https://doi.org/10.17221/25/2020-CJAS

Examination of high-resolution feed intake data of grower finisher pigs confronted with typical short-term disturbances in stable routine

Peter Loibl[1], Wilhelm Windisch[1], Wolfgang Preißinger[2]*

[1]*TUM School of Live Science Weihenstephan, Chair for Animal Nutrition, Technical University of Munich, Freising-Weihenstephan, Germany*
[2]*Institute for Animal Nutrition, Bavarian State Research Center for Agriculture, Grub, Germany*

**Corresponding author: peter.loibl@wzw.tum.de*

Citation: Loibl P., Windisch W., Preißinger W. (2020): Examination of high-resolution feed intake data of grower finisher pigs confronted with typical short-term disturbances in stable routine. Czech J. Anim. Sci., 65: 258–267.

Abstract: Modern pig feeding systems allow the collection of highly detailed feeding data for each animal. These data enable the examination of individual feeding behaviours to assess an animal's wellbeing. As such, four different treatments – undisturbed control, starving (no feed for 24 h, restrictive feeding), feed change (changes in feed composition) and social stress (exchanging of animals between the pens and short-term reduction of accessible water) – were designed to simulate typical short-term disturbances in a practical stable routine. Each treatment was conducted over 2 pens with 12 animals each. Zootechnical performance and feed intake behaviour measures were assessed for each animal. Treatments did not affect zootechnical performance. Results showed that short-term disturbances did not influence feed intake behaviours, such as daily feed intake, amount of intake per feeder visit, number of daily feeder visits and daily feeding action with highest feed intake. Animals developed individual feeding patterns that persisted through artificial short-term disturbances. However, data suggested that an individual animal's behavioural pattern was strongly influenced by the group (pen) due to group dynamics among animals.

Keywords: fattening pigs; feed intake behaviour; single space feeder; feeder visit

Improving animal welfare in agricultural production systems has become increasingly relevant to society and politics over the last decades (Lassen et al. 2006). It is still difficult to evaluate the welfare status of animals quickly at the farm level due to its multifactorial nature (Broom 1988; Hameenoja 2002). In addition to performance and health status, stable hygiene, quality of feed and quality of the pen and stable affect an animal's ability to engage in innate behaviours. Direct measurement of an individual animal's state of wellbeing is difficult with regard to neurological markers, and direct observation of behaviour is thereby a critical component of animal welfare assessment (Veissier and Forkman 2018).

Ongoing structural changes in European pig production have led to increasing herd sizes on farms whilst numbers of supervising staff have remained

Funded by the Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (Bavarian state ministry of food, agriculture and forestry), Project No. A/13/12 „Schweinefütterung – Beiträge zur Tiergesundheit und zum Tierwohl (Versuche, Beratungsoptimierung)“ ["Pig Feeding - Contributions to Animal Health and Animal Welfare (Experiments, Consulting Optimization)"].

https://doi.org/10.17221/25/2020-CJAS

constant or decreased (Eurostat 2019). This has led to a reduced amount of disposable time for animal observation. It has thus become increasingly important to develop an easily accessible measurement system that can be integrated into the daily workflow of the stable without requiring additional time.

Progressive digitalisation has enabled the near real-time assessment of a great deal of data in the modern stable, including air temperature, humidity, water efflux at the drinkers, and physiological measures of individual animals such as rumen pH in dairy cows (Cox 2007). The locomotion of individual animals within a pen can be examined under practical laboratory conditions (Ott et al. 2014), and even the vocalisation of pigs in pens is a viable measure of the animal group's wellbeing (Vandermeulen et al. 2015). The implementation of these data in [semi-]automatic animal welfare assessment systems will be an irreplaceable component of welfare control. However, many of these systems are still under development and will not be available for industrial use for several years.

In the area of pig nutrition, the focus was originally on meeting nutritional requirements to support animal health and performance. Over the course of the past decade, however, behavioural aspects related to nutrition have also aroused interest (Czycholl 2018; Preißinger 2018). Many recent husbandry challenges can be linked to restrictions of innate animal behaviours. The feeding behavioural axis in swine is complex and normally consists of foraging, grazing and some predating (Ballari and Barrios-Garcia 2014). Under natural conditions, pigs spend 6 h to 7 h a day feeding and are not active at night (Signoret et al. 1975). The diets of wild boars are immensely diverse, consisting of herbs and grains, in addition to animal protein (Signoret et al. 1975; Ballari and Barrios-Garcia 2014).

In modern intensive systems, however, pigs are fed highly concentrated, purely vegetarian feed. This has led to reduced feeding times, even under *ad libitum* conditions, with the pig needing other stimuli to fulfil its behavioural needs. The feeding patterns of conventionally housed pigs can provide many behavioural indicators besides the amount of feed intake, such as social status (Nielsen 1999).

Examination of feeding behaviours of pigs in practical housing conditions has historically utilised group-based, long-term data because of typical practical feeding techniques, such as trough feeding. Automatic single space feeders, however, allow the examination of an individual animal's feeding pattern without having to change its housing environment. Every single visit to the feeder by every individual animal is recorded, enabling assessments of feeding patterns of a group of housed pigs on the single day and at the single animal level. The goal of the present study was to evaluate whether group-housed pigs develop individualised constant feeding patterns. Additionally, typical short-term technical disturbances (< 48 h) were simulated to assess whether they altered regular feeding behaviour sustainably. If so, individualised feeding behaviour recording could be an additional indicator of an animal's wellbeing.

