CONTROL OF INDIVIDUAL DAILY GROWTH IN GROUP-HOUSED PIGS USING FEEDING STATIONS

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Peter J.L. Ramaekers

Proefschrift

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STELLINGEN

Voorhandweging (methode waarbij het varken alleen met de voorpoten op een kleine weegschaal staat) is een goede methode voor het bepalen van het individuele lichaamsgewicht bij in groepen gehuisveste vleesvarkens. (Dit proefschrift)

Door gebruik van informatie over de gewichtsontwikkeling van varkens tijdens de groeiperiode wordt het produktiedoel beter bereikt. (Dit proefschrift)

De variatie in spekdikte tussen dieren bij 60 kg lichaamsgewicht geeft aan dat voerstrategieën voor vleesvarkens in een eerder stadium van de mestperiode moeten worden geïmplementeerd. (Dit proefschrift)

Er is een duidelijk verband tussen het aantal maaltijden per dag en karkaskenmerken bij gelijke voer-energieopname per dag. (Dit proefschrift)

Toename van het aantal maaltijden per dag per dier (nibblers) leidt waarschijnlijk tot vleesvarkens met een verhoogde onderhoudsbehoefte. (Dit proefschrift)

De benaming voerstation suggereert ten onrechte dat het station de varkens voert. Afhaalstation (McPig) zou een betere benaming zijn!

In het spraakgebruik kan de term "forelegs weight" gemakkelijk verward worden met "four legs weight". "Front legs weight" zou dan beter gebruikt kunnen worden.

Het overplaatsen van biggen is het beste bewijs, dat het grootbrengen van biggen door zeugen "teamwork" is.

Het kengetal "voerkosten per kg vleesgroei" geeft een beter inzicht in de vleesproduktiekosten dan het kengetal "voerkosten per kg groei".

Dier-identificatie en schaalvergroting zijn niet tegenstrijdig.

Motorrijders die te kort door de bocht gaan, bijten vroeg of laat in het stof.

Peter J.L. Ramaekers
Control of individual daily growth in group-housed pigs using feeding stations.
Wageningen, 20 november 1996

Abstract

Control of individual daily growth in group-housed pigs using feeding stations

Peter J.L. Ramaekers, 1996.

In this thesis, it was examined whether it is possible to control individual daily growth and carcass composition in group-housed pigs using feeding stations. A forelegs weighing system to estimate the daily individual body weight (BW) of group-housed pigs was developed and validated. In two experiments, BW dependent feeding strategies in the finishing period were examined in relation to performance and carcass traits. In Exp. 1, the daily energy allowance of barrows was restricted to 18 MJ ME per day above maintenance. In Exp. 2, barrows were restricted to a feeding level at which their growth was similar to the mean growth of a group of *ad libitum* fed gilts. In Exp. 1, feed restriction improved lean meat tissue percentage with 2.6 units. In Exp. 2, feed restriction resulted in a similar growth as the *ad libitum* fed gilts, but gave no improvement of the lean meat tissue percentage. In both experiments, feed restriction decreased the between animal variance in energy intake, but not in energy conversion ratio, growth or lean meat tissue percentage. In addition to energy intake, carry-over effects from the growing period and number of meals per day of *ad libitum* fed pigs explained part of the variance in lean meat tissue percentage. In conclusion, feeding stations and forelegs weighing devices can be used to control individual daily growth and carcass traits of group-housed pigs. However, the variance in performance and carcass traits was not only related to the variance in energy intake.

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Contents

GENERAL INTRODUCTION

Introduction

In the Netherlands, injectable transponders are proposed to identify growing-finishing pigs from birth to slaughter as part of a nation wide identification and registration program (Odink, 1991). In the production chain, transponders can be used as means of identification for slaughter and weighing regulations, integrated quality control, and breeding programmes (Huiskes, 1991). Transponders can provide the farmer with the opportunity to monitor production, i.e., feed intake and body weight development (Huiskes, 1991).

Pig growth models derive growth and growth composition from the level and properties of nutrient intake (Moughan and Verstegen, 1988). The main assumption in growth models is that energy is used for three processes: maintenance, protein deposition and lipid deposition. Although maintenance and growth (additions of protein, fat, water and ash) are continuous processes of anabolism and catabolism, they can be considered independently (De Greef, 1995). Requirements for maintenance have priority and are strongly related to the metabolic body weight of the pig (ARC, 1981). The remaining nutrient intake is used for processes associated with growth. Protein growth or protein deposition in the pig's body is limited by amino acid intake, energy intake, the genetic protein deposition capacity of the pig (Campbell, 1988) and/or the environment (e.g. climate, health and housing).

In practice, feeding strategies focus on optimizing lean tissue gain in relation to carcass fatness. Following the linear plateau concept, the optimal feeding strategy maximizes protein deposition combined with a minimum lipid deposition rate. If the marginal ratio between extra lipid deposition and extra protein deposition is considered too high, the optimal feeding strategy will change (De Greef, 1992). To control growth and growth composition of pigs, the pig's body weight, and the individually energy and nutrient intake should be measured and controlled throughout the growing-finishing period (De Greef, 1992). Group housing increases variation in feed intake compared with individual housing (De Haer, 1992).

Using feeding stations and automatic weighing devices, individual feeding schemes for group-housed pigs can be used to achieve the preset production goals. Feed intake and body weight of group-housed pigs should be measured automatically and should mimic a practical situation, i.e., which allows competition at the feeder. Devices to monitor the individual feed intake of group-housed pigs were described in several studies (Berberich, 1988; Slader and Gregory, 1988; De Haer et al., 1992). Techniques to measure the individual body weight of group-housed animals automatically without isolating the animal from its penmates were described by Schofield (1990) for pigs and Engelhardt (1990) for veal-calves.

The overall objective of the research addressed in this thesis is to examine whether it is possible to control individual daily growth and carcass composition in group-housed pigs using feeding stations. More specific the objectives were:

1) to evaluate the perspective of forelegs weighing for monitoring body weight,
2) to examine the effect of body weight dependent feeding schemes on performance and carcass traits.

Based on the results of the experiments with the body weight dependent feeding schemes, a third objective was added:

3) to study the effect of feed restriction on eating traits and on their relation with performance and carcass traits.

In testing these hypotheses, the applicability of electronic identification will be demonstrated. Moreover, the biological aspects of the animal growth (protein and fat) will be quantified using a pig growth model (Van der Peet-Schwering et al., 1994).

Outline of this thesis

In chapter 1, technologies for automatic weighing of group-housed pigs are reviewed as described in literature. Special attention was paid to the forelegs weighing method and the method of estimating the body weight from a computerized foto image of the pig's back surface area. An experiment was conducted to evaluate the use of a forelegs weighing system for automatic determination of individual body weights of group-housed pigs. The development and validation of a forelegs weighing system as a device for automatic weighing of individual pigs are described in chapter 2. This system enables automatic monitoring of individual body weights of group-housed pigs.

In chapters 3 and 4, two different feeding strategies in the finishing period (55 - 110 kg BW) were examined in relation to performance and carcass traits.

In chapter 5, the effect of feed restriction on eating behaviour is examined. In chapter 6, the relation between eating behaviour, and performance and carcass traits is studied. In the general discussion, the use of feeding stations and forelegs weighing in combination with electronic identification to control performance and carcass traits of group-housed pigs is evaluated.

References

ARC, 1981. The nutrient requirements of pigs. Technical review by an ARC Working Party. Farnham Royal, Slough, Commonwealth Agricultural Bureaux, 307 pp.

Berberich, R., 1988. Die automatische Wägung wachsender Schweine als element der rechnergestützten Prozeßsteuerung. PhD Thesis University, Gießen, Germany, 196 pp.

Campbell, R.G. 1988. Nutritional constraints to lean tissue accretion in farm animals. Nutr. Res. Rev., 1:233-253.

De Greef, K.H., 1992. Prediction of production, nutrition induced tissue partitioning in growing pigs. PhD Thesis, Agricultural University, Wageningen, The Netherlands, 117 pp.

De Greef, K.H., 1995. Prediction of growth and carcass parameters. In : P.J. Moughan, M.W.A. Verstegen and M.I. Visser-Reyneveld (Eds), Modelling growth in the pig. EAAP Publication No. 78, Wageningen Press, Wageningen, The Netherlands, p 151-163.

De Haer, L.C.M., 1992. Relevance of eating pattern for selection of growing pigs. PhD Thesis, Agricultural University, Wageningen, 159 pp.

De Haer, L.C.M., J.W.M. Merks, H.G. Kooper, G.A.J. Buiting and J.A. Van Hattum. 1992. A note on the IVOG®- station: a feeding station to record the individual feed intake of group housed growing pigs. Anim. Prod., 54:160-162.

Engelhardt, K.M., 1990. Experimentelle Untersuchungen zur automatisierten Tiergewichtserfassung bei Milchkühen, Mastbullen und Aufzuchtkälbern. PhD Thesis Technical University, München, Germany, 222 pp.

Huiskes, J.H., 1991. The use of electronic identifcation in breeding and fattening management of pigs. In: E. Lambooij (Ed.), Automatic electronic identification systems for farm animals. Proc. of a seminar in the Community programme of research and technological development, Brussels 17-19 October, 1990, p 68-72.

Moughan, P.J. and Verstegen, M.W.A, 1988. The modelling of growth in the pig. Neth. J. Agric. Sci., 36:145-166.

Odink, B.J., 1991. Organisatorische en infrastructurele aspecten van electronische dierherkenning. In: Texas Instruments (Ed.), Symposium over Elektronische Dierherkenning in de Praktijk, oktober 31 1991, Scheveningen, The Netherlands, p 12-23.

Schofield, C.P., 1990. Evaluation of image analysis as a means of estimating the weight of pigs. J. Agric. Eng. Res., 47: 287-296.

Slader, R.W. and Gregory, A.M.S., 1988. An automatic feeding and weighing system for ad libitum fed pigs. Comput. Electron. Agric., 3:157-170.

Van der Peet-Schwering, C.M.C., Vos, H.P.J.M., Van der Peet, G.F.V., Verstegen, M.W.A., Kanis, E., Smits, C.H.M., De Vries, A.G. and Lenis, N.P., 1994. Informatiemodel Technisch Model Varkensvoeding (TMV). Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.117, 126 pp.

Chapter 1

Modern techniques for automatic determination of individual body weight of group-housed growing-finishing pigs

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Abstract

The body weight of a growing-finishing pig is an important trait to determine time of slaughter and to derive data on growth and feed to gain ratio. It is also an important indicator for controlling individual feeding schemes for group-housed animals. To determine the mean pig's daily body weight accurately, the pig should be weighed several times per day. An automatic weighing system consisting of a weighing device, an electronic identification system and a data recording and analysis system are used to monitor the pig's body weight. Two modern techniques used to estimate the body weight of pigs are: 1) video image analysis and 2) forelegs weighing. Studies with video image analysis have shown that it is possible to measure the top view area of group-housed pigs automatically. With the pig's top view area (without head and neck), the pig's body weight can be estimated with a deviation of less than 5% of the actual body weight. Studies with cattle suggest that forelegs weighing systems can be used to estimate the individual body weight of group-housed pigs. Studies of eating and drinking behaviour of pigs have shown that at the feeder there is more time available to record weighing data than at the drinker.

