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Behaviour of growing pigs kept in pens with outdoor runs I. Effect of access to roughage and shelter on oral activities

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Abstract

The aim of this study was to examine the effects of roughage, in addition to straw and access to shelter in pens with outdoor runs on oral activity towards penmates and other environmental stimuli. Seven replicates, each consisting of 96 pigs, were raised outdoors until 4 weeks of age. At about 10 weeks of age the pigs were randomly distributed to eight experimental pens with outdoor runs. The experiment was arranged as a 2×2 factorial design in the outdoor runs for each side of the building (north/south), and including with/without free access to roughage (wholecrop silage of barley and peas (*Hordeum vulgare* and *Pisum sativum* ssp. *arvense*)), and with/without shelter (partial coverage). The results showed that even if the pigs had access to ample straw, space and activity areas, access to a combination of roughage and shelter reduced penmate-directed oral activities. However, access to roughage in particular reduced redirected oral activities and skin lesions. We suggest that this type of roughage is an appropriate rooting substrate for pigs. © 2001 Published by Elsevier Science B.V.

Keywords: Pig-behaviour; Oral behaviour; Organic farming; Housing system; Health and welfare

1. Introduction

One of the most important objectives of organic farming in Denmark is to consider the physiological and behavioural needs of the animals. In Denmark, organically raised pigs must be kept outside. However, after weaning, growing pigs may be kept indoors if they have a lying area supplied with straw, free access to roughage for rooting and chewing, and access to an outdoor run (BØJ, 1994).

In nature pigs spend most of their active time in oral activities such as rooting, grazing and chewing nutritional elements in their surroundings (Briedermann, 1971). However, in barren environments with a lack of appropriate rooting substrates, pigs often redirect their oral behaviour towards pen hardware and penmates (van Putten, 1980). Oral activities directed to penmates can lead to injuries such as tail-biting and other kinds of lesions which may cause pain and health problems for the pigs, leading to economic losses.

These kinds of oral activities can often be reduced by giving the pigs straw (van Putten, 1980; Spoolder

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et al., 1995); however, the overall complexity of the environment may also be important. In this respect, we housed growing pigs in pens with ample straw (deep-litter), and space (2 m^2 per pig), as well as different activity areas, to provide a more diverse environment. In these enriched conditions we tested if we could further improve the pigs' environment by giving them access to roughage and to an outdoor shelter. In this paper, we describe the effects of roughage and shelter on oral behaviour directed towards penmates and other environmental stimuli. Part II of this paper will deal with the pigs' comfort, dunging and temperature regulatory behaviour (Olsen et al., 2001).

2. Materials and methods

2.1. Animals

Seven replicates, each consisting of 96 LYDY-crossed pigs (i.e. crossbred sows of 25% Danish Landrace, 25% Yorkshire and 50% Duroc, crossed with Yorkshire boars) were used for the investigation. The pigs (half females, half males) were born in huts in an outdoor herd; they were individually earmarked and tails were left intact. All pigs in a replicate were born in the same week, and were familiar with each other as they were raised in the same or in neighbouring enclosures between which the piglets could cross freely.

At about 4 weeks of age (mean = 27 days, S.D. = 2.1) the pigs were moved to deep-litter pens with outdoor runs. Six weeks later, when the pigs were about 10 weeks of age (mean = 68.6 days, S.D. = 5.0) and weighing on average 24.4 kg (S.D. = 4.5), they were randomly distributed to the eight experimental pens — each pen holding 12 pigs. They were kept in the experimental barn for an average of 81.1 days (S.D. = 4.3) until being sent for slaughter at a mean weight of 100.3 kg (S.D. = 9.2). The daily weight gain averaged 938 g per pig (S.D. = 9.5), and the carcass meat percentage averaged 58.1% (S.D. = 3.0).

2.2. Housing

The investigation was carried out in an insulated, naturally ventilated building (Fig. 1), where four pens were located on the north side of the building and four on the south side, each pen with an outdoor run.

