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Oral/nasal/facial and other behaviors of sows kept individually outdoors on pasture, soil or indoors in gestation crates

Jeffery W. Dailey [1], John J. McGlone [*]

Pork Industry Institute, Department of Animal Science and Food Technology, Texas Tech University, Lubbock, TX 79409-2141, USA

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Abstract

The behavior of individually kept PIC Camborough-15 sows was compared when they were housed in three systems: pasture, soil or gestation crates. All sows were fed 2.0 kg of fortified, sorghum–soybean diet each day. Crated sows were divided into two groups: those fed meal and those fed pellets. As is common among sows on pasture and soil, outdoor sows were fed pellets. Eight sows per treatment were studied. Observers recorded the occurrences of standing, lying, sitting, feeding, drinking, and oral/nasal/facial manipulation of environment using a scan technique every 5 min for 24 h. Oral/nasal/facial behaviors recorded included: chew/bite grass, chew/bite fence/bars, chew rocks/soil and rooting the ground or trough. Sows in each treatment group performed statistically similar frequencies of total oral/nasal/facial behaviors during the 24 h sample period. Pasture-kept sows chewed grass, soil-kept sows chewed rocks and soil, and crated sows chewed the bars. All sows rooted and chewed on the substrate available to them. Frequency, duration and sequential analyses of sow behaviors for an intensive 2 h period starting 30 min post feeding then were investigated. Ten sows per treatment were investigated. Once again, while the precise substrate differed depending on availability, sows on pasture, soil and in gestation crates showed similar overall durations of stereotyped and non-stereotyped oral/nasal/facial behaviors. Sequential analyses showed subtle differences in oral/nasal/facial behavioral sequences. Sows engaged in repeated behavior patterns that provide the greatest stimulation to the oral/nasal/facial region least stimulated by the available substrates within an

* Corresponding author. Tel: +1-806-7422335; Fax: +1-806-7420898.

[1] Present address: USDA–ARS Livestock Behavior Research Unit, 215 Poultry Science Building, Purdue University, West Lafayette, IN 47907, USA.

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environment. These stereotyped behaviors may be natural pre- and post-feeding appetitive and consummatory chewing and rooting activities modified in sequences and form by the available substrates.

Keywords: Pig; Anomalous behavior; Housing; Welfare

1. Introduction

Sows are housed in a wide variety of systems throughout the world. Housing systems in European countries have been regulated based on welfare concerns (Lehmann, 1990). The expression of stereotypic oral/nasal behaviors found among intensively housed sows are considered indicators of reduced welfare (Duncan, 1985; Mason, 1993).

Group-housed sows on a soil paddock expressed oral/nasal behaviors (licking, biting and nosing) at a higher frequency than sows housed on concrete indoors or outdoors (Barnett et al., 1984a,Barnett et al., 1984b). Group-housed sows on a soil paddock express oral/nasal and inactive behaviors at the same frequency as sows housed on concrete indoors (Barnett et al., 1985). Group-housed gilts outdoors on soil had higher levels of oral/nasal behaviors than those housed indoors on concrete (Dailey and McGlone, 1997). Vieuille-Thomas et al. (1995) found that the same proportion of stall- and tether-housed sows developed stereotypic behaviors; however, more stall-housed sows expressed stereotypic behaviors than group-housed sows. An evaluation of possible differences in oral/nasal/facial behaviors exhibited by sows housed indoors or outdoors is needed to understand the effects of housing systems on stereotypic behavior.

Mason (1993) suggested that a detailed assessment of stereotypic behaviors is needed, noting that the description and measurement of stereotypic behaviors should include different properties such as current morphology, timing and stage of development. The adaptation of sequential methods for evaluating stereotypic behaviors was recommended by Mason.

Only Stolba et al. (1983) and Cronin and Wiepkema (1984) conducted limited sequential analyses of sow oral/nasal behaviors. Stolba et al. (1983) conducted an analysis of stereotypic behaviors in indoor-stalled sows. Sows were followed through three stages of pregnancy. Human observers collected sequential data for a 20 min period when sows were not feeding, sleeping or being handled. These observations were divided into ten 2-min blocks that were coded as variable, stereotyped, ingestive or positional. Behavioral intervals that were judged stereotypic had an increase in the calculated redundancy value compared to variable behaviors. Increased stereotypic and variable behavior caused the overall redundancy value to increase with parity and stage of gestation. The same analysis using outdoor-kept sows showed a similar redundancy value as the indoor-kept sows (Stolba et al., 1983).

Cronin and Wiepkema (1984) used sequential analysis to classify the stereotypic behavior patterns of tethered sows. This analysis focused on individual patterns of 'abnormal' behaviors exhibited by tethered sows 2.25 h after feeding. An observer recorded sequential data on four sows for 55 min each on a given day. Each sow was observed for only a 5 min period, then the next of the four sows that day was observed.

This cycle was repeated seven times before a 20 min break, then the remaining four cycles of observations were conducted. Individual sows were observed once in that study. Sows increased their performances of fixed complete routines and fixed subroutines of stereotypic behaviors as stage of gestation increased. Older sows exhibited stereotypic behaviors in patterns that were less flexible than younger sows.

This study examined the oral/nasal/facial and other behaviors of sows housed in four treatment groups that included indoor and outdoor environments and managed in a manner consistent with commercial production (limited ration, commercial genotype and management). Maintenance and oral/nasal/facial behaviors of sows kept outdoors on pasture or soil, or indoors in gestation crates were investigated based upon 24-h observations and an intensive 2 h analysis of these behaviors during the period of highest activity common to all environments. Unlike earlier work, we have the benefit of video and computer equipment to allow more complete quantification of behaviors and behavioral sequences.

2. Animals, materials and methods

2.1. Animals

Forty Camborough 15 (C-15) sows were used in this study. The C-15 sow line is a commercial cross-breed derived from Yorkshire, Landrace and Duroc breeds. All sows used in this study were obtained as gilts from PIC (Franklin, KY), where they had been reared indoors in a commercial indoor breeding stock situation. Gilts arrived at the Texas Tech University farm and were then maintained in their treatment environment for 2 months prior to first breeding. Data were collected after the gilts had been acclimated to the indoor or outdoor treatment environment at least 8 months and at least one full pregnancy.

