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Performance, lean meat proportion and behaviour of fattening pigs given a liquid diet at different animal/feeding-place ratios

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Abstract

Sensor feeding is a liquid feeding system for fattening pigs that is operated with a restricted animal/feeding-place ratio (AFR). The aim of the present study was to quantify the effect of three different AFRs (4:1, 7:1 and 13:1, calculated with a feeding space of 33 cm per animal) on the performance and behaviour of fattening pigs (mean initial weight 26·3 (s.d. 3·3) kg, live weight at slaughter 102 (s.d. 5) kg). The pigs were housed in groups of 40 and each AFR was tested with seven groups (21 groups in total). The daily weight gain of the individual pigs was calculated from the beginning of the experiments until slaughter. Additionally, the lean meat percentage was recorded (AutoFOM). Feeding behaviour was observed by means of 24-h video recording at the ages of 14 and 17 weeks with scan sampling every 5 min.

The daily weight gain decreased with increasing AFR ($P < 0{\cdot}01$) and females had lower weight gains than barrows ($P < 0{\cdot}001$). The lean meat proportion was influenced by the AFR ($P < 0{\cdot}01$) and sex of the pigs ($P < 0{\cdot}001$). Proportions were highest with the AFR 13:1 and in females. The average number of pigs feeding simultaneously was highest for the AFR of 4:1 ($P < 0{\cdot}01$). Moreover, the ingestion rate per day (kg/min) increased with increasing AFR ($P < 0{\cdot}05$). The average number of pigs waiting behind other pigs feeding at the trough was highest with the AFR 13:1 ($P < 0{\cdot}001$).

In conclusion, growth performance and pig behaviour were negatively affected by an AFR of 13:1, which cannot be recommended for use with this feeding system. With an AFR of 4:1 lean meat values were low.

Keywords: *fattening performance, feeding behaviour, liquid feed dispensers, pigs, space requirements.*

Introduction

Various new feeding systems have been developed over the past few years, including sensor-controlled feeding, where the animals are given a liquid diet. With this feeding system, the liquid level in the trough is registered by a sensor and the trough is automatically refilled if empty. Unlike *ad libitum* feeding systems with dry food, sensor feeding occurs at distinct periods and the trough is left empty in between these periods. The total amount of food provided per day is usually at the upper limit of the pigs' consumption capacity and is equivalent to the amount of dry matter for *ad libitum* dry feeding. Sensor-controlled liquid feeding is operated with a restricted animal/feeding-place ratio (AFR).

Restriction of feeding places may lead to competition for food, resulting in lower weight gains or more variation in weight between individuals (Hansen *et al.*, 1982; Petherick and Blackshaw, 1987; Gonyou and Stricklin, 1998; Botermans and Georgsson, 2001; Georgsson and Svendsen, 2001; Turner *et al.*, 2002). With dry feeding systems, restricted feeding leads to higher lean meat proportions compared with *ad libitum* feeding (Cameron, 1990; Ramaekers *et al.*, 1996; Kirchgeβner, 1997; Oksbjerg *et al.*, 2002).

Besides performance, the behaviour of the pigs is altered by increased competition. The duration of feeding bouts is reduced (Rasmussen *et al.*, 2006) and the pigs' ingestion rate is increased (Walker, 1991; Nielsen and Lawrence, 1993). Moreover, the individuals show more aggressive interactions at the feeding trough (Morrow and Walker, 1994; Kircher, 2001) and spend more time waiting to get access to the trough (Walker, 1991; Rasmussen *et al.*, 2006). Botermans and Georgsson (2001) also observed that an increased AFR was associated with more feeding at night, especially by the subordinate individuals. The effects of a restricted AFR on the performance and behaviour of fatteners may be different for dry and liquid feeding systems.

Liquid feeding systems differ from dry feeding systems in many respects. The pigs need more time to consume the same amount of digestible energy in the form of a liquid diet compared with a dry diet. They consume larger volumes of food and a satiation feeling may be reached sooner. This is dependent, though, on the water to food ratio of the liquid food and therefore on how fluid it is.