Introduction

In practice, growing-finishing pigs are housed in groups. Most farmers in the Netherlands with growing-finishing pigs use the all-in all-out management system (IKC, 1991). Studies have shown that the all-in all-out management system is the most economic way of pig production (Arkes et al., 1986; IKC, 1991). However, the system has some disadvantages (Giesen et al., 1988). The occupation rate is low, because pigs in a compartment are delivered to the slaughter house in more than one batch. Otherwise the carcass weight of some pigs will not be within the weight range (73 - 93 kg) that pays the highest price per kg carcass weight. Although most farmers deliver their pigs in two or three batches, 15% of the pigs slaughtered in 1991 were not within the carcass weight range that pays the highest price per kg carcass weight (Dutch Product Board for Livestock and Meat, 1992). Using an automatic weighing system, the percentage of pigs delivered within the optimum carcass weight range could be improved. Jørgensen (1993) estimated that the economic value of an improved weighing precision of an automatic weighing system was about 0.5 Dutch Guilder per delivered pig.

Furthermore, pigs with high carcass weights tend to have low percentages of lean meat. One extra percentage lean meat in the pig's carcass has a value of about four Dutch Guilders per pig.

Although pigs have similar weights at the beginning of the growing-finishing period, differences in growth and growth composition resulting from differences in feed intake and feed efficiency occur during the growing-finishing period. Monitoring the pig's body weight (BW) development with an automatic weighing system could be a useful tool to improve performance by controlling the feed intake (Schofield, 1990).

Metabolizable energy of feed is used for processes associated with maintenance and growth. The energy requirement for maintenance is associated with the pig's metabolic BW (ARC, 1981). Methods for predicting growth and growth composition of growing-finishing pigs are reported by Cöp (1974), Whittemore (1983), Campbell et al. (1985) and De Greef (1992). However, individual housed pigs were used in these studies. De Haer (1992) found that housing pigs individually or in a group influenced their performance. She described a feeding station to record the individual feed intake of group-housed pigs during the growing-finishing period. In addition, measuring the individual BW of group-housed pigs, not only feed intake, but growth, feed efficiency and growth composition could also be estimated (De Greef, 1992).

In this review two weighing systems that can measure individual BW of growing-finishing pigs housed in groups are discussed.

Weighing pigs during the growing-finishing period

Frequent manual weighing of pigs (daily or weekly) during the growing-finishing period is not a common procedure, even on experimental farms. The weighing takes too much time and labour and there is a risk of harmful stress and injuries to the pigs (Turner and Cox, 1983).

The BW of an animal varies within a day due to feed and water intake, gut and bladder fill, and manure production in pigs (Berberich, 1988) and cattle (Engelhardt, 1990). In calves of about 90 kg, Engelhardt (1990) found that the minimum and maximum BW could vary up to 3 kg within a day (Table 1). Between two successive days, the BW of an animal, measured at approximately the same time of the day, could vary up to 2 kg (Table 1). Measuring the BW once weekly manually, a part of the variation in BW gain could be the result from differences in gut fill and bladder fill, and/or weighing errors. In cattle, it was shown that the BW of an animal could be determined more precisely by measuring BW several times a day (Engelhardt, 1990). Therefore, automatic weighing of pigs in the pen may improve the accuracy of measuring BW (Turner and Cox, 1983).

Table 1. Variation of body weight of a rearing calf during two successive days (adapted from Engelhardt, 1990).

day 1		day 2	
hour	body weight (kg)	hour	body weight (kg)
01:02	98.7	00:04	97.9
01:56	97.0	00:38	97.5
06:09	97.3	04:04	97.3
06:28	98.6	05:25	96.0
14:18	98.0	05:40	95.5
14:39	97.2	07:40	97.0
15:04	97.2	10:41	97.9
15:34	99.1	13:02	97.4
17:32	98.8	13:43	96.9
18:03	100.4	14:24	97.0
21:09	97.9	15:39	99.0
		23:22	97.3
		23:36	97.2

Automatic weighing systems

Automatic weighing systems for individual farm animals are already implemented on broiler farms. Hughes and Elson (1977) and Turner et al. (1984) described weighing devices for poultry. In these systems, weighing balances are placed above the floor of the pen. Every time a broiler perches on the balance BW, date, and time are recorded without identifying the individual animal. The results of Hughes and Elson (1977) showed that there are differences in number of perches on the balances among broilers. However, the mean BW of the birds that used the balance was similar to the mean BW of all birds in the pen.

Turner and Cox (1983) concluded that weighing systems that record the BW of an animal without identification, are not useful for group-housed pigs, because each pig is weighed at different frequency. Compared with poultry, the number of pigs per pen is small and the between animal variation in BW is large. Therefore, to get a reliable estimate of the mean body weight of group-housed pigs, an electronic identification system in addition to an electronic balance, and a data recording and analysis system is needed (Engelhardt, 1990).

Electronic identification

In the future pigs in the Netherlands will probably be identified by electronic devices based on injectable transponders as part of the nation wide identification and registration program (Odink, 1991). The nation wide introduction of the injectable transponder is delayed, due to the cost for injection on the piggery, the percentage of transponders lost and the removal time on the slaughter line (Langeveld et al., 1993). On cattle farms, collar-borne electronic identification devices are used widely as part of concentrate feeding systems.

Walk-through weighing systems

Walk-through weighing systems are described for cows (Filby et al., 1979; Peiper et al., 1987; Long et al., 1991a; Long et al., 1991b). When a cow walks over the balance, for example after milking, the BW is measured and recorded together with the electronic identification number (Filby et al., 1979; Peiper et al., 1987). Furthermore, Long et al. (1991a) have described a walk-through weighing system with separation for cattle, in which each animal is identified and weighed individually after separation. Measuring the BW of growing-finishing pigs in a similar way is not practical, because a walk-through weighing system demands too much space in the pen. On pig farms, the walk-through weighing system could be used outside the pen for weighing pigs at the start and the end of the growing-finishing period.

Measuring the pig's BW in the pen

Within a pen, a balance can be best placed adjacent to the feeder or drinker (Bockfisch et al., 1991). At these locations, each pig can be weighed several times per day. Furthermore, the eating and drinking pig is not restless during the weighing process.

De Haer (1992) studied the eating patterns of group-housed growing-finishing pigs that had ad libitum access to feed in single space feeders. Her results presented in Table 2 show that the

mean number of visits and the visiting time per pig to the feeder were 14.4 visits per day and 63.5 minutes per day, respectively, during the growing-finishing period. The mean number of visits to the feeder decreased from about 25 per day per pig in the first month to about 10 per day per pig at the end of the growing-finishing period. The mean daily visiting time per pig decreased from about 70 minutes to about 50 minutes during the growing-finishing period (De Haer, personal communication, 1992). The standard error of the eating frequency was 0.9. This supports the conclusion of Turner and Cox (1983) that it is necessary to identify the pigs individually due to the differences in eating frequency per day among pigs (Table 2).
The results of Nielsen and Lawrence (1993) are similar to the results of De Haer (1992) (Table 2).

Table 2. Feed intake characteristics of group-housed growing-finishing pigs (between brackets standard error)

	De Haer (1992)	Hammell and Hurnik (1987)	Nielsen and Lawrence (1993)
Sexe	boars and gilts	gilts	boars
n (pigs)	240	48	30
Pigs per pen	8	4	10
Production performance			
Body weight range (kg)	25 - 100	48 - 90	35 - 57
Feed intake (kg/day)	2.1	2.1	1.6
Behavioural activities			
Eating time (minutes/day)	63.5 (2.4)	52.5 (1.3)	61.4
Eating frequency (visits/day)	14.4 (0.9)		13.6
Drinking time (minutes/day)		14.0 (0.6)	

Hammell and Hurnik (1987) found that eating and drinking times for growing-finishing gilts that had free access to feed and water were on average 53 and 14 minutes per pig per day, respectively (Table 2).

The mean visiting time to the feeder was about 4.5 minutes per visit (Hammell and Hurnik, 1987; De Haer, 1992). Results of a 24-hour trial (15 pigs) of Schofield (1993) showed that the mean visiting time to the drinker was about 40 seconds per visit.

From the available literature it can be concluded that the mean visiting time per visit to the feeder of a growing-finishing pig is about six to seven times longer than to the drinker. It is not known whether there is a difference in restlessness between eating and drinking behaviour.

Based on the time per visit, a balance can be best placed adjacent to the feeder.

Estimating BW of group-housed pigs

A disadvantage of measuring the pig's whole BW is that the pig should be separated from it's penmates. This can be done by fences, which are adjustable in length and in width. The adjustable fences are important to ensure that only one pig uses the balance at a the same time and that the pig stands on the balance with all four legs (Berberich, 1988; Slader and Gregory, 1988). However, the fences and the balance take up a large area of the pen and are, therefore, less suitable to determine the individual BW of growing-finishing pigs housed in groups.

To overcome the space requirement, two devices were developed that estimate the individual BW of group-housed animals: video image analysis (Schofield, 1990; Minagawa and Ichikawa, 1994) and forelegs weighing (Stanzel and Emberger, 1987; Engelhardt, 1990).

Video image analysis

The first attempts to use video image analysis to estimate the pig's BW were made by Schofield (1990). He discarded bad video images manually and used a linear regression equation to predict the pig's BW from the pig's top view area (Table 3). His results show that from 83% of the images, the pig's BW could be determined from the pig's top view area (without the areas of head and neck) within ± 5% of the actual BW.

Minagawa and Ichikawa (1994) used an allometric regression equation to estimate the pig's BW from the top view area of the pig (head and neck included). The allometric regression equation was based on an ASAE (1988) study that showed nonlinear relations between the length, height and width of the pig and its BW. The top view areas of 33 pigs (Figure 1), in the BW range of 7 to 120 kg increased from about 500 to about 5000 cm^2 (Minagawa and Ichikawa, 1994). They obtained a 99.9% coefficient of determination of the variance (R^2) in pig's BW with a standard error of 0.9 kg (Table 3).

Minagawa et al. (1993), obtained with an allometric equation a R^2 of 99.6% and a standard error of 2.4 kg (Table 3). Minagawa et al. (1993) found differences in the relationship between BW and the top view area among pig breeds.

Table 3. Regression equations for calculating body weight (BW, kg) from the top view area (A, cm^2).

Regression equation	R^2	se[1]	n (pigs)	breed[2]	Author(s)
BW = 0.0438 x A - 35.65	0.97		7	nr	Schofield (1990)[3]
$BW = (0.0065 \times A)^{1.328}$	0.996	2.4	54	HA	Minagawa et al. (1993)
$BW = (0.005 \times A)^{1.495}$	0.999	0.9	33	DL	Minagawa and Ichikawa (1994)

1 standard error (se) in kg,
2 nr = not reported, DL = Landrace x Duroc and (Large White x Landrace) x Duroc, HA = Large White x Hampshire, Landrace x Hampshire and (Large White x Landrace) x Hampshire,
3 Top view area of the pig without the areas of neck, head and ears.