Sows were observed on an average (mean $\pm$ SE) 72 ± 3 days of gestation and 2.7 ± 1.1 parity. Sows were mixed by parity and genotype outdoors and were individually housed indoors. Other genotypes (not used here) maintained in the herds included York–Landrace crosses bred on site, Camborough Blue (PIC) and an experimental Meishan cross (PIC).

Indoor sows were individually housed in 0.6×2.2 m^2 gestation crates after having farrowed in crates. Sows were heat checked daily from these crates and rebred. Sows were then either housed in crates or housed in pens of 12 to 14 in a mechanically ventilated, slotted floor gestation building. Indoor group-housed sows had access to feeding stalls and an open common area behind these stalls. Indoor sows were on treatment for 30 days prior to observation. Indoor and outdoor sows had ad libitum access to water.

Outdoor sows prior to this experiment were maintained in a group of 16 to 20 on a 0.87 ha paddock with electric wire fencing and with access to huts for shelter. These sows had farrowed in individual huts and were rebred prior to treatment. Outdoor sows were moved to the individual treatment area at least 7 days prior to observation.

2.2. Treatments

C-15 sows were kept in three individual housing systems: soil, pasture or gestation crates. Indoor crated sows were divided into two groups, those fed meal (In-Meal) and those fed pellets (In-Pellet). Indoor sows had been fed meal until the initiation of the study. The environment for the indoor sows had five 13-mm-diameter bars spaced 153 mm apart running horizontally in front of the sows. A concrete trough measuring 10 cm in height ran along the front of the crate and a nipple waterer was available in the front of the crate. Indoor sows had 1.3 m^2 in each crate in the indoor environment. Continuous red lighting was used to illuminate the indoor sows during the study (which allowed night video recording). Fluorescent lighting with a 14:10 h light/dark pattern was used.

Outdoor treatments consisted of either a soil lot (Out-Soil), which had no visible vegetation or pig traffic for 14 days prior to treatment; or a wheat/rye–alfalfa pasture (Out-Grass) that was flood irrigated a minimum of 10 days prior to sows being placed on treatment. Sows were placed in a 3.0×9.1 m^2 pen adjacent to another sow with which they shared a 1.8×2.4 m^2 corrugated steel hut divided in half by welded wire. Sows had 30.0 m^2 per sow, including the hut, in each paddock in the outdoor environments.

Two feeding forms were used in this study, meal and pellet. In USA commercial pork production, indoor sows are typically fed meal and outdoor sows typically are fed pellets. Indoor sows in this study were fed either meal (In-Meal) or pellets (In-Pellet). Pelleted rations were fed in the outdoor environments. Pelleted rations were fed indoors as a control for the pelleted ration fed in the outdoor environment. Pellets were about 20 mm in diameter and 2–4 cm in length. Rations were 14% CP sorghum–soybean meal based diets formulated to meet or exceed the National Research Council (NRC, 1988) requirements. Sows were fed 2 kg once daily in the morning for all environments and feed forms.

2.3. Observations

Two experiments were conducted. Experiment 1 examined the 24 h behavior of animals kept in the different treatments. Experiment 2 was an intensive analysis of a 2 h period of highest activity for oral/nasal/facial activity, 30 min after feeding, for the animals under each treatment.

2.3.1. Experiment 1

Ten sows from each treatment were investigated. Behavior of each sow was recorded every 5 min for 24 h. The following behaviors were defined and recorded as mutually exclusive: feeding, drinking, lying, standing, sitting, rooting, grazing, chew metal and chew rocks. For a complete definition of these behaviors, see Table 1. At each 5 min interval, observers noted the behavior each animal was expressing. A given observer documented the behavior of no more than four animals at each 5 min scan. The observations for both outdoor environments were conducted simultaneously with live observers. Night time observations were facilitated by 150-W spotlights that were used

Table 1
24-h behavior definitions

Behavior	Description	Chew	Oral/nasal / facial	Oral/nasal/facial + Feed + Drink
Feeding	Snout contact with ground while moving jaw with feed present			✓
Drinking	Mouth contact with drinker			✓
Lying	Animal not supported by its legs			
Standing	Supported by all legs, no mouth movements, includes walking			
Sitting	Not supported by hind legs			
Rooting	Rooting disk contact with the ground/floor		✓	✓
Grazing [a]	Mouth movement with contact with grass	✓	✓	✓
Chew metal	Mouth contact with contact with metal	✓	✓	✓
Sham chew	Mouth movement without contact with any substrate	✓	✓	✓

[a] Outdoor grass environment only.
✓, Behaviors summed for measure in the heading.

to illuminate the sows during the 24 h observation. This light was present for at least 7 days prior to observation. Indoor sows were videotaped using time-lapse video-recorders (Panasonic AG6010). Cameras were mounted to give a head on view of the sow. Indoor observations were obtained by reviewing a video recording at 5-min intervals for 24 h periods.

2.3.2. *Experiment 2*

Outdoor sows were videotaped with a portable camcorder mounted on a tripod 6–7 m from the perimeter of the enclosure. A camcorder was moved by hand on a tripod so that the sow's head composed at least 50% of the frame during this filming. Indoor sows were videotaped from a similar distance using mounted cameras. Mounting and tripods minimized camera movement.

All videotaping was done at normal speed (30 frames s^{-1}) for a 2 h period starting 30 min post-feeding. Data from these tapes were summarized using a computer sequential analysis program that allowed the collection of frequency, duration and sequences of behavior (McGlone et al., 1985).

Behaviors observed in the 2 h intensive sample are reported in Table 2. A total of 20 behaviors were recorded for all treatments. Indoor and outdoor environments had seven common behaviors (lying/lying active, drink, sit, stand, feed, sham chew, paw) and 13 behaviors that were environment specific due to the available substrates. There were seven behaviors only outdoor sows could express (head in hut, walk, grazing, snout contact with fence or metal, root, rooting disk contact with ground, lever root), and six behaviors only indoor sows could show (bite bars with back of mouth, bite bar with front of mouth, nose bar with rooting disk, nose contact with floor, nose feed trough, snout between bars).