MATERIAL AND METHODS

Ethics

The presented experimental protocol was approved by the ethical committee of the Bavarian State Research Centre for Agriculture, Grub, Germany.

Experimental design

A feeding trial using 96 fattening pigs [(German Large White × German Landrace) × Piétrain] was conducted at the experimental site of the Bavarian State Research Centre for Agriculture. One week before the start of the trial, piglets were placed in 8 separate pens (5.0 m × 2.6 m) with fully slatted floors to adapt themselves to the new feeding system.

The animals were distributed equally over the pens considering sex (females to castrated males 1 : 1) and litter (minimally four animals per litter). Each pen contained one single space automatic feeding system (Schauer Compident® MLP). These feeding stations documented the time when an animal entered the feeder and the consumed amount of feed.

For technical reasons, it was not possible to measure the duration of each visit to the feeder. The fatteners were fed three different weight-dependent diets *ad libitum* to meet the following nutritional requirements: starter diet from days 1 to 35; grower diet from days 36 to 63 and finisher diet from day 64 until the end of the experiment. The diets

https://doi.org/10.17221/25/2020-CJAS

were fed dry as coarse meal and consisted of wheat (46–39%), barley (39–46%) and extracted soybean meal (18–12%). A standard macro premix with added synthetic amino acids was supplemented at a 3–2% inclusion rate. These adaptions, according to maturation, led to an analysed energy content of 13.8–13.5 MJ metabolisable energy and a protein content of 16.5–14.3%/kg feed during the fattening progress.

The experiment was designed to simulate short-term disturbances in technical housing management and to measure their possible influences on the animals (Table 1). A pause of 21 days between interferences was considered enough for regeneration. Four experimental groups consisting of two pens each were created:

1. Control: animals experienced no artificial disturbances.
2. Starving: pigs were deprived of feed for 24 h (days 30–31, 12:00–12:00) and restrictively fed (< 1.0 kg/d) for 48 h (days 51–53) to simulate defects in the feeding system. Due to technical reasons the feeders had to be turned off for the 24 h of deprivation.
3. Feed change: Animals were confronted with sudden, short (48 h) changes in feed composition. These were diets consisting only of cereals and macro premix (days 30–32) and the starter diet at the end of the grower phase (days 51–53).
4. Social stress: the fatteners were deprived of water (the efflux of the drinking nipples was reduced from 1.5 l/min to 0.8 l/min for 48 h, days 30–31). Additionally, on day 51, three animals from each pen were exchanged.

From day 77 onwards, animals having grown to 115–120 kg live weight were slaughtered consecutively on a weekly basis. The last animals were slaughtered on day 105.

Obtained parameters

Parameters were measured for each animal individually. In addition to zootechnical performance, weight (kg), daily weight gain (calculated from weekly weighins in g per day), daily feed intake (DFI, kg), feed conversion ratio (FCR, kg feed per kg gain) and meat quality figures [muscle and fat area in cm^2 of the chops, lean meat content in %, measured following the guidelines of the "Central Association of German Pig Production" (Zentralverband der Deutschen Schweineproduktion 2007)] and other parameters of feeding behaviour were obtained from the single space feeders. These included the amount of consumed feed per visit to the feeder (g) and the number of feeder visits per day (n). As the third behavioural figure, the feeding action associated with the most consumed feed (g) was identified for each animal and day. For technical reasons, all feeding events of less than 5 g feed intake were not used for the analyses.

Statistical analyses

The animals were weighed on a weekly basis, and daily weight gain and FCR were calculated on a weekly basis. These data were summarised by individual animal for each fattening period. DFI, feed intake per visit to the feeder, number of daily feeder

Table 1. Experimental design and timetable

Treatment		Control		Starving		Feed change		Social stress	
Pen		1	2	3	4	5	6	7	8
Experimental day	1	start of experiment, starter feed							
	30	–		no feed for 24 h		only cereals and macro-premix for 48 h		reduction of water efflux to 0.8 l/min for 48 h	
	35	change to grower feed							
	51	–		< 1 kg feed per day for 48 h		first period feed fed for 48 h		exchanging of three animals	
	63	change to finisher feed							
	77	start of consecutive slaughtering							
	105	end of the trial							

https://doi.org/10.17221/25/2020-CJAS

visits and feeding action with the highest feed intake were measured individually and summarised by day. The experimental day was the experimental unit. Two different models were designed to analyse the data. Zootechnical performance data were analysed according to the following hierarchical model:

$$y_{ijkr} = \mu + treatment_i + pen_j\ (treatment)_i + + sex_k\ (pen,\ treatment)_{ij} + e_{ijkr} \quad (1)$$

Factors in brackets indicate nested parameters. The factor *sex* (*pen, treatment*) was tested against overall deviation. *Pen* (*treatment*) was tested against *sex* (*pen*, *treatment*) and *treatment* against *pen* (*treatment*).