How sensor-controlled liquid feeding affects the fattening pigs' performance has been measured in only a few descriptive studies (e.g. Hügle and Heege, 1989; Marks *et al*., 2002). In these experiments, the influence of different AFRs on performance was not studied, neither was the pigs' behaviour. The aim of the present study was to investigate the effect of a wide range of AFRs (4:1, 7:1 and 13:1) on the weight gain, lean meat proportion and behaviour of fattening pigs. It was hypothesized that the daily weight gain would decrease and the lean meat proportion increase with increasing AFR. Additionally, more crowding at the feeding trough was expected with increasing AFR.

Material and methods

Animals and housing

The experiment was performed with 840 fattening pigs (Swiss Large White) kept in 21 groups of 40 pigs. The groups were formed when the individuals weighed 26·3 (s.d. 3·3) kg and the pigs remained in the same pen until slaughter at 102 (s.d. 5) kg. They were housed in identical pens with a floor area of 44·4 m^2 (for further details, see Rasmussen *et al*., 2006). The feeding trough was attached to a wall so that the pigs could feed from one side only. Groups were balanced with regard to age, weight and sex (females, barrows). The variation in initial weight within each group was kept as low as possible (s.d. 3·3 kg) by selecting pigs of approximately the same weight from a larger number of fattening pigs of similar age.

Feeding

The pigs had *ad libitum* access to dry feeding before introduction to the fattening facility. In the fattening facility, sensor-controlled liquid feeding was used and the pigs were fed in five feeding periods per day (07:30, 10:30, 15:00, 18:00 and 21:00 h). During a given feeding period the pigs in all four pens in the experimental stable (see below) were given food and these periods lasted 15 to 80 min. The food level in the trough was checked automatically six times during each period by two sensors positioned 3 cm above the bottom of the trough. When the food level was lower than the position of the sensors this was reported to the computer and the trough was replenished with freshly mixed food. The amount of food delivered was independent of the level of food left in the trough below the 3 cm limit. No food was delivered between feeding periods, even when the trough was empty. The pigs were fed in three growing phases with the digestible energy content in the dry matter of the feed being increased from 15·4 MJ/kg (days 1 to 76) to 15·5 MJ/kg (days 77 to 91) and 15·6 MJ/kg (day 92 until slaughter). At the same time, the protein content was decreased (Table 1). The food-to-water ratio was 1:3 and this was controlled throughout the experiment.

Table 1 *Composition of the experimental diet (in grams of dry matter)*

	Growing phases		
	Days 1–76	Days 77–91	Day 92 until slaughter
Crude protein	204·7	187·0	181·2
Crude fibre	41·3	40·9	40·8
Lysine	13·13	11·07	10·40
Calcium	11·4	10·9	10·7
Phosphorus	6·2	5·8	5·7

Experimental design

Three different AFRs were used (4:1, 7:1 and 13:1, corresponding to a trough space per pig of 0·75, 0·5 and 0·25 cm, respectively). The troughs comprised nine (trough length: 3 m), six (trough length: 2 m) and three (trough length: 1 m) feeding places, respectively, corresponding to a feeding space of 33 cm per individual pig at the end of the fattening period. The troughs had no dividers between feeding places. The amount of liquid food delivered to the trough on a given occasion varied with trough length and was 40 (4:1), 30 (7:1) and 20 kg (13:1) per delivery. Shorter troughs were, however, refilled more often, resulting in a similar amount of food delivered per day irrespective of the AFR.

The experimental stable contained four identical pens. Every 4th week, new groups of pigs (replicates) were introduced to these pens and stayed until slaughter. The allocation of the AFR to the pens was randomized and each AFR was replicated seven times (21 groups in total). Consequently, the whole experiment was carried out in six batches with two to four groups in each batch. To exclude a bias due to seasonal effects, replicates for each AFR were distributed over the year (see Table 1, Rasmussen *et al*., 2006).