Oral/nasal/facial behaviors were coded based on which of three areas of the oral/nasal/facial anatomy (mouth, snout or top-of-snout) were most stimulated by a

Table 2
2-h behavior definitions

Oral/nasal/facial	Oral/nasal/facial region			Envt	Behavior	Description
	Mouth	Snout	Top-of-snout			
✓				In/Out	Lying/lying active [a]	Recumbence
				In/Out	Drink	Mouth contact with a drinker
				In/Out	Sit [b]	Not supported by hind legs
				In/Out	Stand [b]	Supported by all legs with no other movement
				Out	Head in hut [b]	Out of view
				Out	Walk [b]	Locomotion
✓				In/Out	Feeding [c]	Rooting disk and mouth movement on a substrate
✓				Out	Grazing [c]	Jaw movement with contact with vegetable matter
✓	✓			In	Bite bars with back of mouth	Enclosure of crate bars with posterior of mouth
✓	✓			In	Bite bar with front of mouth	Enclosure of crate bars with anterior mouth
✓	✓			Out	Snout contact with fence or metal	Snout touches metal, e.g. rooting fence
✓	✓			In/Out	Sham chew	Jaw movement without contact with anything
✓		✓		In	Nose bar with rooting disk	Touching rooting disk on the bars
✓		✓		In	Nose contact with floor	Touching rooting disk on the floor
✓		✓		Out	Root	Rooting disk contact on the ground with movement
✓		✓		Out	Rooting disk contact with ground	Touching rooting disk on the ground
✓		✓		Out	Lever root	Movement of substrate with snout, e.g. tossing of soil
✓		✓		In	Nose feed trough	Rooting disk contact on the feed trough with movement
✓		✓		In	Snout between bars	Both mandibles contact bars without movement
				In/Out	Paw [d]	Drag front leg dorsal along ground

[a] Lying active and lying inactive were combined.
[b] Postional behaviors.
[c] Appetitive behaviors, excluded from sequential analysis of oral/nasal/facial behavior by motor region.
[d] Behaviors dropped from analysis due to low occurrence or lack of corresponding behavior in other environments.
✓, Behaviors summed for measure in the column heading.

given behavior. For example, the 'top-of-snout' was coded when indoor sows nosed the feed trough and when outdoor sows lever rooted. The behaviors grazing, head in hut and walk were exclusive to the outdoor treatments. The behavior 'paw ground' was dropped

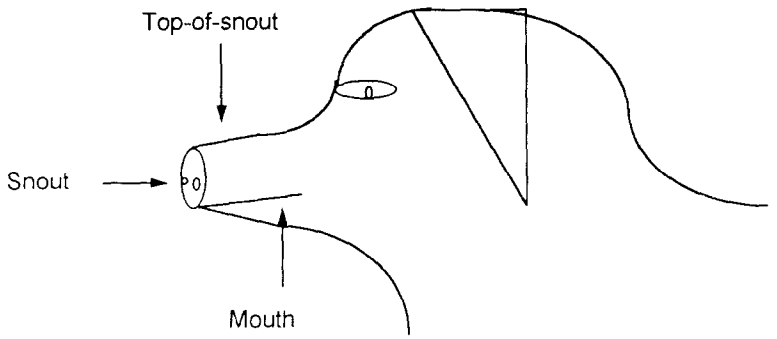

Fig. 1. Diagram of oral/nasal/facial anatomy.

from the analyses due to low occurrence. Table 2 provides a description and grouping of the behaviors observed. Fig. 1 illustrates the oral/nasal/facial areas.

The vegetation mass before treatment for the Out-Grass was collected. Five frames (50×50 cm^2) were clipped to ground level in each pen before placing the animal on treatment to provide an estimate of initial vegetation condition. The samples were dried and weighed. The data indicate that sows in the Out-Grass treatment removed (by eating or trampling) about 0.44 kg day^{-1} of dry matter.

2.4. Statistical analysis

The 24 h scan and 2 h frequency and duration intensive samples were analyzed using the GLM procedure in Statistical Analysis Systems (SAS) Institute Inc. Linear contrasts were computed for the treatment groupings (In vs. Out, Meal vs. Pellet, In-Meal vs. In-Pellet, and Out-Soil vs. Out-Grass). Animals were randomly allocated to treatments among treatment environments.

A split-plot completely random design was used for Experiment 1. The 24 h scan sample was analyzed using the GLM procedure in SAS (1990) with sow within treatment as the error term for the treatment effects. Time and time by treatment interaction were tested with the residual error.

For Experiment 2 treatment effects and linear contrasts were examined for frequency and duration of behavior. The model was a completely random design.

Behavioral transitions were collected for behaviors in the 2 h observation (Table 2). The behaviors were tested on two levels: all behaviors plus oral/nasal/facial as one category and at the second level by breaking out each component of oral/nasal/facial behavior. 'All behaviors' classified behaviors as either drink, lying, positional or oral/nasal/facial. 'Oral/nasal/facial components' took behaviors classified as oral/nasal/facial in the 'All behaviors' analyses and examined the transitions among the three oral/nasal/facial anatomy regions (Table 2). 'Oral/nasal/facial components' excluded the behaviors grazing and feed because they are consummatory behaviors.

These data were subjected to sequential analyses as a first-order model that assumed that behavioral states occurred as often as they did, but the order of the codes was random (Bakeman and Gottman, 1987). Transitions between behavior states were mutually exclusive and could not follow a like behavior (i.e. drinking could not follow

drinking). Therefore, by design, structural zeros were present in the data set. Chi-square analyses that included a correction factor that adjusted the expected and chi-square values for structural zeros was used for the within-treatment sequential analyses. This analysis was a modification of the Anderson–Goodman test described by Bakeman and Gottman (1987).

Transitions from each treatment were compared to test for differences in observed transition frequencies occurring among treatments (modified from McGlone, 1985). In this analysis, a chi-square matrix was constructed that had treatments as columns and sequences significant in the previous analysis as rows. Chi-square analyses were used to determine if a given cell value occurred at a rate higher or lower than expected. While the first sequential analysis identified within-treatment effects, the second analysis allowed comparisons of sequences among treatments.

3. Results

3.1. Experiment 1

The sum of all active behaviors (called 'active') differed ($P = 0.033$) among treatments. Sows in In-Meal were more active than In-Pellet (2.44 vs. 1.61, SE 0.268, $P = 0.04$, frequency per h, max. = 12). In-Meal sows tended to eat at a higher frequency (0.30 vs. 0. 19, SE 0.040, $P = 0.08$) than In-Pellet sows. Outdoor sows drank more often than the indoor-housed sows ($P < 0.01$). Lying behaviors differed by treatment ($P = 0.03$), with In-Pellet sows lying more than In-Meal sows (10.39 vs. 9.56, SE 0.268).