For feeding behavioural measures, data were analysed only for the first two fattening periods, because the first animals were slaughtered shortly after the switch to the finisher period. This might have led to non-treatment-related effects. The following model was used:

$$y_{ijklr} = \mu + treatment_i + pen_j\ (treatment)_i + sex_k\ (pen,\ treatment)_{ij} + animal_l\ (sex,\ pen,\ treatment)_{ijk} + e_{ijklr} \quad (2)$$

The *animal* (*sex*, *pen*, *treatment*) was then tested against residual deviation, and then the factor *sex* (*pen*, *treatment*) was tested against *animal* (*sex*, *pen*, *treatment*), and so on.

To examine the persistency of feed intake parameters (DFI, feed intake per visit to feeder, number of visits to feeder and feed intake of the most extreme feeding event per day) linear regressions were calculated using individual animal means for the respective fattening period:

$$grower\ period = a + b \times starter\ period \quad (3)$$

SAS v9.4 (SAS Institute, Cary, United States of America) was used for all statistical analyses and graphs. A *P*-value of less than 0.05 was considered statistically significant. Significant differences between pens were identified using the Student-Newman-Keuls test.

RESULTS

One animal was excluded from the trial and analyses due to non-treatment-related reasons.

Zootechnical performance

Table 2 shows zootechnical performance parameters. *Treatment* did not affect any parameter other than FCR and grower periods. *Pen* (*treatment*) had no influence on any parameter. *Sex* (*pen*, *treatment*) was associated with expected differences.

Feed intake measures

Distribution of daily numbers of feeder visits and amounts of consumed feed. Figure 1 shows histograms of the number of visits to the feeder per animal per day and the amount of consumed feed per visit. Median values were 12 visits per day and 105 g of feed per visit, whereas means were approximately 12.5 visits per day and 158.0 g per visit.

Time patterns of assessed feeding behavioural measures. Figure 2 presents feeding measures plotted per pen over the observation period. DFI increased over time in all pens. Feeding behavioural traits differed by pen independently of the treatment group. Pen 2 consistently showed fewer daily visits to the feeder alongside higher feed intake per visit. Similar indications were evident for all pens.

The starving treatment group showed evidence of behavioural impacts from both artificial disturbances. These disturbances directly influenced the amount of ingested feed, and impacts were expected as part of the methodology. All other pens showed fluctuations that were not statistically related to the simulated treatments. By visual judgement, Pen 4 presented the highest fluctuations in DFI and Pen 6 in the amount of consumed feed per visit and feed intake during the feeding action with highest feed intake. Their partner pens did not change patterns.

Examination of grouping factors within the feeding behavioural data. Table 3 shows mean values for feed intake parameters, DFI, feed intake per feeder visit, daily visits to the feeder, and feed intake of the feeding action with highest feed intake. *Treatment* did not affect any of the measurements. *Pen* (*treatment*) significantly influenced feed intake per visit during the starter period, wherein Pens 2 and 3 showed the lowest feed intake per visit at 133 g and 134 g, respectively, and Pen 1 showed the highest average feed intake per visit at 179 g. The pens with the lowest feed intake per visit tended to show an increased frequency

https://doi.org/10.17221/25/2020-CJAS

Table 2. Zootechnical performance results for all eight pens

Treatment		Control		Starving		Feed change		Social stress		overall	SEM	*P*-value		
Pen		1	2	3	4	5	6	7	8			treatment	pen	sex
Animals	*n*	12	12	12	11	12	12	12	12	95	–	–	–	–
Feeding days of an individual animal (d)														
Duration	d	95	97	98	98	92	96	96	94	96	0.91	0.20	0.96	< 0.01
Weight (kg)														
Day 1	kg	40.7	40.3	39.7	40.9	40.3	35.5	41.7	41.1	40.0	0.38	0.34	0.20	0.26
Day 35	kg	71.4	69.7	69.7	70.2	70.9	64.7	70.6	72.2	79.9	0.68	0.53	0.66	< 0.05
Day 63	kg	94.6	93.0	92.3	90.6	96.6	90.5	92.1	96.0	93.2	0.90	0.71	0.82	< 0.01
Final	kg	123.0	117.3	119.1	115.3	119.0	118.0	117.0	119.8	118.6	0.59	0.72	0.58	< 0.01
Daily weight gain (g/d)														
Starter	g/d	879	838	857	838	876	832	827	887	854	12	0.96	0.87	< 0.01
Grower	g/d	827	833	805	727	917	921	768	853	833	13	0.08	0.79	< 0.01
Finisher	g/d	920	734	797	723	786	858	756	802	798	15	0.77	0.21	0.07
Overall	g/d	881	809	825	773	872	879	797	864	838	11	0.38	0.77	< 0.01
Overall feed intake (kg)														
Starter	kg	66.7	64.0	63.1	63.2	62.6	59.0	60.8	66.2	63.2	0.02	0.32	0.92	< 0.01
Grower	kg	64.5	59.8	61.2	54.6	63.1	61.9	59.5	62.9	61.0	0.03	0.28	0.98	< 0.01
Finisher	kg	57.9	50.2	56.5	58.2	47.3	66.1	50.9	50.3	54.6	0.03	0.75	0.90	< 0.01
Overall	kg	189.0	174.0	180.9	176.1	173.0	187.0	171.2	179.4	178.9	0.02	0.48	0.97	< 0.01
Feed conversion ratio (FCR, kg feed intake per kg gain)														
Starter	kg/kg	2.2	2.2	2.1	2.2	2.1	2.0	2.2	2.2	2.1	0.02	< 0.01	0.93	0.52
Grower	kg/kg	2.8	2.7	2.7	2.9	2.5	2.4	2.9	2.7	2.7	0.03	0.03	0.78	0.19
Finisher	kg/kg	3.0	3.2	3.1	3.4	3.2	3.0	3.4	3.3	3.2	0.04	0.49	0.07	0.80
Overall	kg/kg	2.6	2.7	2.6	2.8	2.5	2.5	2.7	2.7	2.6	0.02	0.07	0.30	0.56
Meat quality measures														
Muscle area	cm^2	59	60	60	61	60	62	61	61	61	0.48	0.63	0.90	0.02
Fat area	cm^2	16	14	15	14	15	15	16	16	15	0.28	0.34	0.96	< 0.01
Lean meat	%	60.3	61.3	61.0	61.6	61.0	60.6	60.5	60.1	60.8	0.25	0.33	0.94	0.01