Each pen contained a deep straw area of 6.2 m^2 sunk 50 cm below the level of the pen, a 6% sloping 'straw-flow' area (Bruce, 1990) of 3.9 m^2, and a 2.7 m^2 slatted-floor area. A two-pig self-dispenser for ad libitum feeding with cereal food was placed in the straw-flow area, and a water bowl on the slatted floor. The outdoor runs as well as the indoor pens were each 12.8 m^2, thus providing about 1 m^2 per pig both indoors and outdoors. The outdoor runs consisted of a 10.1 m^2 concrete floor, sloping 3% towards the 2.7 m^2 slatted-floor area. There, a wallow (1.0 m wide, 2.0 m long and 0.1 m deep) was constructed along the wall, close to the pen entrance.

2.3. Treatments and design

The experiment was arranged as a 2×2 factorial design in the outdoor runs for each side of the building (north/south), including with/without (±) free access to roughage (wholecrop silage of barley and peas (*Hordeum vulgare* and *Pisum sativum* ssp. *arvense*)), and with/without shelter (partial coverage).

Within each replicate, shelter and roughage were assigned randomly to the pens on each side of the building. The shelter was made of a sheet of plywood (2.7×2.0 m) placed at the pen-fixtures 1.1 m above floor level at the end of the run, closest to the building wall. Roughage was given in 2.7-m long, 0.4-m wide and 0.2-m deep troughs, placed on the ground in the outdoor run furthest away from the building wall. The pigs had free access to roughage by supplies each morning and afternoon. On average 5.8 kg (S.D. = 0.5) was distributed daily in each trough. To prevent rain and snow from falling into the roughage, the troughs were covered with a length of plywood about 1 m above floor level.

2.4. Management

Before the pigs were moved into the experimental pens, a conventional straw bale was spread in the deep bedding area and more straw was supplied daily to the deep litter. The combined daily mean supply was 2.9 kg per pen (S.D. = 0.7).