Standing differed among treatments ($P < 0.05$); Outdoor sows stood more than Indoor sows (0.90 vs. 0.49, SE 0.108, $P = 0.0007$). In-Meal sows stood more than In-Pellet sows (0.70 vs. 0.28, SE 0.108, $P = 0.01$). Chewing or touching metal behaviors differed by treatment ($P < 0.05$). Indoor sows chewed metal fences at a higher frequency than outdoor sows ($P < 0.05$). Out-Soil was the only treatment that substantially sham chewed and therefore differed from other treatments ($P < 0.05$).

No differences ($P > 0.10$) were found between treatments for sitting, rooting, total oral/nasal/facial or oral/nasal/facial plus feed and drink. The analyses of the 24 h frequency data are given in Table 3.

The treatment by time interaction was significant ($P < 0.05$) for the 'active' (Table 4), 'chew' (Table 5), 'oral/nasal/facial' (Table 6) and 'oral/nasal/facial + feed + drink' (Table 7) combined behaviors. Indoor-housed sows exhibited behaviors over a smaller range of time periods that appear to be linked with feeding at 08:00 h each day. Outdoor-housed sows showed a higher ($P > 0.05$) frequency of active behavior prior to the feeding period than did indoor-kept sows. Sows housed outdoors showed a bimodal activity pattern compared to indoor-housed sows. Outdoor-kept sows had two periods of active behaviors during the 24 h observation, the first in the early morning and a second period of active behaviors towards evening. Outdoor-kept sows exhibited a decreased frequency of activity in afternoon observation periods. Indoor sows maintained a relatively constant level of activity from feeding until mid-afternoon (Table 4).

Table 3
Frequency of behaviors summed over 24 h and test for treatment differences (max. 12 period)

Measure	Treatment				SE_p	*P* value				
	In-Meal	In-Pellet	Out-Soil	Out-Grass		Treatment effect [a]	In vs. Out [a]	Meal vs. Pellet [a]	In-Meal vs. In-Pellet [a]	Out-Soil vs. Out-Grass [a]
N	8	8	8	8						
Feed	0.30	0.19	0.30	0.25	0.040	0.21	0.48	0.28	0.078	0.32
Drink	0.13	0.09	0.23	0.19	0.037	0.057	0.01	0.32	0.50	0.44
Lying	9.56	10.39	9.77	9.21	0.268	0.033	0.084	0.46	0.038	0.16
Stand	0.70	0.28	0.85	0.94	0.108	0.0008	0.0007	0.96	0.010	0.57
Sit	0.03	0.07	0.06	0.005	0.029	0.37	0.54	0.57	0.27	0.22
Root	0.63	0.63	0.61	0.50	0.102	0.78	0.48	0.70	0.97	0.45
Graze	–	–	–	0.90	0.093	–	–	–	–	–
Chew metal	0.67	0.35	0.01	0.01	0.161	0.020	0.0045	0.0067	0.17	1.0
Sham chew	0.0	0.0	0.20	0.0	0.027	0.0001	0.0001	0.0059	1.0	0.0001
Active [b]	2.44	1.61	2.23	2.79	0.268	0.033	0.084	0.46	0.038	0.16
Chew [c]	0.67	0.35	0.21	0.91	0.169	0.029	0.76	0.37	0.20	0.0066
Oral/nasal/facial [d]	1.29	0.98	0.82	1.41	0.214	0.20	0.92	0.37	0.31	0.060
Oral/nasal/facial + feed + drink	1.72	1.27	1.35	1.85	0.224	0.22	0.63	0.38	0.16	0.13

[a] Linear contrasts and overall treatment effects.
[b] Sum of all behaviors excluding Lying.
[c] Grazing + Chew metal + Sham chew.
[d] Chew + Root. SE_p is The pooled standard error

Table 4
Time by treatment interactions for 24-h 'Active' behaviors, Least square means, frequency (max. 12 period)

Time	Treatment			
	In-Meal	In-Pellet	Out-Soil	Out-Grass
$N=$	8	8	8	8
00:00–01:55	0	0	0	0
02:00–03:55	0.13 [a]	0 [a]	0 [a]	2.63 [b]
04:00–05:55	0.06 [a]	0.19 [a]	0.56 [a]	3.63 [b]
06:00–07:55	3.56 [a]	2.00 [a]	5.19 [b]	7.56 [c]
08:00–09:55	9.06 [ab]	8.19 [a]	10.81 [c]	10.13 [bc]
10:00–11:55	6.56 [c]	3.56 [ab]	3.00 [a]	4.94 [b]
12:00–13:55	5.13 [c]	2.63 [b]	1.56 [ab]	0.63 [a]
14:00–15:55	3.81 [b]	2.25 [ab]	1.19 [a]	1.00 [a]
16:00–17:55	0.88 [ab]	0.06 [a]	2.75 [c]	2.38 [bc]
18:00–19:55	0.13	0.31	0.38	0.44
20:00–21:55	0	0.06	1.38	0.13
22:00–23:55	0	0.13	0	0

[a,b,c] Means within a row with superscripts differ $P < 0.05$.

3.2. Experiment 2

For the 2 h intensive observation lying behaviors differed among treatments ($P = 0.019$).

Indoor sows were more inactive than outdoor sows (53.67 vs. 26.10, SE 9.83, min. per 2 h). In-Pellet sows tended to be less active than In-Meal sows (66.62 vs. 40.72, SE 9.83, $P = 0.07$).

Table 5
Time by treatment interactions for 24-h 'Chewing' behaviors, Least square means, frequency (max. 12 period)

Time	Treatment			
	In-Meal	In-Pellet	Out-Soil	Out-Grass
$N=$	8	8	8	8
00:00–01:55	0	0	0	0
02:00–03:55	0	0	0	0.44
04:00–05:55	0 [a]	0 [a]	0 [a]	2.50 [b]
06:00–07:55	0.25 [a]	0.31 [a]	0.81 [a]	1.81 [b]
08:00–09:55	2.13 [b]	1.88 [b]	0 [a]	1.44 [b]
10:00–11:55	3.14 [b]	0.94 [a]	1.13 [a]	2.63 [b]
12:00–13:55	1.19 [b]	0.81 [ab]	0.25 [a]	0.25 [a]
14:00–15:55	0.88	0.25	0	0.25
16:00–17:55	0.13 [a]	0 [a]	0.19 [a]	1.63 [b]
18:00–19:55	0	0	0.13	0
20:00–21:55	0	0	0	0
22:00–23:55	0	0	0	0

[a,b,c] Means within a row with superscripts differ $P < 0.05$.