Performance

The amount provided (food + water) was recorded daily by the feeding computer for each pen, from the day of introduction of the pigs into the pen until slaughter at an average weight of 102 (s.d. 5) kg. The feeding mixer consisted of a scale, where the exact amount (kg) of food and water could be controlled and the scale was calibrated at intervals. The pigs were individually weighed every 2nd week. From these data, the average daily weight gain and the within-pen variation in daily weight gain were calculated. In addition, the lean meat proportion of each individual was recorded at slaughter using AutoFOM (fully automatic ultrasonic carcass grading, SFK Technology A/S), a technique based on a fully automatic 3-D ultrasound scanning of carcasses (Brøndum *et al*., 1998).

Behavioural observations

Each group was observed by means of video for one 24-h period each when the pigs were 14 and 17 weeks of age. Feeding behaviour was registered using scan sampling at 5-min intervals. For each scan, the following behaviours were recorded: (1) feeding (number of pigs with their heads in the trough simultaneously); (2) waiting (number of pigs standing behind the trough with body contact with feeding pigs and with their heads facing the trough). The ingestion rate per day (kg/min per pig) was calculated from the total amount of food provision per individual on the observation day divided by the average number of simultaneously feeding pigs per min in the scan samples on the same day.

Statistical analysis
Taking into account that repeated measurements were used, all the data were analysed using linear mixed-effects models in S-Plus ('lme' method in S-PLUS® 6·1 for Windows; Pinheiro and Bates (2000)). For the performance parameters, the fixed effects were AFR (factor), sex (factor) and amount (kg) of food provision (amount of liquid food provided per individual per day) (continuous). For the behavioural parameters, the fixed effects were AFR and age. All two-way interactions between these factors were considered as well. Random effects of the intercept were included for the individuals nested in groups nested in batches. These were adjusted according to the level at which the response variable was collected, either individual level (individual nested in groups nested in batches) or group level (group nested in batches). The parameters of daily weight gain and lean meat proportion were at the individual level and the rest at group level: food provision, feeding, within-group variation in weight gain, ingestion rate, waiting. To avoid masking of variation between individuals by averaging, data were used in the statistical analysis on the same level (individual, group) as they were collected. Nesting of individuals within groups was explicitly included in the mixed-effects models. Assumptions regarding the mixed-effects models were checked graphically, i.e. residuals and random effects were plotted to assess normality and homoscedasticity. In case of deviations from the assumptions, data were transformed logarithmically (within-group variation in weight gain, ingestion rate, waiting).

Results

The average food provision per individual for the whole fattening period varied from 11·0 (s.e. 0·5) (4:1) to 10·4 (s.e. 0·5) (7:1) and 9·6 (s.e. 0·5) kg/day (13:1) and was not significantly affected by AFR. With increasing AFR, the average daily weight gain decreased significantly from 918 (s.e. 17) (4:1) to 883 (s.e. 13) (7:1) and 817 (s.e. 18) g/day (13:1) ($P < 0{\cdot}01$, $F_{2,8} = 17{\cdot}9$). This effect was evident in both sexes (Figure 1) but barrows grew better than females ($P < 0{\cdot}001$, $F_{1,790} = 69{\cdot}93$). Moreover, there were minor interactions between AFR and sex (AFR:sex; $F_{2,790} = 3{\cdot}2$, Figure 1) and AFR and food provision ($P < 0{\cdot}05$, $F_{2,8} = 6{\cdot}2$), with food provision not systematically increasing or decreasing weight gain with increasing AFR.

Carcass weight varied between 79·1 (s.e. 0·5) (7:1) and 80·8 (s.e. 1·1) kg (4:1). It was not affected by AFR but was higher for barrows ($P < 0{\cdot}001$, $F_{1,718} = 12{\cdot}08$). The duration of the fattening period increased significantly with increasing AFR from 81·2 ± 3·5 (4:1) to 87·0 (s.e.1·8) (7:1) and 94·1 (s.e. 3·1) days (13:1) ($P < 0{\cdot}01$, $F_{2,8} = 12{\cdot}5$). Additionally, females reached slaughter weight later than barrows ($P < 0{\cdot}001$, $F_{1,718} = 41{\cdot}0$).