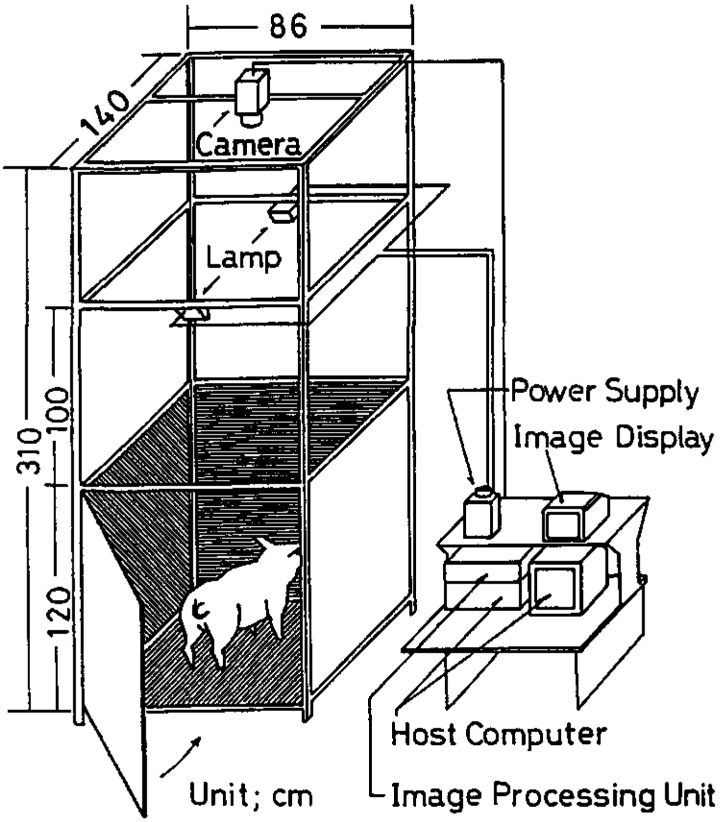

Fig. 1. System for taking projected image area of a pig with a video camera from above (adapted from Minagawa and Ichikawa, 1994)

Schofield (1990) and Ali (1993) found that the variation of the top view area among images of the same pig can be diminished when the areas of neck and head were omitted. Differences in the top view area among breeds as found by Minagawa et al. (1993) may result from differences in the top view areas of the neck and head among breeds. When the camera is placed above the feeder area, video images of the top view area of the eating pig could be made without the pig's head and neck. More research is needed to examine the effect of the neck and head area on the relationship between the pig's top view area and the pig's BW.

For a 24 hours automatic video image analysis system it is important that there is a clear contrast between the pig view and the floor area (Schofield, 1990; Minagawa and Ichikawa, 1994). Placing the video camera above the feeder or drinker area, the camera angle, focus, and lighting could be optimised to achieve good images (Schofield, 1993). The pig's behaviour may be disturbed with too much light (Schofield, 1993). Schofield (1993) collected images of satisfactory quality at an illumination level (at camera location) of 2.2 cd/m^2, using a low light (4 lx) CCD video camera. Pigs of non monochrome breeds may give problems to achieve a clear contrast between the pig and its background (Minagawa and Ichikawa, 1994).

Video camera image analysis technique, in combination with electronic identification, could be used to estimate the individual BW of growing-finishing pigs housed in groups (Minagawa et al., 1993). The camera does not come in contact with manure, pigs or cleaning water, which warrants a long durability of the equipment. For commercial use, the camera could be mounted on a rail and could move from pen to pen. It is not known how often the camera lens needs to be cleaned when it is used on commercial farms.

Some video images obtained from pigs housed in groups are difficult to process automatically. Indistinct or incomplete boundaries result from shadows, overlapping, and touching pigs (Marchant and Schofield, 1993). Results of Marchant and Schofield (1993) and Davis and Marchant (1993) show that the outlining of the pig's top view area could be improved using a snake image processing algorithm. However, some outliers may still be included. When a sufficient number of video images per pig are obtained during each visit to the feeder or drinker, it should be possible to erase these outliers using statistics (Ali, 1993). To capture and process an image for estimating the pig's BW, approximately eight seconds are needed (Schofield, 1993). This means that both the drinker and the feeder are suitable places to obtain several images per visit.

Forelegs weighing

A balance that measures forelegs weights has several advantages over a whole BW balance (Figure 2). These advantages are:

- The balance and the fences can be made smaller (Stanzel and Emberger, 1987).
- The implementation in the pen is easier, because the balance needs little space (Stanzel and Emberger, 1987).
- The dimensions of the balance are independent of the length of the animal (Stanzel and Emberger, 1987). When the pig is in an eating or drinking position, the distance from the pig's forelegs to the feeder or drinker changes only slightly during the growing-finishing period (ASAE, 1988).
- The risk of errors due to build up of manure on the balance is minor.

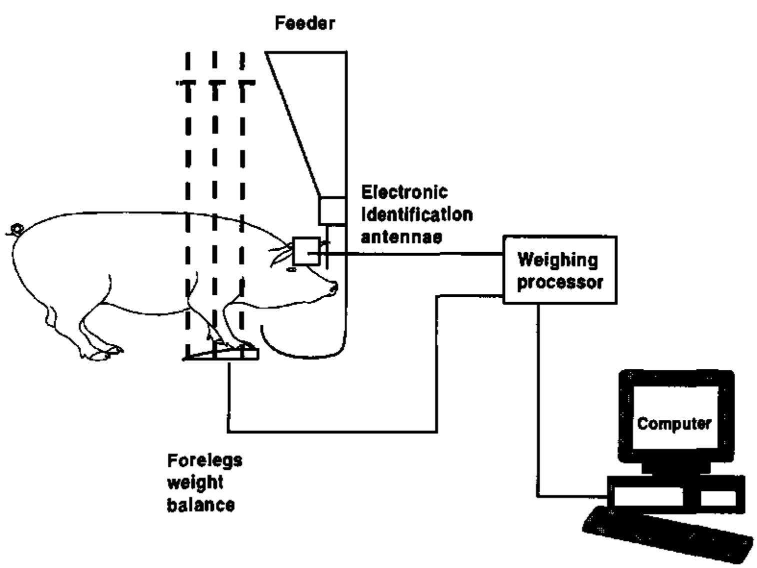

Fig. 2. Forelegs weighing system in front of a feeder

Geyer (1979) estimated ratios of 0.563 (sd = 0.029) and 0.556 (sd = 0.023) between the forelegs weight and the BW of about 45 growing-finishing pigs at a BW of about 50 and 90 kg, respectively (Table 4). The BW and forelegs weights were measured manually using a balance.

Table 4. Ratio between forelegs weight (FW) and body weight (BW) in pigs

Ratio of FW/BW	n (pigs)	BW (kg)	breed[1]	Author(s)
0.563	44	ca. 50 kg	GL	Geyer (1979)
0.556	48	ca. 90 kg	GL	Geyer (1979)
0.35 - 0.55	12	ca. 70 kg	nr	Sharp and Turner (1985)

[1] GL = German Landrace, nr = not reported.

Sharp and Turner (1985) examined the ratio between forelegs weight and BW of 12 growing-finishing pigs on two days. The forelegs weight was measured while a pig was standing at the drinker using an automatic weighing system. Body weight was measured manually using a weighing crate, on the day before the forelegs weights were measured. Among a group of pigs, the ratio between the forelegs weight and the BW ranged from 0.35 to 0.55 (Table 4; Sharp and Turner, 1985).

This variation in the ratio is larger than the variation in the ratios reported by Geyer (1979). Sharp and Turner (1985) used twenty input readings from the balance to calculate a mean weight (described by Turner et al., 1985). When all twenty input readings were within a band of 6% or ± 1 kg of the latest mean weight, whichever was the greater, the mean weight of the twenty weights was accepted.

Probably, twenty input readings are not enough to obtain a reliable mean forelegs weight. This is suggested by the large mean coefficient of variation (11.3 %) in the pig's forelegs weights within a day, computed from the data of Turner et al. (1985) (Table 5).

Table 5. Mean coefficient of variation of the animal's forelegs weight within a day.

	Turner et al. (1985)	Engelhardt[1] (1990)
species	Pigs	Calves
number of animals	6	5
body weight range (kg)	48-74	85-130
mean standard deviation (kg)	3.1	1.1
mean coefficient of variation (%)	11.3	1.8

[1] Engelhardt (1990) calculated a standard deviation over the difference between maximum and minimum forelegs weight of a calve within a day.

Results from Engelhardt (1990) with calves showed that the mean coefficient of variation could be diminished by deleting outliers (Table 5). Engelhardt recorded all forelegs weight measurements during one visit to the drinker.

The mean number of forelegs weight measurements per visit used was about 150. She did not report the minimum number of measurements or duration time per visit required to obtain a reliable forelegs weight per visit. She compared several methods to delete outliers from the measured data. Outliers can result from, for example an animal entering or leaving the balance, an animal standing with only one leg on the balance or an animal that is mounted by another animal. Engelhardt (1990) concluded that measurements that deviated 10% or more from the mean BW of the previous day should be omitted from the data. The method of Engelhardt (1990) has the disadvantage that no reference weight is available at the beginning of a growing-finishing period and after a day on which no weights were measured. Robust calculation techniques like modus or median could be useful tools to deal with outliers without using a reference weight.

Engelhardt (1990) found correlation values between forelegs weight and BW of beef bulls and rearing calves of 0.99 and 0.96, respectively. Furthermore, she noted that the ratio between the forelegs weight and BW of 18 beef bulls during the growing period (100 - 400 kg) increased from 0.56 to 0.59 (Table 6).

Table 6. Ratio between forelegs weight and body weight of 18 bulls at different weight ranges (adapted from Engelhardt, 1990).

body weight range (kg)	n measurements	mean ratio %	sd %
100 - 150	409	55.5	1.1
150 - 200	508	56.1	1.0
200 - 250	477	56.5	1.1
250 - 300	846	57.4	1.3
300 - 350	528	58.6	1.2
350 - 400	99	59.2	1.1

Stanzel and Emberger (1987) used a balance, placed just before the feeder that had a surface area of 0.54 m^2 (600 x 900 mm), for weighing the forelegs weight of beef bulls. About 150 measurements were recorded per minute. A computer program selected the measurements, that were within 10% of the individual mean forelegs weight of the previous day. The weights on the hind legs were recorded and selected in the same way as the forelegs weights. Body weight was calculated as the sum of the weights on the forelegs and hind legs. Their results showed that there was a high correlation ($r = 0.99$) between the forelegs weight and the BW of beef bulls growing in the BW range from 150 to 380 kg.

Conclusions

Body weight information of group-housed growing-finishing pigs is important for adjusting feeding schemes and making delivery decisions. Automatic weighing of individual group-housed pigs is possible using electronic identification and a device for estimating BW. For an accurate estimate of a pig's BW it is important that sufficient measurements can be obtained and that outliers can be deleted. Video image analysis and forelegs weighing are two methods that show potential for use in research and practice.

References

Ali, N.M., 1993. Variance in pig's dimensions as measured by image analysis. In : C.R. Boon and Collins (Editors), Proceedings of the Fourth International Symposium on Livestock Environment, University of Warwick, Coventry, England. American Society of Agricultural Engineers (ASAE), St. Joseph, Michigan, pp 151-158.