Table 6
Time by treatment interactions for 24-h 'Oral/nasal/facial' behaviors. Least square means. frequency (max. 12 period)

Time	Treatment			
	In-Meal	In-Pellet	Out-Soil	Out-Grass
$N =$	8	8	8	8
00:00–01:55	0	0	0	0
02:00–03:55	0	0	0	0.69
04:00–05:55	0 [a]	0.06 [a]	0.06 [a]	2.69 [b]
06:00–07:55	1.00 [a]	0.94 [a]	1.88 [a]	4.19 [b]
08:00–09:55	5.25 [b]	5.06 [b]	3.44 [a]	3.50 [a]
10:00–11:55	4.44 [c]	2.50 [ab]	1.44 [a]	3.25 [bc]
12:00–13:55	2.44 [c]	1.63 [bc]	0.88 [ab]	0.31 [a]
14:00–15:55	1.94 [c]	1.38 [bc]	0.31 [ab]	0.25 [a]
16:00–17:55	0.38 [a]	0.06 [a]	0.75 [a]	2.06 [b]
18:00–19:55	0.06	0.13	0.13	0
20:00–21:55	0	0	0.94	0
22:00–23:55	0	0	0	0

[a,b,c] Means within a row with superscripts differ $P < 0.05$.

The sum of all oral/nasal/facial behaviors was not modified by treatment ($P = 0.16$). Mouth-based oral/nasal/facial behaviors also did not differ by treatment ($P = 0.06$). Snout-based oral/nasal/facial behaviors differed by treatment ($P < 0.01$). outdoor-housed sows had a longer duration of these behaviors than indoor-housed sows (46.51 vs. 21.67, SE 5.51, min. per 2 h, $P < 0.01$). 'Top-of-snout'-based oral/nasal/facial behaviors differed ($P < 0.01$) among treatments; indoor-housed sows performed these

Table 7
Time by treatment interactions for 24-h 'Oral/nasal/facial + Feed + Drink' combined behaviors. Least square means, frequency (max. 12 period)

Time	Treatment			
	In-Meal	In-Pellet	Out-Soil	Out-Grass
$N =$	8	8	8	8
00:00–01:55	0	0	0	0
02:00–03:55	0	0	0	0.75
04:00–05:55	0 [a]	0.06 [a]	0.25 [a]	2.81 [b]
06:00–07:55	1.88 [a]	1.06 [a]	2.13 [a]	4.44 [b]
08:00–09:55	8.44 [b]	7.75 [ab]	7.69 [ab]	7.06 [a]
10:00–11:55	4.69 [c]	2.63 [ab]	2.00 [a]	3.94 [bc]
12:00–13:55	2.88 [c]	1.81 [bc]	1.44 [b]	0.44 [a]
14:00–15:55	2.25 [b]	1.63 [ab]	0.44 [a]	0.50 [a]
16:00–17:55	0.44 [a]	0.06 [a]	1.13 [ab]	2.25 [b]
18:00–19:55	0.06	0.19	0.13	0
20:00–21:55	0	0	1.06	0
22:00–23:55	0	0	0	0

[a,b,c] Means within a row with superscripts differ $P < 0.05$.

Table 8
Summary of treatment effects on duration (min. per 2 h) of detailed behaviors starting 30 min after feeding

Measure	Treatment				SE_p	*P* value				
	In-Meal	In-Pellet	Out-Soil	Out-Grass		Treatment effect [a]	In vs. Out [a]	Meal vs. Pellet [a]	In-Meal vs. In-Pellet [a]	Out-Soil vs. Out-Grass [a]
N =	10	10	10	10						
Lying	40.72	66.62	25.37	26.83	9.83	0.019	0.008	0.92	0.071	0.92
Drink	1.30	2.37	3.72	3.22	0.75	0.13	0.037	0.045	0.32	0.64
Postional	4.19	2.19	16.14	12.62	3.07	0.007	0.0008	0.092	0.65	0.42
Sit	0.032	0.39	0	0	0.13	0.10	0.11	0.51	0.055	1.0
Stand	4.15	1.80	9.90	6.58	2.63	0.18	0.053	0.53	0.53	0.37
Head in hut	–	–	4.08	2.66	1.87	0.60	–	–	–	0.60
Walk	–	–	2.16	3.38	0.50	0.10	–	–	–	0.10
Sum Oral/nasal/facial [b]	73.73	48.83	74.73	77.19	9.83	0.16	0.14	0.55	0.082	0.86
Feed	2.43	0.24	0	0	0.96	0.23	0.17	0.042	0.12	1.0
Graze	–	–	–	3.66	1.39	–	–	–	–	–
Mouth [c]	26.99	8.23	33.97	19.24	6.74	0.062	0.19	0.41	0.057	0.13
Bar bite back of mouth	15.99	0.98	–	-5.66	0.077	–	–	0.077	–	–
Bar bite front of mouth	0.54	0.07	–	–	0.33	0.32	–	–	0.32	–
Bite fence, metal	–	–	1.79	3.14	0.75	0.22	–	–	–	0.22
Sham chew	10.45	7.18	32.18	16.11	5.42	0.012	0.0076	0.21	0.67	0.043
Snout [d]	21.45	21.88	39.71	53.31	5.51	0.0004	0.0001	0.012	0.96	0.089
Nose bar with rooting disk	6.65	8.66	–	–	2.91	0.63	–	–	0.63	–
Nose contact with floor	14.81	13.22	–	–	4.96	0.82	–	–	0.82	–
Root	–	–	4.39	5.90	1.49	0.48	–	–	–	0.48
Rooting disk on ground	–	–	35.32	47.41	3.80	0.037	–	–	–	0.037
Top-of-snout [e]	22.87	18.47	1.06	0.98	3.11	0.0001	0.0001	0.0001	0.32	0.99
Lever root	–	–	1.06	0.98	0.54	0.92	–	–	–	0.92
Nose feed trough	21.71	18.00	–	–	4.34	0.55		–	0.55	–
Snout between bars	1.15	0.47	–	–	0.57	0.40	–	–	0.40	–