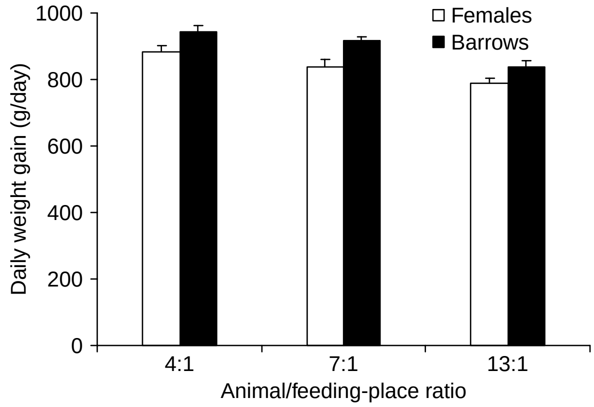

Figure 1 Average daily weight gain (±s.e.) of fattening pigs of different sex given food at different animal/feeding-place ratios.

Mortality percentage throughout the fattening period was 2·5 (s.e. 0·8) (AFR 4:1), 2·1 (s.e. 1·1) (AFR 7:1) and 1·4 (s.e. 0·7)% (AFR 13:1), i.e. seven, six and four individuals, respectively. There was no significant difference in mortality between AFRs.

The average within-pen variation in weight gain of the different AFRs was 0·09 (s.e. 0·01) (4:1), 0·10 (s.e. 0·01) (7:1) and 0·11 (s.e. 0·01) (13:1) and was not affected significantly by AFR, sex or food provision.

The lean meat proportion was influenced by AFR with individuals at 13:1 having the highest proportion ($P < 0{\cdot}01$, $F_{2,8} = 10{\cdot}3$, Figure 2) but not by food provision. Additionally, higher lean meat proportions were observed in females than barrows ($P < 0{\cdot}001$, $F_{1,718} = 17{\cdot}0$).

The number of pigs feeding simultaneously in a given scan sample varied between 0·5 and 1·7 individuals and was highest for the AFR 4:1 ($P < 0{\cdot}01$, $F_{2,12} = 8{\cdot}2$, Table 2). Simultaneous feeding was clustered at the feeding periods and some pigs also visited the trough during the night (Figure 3). Moreover, the number of pigs feeding simultaneously was higher in the 14-week-old than in the 17-week-old pigs ($P < 0{\cdot}001$, $F_{1,17} = 33{\cdot}7$, Table 2).

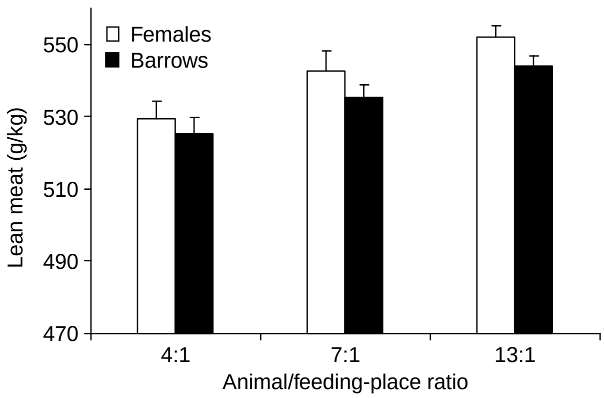

Figure 2 Average lean meat proportion (±s.e.) of fattening pigs of different sex given food at different animal/feeding-place ratios.

Table 2 *Average number (over 24 h) of fattening pigs feeding simultaneously or waiting behind the feeding trough in a given scan sample at different ages and different animal/feeding-place ratios (AFR)*

		AFR						Significance	
		4:1		7:1		13:1			
	Age	Mean	s.e.	Mean	s.e.	Mean	s.e.	AFR	Age
Feeding simultaneously	14 weeks	1·4	0·10	1·2	0·10	1·0	0·10	**	***
	17 weeks	1·2	0·10	1·0	0·10	1·0	0·10		
Waiting behind the trough	14 weeks	0·7	0·10	0·8	0·10	1·4	0·20	***	
	17 weeks	0·6	0·05	0·7	0·10	1·5	0·20		

The ingestion rate was influenced by both AFR and age, with individuals at the AFR 13:1 ($P < 0{\cdot}05$, $F_{2,12} = 5{\cdot}4$, Figure 4) and at the age of 17 weeks ($P < 0{\cdot}001$, $F_{1,17} = 33{\cdot}7$) having the highest ingestion rates. The number of pigs waiting behind other pigs feeding at the trough in a given scan sample varied between 0·3 and 2·1 individuals, with the highest values observed at AFR 13:1 ($P < 0{\cdot}001$, $F_{2,12} = 25{\cdot}4$, Table 2), irrespective of age.