SEM = standard error of the mean

P-values are from hierarchical ANOVA wherein each source of variance was tested against the column on the right; animals were tested against the overall data variation

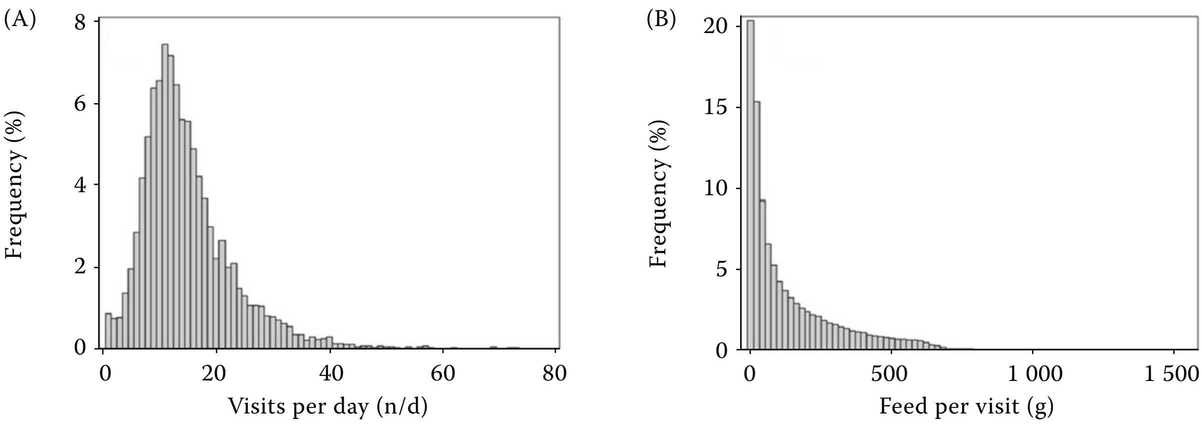

Figure 1. Histograms of the distribution of daily feeder visits per animal (A) and amount of feed consumed per visit (B)