[a] Overall treatment effects and linear contrasts.
[b] Mouth + Snout + Top-of-snout + Grazing + Feed.
[c] Mouth: Bar bite back + Bar bite front + Bite fence, metal + Sham chew.
[d] Snout: Nose bar with rooting disk + Nose contact with floor + Root + Rooting disk on ground.
[e] Top-of-snout: Lever root + Nose feed trough + Snout between bars.
SE_p is the pooled standard error

Table 9
Summary of treatment effects on frequency of detailed behaviors during 2 h period starting 30 min after feeding

Measure	Treatment				SE_p	*P* value				
	In-Meal	In-Pellet	Out-Soil	Out-Grass		Treatment effect [a]	In vs. Out [a]	Meal vs. Pellet [a]	In-Meal vs. In-Pellet [a]	Out-Soil vs. Out-Grass [a]
N =	10	10	10	10						
Lying	2.5	4.8	1.8	2.1	0.71	0.020	0.022	0.63	0.028	0.77
Drink	5.3	6.9	10.5	11.4	2.17	0.17	0.032	0.095	0.61	0.77
Postional	4.2	2.2	16.1	12.6	3.07	0.007	0.0008	0.092	0.65	0.42
Sit	0.1	0.9	0	0	0.28	0.078	0.080	0.54	0.049	1.0
Stand	8.5	6.4	34.8	33.5	6.12	0.0014	0.0001	0.026	0.81	0.88
Head in hut	–	–	2.7	1.8	0.86	0.47	–	–	–	0.47
Walk	–	–	15	22.4	2.78	0.076	–	–	–	0.076
Sum Oral/nasal/facial [b]	450.2	119.3	190.3	227.2	101.0	0.13	0.46	0.026	0.026	0.80
Feed	0.5	0.3	0	0	0.25	0.42	0.12	0.18	0.6	1.0
Graze	–	–	–	12	3.99	–	–	–	–	–
Mouth [c]	287.6	40.4	77.3	78.6	89.80	0.21	0.34	0.039	0.059	0.99
Bar bite back of mouth	162.4	10.5	–	–	66.55	0.12	–	–	0.12	–
Bar bite front of mouth	5.7	0.5	–	–	2.27	0.12	–	–	0.12	–
Bite fence, metal	–	–	14	23.1	5.49	0.26	–	–	–	0.26
Sham chew	119.5	29.4	63.3	55.5	43.2	0.52	0.73	0.17	0.15	0.90
Snout [d]	103.1	51.0	107.9	128.9	19.49	0.049	0.041	0.75	0.067	0.45
Nose bar with rooting disk	81.9	34.7	–	–	20.34	0.12	–	–	0.12	–
Nose contact with floor	21.2	16.3	–	–	4.84	0.48	–	–	0.48	–
Root	–	–	33.7	39.4	7.98	0.62	–	–	–	0.62
Rooting disk on ground	–	–	74.2	89.5	11.09	0.34	–	–	–	0.34
Top-of-snout [e]	59.0	27.6	5.1	7.7	6.95	0.0001	0.0001	0.0001	0.0029	0.79
Lever root	–	–	5.1	7.7	2.43	0.46	–	–	–	0.46
Nose feed trough	54.9	24.8	–	–	9.20	0.033	–	–	0.033	–
Snout between bars	4.1	2.8	–	–	1.56	0.56	–	–	0.56	–

[a] Overall treatment effects and linear contrasts.
[b] Mouth + Snout + Top-of-snout + Graze + Feed.
[c] Mouth: Bar bite back + Bar bite front + Bite fence, metal + Sham chew.
[d] Snout: Nose bar with rooting disk + Nose contact with floor + Root + Rooting disk on ground.
[e] Top-of-snout: Lever root + Nose feed trough + Snout between bars.
SE_p is the pooled standard error

Table 10
Behavior transitions compared within treatments [a]

Behavior 1	Behavior 2	In-Meal		In-Pellet		Out-Soil		Out-Grass	
		Freq [a]	−/+ [b]	Freq [a]	−/+ [b]	Freq [a]	−/+ [b]	Freq [a]	−/+ [b]
Drink	Lying	0	−	0	−	0		0	
Drink	Postional	18		8	−	28	−	37	−
Drink	Oral/nasal/facial	68		60	+	74	+	77	+
Lying	Drink	1		0		0		0	
Lying	Postional	4	+	7	+	6		7	+
Lying	Oral/nasal/facial	0		4		2		1	
Postional	Drink	5	−	5	−	25	−	33	−
Postional	Lying	0		1	−	3		2	−
Postional	Oral/nasal/facial	45	+	55	+	383	+	403	+
Oral/nasal/facial	Drink	80		61		77		81	−
Oral/nasal/facial	Lying	8		19		8		10	
Oral/nasal/facial	Postional	29	−	45		384		398	
Chi-square value [c]		56.07		68.24		77.78		75.85	

[a] Frequency of transition within treatment, ten sows per treatment group.
[b] Behavioral sequences contributing more (+) or less (−) than expected ($P < 0.05$, 1 df, χ^2) to Chi-square value.
[c] Treatment matrix tested at 5 df (Goodman, 1983), ($P < 0.005$) if chi-square value exceeds 16.7.

behaviors more than outdoor-housed sows (20.67 vs. 1.02, SE 3.11, min. per 2 h, $P = 0.0001$). Table 8 provides a summary of the 2-h duration analyses. The analyses of the frequency data provided the same pattern of results as the duration data (Table 9).

The sequential data analyses for within treatment comparison were significant overall. The results for the analysis of 'all behaviors' (Table 10) indicated that sows in all treatments engaged in the positional to oral/nasal/facial sequence more than expected. Oral/nasal/facial transitions within treatments showed that indoor sows exhibit mouth-to-snout behavioral sequences at rate higher than expected. Outdoor sows showed top-of-snout to snout-based transitions at a rate higher than expected (Table 11).

Table 11
Oral/nasal/facial transitions compared within treatments

Behavior 1	Behavior 2	In-Meal		In-Pellet		Out-Soil		Out-Grass	
		Freq [a]	−/+ [b]	Freq [a]	−/+ [b]	Freq [a]	−/+ [b]	Freq [a]	−/+ [b]
Mouth	Snout	651	+	256	+	419		328	+
Mouth	Top-of-snout	235	−	83	−	5	−	25	−
Snout	Mouth	607		250		390		340	
Snout	Top-of-snout	299	−	134		42		41	−
Top-of-snout	Mouth	302		102		9	−	20	
Top-of-snout	Snout	255		131		32	+	42	+
Chi-square value [c]		64.94		27.82		48.03		36.63	

[a] Frequency of transition within treatment, ten sows per treatment group.
[b] Behavior sequences contributing more (+) or less (−) than expected ($P < 0.05$, 1 df, χ^2) to the overall matrix.
[c] Treatment matrix tested at 1 df (Goodman, 1983), ($P < 0.005$) if chi-square value exceeds 7.88.