Arkes, J.G., Baltussen, W.H.M., Ogink, G.J.A. and Schneider, J.,1986. Bedrijven met mestvarkens. Consulentschap in Algemene Dienst voor Varkenshouderij, Report C 1.3, Rosmalen, The Netherlands, 54 pp.

ASAE Standards, 1988. Dimension of livestock and poultry. Amer. Soc. Agr. Engineers Standards. pp 407-413.

Berberich, R., 1988. Die automatische Wägung wachsender Schweine als element der rechnergestützten Prozeßsteuerung. PhD thesis University Gießen, Germany, 196 pp.

Bockfisch, F.J., Schwarz, H.P. and Berberich, R., 1991. Wie lassen sich Tiergewicht und aufgenommene Futtermenge bei Schweinen regelmäßig ermitteln? DGS, 23:683-686.

Campbell, R.G., Taverner, M.R. and Curic, D.M., 1985. Effects of sex and energy intake between 48 and 90 kg body weight on protein deposition in growing pigs. Anim. Prod. 40:497-503.

Cöp, W.A.G., 1974. Protein and fat deposition in pigs in relation to body weight gain and feeding level. Communications Agricultural University, Wageningen, 18:1-78.

Davis, P.F. and Marchant, J.A., 1993. Pig image outlining using artificial neuron parameters in the snake contour method. Comput. Electron. Agric., 8:277-292.

De Greef, K.H., 1992. Prediction of production, Nutrition induced tissue partitioning in growing pigs. PhD thesis Agricultural University Wageningen, The Netherlands, 117 pp.

De Haer, L.C.M., 1992. Relevance of eating pattern for selection of growing pigs. PhD thesis Agricultural University Wageningen, The Netherlands, 159 pp.

Dutch Product Board for Livestock and Meat, 1992. Livestock, meat and eggs in The Netherlands. Product Board for Livestock and Meat, Rijswijk, The Netherlands, 44 pp.

Engelhardt, K.M., 1990. Experimentelle Untersuchungen zur automatisierten Tiergewichtserfassung bei Milchkühen, Mastbullen und Aufzuchtkälbern. PhD thesis Technical University München, Germany, 222 pp.

Filby, D.E., Turner, M.J.B. and Street, M.J., 1979. A walk-through weigher for dairy cows. J. Agric. Eng. Res., 24:67-78.

Giesen, G.W.J., Baltussen, W.H.M. and Oenema, J., 1988. Optimalisering van het afleveren van mestvarkens. Landbouw-Economisch Instituut, publication 3.139, Den Haag, The Netherlands.

Geyer, H., 1979. Morphologie und Wachstum der Schweineklaue. PhD thesis University Zürich, Switzerland, 111 pp.

Hammell, K.L. and Hurnik, J.F., 1987. Fixed-interval conditioned feed intake in swine and cattle. Can. J. Anim. Sci., 67:319-325.

Hughes, B.O. and Elson, H.A., 1977. The use of perches by broilers in floor pens. Br. Poultr. Sci., 18:715-722.

Informatie en Kennis Centrum Varkenshouderij (IKC), 1991. Structuur en mestproblematiek op varkensbedrijven. Informatie en Kennis Centrum Veehouderij, publication 17, Ede, The Netherlands.

Jørgensen, E., 1993. The influence of weighing precision on delivery decisions in slaughter pig production. Acta Agric. Scand., Sect. A., Animal Sci., 43:181-189.

Langeveld, N.G., Lammers, G.H., Lambooij E., Roelofs, P.F.M.M. and Huiskes, J.H., 1993. Electronic identification with injectable transponders in pig production; results of a field trial on commercial farms. IVO B-report 393, Zeist, The Netherlands, 96 pp.

Long, J., Takahata, H., Umetsu, K. Hoshiba, H. and Takeyama, I., 1991a. A livestock walk-through scale system. J. Soc. Agric. Struc. Japan., 21:175-182.

Long, J., Takahata, H., Umetsu, K. Hoshiba, H., Takeyama, I., and Nishioka, Y., 1991b. Walk-through loads and factors influencing the measurement accuracy of cattle weight. J. Soc. Agric. Struc. Japan., 22:95-102.

Marchant, J.A. and Schofield, C.P., 1993. Extending the snake image processing algorithm for outlining pigs in scenes. Comput. Electron. Agric., 8:265-275.

Minagawa, H. and Ichikawa, T., 1994. Determining the weight of pigs with image analysis. Transactions of the ASAE, 37:1011-1015.

Minagawa, H., Saito, S. and Ichikawa, T., 1993. Determining the weight of pigs with an image analysis system. In : C.R. Boon and Collins (Editors), Proceedings of the Fourth International Symposium on Livestock Environment, University of Warwick, Coventry, England. American Society of Agricultural Engineers (ASAE), St. Joseph, Michigan, pp 528-534.

Nielsen, B.L. and Lawrence A.B., 1993. The effect of group size on the behaviour and performance of growing pigs using computerised single-space feeders. Pig News and Information, 14:127N-129N.

Odink, B.J., 1991. Organisatorische en infrastructurele aspecten van electronische dierherkenning. In: Texas Instruments (editors), Symposium over Elektronische Dierherkenning in de Praktijk, oktober 1991, Scheveningen, The Netherlands, pp 12-23.

Peiper, U.M., Maltz, E., Edan, Y., Babazada, M., Schon, H. and Artman, R., 1987. Routine automatic diary cow's body weights measurements for the use of husbandry decisions. In: Imag (editors), Proc. 3th Symposium on Automation in Dairying, september 9, 10 and 11, Wageningen, The Netherlands, pp 116-128.

Schofield, C.P., 1990. Evaluation of image analysis as a means of estimating the weight of pigs. J. Agric. Eng. Res., 47:287-296.

Schofield, C.P., 1993. Image analysis for non-intrusive weight and activity monitoring of live pigs.In : C.R. Boon and Collins (Editors), Proceedings of the Fourth International Symposium on Livestock Environment, University of Warwick, Coventry, England. American Society of Agricultural Engineers (ASAE), St. Joseph, Michigan, pp 503-510.

Sharp, J.R. and Turner, M.J.B., 1985. Automatic weight monitoring of pigs - Part II: Analysis of results from trials of Mk II in-pen pig weigher. Div. Note DN/1267, Silsoe Research Institute.

Slader, R.W. and Gregory, A.M.S., 1988. An automatic feeding and weighing system for ad libitum fed pigs. Comput. Electron. Agric., 3:157-170.

Stanzel, H., and Emberger, K., 1987. Automatische Gewichtserfassung in der Tierhaltung. VDI/MEG kolloquium Landtechnik, Heft 5: Elektronikeinsatz in der Rinderhaltung, december 8 and 9. VDI-fachgruppe Landtechnik (editors), Graf Reckestr. 84, D 4000 Düsseldorf, Germany, pp 140-153

Turner, M.J.B. and Cox, S.W.R., 1983. Automatic weighing of livestock. In: Agricultural electronics - 1983 and beyond. Proceedings of National Conference 11-12 dec. 1983. Chicago voll. II, pp 563-570.

Turner, M.J.B., Gurney, P., Crowther, J.W.S. and Sharp, J.R., 1984. An automatic weighing system for poultry. J. Agric. Eng. Res., 29:17-24.

Turner, M.J.B., Bensons, J.A., Hanley, M. and Hartwell, E.S., 1985. Automatic weight monitoring of pigs - Part I: Trials of prototype weigh platforms. Div Note DN/1266, Silsoe Research Institute, 32 pp.

Whittemore, C.T., 1983. Development of recommended energy and protein allowances for growing pigs. Agric. Systems 11:159-186.

Chapter 2

Estimating individual body weights of group-housed growing-finishing pigs using a forelegs weighing system

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Abstract

In two experiments, a method to estimate the individual body weight of group-housed growing-finishing pigs using a forelegs weighing system was developed. In Exp. 1, the forelegs weight of twelve crossbred pigs (6 gilts and 6 barrows, from 52.8 ± 1.3 to 106.5 ± 1.0 kg) was measured up to 5000 times (20 measurements per second) during every meal at a feeding station using a balance. From these measurements, one forelegs weight per meal was calculated using a mathematical method. In Exp. 2, 24 crossbred pigs were used to develop (trial one, 6 gilts and 6 barrows, from 34.0 ± 0.9 kg to 110.1 ± 1.6 kg) and to validate (trial two, 6 gilts and 6 barrows, from 31.8 ± 0.4 kg to 106.1 ± 0.6 kg) a regression equation for prediction of the individual body weight using the calculated forelegs weight of the pig. Results in Exp. 1 showed that the duration of a meal had to be at least 2 minutes to obtain a calculated forelegs weight of one pig within a day with a SD less than 1 kg. In Exp. 2, the equation used to estimate individual body weight (BW) from the forelegs weight (FW) was: BW = 1.761 x FW. Using the equation the deviation of the estimated body weight was less than 5% of the measured body weight on 95% ± 2.2 of the weighing days for 11 of the 12 pigs. It was concluded that a forelegs weighing system is a suitable method to estimate the individual body weight of growing-finishing pigs housed in groups.

Introduction

The pig's daily ad libitum feed intake capacity, body weight, growth rate and ratio among body components are the basis of alternative feeding schemes for group-housed growing-finishing pigs (De Greef, 1992). Several devices for measuring the feed intake of individual pigs housed in groups have been described (Berberich, 1988; Slader and Gregory, 1988; De Haer, 1992; Young and Lawrence, 1994). By equipping feeding devices with a platform balance and a stall it is possible to measure the individual body weight of a group-housed pig, while separated from its pen mates (Berberich, 1988; Slader and Gregory, 1988). Using a feeding station with a close-fitting stall the eating pig is protected from its pen-mates. However, this is a disadvantage, because competition among growing-finishing pigs can affect feed intake and growth performance (Merks, 1989; De Haer, 1992; Morrow and Walker, 1994).

In cattle, a forelegs weighing system placed in front of a feeder or drinker has proved to be suitable for estimating individual body weight of group-housed animals without bounding the feeding or drinking place with fences (Stanzel and Emberger, 1987; Engelhardt, 1990). From the literature, Ramaekers et al. (1994) concluded that pigs spent four times as much time at the feeder than at the drinker (± 60 minutes vs ± 14 minutes per day, ± 4.5 minutes vs 40 seconds per visit). Therefore, a method to estimate the individual body weight of group-housed pigs was developed and validated using a forelegs weighing system that was placed in front of a feeding station. The forelegs weight of a pig is the weight supported by the forelegs of a pig standing in an eating position.

Material and Methods

The study consisted of two experiments. In Exp. 1, an algorithm was derived to calculate one forelegs weight per meal from recorded forelegs weights. Exp. 2 consisted of two trials. In the first trial a regression equation was developed to estimate the pig's body weight from the forelegs weight per meal. The regression equation was validated in the second trial.

Animals, Diets and Housing

In the two experiments, 18 gilts and 18 barrows were used. These were a combination of a Large White sire line and a rotation cross bred sow line (Dutch Landrace x Large White sow line x Finnish Landrace). During Exp. 1, twelve pigs (6 gilts and 6 barrows) grew from 52.8 ± 1.3 kg to 106.5 ± 1.0 kg. In Exp. 2, twelve pigs (6 six gilts and 6 barrows) grew from 34.0 ± 0.9 kg to 110.1 ± 1.6 kg and from 31.8 ± 0.4 to 106.1 ± 0.6 kg during trials 1 and 2, respectively.