https://doi.org/10.17221/25/2020-CJAS

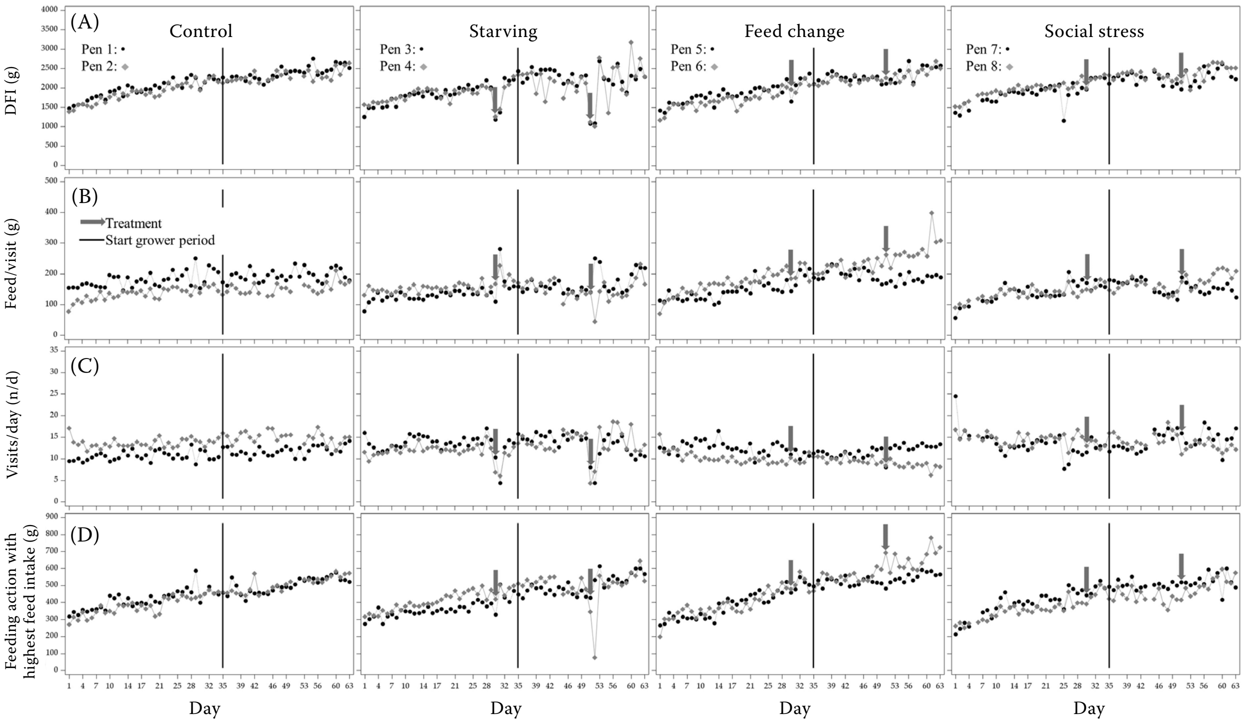

Figure 2. Time series of daily feed intake (A), amount of consumed feed per visit (B), number of daily feeder visits (C) and the feeding action with highest feed intake per day (D); means per animal and day

Table 3. Overall results of feeding behavioural measures (daily feed intake, number of daily visits to the feeder per animal, overall amount of consumed feed per visit and amount of consumed feed of the single visit with highest feed intake per animal and day)

Treatment		Control		Starving		Feed change		Social stress		overall	SEM	*P*-value			
Pen		1	2	3	4	5	6	7	8			treatment	pen	sex	animal
Daily feed intake (kg/d)															
Starter	g	1.9	1.8	1.8	1.8	1.8	1.7	1.8	1.9	1.8	0.01	0.30	0.92	< 0.01	< 0.01
Grower	g	2.3	2.3	2.2	2.1	2.3	2.2	2.2	2.3	2.2	0.01	0.25	0.98	< 0.01	< 0.01
Days 1–63	g	2.1	2.0	2.0	1.9	2.0	1.9	2.0	2.1	2.0	0.01	0.37	0.97	< 0.01	< 0.01
Feed intake per visit (g)															
Starter	g	179[a]	134[e]	133[e]	154[c]	144[d]	165[b]	134[e]	134[e]	145	0.62	0.76	< 0.05	0.48	< 0.01
Grower	g	170	166	175	174	192	211	171	147	174	0.92	0.19	0.14	0.39	< 0.01
Days 1–63	g	186	142	146	151	164	198	143	149	158	0.54	0.48	0.07	0.42	< 0.01
Count of visits to the feeder per animal and day (n/d)															
Starter	n/d	11	14	14	12	12	10	13	14	12	0.07	0.55	0.06	0.40	< 0.01
Grower	n/d	12	14	13	14	12	9	14	13	13	0.08	0.18	0.35	0.25	< 0.01
Days 1–63	n/d	11	14	13	13	12	10	14	14	13	0.05	0.34	0.18	0.23	< 0.01
Feed intake of the most extreme feeding action per animal and day (g)															
Starter	g	416	383	363	413	394	398	396	358	390	1.8	0.79	0.37	0.06	< 0.01
Grower	g	502	495	503	503	534	599	506	461	513	2.1	0.13	0.35	0.21	< 0.01
Days 1–63	g	454	433	425	452	456	487	445	404	445	1.6	0.30	0.49	0.10	< 0.01

SEM = standard error of the mean

P-values are from hierarchical ANOVA wherein each source of variance was tested against the column on the right; animals were tested against the overall data variation; Data shown are LS-means

https://doi.org/10.17221/25/2020-CJAS

of feeder visits (14 per day; $P = 0.06$), although the trend was not statistically significant. Pens with highest feed intake also showed decreased visit frequency (11 visits per day). *Sex* (*pen, treatment*) affected DFI at a rate of around approximately 2.0 kg/d; no other behavioural measures were affected. *Animal* (*sex, pen, treatment*) demonstrated highly significant effects on all measures ($P < 0.01$) throughout the study timeframe.

Regression analyses of feeding parameters. Figures S1 through S4 in electronic supplementary material (ESM) show individual mean values of the assessed feeding behavioural measures. The average standard deviations were around 18.3% for DFI, 90.5% for feed intake per visit to the feeder, 30.2% for the number of daily feeder visits and 23.0% for feeding action with highest feed intake per day, relative to the respective means. This was despite the fact that from visual judgement, means appeared to persist from starter to grower period.

Figure 3 shows the overall regression curves of the means overlaid on scatter plots of individual animals. All parameters showed a high correlation with coefficients of determination ranging from 0.44 to 0.65, upholding this apparent persistency.

DISCUSSION

This study investigated whether short-term technical fluctuations in stable routine altered zootechnical performance, with a focus on highly resolved patterns of an individual animal's feeding behaviour. As such, short-term disturbances were simulated to examine their potential effects on individual daily measures of feeding behaviour.

Zootechnical performance

As expected, *sex* (*pen, treatment*) significantly affected nearly all zootechnical performance parameters, excluding FCR. Literature contends that females and males (castrates) differ in feed intake resulting in differential weight development (Hale and Southwell 1967). Carcass parameters are known to differ between the sexes as well (Cahill et al. 1960).