Table 12
Behavioral transitions compared among treatments

Behavior 1	Behavior 2	In-Meal Freq [b]	−/+ [c]	In-Pellet Freq [b]	−/+ [c]	Out-Soil Freq [b]	−/+ [c]	Out-Grass Freq [b]	−/+ [c]
Drink	Postional	18	+	8		28		37	
Drink	Oral/nasal/facial	68	+	60	+	74		77	−
Lying	Postional	4		7	+	6		7	
Postional	Drink	5		5		25		33	
Postional	Oral/nasal/facial	45	−	55	−	383	+	403	+
Oral/nasal/facial	Drink	80	+	61	+	77	−	81	−
Oral/nasal/facial	Lying	8		19	+	8	−	10	−
Oral/nasal/facial	Postional	29	−	45	−	384	+	398	+

[a] Overall chi-square value 452.90, 21 df, 2548 transitions ($P < 0.005$).
[b] Frequency of transition within treatment, ten sows per treatment group.
[c] Behavior sequences contributing more (+) or less (−) than expected ($P < 0.05$, 1 df, χ^2) to the overall matrix.

The comparison of behavioral sequences among the treatments showed a significant ($P < 0.005$) chi-square value (Table 12). Sows in the indoor treatment drank then engaged in oral nasal behaviors. Outdoor treatments engaged in positional behaviors

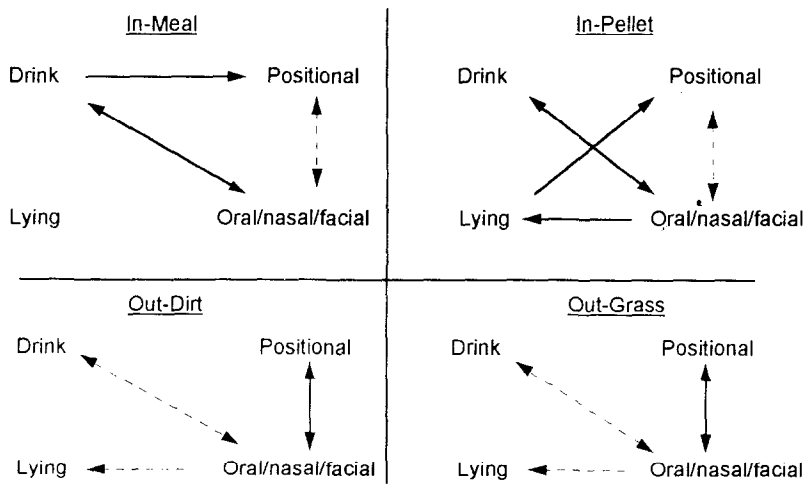

Fig. 2. Combined maintenance and oral/nasal/facial transitions compared among treatments, ten sows per treatment group. Solid lines represent transitions occurring greater than ($P < 0.05$) expected among treatments. Dashed lines represent transitions occurring less than ($P < 0.05$) expected among treatments. Absence of arrow means that possible transition was observed at a frequency not different than due to random chance alone.

Table 13
Oral/nasal/facial transitions compared among treatments

Behavior 1	Behavior 2	In-Meal Freq [b]	−/+ [c]	In-Pellet Freq [b]	−/+ [c]	Out-Sail Freq [b]	−/+ [c]	Out-Grass Freq [b]	−/+ [c]
Mouth	Snout	651	−	256	−	419	+	328	+
Mouth	Top-of-snout	235	+	83	+	5	−	25	−
Snout	Mouth	607	−	250	−	390	+	340	+
Snout	Top-of-snout	299	+	134	+	42	−	41	−
Top-of-snout	Mouth	302	+	102	+	9	−	20	−
Top-of-snout	Snout	255	+	131	+	32	−	42	−

[a] Table tested at 15 df, 4998 total behavior transitions, chi-calculated 501.237 ($P < 0.005$).
[b] Frequency of transition within treatment, ten sows per treatment group.
[c] Behavior sequences contributing more (+) or less (−) than expected ($P < 0.05$, 1 df, χ^2) to the overall matrix.

prior to engaging in oral/nasal/facial activity. Table 12 and Fig. 2 show the pattern of sequential activities for all behaviors among treatments.

Sequential analyses of oral/nasal/facial components among treatments showed differences between the indoor and outdoor treatments. Indoor sows showed higher than expected ($P < 0.05$) mouth and snout to and from the top-of-snout behavioral transitions. Outdoor sows showed higher than expected ($P < 0.05$) mouth to and from snout transitions (Table 13 and Fig. 3). Feeding meal versus pellets to indoor sows or living on

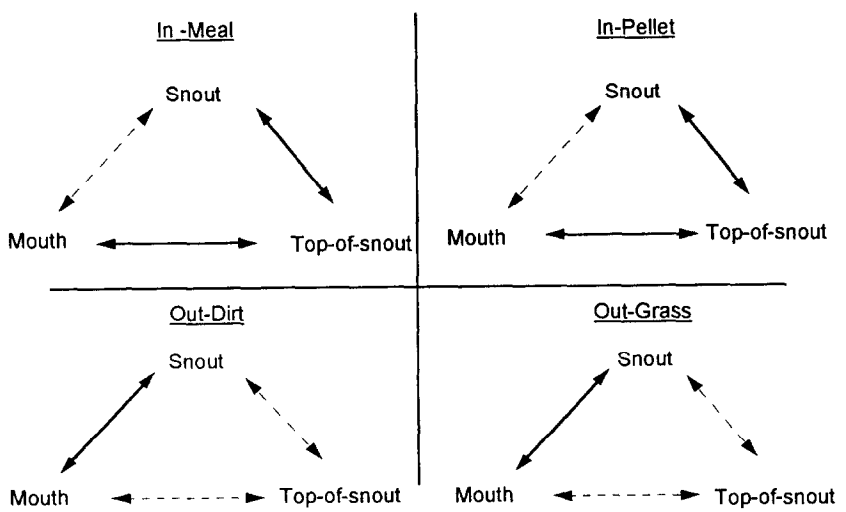

Fig. 3. Oral/nasal/facial transitions compared among treatments, ten sows per treatment group. Solid lines represent transitions occurring greater than ($P < 0.05$) expected among treatments. Dashed lines represent transitions occurring less than ($P < 0.05$) expected among treatments.

soil versus grass to outdoor sows did not influence oral/nasal/facial behavioral transitions.