In both experiments, the pigs were housed in one pen (6.0 m x 2.2 m) with a partially solid, warm-water heated floor and tri-bar metal slats. The room in which the pen was situated was equipped with a computer-controlled heating and mechanical ventilation system. Injectable transponders (Tiris, Texas Instruments, Almelo, The Netherlands), injected in the earbase, (Lambooij and Merks, 1989) and an antenna were used to identify each pig at the feeding station. The transponders were activated and read by antenna in the entrance door and in the trough of the feeding station (Ratiomat, Mannebeck Landtechnik GmbH, Quendorf, Germany). After a pig's identity was recognized at the trough, the feed was dropped into the feeder in 50 g portions. During the growing-finishing period, the time interval between feed portions was adjusted to a feed intake rate of 1.4 g/min/kg$^{0.75}$ (Nienaber et al, 1991).

From the start of the experiments to a body weight of 45 kg, a starter diet was used containing 13.3 MJ ME per kg and 0.82% apparent ileal digestible lysine. From 45 kg on, a finishing diet was used containing 12.9 MJ ME per kg and 0.67% apparent ileal digestible lysine. All pigs were fed according to a restricted feeding scheme : 2.6 x energy requirements for maintenance (M); M = 0.719 MJ ME x $W^{0.63}$; ARC, 1981. Throughout the experiments, the pigs had free access to a drinker adjacent to the feeding station.

Weighing of pigs

In Exp. 1, a forelegs weight balance (0.28 m x 0.48 m) and in Exp. 2, both a forelegs weight balance (0.28 m x 0.48 m) and a body weight balance (1.35 m x 0.48 m) were placed in front of the trough of the feeding station (Figure 1). The electronic weighing system (Welvaarts bv., Den Dungen, The Netherlands) was designed around two components, 1) a weighing processor and 2) aluminium load cells (force range of each load cell is 250 kg with an accuracy ± 100 g). The forelegs weight balance and the body weight balance had one and two load cells, respectively. The weighing system had for both balances auto zero facilities, i.e., every time an animal had left the balance, the weighing processor corrected for dirt and manure on the balances. The auto zero facility was enacted when the measured weighing signal was stable and the load on the balance was within a range of + or - 150 g around zero. Every week the balances were checked using known weights and if necessary, recalibrated.

The weighing processor had a maximum capacity of 5000 measurements per meal for both forelegs weight and body weight measurements. During each meal (De Haer, 1992) at the feeding station, the weighing period started when a pig was identified and ended when one of the three following events occurred:

1) the established number of forelegs weight measurements was reached (5000, Exp. 1; 2500, Exp. 2),
2) the pig was not recognized for 25 seconds,
3) another pig was recognized.

When the pig stayed at the feeder after the weighing period had ended, the meal of the pig continued but no further weighing periods were started during that meal.

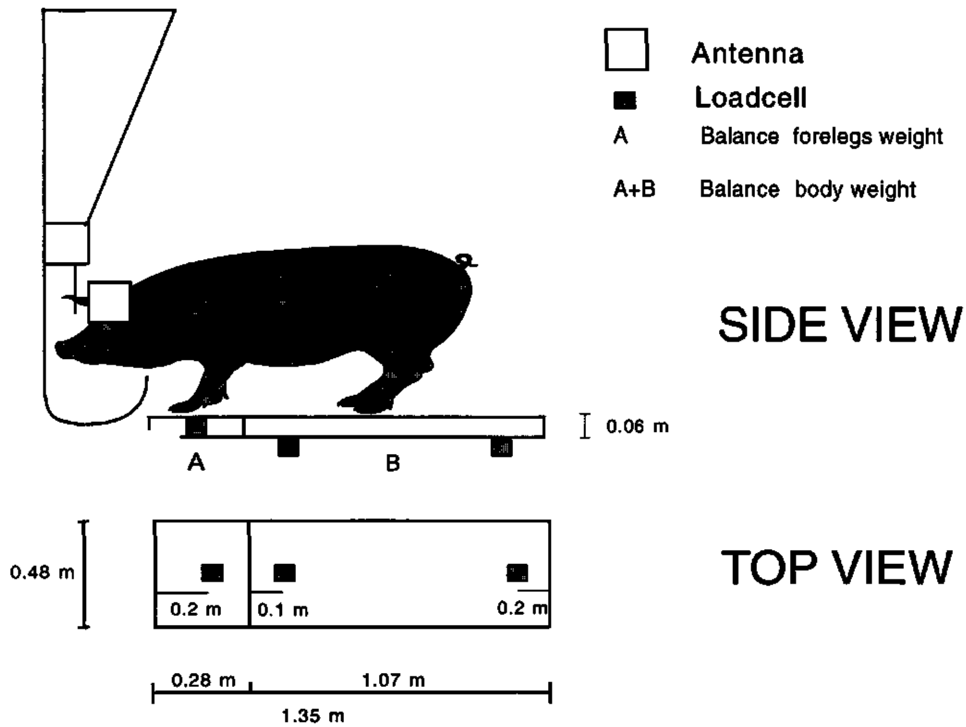

Fig. 1. Feeding station with in front of the feeder a forelegs weight balance (0.28 m x 0.48 m) and a body weight balance (1.35 m x 0.48 m). During a meal the pig is identified by an antenna and a transponder that was implanted in the earbase of the pig.

On every seventh day of the experimental period in Exp. 1, the weighing processor collected 20 forelegs weights per second until the established number per meal of 5000 measurements was reached. After a meal had ended, the pig's identity and the recorded forelegs weights were sent to a computer (IBM- compatible, RS-232c interface).

On every day of the experimental period in Exp. 2, one forelegs weight was calculated using the first 2500 recorded forelegs weights (20/s) at each meal. Furthermore, the initial and final time of each meal at the feeding station were recorded. Once a day the calculated forelegs weight, body weight (mean of the last 64 body weight measurements of the weighing period; 20 measurements/s), initial and final time of a meal and the pig's identity were sent to the same computer as in Exp. 1 using a RS-485 interface. The RS-485 interface was build in cooperation with the TFDL-DLO Institute at Wageningen.

Statistical analyses

In Exp. 1, only meals yielding 5000 forelegs weight measurements were used in the analyses. From the recorded forelegs weights per meal, one forelegs weight was calculated by three mathematical methods, namely the mean, the median and the modus (Snedecor and Cochran, 1980). Further, a new calculation method coined TRIMODUS was developed, because neither the mean, modus nor median were considered accurate enough for calculating one forelegs weight per meal. The TRIMODUS method calculates a forelegs weight, without using measurements with sources of error, e.g., weight measurements where a pig is standing with only one or no legs on the balance. The method was derived from the calculation methods modus and mean. The TRIMODUS was calculated as the weighted mean of the measurements in three classes (class size 1 kg): the class modus and the classes before and after the modus (Figure 2). Results of a unpublished pilot study at the Research Institute for Pig Husbandry, Rosmalen, The Netherlands had shown that pigs with a body weight heavier than 20 kg could not have a forelegs weight below 5 kg. Therefore, forelegs weights lower than 5 kg were not used in the calculation of the TRIMODUS.

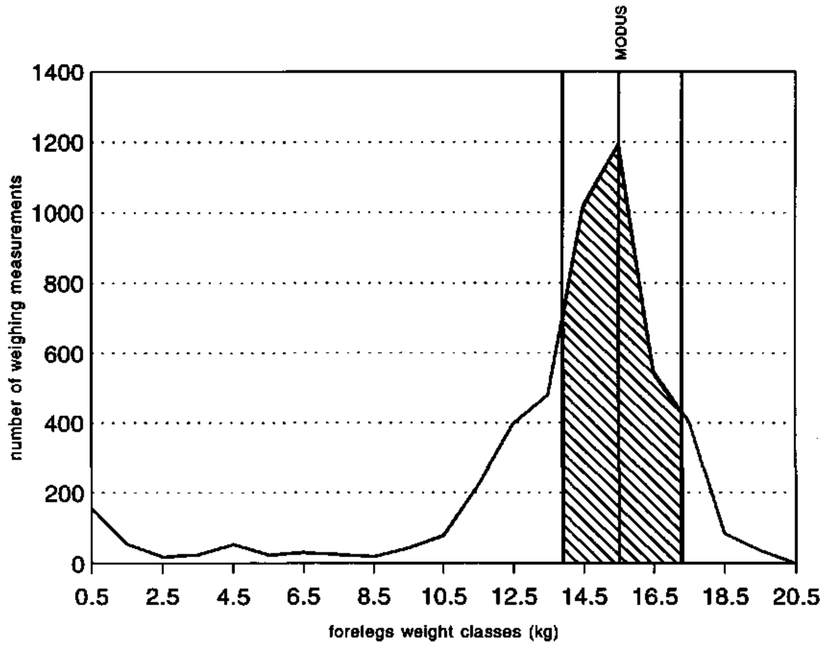

Fig. 2. The TRIMODUS, calculated as the weighted mean of the measurements in three classes (class size 1 kg): the class modus and the classes before and after the modus (the shaded area).

For each mathematical method, the accuracy of estimation of forelegs weight was analyzed by computing the mean of the SDs of forelegs weight per pig per day taken over 10 days. The analyses were performed by calculating a forelegs weight per meal from the first 1250, the first 2500 and all 5000 measurements, respectively.

In the first trial of Exp. 2, overall and per gender regression equations were developed for estimating the pig's body weight from the calculated forelegs weight. Moreover, the effect of body weight and time of day on the daily variation of the pig's body weight and calculated forelegs weight were analyzed.

In deriving and validating the regression equations, the median body weight and the median calculated forelegs weight per day and pig were used in order to balance the data for differences in number of measurements among days and pigs. The following allometric regression equation was used (Walstra, 1980):

$$\text{body weight} = a \times (\text{forelegs weight})^{b}$$

The data of body weight and forelegs weight were transformed to natural logarithms to stabilize the error of variance. For each pig, a robust regression analysis technique (Iteratively Reweighted Least Squares, (Holland and Welsch, 1977; SAS-NLIN, 1989)) was used for estimating the model parameters *a* and *b* of the aforementioned allometric regression equation. In the second trial of Exp. 2, one body weight per day per pig was estimated from the calculated forelegs weight per pig by entering in the aforementioned allometric regression equation the means of the equation parameters *a* and *b* generated in the first trial of Exp. 2. The accuracy of estimation of body weight was expressed as the percentage of days of the growing-finishing period on which the deviation (expressed as % of the measured body weight) between estimated and measured body weight was lower than 3 or 5%.

Results

The results in Table 1 show that the mean of the SDs of the forelegs weight per pig per day was 1.7 kg or higher when using the calculation method mean, median and modus. The high SDs generated by modus were due to meals in which the calculated forelegs weight were zero. Using the calculation method TRIMODUS (Table 1), the mean of the SDs of forelegs weight per pig per day was below 1 kg, when using 2500 measurements. Using 5000 measurements per meal did not improve (decrease) the mean of the SDs of the forelegs weight. Using every other measurement of the first 2500 measurements of a meal in the TRIMODUS calculation method also did not affect the mean of the SDs of the forelegs weight.