During the adaptation phase of the study, animals of pen 6 showed a slight delay in learning the feeder, which entailed the well-known phenomenon of compensatory growth with somewhat lower FCRs during the starter and grower period, respectively (Kirchgeßner et al. 2014). Consequently,

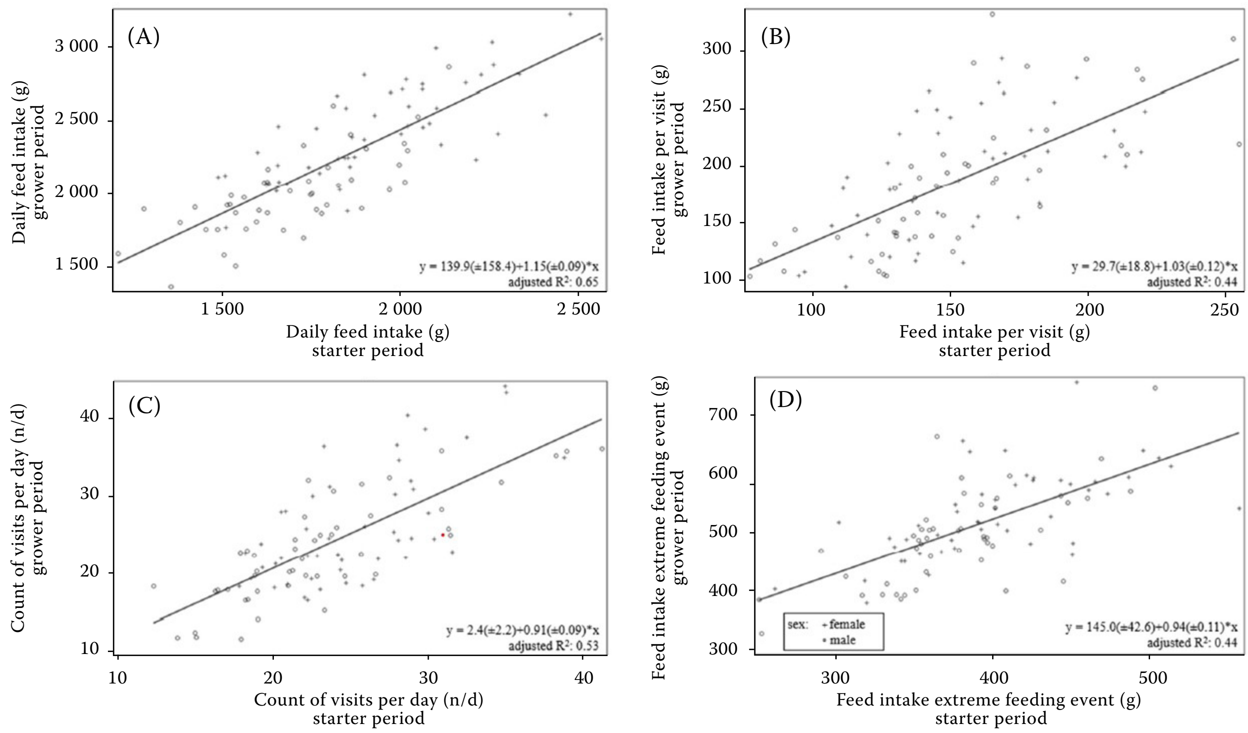

Figure 3. Plots of regression curves for different feed intake parameters. (A) Daily feed intake; (B) Feed intake per visit; (C) Number of visits per day; (D) Extreme feeding events

https://doi.org/10.17221/25/2020-CJAS

the statistically significant effects on FCR observed in the feed change group seem to be artificial in nature. The factors *sex* (*pen, treatment*) and *pen* (*treatment*) did not mediate any deviation in FCR. Female pigs generally show the same FCR as males (Hale and Southwell 1967). In total, short-term disturbances were found to have little to no effect at all on zootechnicaldata.

Feeding behavioural measures

Several reports examining group-housed grower/finisher pigs fed by similar feeding techniques described similar feeding behavioural traits (Nielsen et al. 1995; Nielsen 1999; Kallabis and Kaufmann 2012). Another study (Nielsen et al. 1995) found that the pigs visited the feeder approximately 13 times per day, consuming similar amounts per visit.

Several methods for the examination of feeding behaviour have been published. Ethologists often use so-called 'meal criteria' for different species as the basis for their examinations (Tolkamp et al. 1998; Yeates et al. 2001). In assessing the duration of single feeding actions, a maximum pause based on the distribution of 'non-feeding time' is defined to summarise several feeding actions regarding a single meal. These datasets are compressed and can be more easily examined for rhythmicity, among other parameters, in time series analyses (Shono et al. 2000) or other statistical method. In the present study, the feeders did not document the lengths of these pauses. This is due to practical conditions, as the feeders used recorded only time of entering the feeder and amount of feed consumed. We thereby decided to investigate different deviation factors to determine which factor was causing the observed differences.

Animal (*sex, pen, treatment*) was the predominant source of variation regarding all feed intake measures. This parameter was highly significant over all four feeding parameters indicating strong behavioural differences between the individual animals. *Sex* (*pen, treatment*) was also significant regarding DFI, as discussed above. The feeding actions with highest feed intake also varied by *sex* (*pen, treatment*) (starter period, $P = 0.06$; days 1–63, $P = 0.10$), indicating that the different sexes may have different maximum feed intake capacities. This phenomenon may also be explained by the slower growth seen in female fatteners that could underlie their lower feed intake potential (Cole et al. 1968).