4. Discussion

Frequency of all active behaviors differed for the 24 h observation among treatments. The decreased overall frequency of activity among In-Pellet sows compared to In-Meal sows (1.61 vs. 2.44, SE 0.268, frequency per h, max. = 12, $P = 0.038$) was clear. A possible explanation for this difference is the different eating sensation with pellets compared to the meal form of rations. Perhaps the sensation of eating the higher density pellet caused reduced activity. Alternatively, the meal form may not have provided enough oral stimulation and this might have led to increased sow activity. Rats show a pattern of polydipsia with the introduction of powered vs. pelleted feedstuffs (Beck et al., 1989). Drinking among the rats was not replaced by another behavior, and it was concluded that feeding activity was reciprocally related to the level of drinking. This same relationship between feeding forms might be true in sows.

The 24-h non-consummatory oral/nasal/facial measures showed no differences in sow behavior among treatments ($P = 0.20$). The lack of a difference between sows in the indoor and outdoor environments ($P < 0.05$) follows earlier work. Barnett et al. (1985) found that sows housed in groups on concrete or soil paddocks showed no difference in inactive or resting or oral/nasal/facial (licking, biting, nosing or chewing pen components or concrete) behaviors during a 48 h period. Barnett et al. (1985) reported results on a 48 h observation based on a 2 day dawn-to-dusk scan sample every 10 min with each observer having a 3 h shift. In contrast our technique was a continuous 24 h observation that scanned every 5 min with 2-h shifts with one observer per treatment.

Outdoor sows exhibited a bimodal pattern of activity. The activity of outdoor sows was higher than that of indoor sows early in the day and later in the afternoon. Indoor sows showed an extended period of activity after feeding compared to the outdoor sows (Table 4). Sows kept outdoors on grass spread total active time over a wider range of time periods than the other sows. Sows kept outdoors on grass showed higher frequency of early morning and late afternoon chewing (Table 5), oral/nasal/facial activities (Table 6), and oral/nasal/facial plus feed and drink combined behaviors (Table 7). Foraging opportunities may be increased due to the availability of earthworms and insects in the Out-Grass treatment. The Out-Soil treatment was only soil, making foraging on transient prey less likely. Without grass or easily chewed bars, sows in Out-Soil seem highly motivated to express oral/nasal/facial behaviors, and showed higher ($P < 0.001$) levels of sham chewing than all other treatments (Table 3). In terms of substrates available for oral/nasal/facial activities, the Out-Soil environment seems the most barren of those systems evaluated.

The intensive study of the 2 h period post-feeding showed no differences in combined oral/nasal/facial frequency or duration of these behaviors among treatments ($P = 0.20$). This agrees with Stolba et al. (1983) who found no difference in redundancy value, essentially a measure of frequency, between indoor-housed and outdoor-housed sows.

The sequential analysis of all behaviors showed differences between the indoor and

outdoor treatments (Fig. 2). Sows housed indoors performed oral/nasal/facial behaviors after drinking, while outdoor-housed sows performed oral/nasal/facial behaviors from positional activities. These transitions could be treatment related as the waterer was in front of the indoor-housed sows at all times. Outdoor sows were able to express a wider range of positional behaviors, such as walking, due to the environment.

The detailed sequential analysis of oral/nasal/facial components also revealed differences between the indoor and outdoor treatments. Oral/nasal/facial stimulation patterns differed among indoor and outdoor sows. Results suggest that sows engage in behavior patterns that provide the greatest stimulation to the oral/nasal/facial region that was the least stimulated by the available substrates within an environment. Outdoor-housed sows stimulated the mouth region the most (they did not have bars to stimulate the mouth). Indoor sows stimulated the top-of-snout region the most (they did not have soil substrate to stimulate the top-of-snout).

Outdoor sows had greater ($P < 0.05$) than expected and indoor sows less ($P < 0.05$) than expected levels of mouth-to-snout transitions (Fig. 3). Outdoor sows, mouth-to-snout transitional behaviors (sham chewing and bite fence/metal to and from root and rooting disk on ground) occurred at a rate higher than expected. The indoor sows showed mouth-to-snout transitional behaviors (bar biting with front or back of mouth to and from nose bar with rooting disk and nose contact with floor) at a rate less than expected. The increased level of mouth-to-snout transitions exhibited by outdoor-kept sows could be related to the lack of substrate (i.e. bars or concrete floor) that stimulates the oral/nasal/facial region indoors.

Indoor sows exhibited a pattern of transitions that stimulated the top-of-snout more ($P < 0.05$) than expected by random chance. Indoor sows' transitional frequency to top-of-snout (nose feed trough, snout between bars) was greater than outdoor-kept sows' (lever root). The soil substrate outdoors differed from the concrete indoors. Increased occurrence of these transitions could be an attempt to compensate for differences in substrate stimulation of skin and neural pathways.

Fraser (1975) reported that sows with straw chewed straw significantly more than those without straw. Sows that did not have access to straw engaged in other oral activities labeled stereotypic due to their repetitive nature. Different housing environments may generate differing forms of motor patterns in sows (Vieuille-Thomas et al., 1995).

There was a tendency for certain activities to occur within a particular context. The different sequential patterns of behavior among treatments found in this study show that sows engage in different activities based upon available substrates.

In conclusion, while the precise substrate may differ depending upon availability, sows on pasture, soil and in gestation crates show similar overall frequencies and duration of stereotyped and non-stereotyped oral/nasal/facial behaviors. Oral/nasal/facial stimulation patterns differ among indoor- and outdoor-kept sows. Sows engaged in repeated behavior patterns that provide the greatest stimulation to the oral/nasal/facial region were least stimulated by the available substrates within an environment. Therefore, these behaviors may be quite natural pre- and post-feeding appetitive and post-consummatory chewing and rooting activities for animals in commercial settings fed a limited ration.

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