Table 1. Mean of the SDs (kg, ± SE) of the forelegs weight per pig per day, taken over 10 days, for the calculation methods mean, modus, median, and TRIMODUS using the first 1250, the first 2500 or all 5000 measurements (m) of a meal.

Method	n pigs	SD (m= 1250)	SE	SD (m= 2500)	SE	SD (m= 5000)	SE
MEAN	12	2.8	0.6	2.1	0.3	1.9	0.3
MODUS	12	7.1	1.6	8.6	1.8	9.5	1.6
MEDIAN	12	3.1	1.1	1.7	0.7	1.7	0.7
TRIMODUS	12	2.2	0.9	0.8	0.2	1.1	0.4
TRIMODUS[1]	12			0.8	0.2		

[1] Using every other measurement of 2500 measurements in the TRIMODUS method

Table 2. Estimates and SD of parameters *a* and *b* for regression equations to estimate body weight from forelegs weight. An overall allometric equation, an allometric equation per gender and an overall linear equation were computed.

Equation	n	Parameter *a*		Parameter *b*	
	pigs	Estimate	SD	Estimate	SD
Overall	12	1.756	0.178	1.002	0.027
Barrows	6	1.858	0.110	0.988	0.012
Gilts	6	1.657	0.182	1.017	0.022
Linear	12	1.761	0.02	1.0[1]	

[1] For estimating the *a* parameter for the linear regression equation the *b* parameter of allometric regression equation was fixed at 1.0 .

In Table 2, the means of the model parameters of an overall allometric equation and allometric equations per gender for estimating body weight from the calculated forelegs weight are presented. The values of the *b* parameter in all the allometric equations were not different ($P > 0.05$) from 1. For the overall linear equation the value of the *a* parameter was 1.761 when the value of the *b* parameter was fixed at the value 1. The values of the *a* and *b* parameters were dependent on each other ($P < 0.05$). A student test showed that gender tended ($P < 0.10$) to affect the value of the *a* and the *b* parameters.

Table 3. Mean of the SDs (kg) (± SE) of the body weight and forelegs weight per pig per day per body weight class (kg).

Body weight class (kg)	n (pigs)	Body weight SD	Body weight SE	Forelegs weight SD	Forelegs weight SE
30-40	12	0.6	0.07	0.6	0.08
40-50	12	0.9	0.07	0.6	0.08
50-60	12	0.8	0.07	0.6	0.08
60-70	12	1.0	0.07	0.7	0.08
70-80	12	0.9	0.07	0.7	0.08
80-90	12	0.7	0.07	0.8	0.08
90-110	12	0.8	0.07	0.7	0.08

The results in Table 3 show that body weight had a negligible influence on the mean of the SDs of body weight and forelegs weight per pig per day. Furthermore, the weight changes in terms of percentage of the mean body weight and forelegs weight, respectively, of a pig have similar patterns during the day (Figure 3). The forelegs weight decreased only at the end of the day, whereas the pig's body weight plateaued.

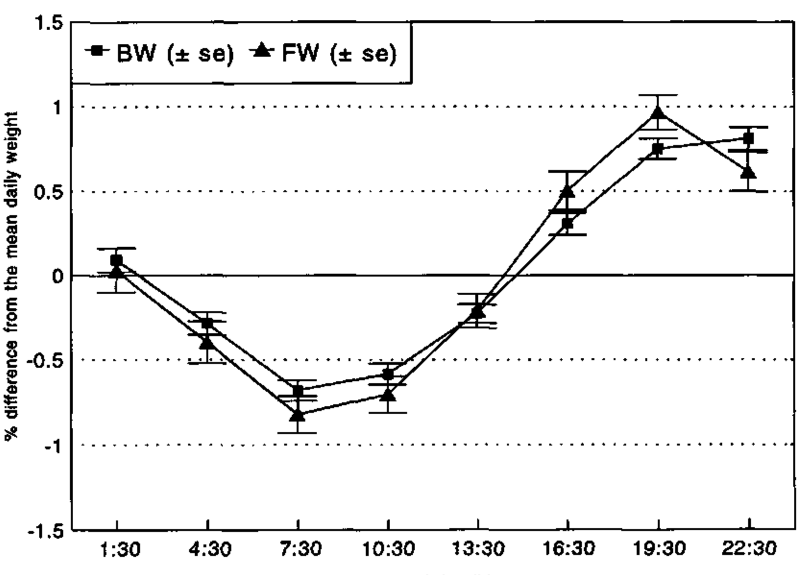

Fig. 3. Patterns (expressed as percentage difference of the mean body weight and forelegs weight per pig per day) in body weight (BW) and forelegs weight (FW) during the day (n = 12 pigs, Exp. 2, trial 1).

Table 4. Validation of the estimation of the body weight from the forelegs weight by entering the estimates of the *a* and *b* parameters (Table 2) in an overall linear equation (LINEAR), an overall allometric equation (ALLOMETRIC) and allometric equations per gender (GENDER). Accuracy of estimation is expressed as number of animals per class of estimation (percentage of days) for two deviations ranges.

	LINEAR deviation within		ALLOMETRIC deviation within		GENDER deviation within	
% of days	± 5%	± 3%	± 5%	± 3%	± 5%	± 3%
> 80%	11	6	11	7	9	7
50 - 80%	-	5	-	2	2	2
0 - 50%	1	1	1	3	1	3

In the second trial of Exp. 2, it was shown that using the overall linear equation for 12 pigs, the body weight of 11 pigs was estimated on more than 80% (mean was 95% ± 2.2) of the days within a deviation of 5% of the measured body weight (Table 4). For one pig, the equations overestimated the body weight systematically by about 7%. Overall allometric equations and allometric equations per gender gave no improvement of the estimation of the body weight (Table 4).

During the experimental period of trial 2 in Exp. 2, the relative Root Mean Square Error of Prediction was consistent (Figure 4). This indicates that body weight was estimated from the forelegs weight with similar accuracy throughout the experimental period.

Discussion

Calculating one forelegs weight per weighing meal

For the forelegs weight measurement, the pig's posture is important. Whether a pig is standing or lying on the balance the body weight will be the same, but the forelegs weight will be totally different. Therefore, in our study the feeder and the position of the balance with respect to the feeder were designed to prevent a pig from standing in the feeder or from lying on the forelegs balance during a meal. Furthermore, a bar can be placed at 0.25 m from the forelegs balance, to prevent a pig from lying or sitting at the feeder.

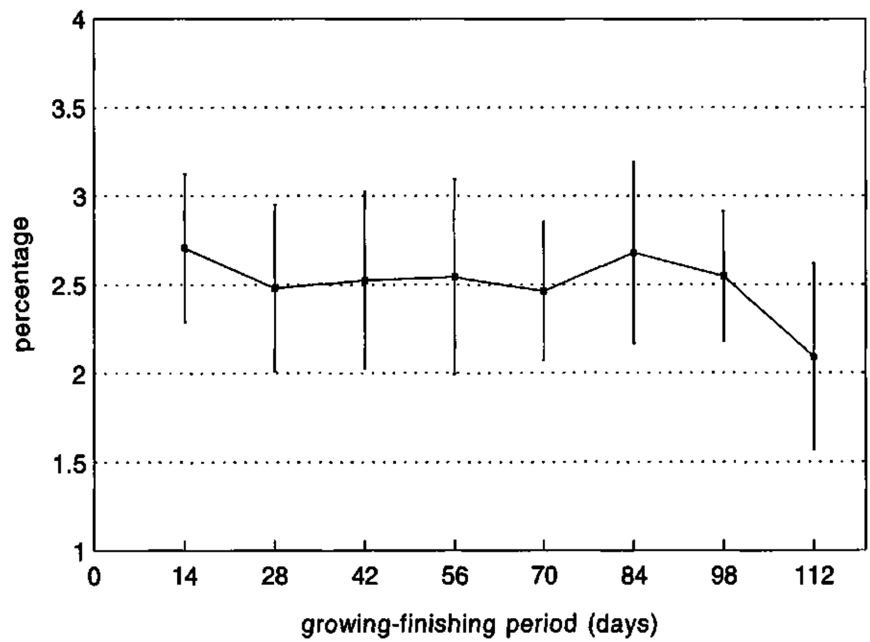

Fig. 4. The relative Root Mean Error of Prediction (± SE) of body weight.

The pig's forelegs weight during the day may vary due to the normal variation of the pig's body weight. However, the calculated forelegs weight per meal can be affected by the pig's standing behaviour on the balance during the weighing period. For example, some pigs left the balance for a few seconds during a meal. Comparing the mean, median and modus calculation methods, it was found that the median forelegs weight gave the lowest mean of the SDs of forelegs weight per pig per day (Table 1). The low mean of the SDs of forelegs weight was achieved using either all 5000 or the first 2500 measurements. It is difficult to compare the mean of the SDs of forelegs weight of the median forelegs weight with other studies (Turner et al., 1985; Engelhardt, 1990), because they used different calculation methods to estimate a forelegs weight from the weight measurements. Using calves, Engelhardt (1990) excluded forelegs weight measurements that were 10% lower or higher than the mean forelegs weight of the previous day to calculate a mean forelegs weight per meal. Engelhardt (1990) found a mean of the SDs of the difference between the maximum and minimum forelegs weight within a day of 1.1 kg. Although the method of Engelhardt appears to be accurate, it has the disadvantage that it needs a reference weight, which is not available at the beginning of a growing-finishing period and after days (illness) on which no forelegs weights were measured. Using pigs, Turner et al. (1985) calculated a mean forelegs weight, when twenty input readings were within a range of either 6% or 1 kg of the last calculated mean weight, whichever was the least limiting. The mean of the SDs of forelegs weight was 3.1 kg (n = 6), which is higher than the means of the SDs of forelegs weight for both the median and mean forelegs weights (5000 measurements) of 1.7 and 1.9, respectively, that were calculated in our study.

Comparing the TRIMODUS with the median shows that the mean of the SDs of the forelegs weight decreased (Table 1).

Using every other measurement of the first 2500 measurements of a meal, equal to about a 2 minute weighing period, in the TRIMODUS calculation method did not affect the mean of the SDs of forelegs weight. This suggests that duration of the weighing period is of more importance than the number of measurements within a weighing period.

Based on the results in Exp. 1, it was decided to use the TRIMODUS with 2500 measurements recorded over about 2 minutes during a meal to calculate a forelegs weight per meal in Exp. 2. The TRIMODUS not only provided the lowest mean of the SDs of the forelegs weight, but also a mean of the SDs of forelegs weight that was considered accurate enough for calculating one forelegs weight per meal.

Effectiveness of forelegs weight for estimating body weight

The ratio between body weight and forelegs weight of 1.761 found in our study (Table 2) is comparable to the ratios of 1.776 and 1.798 in growing-finishing pigs with mean body weights of 50 kg and 90 kg, respectively, found by Geyer (1979). However, comparison with our results is difficult because Geyer did not describe whether the forelegs weight balance was placed in (horizontal standing position) or on the floor (plateaued standing position of the forelegs). A plateaued standing position alters the ratio between body weight and forelegs weight.