Highly individualised feeding behaviours led to somewhat significant differences caused by *pen* (*treatment*) (feed intake per visit to the feeder in the starter period, $P < 0.05$; days 1–63, $P = 0.07$; number of feeder visits in the starter period, $P = 0.06$). The pen is equivalent to the feeder in this trial. Schamun and Hoy (2011) combining similar single space feeders with ethological analysis revealed that the group of fatteners within a pen developed a 'group' behaviour based on the constant behaviour of an individual pig that was presumably linked to the animal's rank within the group. Group dynamics may thereby affect other present findings. Highly individualised feeding behaviour led to immense variation among animals. Despite a range of mean values per pen [e.g., the lowest daily feeder visit mean in the grower period was 9 (Pen 6), and the highest was 14 (Pens 2, 4 and 7)]; however, no significant influence of *pen* (*treatment*) was found.

Across the two examined feeding periods, the number of daily feeder visits remained constant whilst feed intake parameters increased. Only Pen 6 showed a reduction in the number of daily visits. This is also indicative of effects on the group behaviour caused by an individual in each group. Additionally, the animals appeared to react to increasing energy requirements over the course of maturation by increasing feed intake per visit rather than frequency of visits. Another report (Schamun and Hoy 2011) found similar results.

The development of feeding behavioural parameters over time (Figure 2) was constant within a given pen over time. By visual judgement, the starving group appeared to be slightly affected by 48 h of restrictive feeding. After day 53, the mean DFI in Pen 4 began to fluctuate significantly. The effect of 24 h of deprivation was not visible, however. Since the feeders were turned off to starve the animals, it could not be monitored if the animals tried to feed. Also, possible short-term increases in feed intake of individual animal following the starving period could not be identified as statistically relevant. All the other groups remained on a constant course of increasing DFI after each short-term disturbance.

Looking at the standard deviations (Figures S1–S4 in ESM), detailed feeding parameters were found to diverge immensely, in part due to high day-to-

https://doi.org/10.17221/25/2020-CJAS

day fluctuation in measured parameters within individual animal data. This resulted in poor predictability of these measurements. The exchange of animals did not lead to drastic changes in feeding behaviour, an unexpected result. Establishment of a new hierarchy within pig groups takes around 48 hours (Ewbank 1976). However, no drastic changes were visible in feeding behaviour even over this short timeframe.

The short-term disturbances simulated in the present study were insufficient to alter long-term feeding behaviours, and observed differences disappeared among the daily variation of the assessed parameters.

Regression analyses

Although individual animals showed significant day-to-day variation in their feeding behaviours, the means of the assessed factors remained similar throughout the starter and grower periods (Figures S1–S4 in ESM). We thereby calculated linear regressions for these measures to assess their persistency (Figure 3). Altogether, the slopes of the regression curves were significantly different from 0. An overall R^2 of 0.40–0.60 indicated that an individual animal's feeding behaviour persisted over the two feeding periods. However, due to the large daily variation in examined parameters, longer examination periods will be needed to assess any correlations.

One study (Schamun and Hoy 2011) showed that fatteners presented rank-dependent feeding patterns. High-ranking animals showed a significantly lower feeding frequency with significantly higher feed intake per feeder visit. From the regression curves shown in Figure 3 one might assume that a similar situation was observed in the present study.

However, due to the paucity of visual data, an individual animal's rank could not be conclusively determined. The same study (Schamun and Hoy 2011) also showed that due to rather constant hierarchy maintenance (R^2 = 0.61), all other traits, visits within 48 h and feed intake per visit remained constant throughout the fattening period. In the present study, since *animal* (*sex, pen, treatment*) was found to be the only significant parameter affecting feeding behaviour, a constant hierarchy within the groups could be a major reason for this result. The short-term disturbances in this case did not alter the system sustainably. As such, the assessment of feeding patterns of individual animals does not appear to be a viable welfare indicator, as in this study it was not sensitive enough to show an effect.

CONCLUSIONS

The present study found that group-housed fattening pigs receiving feed from automatic single space feeders developed discrete individual feed intake behaviours. Individual parameters of feed intake per day, number of daily feeder visits, feed intake per visit and feeding action with highest feed intake per day were largely constant over time. The individual animal was the dominant factor that influenced these parameters. For DFI, sex was also found to have a significant influence. However, not even drastic short-term changes in stable routine such as exchanging a set of animals between pens significantly affected feeding behaviour.

Since individual feeding behaviour is consistent yet dispersive over time, the simulated artificial short-term (max. 48 h) disturbances in stable routine did not produce any sustained effects. As such, feeding patterns of group-housed pigs are not an effective early warning system for short-term fluctuations in behaviour caused by technical problems.

Overall, pigs appear to quickly develop complex social structures and ranks within a group of animals that persist despite exogenous short-term impairments.

Therefore, an animal group (in the present study, the animals housed in a single pen) seems to be the most suitable unit to study feeding behaviour documented by feeders.

Acknowledgement

The authors wish to thank the technical staff of the LVFZ Schwarzenau research station for all their practical on-site support during the trial.