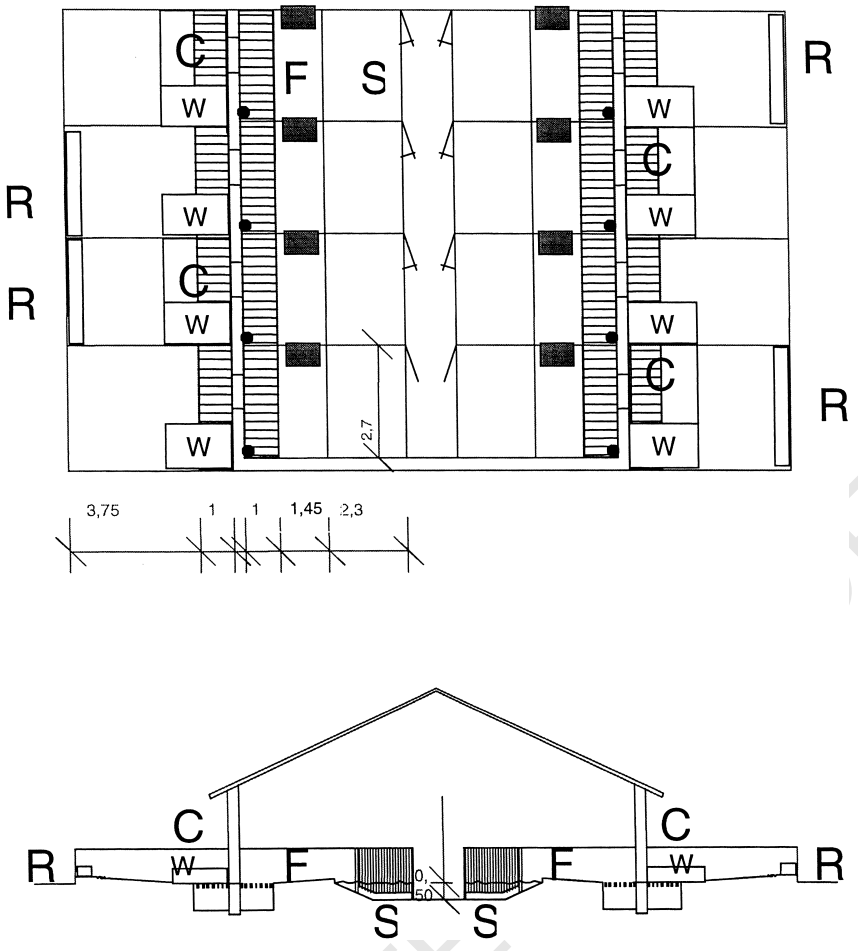

Fig. 1. Drawing of the experimental barn. (R) Roughage, (C) coverage/shelter, (S) straw bedded area (deep litter), (F) straw-flow, (W) wallow. The black dots are the water bowls (●), and the grey boxes illustrate the location of the self-feeders (▒).

The wallows were filled to the brim with clear water every morning, except when the dry bulb temperature was below 0°C. On hot days, however, more pigs used the wallows, the wallows flooded, and were therefore refilled at noon. The wallows were cleaned before filling each Monday and Thursday.

The dung in the outdoor runs was removed daily by shovelling it onto the slats. The indoor straw-flow areas were shovelled when required — about once a week. Between each replicate all dung and straw were removed, and the pens were pressure-washed indoors and out.

To ensure that the pigs would not use the roughage because of hunger or nutritional needs, they were fed ad libitum with a standard feed for growing pigs. The pigs' daily mean consumption of cereal feed was 28.5 kg per pen (S.D. = 1.3).

2.5. Behavioral measurements

After moving the pigs into the experimental barn, there was a 2-week adaptation period before the behavioural observations began in week 3, and were repeated in weeks 5, 7, 9, 11 and 12. In each of these weeks, the observations were made between 08:00 and 16:00 h on 2 successive days.

Direct observations were used in recording the pigs' behaviour. Simultaneously, two different people observed the same animal; one person observed the current focal pig when located outdoors, and the other person observed the current pig when indoors.

In advance, the start positions (outdoor/indoor) of the two observers were determined randomly, and the observers changed positions each day at noon when observing 25% of the pigs (day 1) and again after observing 75% of the pigs (day 2). Thus, by the end of each 2-day observation period all 96 pigs had been observed, and the observations were distributed equally between observers indoor and outdoor on mornings and afternoons.

The observation order for pigs and pens was determined randomly in advance. In the first randomly chosen pen, the first randomly chosen pig was observed for 5 min by use of all-occurrence sampling; however, if the pig to be observed was not active, the next randomly listed pig was chosen for the observation (Dybkjær, 1992). The observation of the first pig was then followed by a scan to determine the pigs' locations in the different areas of the pen and outdoor run. Thereafter, by all-occurrence sampling, the second randomly chosen pig was observed for 5 min, followed by a scan, then the third randomly chosen pig was observed, and finally one more scan was made. After observing the first three pigs in the first pen, we moved on to observe three pigs in the next randomly chosen pen. By use of this method, three pigs in each of the eight pens were observed by noon (day 1). The procedure was then repeated in the afternoon (day 1) as well as in the morning and in the afternoon (day 2), and so by the end of each 2-day observation period all 96 pigs were observed and the observations distributed evenly at pens on mornings and afternoons.

Handheld computers (Psion Organizer II and Psion Work About from Psion PLC (www.psion-.com)) were used for data collection.

Definitions of the pigs' general activity and oral behaviour are shown in Table 1.