Overall allometric equations or allometric equations per gender gave no improvement of the estimation of body weights compared with an overall linear equation (Table 4). However, gender showed a tendency to affect the change in the ratio between forelegs weight and body weight (Table 2). Although not observed clearly in our research, other studies have found that the ratio between the body weight and the forelegs weight may be influenced by gender and body weight (Walstra, 1980; Baxter, 1984). The differences between genders may be due to a change of the weight distribution of the cranial and caudal parts of the carcass in the body weight range 26 to 133 kg (Walstra, 1980). Furthermore, the differences in ratio between body weight and forelegs weight may be due to change of the height between the shoulder and backend during the growing-finishing period (Baxter, 1984).

It was expected that the daily variation in weight would increase with increase of body weight, because of the higher feed intake. However, it was found that the body weight per se hardly affects the daily variation of the pig's body weight and forelegs weight (Table 3).

The pig's body weight and forelegs weight changed in a similar way during most of the day (Figure 3), except the end of the day. A possible explanation for the observed decrease in forelegs weight is that after 18:00 h the feed intake of the pigs has been shown to be low (De Haer, 1992). When the digesta move to the caudal part of the gut, the forelegs weight may decrease, whereas the body weight remains similar. Moreover, a full bladder could explain the observed difference in pattern.

As part of the validation of the estimation, it was found that the body weight was estimated for 11 of the 12 pigs within 5% of the actual body weight on 95% ± 2.2 of the days by using a linear equation. Our results are even better than the results of Schofield (1990) who used image analysis to estimate body weight. He found that after manual adjustments of the images, the pig's body weight could be estimated from the top view surface of that pig in 83% of the cases within ± 5% of the actual body weight. A further validation of our calculation method (TRIMODUS, 2500 measurements) is shown in Figure 3 and Table 3. During the growing-finishing period in trial 1 of Exp. 2, the variations of the mean forelegs weight and the mean body weight were similar.

Conclusions

The pig's body weight is an important trait both in commercial practice and in research (Ramaekers et al., 1995). The advantage of a forelegs weighing system is that the individual body weight of group-housed pigs can be monitored automatically throughout either the growing-finishing period or the experimental period. There is less demand for labour and other measurements, e.g. heat production in climate respiration chambers, can be continued without interference (Schrama et al., 1993). From this study, it was concluded that a forelegs weighing system is suitable for estimating individual body weights of growing-finishing pigs housed in groups.

References

ARC, 1981. The nutrient requirements of pigs. Technical review by an ARC Working Party. Farnham Royal, Slough, Commonwealth Agricultural Bureaux, 307 pp.

Baxter, S., 1984. Intensive pig production. Granada Technical Books, London, pp 210-254.

Berberich, R., 1988. Die automatische Wägung wachsender Schweine als element der rechnergestützten Prozeßsteuerung. PhD thesis University Gießen, Germany, 196 pp.

De Greef, K.H., 1992. Prediction of production, Nutrition induced tissue partitioning in growing pigs. PhD thesis Agricultural University Wageningen, The Netherlands, 117 pp.

De Haer, L.C.M., 1992. Relevance of eating pattern for selection of growing pigs. PhD thesis Agricultural University Wageningen, The Netherlands, 159 pp.

Engelhardt, K.M., 1990. Experimentelle Untersuchungen zur automatisierten Tiergewichtserfassung bei Milchkühen, Mastbullen und Aufzuchtkälbern. PhD thesis Technical University München, Germany, 222 pp.

Geyer, H., 1979. Morphologie und Wachstum der Schweineklaue. PhD thesis University Zürich, Switzerland, 111 pp.

Holland, P.W. and Welsch, R.E., 1977. Robust regression using iteratively reweighted least squares. Communications Statistics: Theory and Methods, 6:813-827.

Lambooij, E. and Merks, J.W.M., 1989. Technique and injection place of electronic identification numbers in pigs. IVO B-rapport 335, Zeist, The Netherlands, 12 pp.

Merks, J.W.M., 1989. Genotype x environment interactions in pig breeding programmes. VI Genetic relations between performances in central test, on-farm test and commercial fattening. Livest. Prod. Sci., 22:325-339.

Morrow, A.T.S and Walker, N., 1994. A note on changes to feeding behaviour of growing pigs by fitting stalls to single-space feeders. Anim. Prod., 59:151-153.

Nienaber, J.A., McDonald, T.P., Hahn, G.L. and Chen, Y.R., 1991. Group feeding behavior of swine. Trans. ASAE, 34:289-294.

Ramaekers, P.J.L., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C., Swinkels, J.W.G.M. and Van der Peet-Schwering, C.M.C., 1995. Modern techniques for automatic determination of individual body weight of growing-finishing pigs housed in groups. Übers. Tierernähr., 23:215-228.

SAS Institute Inc., 1989. SAS/SAS® Users Guide, version 6, Fourth Edition, Volume 2. Cary NC 846 pp.

Schofield, C.P., 1990. Evaluation of image analysis as a means of estimating the weight of pigs. J. Agric. Eng. Res., 47:287-296.

Schrama, J.W., Del Bario, A.S., Verstegen, M.W.A., Brandsma, H.A. and Van der Hel, W., 1993. Alteration of energy metabolism in pigs fed at three feeding levels after transport in relation to physical activity. In: C.R. Boon and E. Collins (editors), proc. Fourth International Symposium on Livestock Environment, University of

Warwick, Coventry, England. American Society of Agricultural Engineers (ASAE), St. Josph, Michigan, USA, pp 570-571.

Slader, R.W. and Gregory, A.M.S., 1988. An automatic feeding and weighing system for ad libitum fed pigs. Comput. Electron. Agric. 3:157-170.

Snedecor, G.W. and Cochran, W.G., 1980. Statistical methods. The Iowa State University Press, Iowa, 507 pp.

Stanzel, H. and Emberger, K., 1987. Automatische Gewichtserfassung in der Tierhaltung. VDI/MEG kolloquium Landtechnik, Heft 5: Elektronikeinsatz in der Rinderhaltung, december 8 and 9. VDI-fachgruppe Landtechnik (editors), Graf Reckestr. 84, D 4000 Düsseldorf, Germany, pp 140-153.

Turner, M.J.B., Benson, J.A., Hanley, M., Hartwell, E.S., 1985. Automatic weight monitoring of pigs - Part I: Trials of prototype weigh platforms. Div Note DN/1266, Silsoe Research Institute, 32 pp.

Walstra, P., 1980. Growth and carcass composition from birth to maturity in relation to feeding level and sex in Dutch Landrace pigs. PhD thesis Agricultural University Wageningen, The Netherlands, 207 pp.

Young, R.J. and Lawrence, A.B., 1994. Feeding behaviour of pigs in groups monitored by a computerized feeding system. Anim. Prod., 58:145-152.

Chapter 3

Performance and carcass traits of individual pigs housed in groups as affected by ad libitum and restricted feeding

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Abstract

One hundred and eight crossbred castrated males were used to examine the effect of *ad libitum* and restricted feeding on performance and carcass traits of individual pigs housed in groups. The experiment included three replicates, each consisting of 36 pigs. From day 1 to 36, all pigs were given free access to feed. From day 36 to the end of the experiment, the pigs in Treatment 1 were maintained with free access to feed. For pigs in Treatments 2 and 3 the daily energy allowance per pig was restricted to 18 MJ ME above the daily energy requirement for maintenance. The weekly measured BW was used to compute the energy requirements for maintenance ($M = 0.719$ MJ ME x BW(kg)$^{0.63}$). Daily feed intake per pig was determined by using electronic feeding stations (IVOG®). During the restriction period the pigs of Treatment 1 had higher total energy intake, higher energy intake for production (energy intake above maintenance), higher growth and higher energy conversion ratio for production than the restricted pigs. Energy conversion ratio was not affected by energy restriction. In Treatments 2 and 3 the variances of energy intake, and of energy intake for production were lower than in Treatment 1. The pigs in Treatment 2 and 3 had a 2.6 units higher lean tissue percentage in the carcass than pigs given free access to feed. It was concluded that restricting individual energy intake in group-housed castrated males can improve lean tissue percentage in the carcass.

Introduction

Today's pricing scheme for slaughter pigs continue to put extra value on carcass leanness resulting from the consumer's demand for lean meat. Castrated males and gilts should be distinguished for choosing the adequate plane of feeding to achieve the highest lean meat content (Cöp, 1974). Castrated males with free access to feed have a lower lean meat content than gilts at the time of slaughter (Walstra, 1980; Leymaster and Mersmann, 1991; Affentranger, 1994). The relatively low lean meat content of castrated males is associated with 1) a low ratio between protein and lipid depositions of 1:8 to 1:3 (Tullis, 1981; Campbell and Taverner, 1988), 2) a relatively low level of protein deposition of 70 to 120 g/day (Tullis, 1981; Tess, 1986; Campbell and Taverner, 1988), and 3) a high capacity of *ad libitum* energy intake of 30 to 35 MJ ME/day on average during a fattening period of 25 to 110 kg (Kanis, 1988; Affentranger, 1994).

To improve lean meat content of castrated males, restriction of energy intake has to be fixed according to actual performance, *i.e.*, energy requirements for maintenance and growth (Whittemore and Fawcett, 1976; Moughan et al., 1987). Using individually housed castrated males, restriction of energy intake has been shown to improve the ratio between protein and lipid depositions (Campbell and Taverner, 1988). In practice, *ad libitum* (single space) feeding systems for group-housed pigs are widely used. To reduce the energy intake of *ad libitum* fed castrated males, low energy diets can be used (Cole et al., 1972; Rundgren, 1988). However, the performance of castrated males with a low feed intake capacity may be negatively affected (Labroue et al., 1994).

With the use of feeding stations in group-housed growing pigs, controlled feeding of the individual pig is possible. When the feeding station contains a weighing scale it is even possible to use a weight-dependent feeding scheme (Ramaekers et al., 1995). This study was intended to examine the effects of *ad libitum* and restricted feeding on growth performance and carcass traits of individual pigs housed in groups.

Materials and methods

Animals, experimental design and diets

One hundred and eight crossbred castrated males (BW 28.7 ± 0.3 kg) of a combination of Large White sire line and a rotation crossbred sow line (Dutch Landrace, Dutch Large White sow line and Finnish Landrace) were used. The experiment included three replicates, each consisting of 36 pigs. The pigs were allotted to one of three treatments on the basis of body weight (BW) and litter. The experimental period started after the pigs were allowed to adapt to pen and feed during a period of one week. From day 1 to 36, all pigs were maintained with free access to a starter diet containing 12.7 MJ ME per kg and 0.82 % apparent ileal digestible lysine (Table 1). From day 36 to the end of the experiment, the pigs in Treatment 1 were given free access to feed, whereas, the pigs in Treatments 2 and 3 were restrictively fed at the same energy level. The pigs in Treatments 1 and 2 were fed a high energy diet containing 13.1 MJ ME and 0.71% apparent ileal digestible lysine. The pigs in Treatment 3 received a low energy diet containing 12.5 MJ ME and 0.67% apparent ileal digestible lysine. In Treatments 2 and 3 the daily energy allowance per pig was 18 MJ ME above maintenance requirement. The maintenance requirement was computed as 0.719 MJ ME x $BW(kg)^{0.63}$ (ARC,1981). All other nutrients met or exceeded ARC (1981) recommended levels.