Discussion

An increased AFR had a significant negative effect on daily weight gain, indicating greater competition for food, as has also been reported by Hicks *et al.* (1998), Turner *et al.* (2002) and Rasmussen *et al.* (2006). In our study, there was no within-pen variation in the daily weight gain between AFRs. Other studies have found contradictory results for this measurement. Walker (1991), Botermans and Svendsen (2000) and Kircher (2001), as in our study, found no change in the within-pen variation in daily weight gain for *ad libitum* dry-fed fattening pigs with restricted feeding space, whereas Hansen *et al.* (1982) and Georgsson and Svendsen (2001) observed a greater variation between group members. Our findings indicate that the distribution of food intake over the individuals of a given group was similar in groups given food at different AFRs and that the lower weight gain observed with increased AFR could have resulted from a poorer utilization of food because of competition-induced stress (Hyun *et al.*, 1998).

The lean meat proportion was influenced by AFR with individuals at 13:1 having the highest proportion. Other studies with dry *ad libitum* feeding and a restricted number of feeding places found no effect of the AFR on the lean meat proportion (Hansen *et al.*, 1982; Walker, 1991). The lean meat proportions of most pigs fed at the AFR 7:1 or 13:1 in our study were within the quality range defined for Switzerland (lean meat proportion 540 to 595 g/kg: bonus on meat price; lean meat proportion 530 to 540 or 595 to 610 g/kg: normal prices; lean meat proportion <530 or >610 g/kg: reduction in meat price; Proviande, 2003). However, for many of the individuals fed at the AFR 4:1 the price of the meat was reduced due to the low lean meat proportion. Usually, fattening pigs are given food at a restricted level at the end of the fattening period to prevent them becoming too fat (Thomke *et al.*, 1995; Kirchgeβner, 1997; Botermans and Svendsen, 2000), whereas in the present study the pigs were given food at the upper limit of their consumption capacity over the whole fattening period. This, together with the less restricted AFR 4:1, could explain the low lean meat proportion of the individuals from these groups.

The effects of a restricted AFR on lean meat proportion were most pronounced in females, as has also been observed in various other studies with dry feeding systems (Cameron, 1990; Thomke *et al.*, 1995; Kirchgeβner, 1997). In a study with sensor-controlled liquid feeding, the average daily weight gain was 817 g/day for groups of 10 individuals with a trough length between 100 and 160 cm (Hügle and Heege, 1989). However, this resulted in a low average lean meat proportion which was most pronounced for barrows.

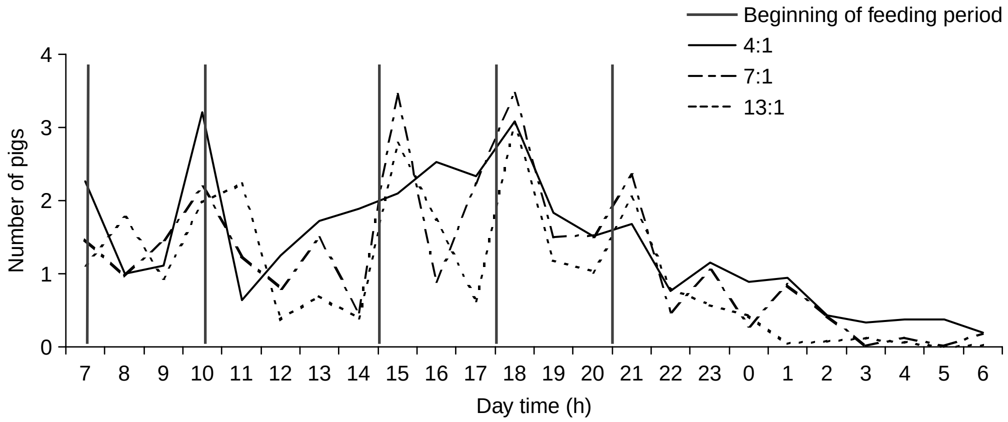

Figure 3 Occupation of the feeding trough by fattening pigs given food at different animal/feeding-place ratios at 17 weeks of age. Average number (per h) of pigs feeding simultaneously in scan samples recorded at 5-min intervals.