2.6. Other measurements

Weather conditions were also recorded. During the scans, the outdoor observer noted weather conditions — rain, snow, wind, overcast or sunshine (for each weather recording: yes/no). Dry bulb temperature

Table 1
Definitions of oral behaviour and the pigs general activity

Behaviour	Definition
General activity	The pig is not sleeping (i.e. all except from lying passive with eyes closed)
Oral behaviour towards:	
Pen hardware	The pig is sniffing or biting the pen hardware, or rooting[a] on the pen hardware surface
Dung	The pig is sniffing or rooting in a distinct lump of dung, or distinctly chewing dung
Straw	The pig is sniffing or rooting in the straw, or distinctly chewing straw
Outdoor floor	The pig is sniffing or making attempt to bite the outdoor concrete floor, or rooting on the outdoor concrete floor surface (with or without materials presented)
Cereal feed	The pig is eating feed (i.e. having its head inside the self-feeder) or chewing while removing its head from the feeder
Penmates	The pig is sniffing, chewing, sucking or making rooting movements at any part of a penmates' body in a non-aggressive way
Drinker	Sound comes from the water nipple while the pigs' snout is placed in the drinking bowl (i.e. the pig is drinking)
Wallow water	The pig is sniffing or chewing the wallow water, rooting in the water, holding its snout passive in the water, or making air bubbles in the water
Straw-flow	The pig is sniffing or making attempt to bite the indoor straw-flow, or rooting on the indoor straw-flow surface (with or without materials presented)
Roughage	The pig is sniffing or chewing roughage, or rooting in the roughage
Indoor slats	The pig is sniffing or making attempt to bite the indoor slats, or rooting on the indoor slats surface (with or without materials presented)

[a] Rooting, the pigs' snout is in contact with the substrate while the snout is moved with forwards and backwards pointed movements, or only with forward pointed movements.

and humidity recordings were logged automatically indoors and outdoors. From now 'dry bulb temperature' will be referred to as 'temperature' only. Due to only four records of snow this variable was not included in any analysis.

When moving to the experimental barn the pigs were weighed and scored for lesions on tail, ears and the rest of the body (scores: 0, no lesions; 1, lesions on less than 30% of the skin area; 2, lesions on more than 30% of the skin area). In a similar way the pigs were scored for dirtiness, sun-scorch, and eczema, and a note was made if any leg injury was found. This procedure was repeated in weeks 4, 8, and 12. Recordings of medical treatments were made on a regular basis.

2.7. Statistical analyses

Because the pen was the experimental unit, pen-means were calculated on the basis of the 12 pig-means per pen for each behavioural measurement (Table 1). All continuous variables were analysed by mixed linear models using PROC MIXED with RANDOM statement of SAS (SAS Institute Inc, 1995). Class variables were replicate (1–7), observation week (repeated measures; 1–6), pen (1–8), side of the building (north/south), roughage (+ / −) and shelter (+ / −). The model statement included single effects of roughage (df = 1), shelter (df = 1), side of the building (df = 1), and week (df = 5) as general fixed effects, and all interactions between these variables if $P < 0.05$. Random variables included pen and replicate and all interactions involving them. Outdoor temperature (min: − 4.4°C, max: + 23.7°C) and humidity (min: 56.8%, max: 99.3%), number of recordings of sunshine (min: 0, max: 12), number of rain recordings (min: 0, max: 12) and number of wind recordings (min: 0, max: 12) were included as covariates if $P < 0.05$. Indoor temperature and humidity were not included in the analysis as they were highly correlated with outdoor temperature and humidity ($R_S > 0.9$, $P = 0.0001$ for both). If any covariate gave $P < 0.05$, the relationship was investigated further by use of the parametric (Pearson) correlation coefficients for the continuous variables (humidity and temperature), and Spearman correlation coefficients for the ordinal variables (weather recordings).

The non-parametric Wilcoxon rank sum test was used for behaviour directed to the wallows because of non-normal distribution, and for lesion scores because these were ordinal variables (Cody and Smith, 1991).

Results of the wallow-directed oral behaviour from the non-parametric statistics are given in ordinary means and standard deviations, but all other results are given in least-square means and standard errors printed using PROC MIXED with the LSMEAN statement.

3. Results

Oral activities were mainly affected by access to roughage, whereas only a few significant interactions between roughage and shelter emerged. Therefore, in the following, most emphasis is put onto the effects of roughage.

