic behaviour and feeding-related variables in group-housed sows requires further investigation and this is currently being investigated by the researchers.
3. Outcomes

1. Sham chewing was recorded in 97% of the 170-nulliparous group-housed sows observed on day 8 of gestation, and 91% of the 150-nulliparous group-housed sows observed on day 52 of gestation. This is substantially higher than expected based on the limited literature on sham chewing. Sows on average were observed in the present study performing sham chewing at 10% and 9% of the visible observation points on days 8 and 52 of gestation.

2. There were few significant relationships found between sham chewing and sow behaviour, welfare and productivity variables. Sows that performed sham chewing behaviour in less than or equal to 5% of visible observations on days 8 and 52 had less still-born piglets and lower cortisol concentrations on day 8, respectively.

4. Application of Research

1. Sham chewing was recorded in over 90% of the 170-nulliparous group-housed sows observed in the present study. Based on the limited literature on sham chewing this is substantially higher than expected.

2. Sows on average were observed in the present study performing sham chewing at 10% and 9% of the visible observation points on days 8 and 52 of gestation.

3. While the present findings provide limited evidence of relationships between sham chewing and sow welfare and productivity, a better understanding of the aetiology of the behaviour would assist in appreciating the implications of sham chewing. For example, understanding the factor(s) leading to sham chewing would provide an opportunity to manipulate this causal factor(s) in controlled experiments to examine the effects on sow welfare and productivity.
5. Conclusion

In relation to livestock production, the focus of welfare concerns by the community has been on intensive production systems. Indoor production systems are considered by some to provide barren environments for animals and barren environments have been implicated in the development of stereotypies in captive animals. Since the present study shows a high level of sham chewing in group-housed sows and some limited evidence of relationships between sham chewing and sow welfare and productivity, and with the ongoing discussion and research on the welfare and productivity implications of stereotypies, further research of the welfare and productivity implications is recommended. In particular, further research may be both pertinent from a sow welfare and productivity perspective and prudent in terms of addressing community and NGO criticisms of indoor sow group housing.

6. Limitations/Risks

Limitations of the study:

1. The method employed using archive video footage to sample sham chewing behaviour required a clear view of the sow’s snout and jaw to detect the distinct jaw movement associated with sham chewing. Sows that were out of the camera’s field of view, in the camera’s field of view but their snout and jaw was not clearly visible, drinking, or standing with substrate contact and visible jaw movement were recorded as ‘not visible’. A clear view of sow jaw movements in this study was limited by obstruction by other sows and the archive video footage in which one camera was used to provide coverage of the entire group.

2. Caution is required in interpreting the relationships sham chewing and welfare and productivity variables in the present study. Forty-two relationships were examined and we would expected that significant statistical correlation for about one of these correlations by chance alone.

3. Caution is also required in interpreting these relationships because they were observational and correlational, rather than experimental and comparative, making causality difficult, if not impossible, to determine.
Strengths of the study:

1. Frequent observations were made on a large number of animals over a substantial period. Furthermore, our preliminary data, which are the only data available, indicate that instantaneous point sampling at 30-s intervals should be a reliable estimate of actual duration of sham chewing. Thus, the sampling method used in the present study provided a reliable estimation of sow sham chewing.

2. The limited evidence of relationships between sham chewing and sow welfare and productivity together with the ongoing discussion and research on the welfare and productivity implications of stereotypies, highlight the need for experimental and comparative research to determine the factors affecting sham chewing and their welfare and productivity implications.

7. Recommendations

While the present findings provide limited evidence of relationships between sham chewing and sow welfare and productivity, answering this question of the welfare and productivity implications of sham chewing relies on a well-developed understanding the aetiology of the behaviour. Understanding the factor(s) leading to sham chewing would provide an opportunity to manipulate this causal factor(s) in controlled experiments to examine the effects on sow welfare and productivity. Since the present study shows a high level of sham chewing in group-housed sows, research of this nature may be both pertinent from a sow welfare and productivity perspective and prudent in terms of addressing community and NGO criticisms of indoor sow group-housing.
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