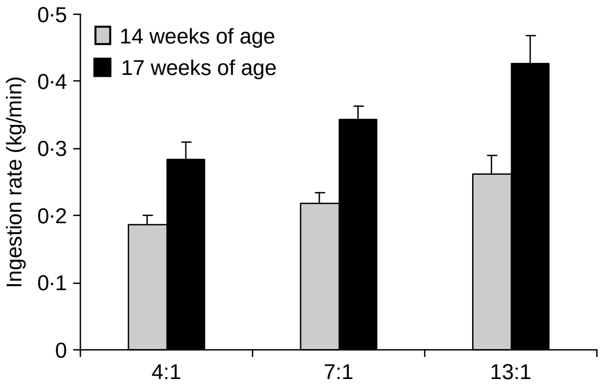

Figure 4 Average ingestion rate (± s.e.) of fattening pigs given food at different animal/feeding-place ratios at different ages.

In the present investigation, weight gain was high but within the range of the results found in other studies with both liquid and dry *ad libitum* feeding systems. For example, Hansen *et al.* (1982) and Kircher (2001), investigating weight gain of fatteners given *ad libitum* dry feeding at restricted AFRs ranging from 5:1 to 10:1, reported values varying between 670 and 876 g/day. With regard to sensor-controlled liquid feeding it has been stated that daily weight gain is higher compared with *ad libitum* dry feeding systems (Hügle and Heege, 1989), and Marks *et al.* (2002) reported values from 850 and 900 g/day. However, in this latter study too, the pigs were too fat at slaughter.

The average number of pigs feeding simultaneously decreased with increasing AFR and, in parallel, the ingestion rate increased. Nielsen and Lawrence (1993) and Nielsen (1999) also observed that pigs in groups with strong competition at feedings increased their ingestion rate. In our study, fewer pigs were feeding simultaneously at the age of 17 weeks than at 14 weeks. This was expected, as 17-week-old pigs are bigger and need more space at the trough. Probably also due to increased competition, the ingestion rate was higher for 17-week-old pigs. An increase in the ingestion rate with the age of the pigs was also found by Fàbrega *et al.* (2003). The method used in our study to calculate the ingestion rate was not very accurate, but was identical for every treatment (AFR), thus allowing a comparison between the treatments.

Studies with dry feeding systems have shown that the amount of time a feeder was occupied by feeding pigs during the day was higher with increased AFR (Kircher, 2001; Botermans and Svendsen, 2000). This was not observed in our study, as the trough was usually emptied soon after the end of a feeding period, especially for the AFR 13:1. Therefore, no food was available until the beginning of the next feeding period. Comparing the behaviour of fattening pigs given food by dry feeders with different AFRs, Botermans and Georgsson (2001) and Kircher (2001) also observed more pigs feeding at night with an increased AFR. Such a pattern could not be found in the present study with sensor-controlled liquid feeding. This is explained by the fact that there was no feeding at night.

One could expect the number of pigs waiting behind the trough without feeding to increase linearly with increasing AFR. Contrary to expectation, the average number of pigs waiting behind the feeding trough was almost the same for AFR 4:1 and 7:1, but increased for AFR 13:1. This suggests that first at this AFR, the pigs were markedly disadvantaged, as they had to wait longer to eat.

In conclusion, the results of the present study show that an AFR of 13:1 has marked negative effects on the performance and behaviour of fattening pigs given food via sensor-controlled liquid feeding. With an AFR of 4:1 lean meat proportion was low. Thus, from a production point of view an AFR of 7:1 can be recommended, whereas an AFR of 13:1 is not suitable for this feeding system because of low weight gains.

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