Pigs having access to roughage spent on average 189.5 s/h (S.D. = 216.5) in sniffing, rooting or chewing the roughage, with no significant effects of shelter or pen location ($P > 0.05$). Pigs with access to roughage spent less time in oral behaviour directed towards pen hardware, dung, and outdoor floor, compared to pigs without roughage ($P = 0.001$, $P = 0.024$ and $P = 0.0004$, respectively; Table 2). The roughage pigs also performed these types of behaviour less frequently ($P = 0.0008$, $P = 0.050$ and $P = 0.002$, respectively; Table 3). There was a tendency for less time to be spent in oral behaviour directed towards straw when the pigs had access to roughage ($P = 0.06$; Table 2), but no differences in frequencies emerged (overall mean = 30.3 times per hour, S.D. = 22.5). Pigs without roughage tended to spend more time on cereal feed-directed oral behaviours ($P = 0.056$; Table 2), but again, no differences in frequencies emerged (overall mean = 23.3 times per hour, S.D. = 15.7), and the amount of cereal food consumed was not affected by any treatment ($P > 0.05$).

Effect of roughage and shelter interacted with regards to duration of oral activities directed towards penmates with the behaviour occurring least in pens where both roughage and shelter were available ($P < 0.05$; Table 2). This treatment combination also gave the significantly lowest frequency of this behaviour

Table 2
Duration of different types of oral behaviour (s/h) with or without access to roughage. Data are least-square means and standard errors (S.E.)

Oral behaviour directed towards:	Treatment		S.E.	*P*-value
	Roughage	No roughage		
Pen hardware	79.9	115.3 (14.3)	14.3	0.001
Dung	18.2	30.48 (6.48)	6.5	0.024
Straw	360.1	425.2 (34.6)	34.6	0.061
Outdoor floor	64.2	116.8 (13.2)	13.2	0.0004
Cereal feed	462.7	532.9 (31.2)	31.2	0.056
Penmates[a]	S: 96.0[b]	S: 130.4[c]	13.4	0.048
	NS: 136.9[c]	NS: 127.3[c]		

[a] Roughage interaction with shelter. S, shelter; NS, no shelter. Values with different superscripts are significantly different at $P < 0.05$.

Table 3
Frequency of different types of oral behaviour (events per hour) with or without access to roughage. Data are least-square means and standard errors (S.E.)

Oral behaviour directed towards:	Treatment		S.E.	*P*-value
	Roughage	No roughage		
Pen hardware	11.6	16.5	2.0	0.0008
Dung	2.7	4.0	0.6	0.050
Outdoor floor	7.8	12.3	1.4	0.002
Penmates[a]	S: 14.1[b]	S: 17.3[c]	2.1	0.015
	NS: 17.3[c]	NS: 16.5[bc]		
Drinker[a]	S: 1.9[b]	S: 2.7[c]	0.3	0.006
	NS: 2.9[c]	NS: 2.4[bc]		

[a] Roughage interaction with shelter. S, shelter; NS, no shelter. Values with different superscripts are significantly different at $P < 0.05$.

performed. Access to both roughage and shelter also gave the significantly lowest frequency of oral behaviour towards the drinker ($P = 0.006$; Table 3), but there was no significant effect regarding the duration of this behaviour ($P > 0.05$) (on average 39.7 s/h, S.D. = 2.1). There was an overall tendency for pigs given roughage to spend less time in oral behaviour directed towards the straw-flow than those not given roughage (LS-mean = 52.9 (S.E. = 8.6) vs. 70.1 (S.E. = 8.6), $P = 0.065$). The frequency of this behaviour, however, was not affected by any treatment ($P > 0.05$). No significant treatment effects were found on the time the pigs spend in oral behaviour towards the wallow water (Wilcoxon rank sum test; $P > 0.05$) (over-all means were 2.5 times per hour (S.D. = 0.6) and 24.0 s/h (S.D. = 3.0), respectively). Duration of oral behaviour towards roughage, pen hardware, dung, and indoor slats, were all affected by observation week ($P < 0.05$) (Fig. 2).