Conflict of interest

The authors declare no conflict of interest.

https://doi.org/10.17221/25/2020-CJAS

REFERENCES

Ballari SA, Barrios-Garcia MN. A review of wild boar Sus scrofa diet and factors affecting food selection in native and introduced ranges. Mam Rev. 2014 Apr;44(2):124-34.

Broom DM. The scientific assessment of animal welfare. Appl Anim Behav Sci. 1988 Jul 1;20(1-2):5-19.

Cahill VR, Teague HS, Kunkle LE, Moxon AL, Rutledge EA. Measurement of and ways of affecting sex-influenced performance of growing-finishing swine. J Anim Sci. 1960 Nov 1;19(4):1036-40.

Cole DJA, Duckworth JE, Holmes W. Factors affecting voluntary feed intake in pigs – 3. The effect of a period of feed restriction, nutrient density of the diet and sex on intake, performance and carcass characteristics. Anim Sci. 1968 Nov;10(4):345-57.

Cox S. Precision livestock farming'07: Papers Presented at the 3rd European Conference on Precision Livestock Farming, Skiathos, Greece, 3–6 June 2007. Wageningen Academic Pub; 2007.

Czycholl I. The role of fibre with respect to feeding behaviour. Proceedings of the Conference of the Society of Nutrition Physiology, March 13th to 15th, 2018. Göttingen; 2018. p. 193-5.

Eurostat. Agriculture, forestry and fishery statistics. Luxembourg; 2019.

Ewbank R. Social hierarchy in suckling and fattening pigs: A review. Livest Prod Sci. 1976 Dec 1;3(4):363-72.

Hale OM, Southwell BL. Differences in swine performance and carcass characteristics because of dietary protein level, sex and breed. J Anim Sci. 1967 Mar 1;26(2):341-4.

Hameenoja P. Animal health and welfare – Pig production. Acta Vet Scand Suppl. 2002 Mar 1;95:33-6.

Kallabis KE, Kaufmann O. Effect of a high-fibre diet on the feeding behaviour of fattening pigs. Arch Tierzucht. 2012 Oct 10;55(3):272-84.

Kirchgeßner M, Stangl G, Schwarz FJ, Roth FX, Sudekum KH, Eder K. Tierernährung [Animal nutrition]. 14th ed. Frankfurt: DLG-Verlag; 2014. German.

Lassen J, Sandoe P, Forkman B. Happy pigs are dirty! – Conflicting perspectives on animal welfare. Livest Sci. 2006 Sep 1;103(3):221-30.

Nielsen BL. On the interpretation of feeding behaviour measures and the use of feeding rate as an indicator of social constraint. Appl Anim Behav Sci. 1999 Mar 1;63(1):79-91.

Nielsen BL, Lawrence AB, Whittemore CT. Effects of single-space feeder design on feeding behaviour and performance of growing pigs. Anim Sci. 1995 Mar;61:575-9.

Ott S, Moons CPH, Kashiha MA, Bahr C, Tuyttens FAM, Berckmans D, Niewold TA. Automated video analysis of pig activity at pen level highly correlates to human observations of behavioural activities. Livest Sci. 2014 Feb 1;160:132-7.

Preißinger W. Dietary fiber displaces no concentrated feed and makes pigs less aggressive. Proceedings of the Conference of the Society of Nutrition Physiology, March 13th to 15th, 2018. Göttingen; 2018. p. 196-200.

Schamun S, Hoy S. Untersuchungen zum Futteraufnahmeverhalten von Mastschweinen an einer elektronischen Abrufstation unter Berücksichtigung der Rangordnung [Investigations on feed intake behaviour of fattening pigs fed at an electronic feeding station taking into account the rank order]. Züchtungsk. 2011;83(6):426-38. German.

Shono M, Shono H, Ito Y, Muro M, Maeda Y, Sugimori H. A new periodogram using one-way analysis of variance for circadian rhythms. Psych Clin Neurosci. 2000 Jun; 54(3):307-8.

Signoret JP, Baldwin BA, Fraser D, Hafez ESE. The behaviour of swine. In: Hafez ESE, editor. Behaviour of domestic animals. London: Baillière Tindall; 1975. p. 295-329.

Tolkamp BJ, Allcroft DJ, Austin EJ, Nielsen BL, Kyriazakis I. Satiety splits feeding behaviour into bouts. J Theor Biol. 1998 Sep 21;194(2:235-50.

Vandermeulen J, Bahr C, Tullo E, Fontana I, Ott S, Kashiha M, Guarino M, Moons CPH, Tuyttens FAM, Niewold TA, Berckmans D. Discerning pig screams in production environments. PLoS One. 2015 Apr 29;10(4):e0123111.

Veissier I, Forkman B. The nature of animal welfare science. Annu Rev Biomed Sci. 2018 Dec 1;10:T15-T26.

Yeates MP, Tolkamp BJ, Allcroft DJ, Kyriazakis I. The use of mixed distribution models to determine bout criteria for analysis of animal behaviour. J Theor Biol. 2001 Dec 7; 213(3):413-25.

Zentral Verband der Deutschen Schweineproduktion. Richtlinie für die Stationsprüfung auf Mastleistung, Schlachtkörperwert und Fleischbeschaffenheit beim Schwein [Guidelines for station testing of growth, carcase worth and meat quality of pigs]. 2007. German.

Received: February 7, 2020
Accepted: June 30, 2020