Fig. 2 shows that significantly more time was spent in oral behaviour towards roughage in week 5 as compared to all other observation weeks ($P < 0.05$). Also, time spent on oral behaviour towards pen hardware, dung, and indoor slats, increased significantly from week 3 to week 7 ($P < 0.05$), whereas weeks 9–12 did not differ from week 3. However, no significant time effect on the frequency of these types of behaviour on the pigs' general activity was found ($P > 0.05$).

Pen location (north/south) and climatic conditions (i.e. weather conditions, temperature and humidity) had no effect on the pigs' general activity, on the frequency and the time spent drinking, or on the majority of the oral activities. However, the duration of oral behaviour towards the wallow showed a slightly positive relationship with temperature and the number of sunshine recordings ($R_s = 0.20$ and $P < 0.001$ for both). Moreover, regression analysis showed an almost horizontal linear relationship when temperature ranged from -4 to $+15$°C, but a steep increase when temperature increased from $+15$ to $+24$°C ($P = 0.05$ and $P = 0.0004$ respectively; Fig.

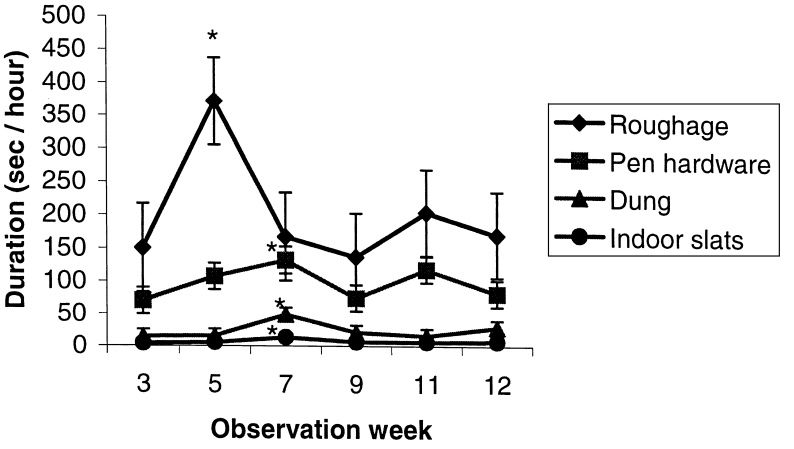

Fig. 2. Time spent in oral behaviours towards roughage, pen hardware, dung, and indoor slats (s/h) in the different weeks of observation. Data are least-square means±standard errors (S.E.). *Shows significant differences within each oral behaviour compared to week 3 ($P < 0.05$).

3). Also a polynomial relationship was found between the duration of this behaviour and the number of observations of sunshine (intercept = 18.2 (S.E. = 5.2), number of sunshine observations^2 = 0.4 (S.E. = 0.2); $P < 0.004$). The time spent in oral behaviours towards pen hardware and penmates were affected by rainy weather ($P < 0.05$). A Spearman correlation analysis showed slightly positive correlation coefficients ($R_s = 0.39$ and $R_s = 0.26$, respectively; $P < 0.01$ for both). By using PROC MIXED analysis we could determine if this was due to increased use of either the indoor or outdoor area in rainy weather; however, that was not the case ($P > 0.05$). Analysis showed that rainy weather did not affect the pigs' sniffing at each other ($P > 0.05$). However, rainy weather slightly increased the pigs' chewing, suck-

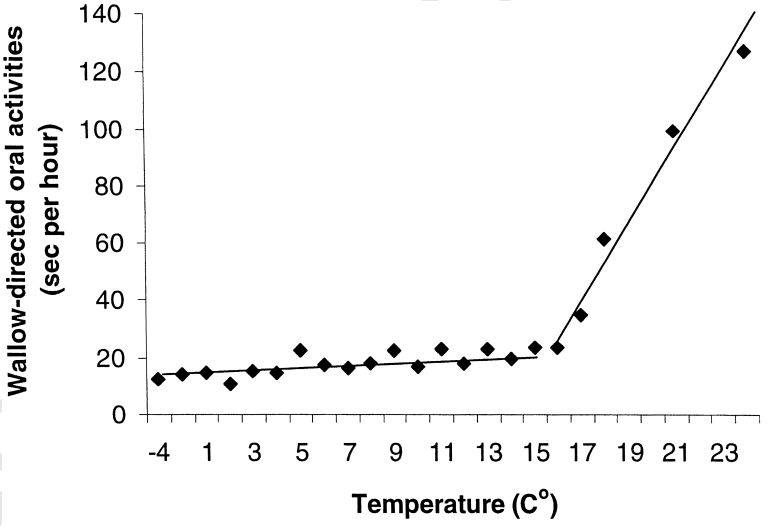

Fig. 3. This smoothed curve illustrates duration of oral behaviour towards wallow water in relation to environmental temperature (°C). Each point is the mean value from three adjacent degrees of temperature. The straight lines show the linear relationship when the temperature varies from −4 to +15°C (intercept = 17.0 (S.E. = 4.2), temperature = −0.03 (S.E. = 0.6); $P = 0.05$) and from +15 to +24°C (intercept = −170.0 (S.E. = 58.6), temperature = 12.3 (S.E. = 3.4); $P = 0.0004$).

ing, or rooting movements towards penmates in the indoor area ($P < 0.01$) and towards pen hardware in the outdoor run ($P < 0.01$) ($R_s = 0.30$ and $R_s = 0.26$, respectively; $P < 0.001$ for both).

Pigs having access to roughage had significantly lower scores for lesions on the tail in week 4 compared to the no-roughage pigs (Wilcoxon rank sum test; on average 0.03 (S.D. = 0.01) vs. 0.06 (S.D. = 0.01); $P < 0.05$). Significant differences between these two groups of pigs also emerged in week 8 as regards lesions on the ears (0.11 (S.D. = 0.02) vs. 0.18 (S.D. = 0.02); $P < 0.05$) and the body (0.13 (S.D. = 0.02) vs. 0.23 (0.02); $P < 0.05$), whereas no other differences between any treatment emerged. Across scoring times, on average 2.6% of the pigs were classified as dirty (score 1 or more), 0.5% of the pigs were sun-scorched, and less than 1% had eczema or suffered from leg injury.

There were no significant differences between treatments as regards medical treatment. On average, 3.0% of the pigs (S.D. = 4.0) were treated individually with antibiotics for different infections. However, all pigs in replicates 5 and 6 were treated with Tiamulin (100 ppm) given in the feed because the whole barn became infected with swine dysentery (caused by *Brachyspira hyodysenteri* formerly known as *Serpulina hyodysenteri*). However, we found only a few lumps of bloodstained faeces, and the pigs' behaviour, for example activity, was not different from the other replicates. In general, we considered the pigs housed in these experimental pens to be in good health.

4. Discussion

The present results show that even when growing pigs had access to ample straw, space, and different activity areas, wholecrop silage of barley and peas in addition to straw, reduced the majority of the pigs' oral activities towards their environment and reduced the incidence of lesions of the skin. However, access to shelter, in combination with access to roughage, reduced oral behaviour towards penmates and the water bowl. Consequently, both additional roughage and other environmental improvements may have reducing effects on redirected oral behaviour in pigs. Therefore, the complexity of the pigs' environment may be important in avoiding redirected oral behaviour.

We found that the pigs spent 2.2–3.2% of the observation time in oral behaviour towards pen hardware (i.e. 79.9–115.3 s/h; Table 2) and 2.7–3.8% in oral activities towards penmates (lowest in the group with access to both roughage and shelter; i.e. 96 s/h — see Table 2). Comparatively, Lyons et al. (1995) found that pigs housed on straw spent about 2% of their daytime in oral behaviour towards pen hardware (without straw: about 12%). Beattie et al. (1993) also found that pigs in an enriched environment spent about 1% of their daytime in oral activities towards penmates (barren environment: 10.8%). Similar effects of straw are found in younger pigs (Fraser et al., 1991) and sows (Spoolder et al., 1995), but juvenile pigs in semi-natural conditions did not show any oral activities towards other pigs (Petersen, 1994). As oral behaviour towards penmates is considered to be redirected behaviour in the absence of more appropriate stimuli (van Putten, 1980), any initiative to enrich the pigs' environment with appropriate stimuli is desirable. However, it is doubtful if this behaviour can be completely avoided in indoor systems where the pigs, regardless of enrichment, are kept in a confined space with restricted possibilities for rooting compared to pigs kept in natural conditions. Neither indoor- or outdoor-kept pigs have full control over their environment, however, the more natural the conditions the more complex the environment, giving pigs more choices of what to manipulate, where to locate themselves, and who to socialise with. This may give more control over their environment compared to pigs in indoor systems, even when they are enriched. However, to maintain the pig production at today's level, indoor housing is necessary, but by enriching the environment 'inappropriate' oral activities towards other pigs may be reduced.

We found that access to roughage tended to reduce the pigs' time spent in oral activities towards straw and cereal feed. This may suggest that access to roughage could reduce competition for these attractive elements in the pen. Nevertheless, no effect on cereal feed consumption was apparent, indicating that no-roughage pigs consumed the cereal food

more slowly, which might be one way of satisfying their need for oral activities.

The pigs' age did not influence the pigs' general activity, but age, however, influenced the time they spent on oral activities towards roughage, pen hardware, dung, and indoor slats. These oral activities increased when the pigs were 15–17 weeks old (i.e. observation week 5–7) compared to 13 weeks of age (i.e. observation week 3), but age had no effect when the pigs exceeded 17 weeks of age. Similarly, Petersen (1994) and Newberry and Wood-Gush (1988) reported that free-ranging domestic pigs generally increased their rooting activities with increasing age (measured until week 18 and 14, respectively). Age may also be important regarding the effects of roughage on other oral activities. In the present study, the no-roughage pigs increased their time spent on straw-flow-directed oral behaviour in observation weeks 5 and 11, compared to pigs that had access to roughage. The increase in week 15 is similar to the increase in rooting behaviour found in semi-natural conditions at the same age, but the increase in week 21 most likely appeared 'by chance'. Thus, our results indicate that age (at 13–22 weeks of age) does not influence general activity but the time allotted to different oral activities.

Although, weather conditions, temperature and humidity did not affect general activity and most oral activities, we found a steep increase in the time the pigs spent in oral activities towards the wallow when temperature exceeded 15°C, and with increasing number of sunshine observations. This could indicate that oral activities gradually changed from foraging/explorative rooting to rooting in connection with temperature regulatory behaviour. Andresen and Redbo (1999) did not find relationships between temperature and rooting behaviour in outdoor raised growing pigs, but found increased rooting in the wallow at 20°C. In this experiment, we also found that increased rain increased the time spent on chewing, sucking or making rooting movements towards penmates in the indoor part of the pen, and biting or rooting towards pen hardware in the outdoor run. If rain increases oral activities towards penmates regardless of housing system, this may impact the damaging behaviour (e.g. tail-biting), that is undesirable from both an economic and welfare point of view. However, further studies are required to reveal if oral activities towards penmates generally are affected by rain.

Based on the present study, we suggest that supplying growing pigs with roughage as rooting and chewing substrate, in addition to straw, might provide environmental enrichment of biological relevance for pigs. However, how well the substrates are suited may depend on their composition (see Olsen et al. (2000)). Therefore, types of roughage other than wholecrop silage of barley and peas may improve the biological relevance of the rooting and chewing substrate further.

5. Conclusion

Even if pigs have access to ample straw, space and different activity areas, wholecrop silage of barley and peas can apparently reduce redirected oral behaviour, but giving them access to shelter may also reduce redirected oral activities. Therefore, the overall complexity of the environment may be an important factor in avoiding redirected oral behaviour directed towards penmates, which impacts negatively on both farm economics and pigs' welfare.

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