Table 1. Composition of diets

	Starter diet	Diet Treatments 1 and 2	Diet Treatment 3
Ingredients (g/kg)			
Cassava	230	400	400
Barley	225		
Soya bean meal, solvent extracted	150	182	201
Maize		108	109
Peas	100	75	20
Rape seed, extracted	40	86	50
Cane molasses	40	75	65
Wheat middlings	75		95
Wheat	50		
Sunflower seed, extracted	20	20	20
Fish meal	20		
Animal fat	12	24	11
Vegetable fat (soja and rape seed oil)	10	10	7
Monocalcium phosphate	4	1	1
Limestone	15	10	12
Salt	2	3	3
Vitamins and minerals[a]	7	6	6
Composition analyzed (g/kg)			
Dry matter	893	896	893
Crude protein	177	166	164
Crude fat	35	48	35
Crude fibre	52	62	63
Crude ash	64	66	69
Metabolizable energy (MJ/kg)[b]	12.7	13.1	12.5

[a] Contributed the following per kg of diet: Starter diet, renitol, 10000 IU; cholecalciferol, 1500 IU; α-tocopherol, 15 mg; menadione dimethyl-pyrimidinol, 3 mg; thiamin, .75 mg; riboflavin, 4 mg; niacin, 20 mg; pantothenic acid, 10 mg; pyridoxine, .75 mg; vitamin B_{12}, 30 µg; choline, 100 mg; copper, 160 mg, cobalt, .15 mg; iodine, .50 mg; iron, 75 mg; manganese, 30 mg; selenium, .15 mg; zinc, 60 mg. Diets Treatments 1 and 2, and Treatment 3, renitol, 5000 IU; cholecalciferol, 1000 IU; α-tocopherol, 10 mg; menadione dimethyl-pyrimidinol, 2 mg; thiamin, 0.5 mg; riboflavin, 3.5 mg; niacin, 18 mg; pantothenic acid, 7 mg; pyridoxine, 0.5 mg; vitamin B_{12}, 15 µg; choline, 100 mg; copper, 20 mg, cobalt, .15 mg; iodine, .40 mg; iron, 50 mg; manganese, 30 mg; selenium, .10 mg; zinc, 45 mg.
[b] Calculated from the composition table values (CVB, 1994)

Identification, feeding stations and housing

A transponder (Tiris, Texas Instruments, Almelo, The Netherlands) injected in the earbase, was used as an electronic identification device (Lambooij and Merks, 1989).

Each pen was equipped with an IVOG® feeding station (Hokofarm BV., Marknesse, The Netherlands). The feeding station consisted of a single space feeder, placed on a load cell, and an antenna (De Haer et al., 1992). The load cell under the feeder had an accuracy of ± 10 grams within a range of 0 to 50 kg (Hokofarm BV., Marknesse, The Netherlands). The entrance to the feeder was always open to mimic a practical situation, *i.e.,* which allowed competition for feed.

At each visit to the feeder, the pig's identity and the weight of the feeder were recorded automatically at the beginning and at the end of the visit. Feed intake was calculated as the difference between the weights of the feeder measured at the beginning and at the end of a visit, respectively.

The amount of feed that was dispensed into the trough, when the pig pushed the operating flap, was fixed at about 5 g per push. The dispensing rate of each feeder was checked once a week by weighing the feed after 10 pushes and, if necessary, adjusted.

In the restricted treatments the remaining feed allowance was estimated every 10 seconds during each visit. When a pig had eaten its daily ration, the operating flap in the feeder was blocked for the rest of the day. The operating flaps of the feeders in Treatments 2 and 3 were blocked every 30 seconds for 25 seconds during each visit over the restriction period to minimize the amount of ort in the feeder. Weighing the feeder at the beginning and at the end of each visit guaranteed that feed consumption was recorded correctly for each pig. On each day, a new eating period started at 00:00 hour.

All pigs had free access to water from a nipple adjacent to the feeder. The pens (6.0 m x 2.2 m) had partially solid, warm-water heated floors, and tri-bar metal slats. The room, in which the pens were situated, had a computer-controlled heating and mechanical ventilation system. At the beginning of the growing-finishing period, room temperature was set at 24°C. During the adaptation week, room temperature was gradually decreased from 24°C to 22°C. Thereafter, room temperature was decreased by 0.6°C per week to a minimum of 18°C.

Measurements

Body weight was measured weekly on Thursday between 9.00 and 10.00 h using a weighing scale (Welvaarts W2000, Den Dungen, The Netherlands). From day 36 to the end of the experiment, backfat thickness was scanned ultrasonically (Renco Lean-Meater, Renco Corporation, Minnesota, USA) on the day of weighing. Backfat thickness was measured on the back at a point marked by a tattoo on day 29 of the experimental period (Zhang et al., 1993). The tattoo was made between the third and fourth last rib positions and at 4 cm from the dorsal mid-line.

When attaining a BW of 105 kg or above on the day of weighing, the pigs were slaughtered on the subsequent Tuesday. The pigs were killed by exsanguination after electrical stunning. The carcass was scalded, scraped and split longitudinally.

In each replicate, the right half-carcass (including feet and head) of 8 randomly selected pigs per treatment were dissected into trimmed major cuts according to the Dutch standard dissection method (Bergström and Kroeske, 1968). All cuts were weighed. Lean meat tissue was defined as the weight of trimmed ham and other trimmed lean meat tissue joints, *i.e.*, shoulder, cutlets and meat scraps. The fat tissue was defined as the weight of subcutaneous fat tissue and other fat tissue. Subcutaneous fat tissue was trimmed from back, ham, loin and shoulder, lower jaw, flare and kidney. The other fat tissue consisted of belly and breast-tip.

Computations

The daily energy intake per pig was calculated using the ME content of diets (Table 1). The daily energy intake for production (PEI) was calculated as the energy intake minus the energy requirement for maintenance. Maintenance requirement was computed using the pig's mean BW (mean of the BW at the beginning and at the end of the week). Protein and lipid depositions were estimated from PEI and body gain (De Greef, 1992). In order to derive the energy intake at fixed BW, the data were fitted per pig using the following non-linear model (SAS, 1989; Kanis and Koops, 1990):

$$Y_i = a\, e^{-b\, W_i \,-\, c/W_i} \qquad [1]$$

where:

Y_i = Mean daily energy intake in week i,

W_i = BW in week i (mean of the weights at the beginning and the end of week i),

e = base of natural logarithm,

and a, b, c are the parameters of the equation.

The number of fattening days and backfat thickness were estimated per pig at fixed body weights using a third degree polynomial regression.

Statistical analysis

The tested contrasts were Treatment 2 vs Treatment 3 and Treatment 1 vs the two restricted Treatments 2 and 3. The homogeneity of variance between the restricted treatments and Treatment 1 was tested (Snedecor and Cochran, 1980). Treatment effects on growth performance and carcass traits with similar ($P > 0.05$) variances were assessed by analysis of variance using GLM model [2] (SAS, 1989), otherwise a Student test was used. The pig was the experimental unit. The model used was the following:

$$Y_{ijk} = \mu + T_i + R_j + T_i \times R_j + \beta W_{ijk} + e_{ijk} \qquad [2]$$

where:

Y_{ijk} = variable,

μ = overall mean,

T_i = Treatment (i = 1, 2 or 3),

R_j = Replicate (j = 1,2 or 3),

W_{ijk} = Covariable, BW at day 36 (for growth performance traits) or carcass weight (for carcass traits),

e_{ijk} = residual error.

Results and discussion

In replicates 1 and 2, the daily voluntary energy intake in Treatment 1 increased with BW during the fattening period (Table 2). In replicate 3, during the Summer period of 1994, the energy intake in Treatment 1 was much lower after 50 kg BW than in replicates 1 and 2. During the last month of replicate 3, the daily average ambient room temperature was 1 to 3°C above the upper critical temperature of 26 °C (Sterrenburg and Ouwerkerk, 1986) for about 20 days. Therefore, replicate 3 was omitted from the analyses.

Table 2. Daily energy intake (MJ ME, estimated per pig with model 1) and standard deviation (SD) in relation to body weight for the three treatments per replicate.

Level of feeding		Treatment 1 *Ad libitum*	Treatment 2 Restricted	Treatment 3 Restricted	
Energy density (MJ ME/kg)		13.1	13.1	12.5	SD[a]
	Body weight (kg)				
Replicate 1		(N = 12)[b]	(N = 12)	(N = 12)	
	30	15.1	14.6	15.6	2.2
	50	26.4	26.2	24.4	2.1
	70	33.6	30.7	28.7	2.7
	90	38.6	31.3	30.7	3.8
	110	42.5	30.5	31.7	6.2
Replicate 2		(N = 12)	(N = 12)	(N = 12)	
	30	13.1	13.4	13.6	2.2
	50	26.7	23.9	23.4	2.1
	70	35.5	29.2	28.4	2.5
	90	40.8	31.4	30.6	2.9
	110	43.8	31.8	31.3	3.8
Replicate 3		(N = 12)	(N = 12)	(N = 12)	
	30	15.0	15.1	14.7	2.2
	50	22.7	22.7	22.8	1.7
	70	28.0	27.3	27.8	2.1
	90	32.1	30.4	31.1	2.0
	110	35.1	32.9	33.6	2.5

a SD, pooled standard deviation of the three treatments.

b N = number of pigs

Energy density, performance and carcass traits

Growth performance and carcass traits were similar ($P > 0.10$) in the two restricted treatments (Table 3). In Treatment 1, the daily voluntary energy intake of 95% of the pigs (mean energy intake ± two times the SD) ranged from 29.7 to 45.3 MJ/d. The mean energy intakes in Treatments 2 and 3 were similar to the low level of energy intake of 29.7 MJ/d in Treatment 1. This indicates that in the restricted treatments the pigs with a low feed intake capacity were able to eat their feed allowances, which could explain the similar performance and carcass results.

Table 3. Least square means of performance during the restriction period and carcass traits of the three treatments

	Treatment 1	Treatment 2	Treatment 3		
Level of feeding	*Ad libitum*	Restricted	Restricted		
Energy density (MJ ME/kg)	13.1	13.1	12.5	SEM[a]	Contrast Treatments 1 vs (2+3)[b]
Performance					
Number of pigs	24	24	24		
Initial body weight (kg)[c]	57.5	57.5	52.8	0.7	
Final body weight (kg)[c]	112.4	110.1	108.2	0.6	
Energy intake (MJ ME/d)[d]	37.5 (0.8)	30.2 (0.4)	29.2 (0.4)		***
PEI (MJ ME/d)[d, e]	25.8 (0.8)	18.5 (0.4)	17.7 (0.4)		***
Estimated lipid deposition (g/d)[d, f]	358 (15)	235 (8)	225 (8)		***
Growth (g/d)[g]	958	764	723	23	***
EC (MJ ME/kg gain)[h]	39.1	39.6	40.8	0.7	
EC for production (MJ ME/kg gain)[h]	26.7	24.1	24.7	0.5	***
Estimated protein deposition (g/d)[f]	127	113	106	4.0	***
Carcass traits					
Number of pigs	16	16	16		
Carcass weight (kg)[c]	91.5	88.5	86.7	0.5	
Lean meat tissue %	53.4	56.0	56.1	0.7	***
Ham %	21.4	23.1	23.5	0.3	***
Other lean meat tissue %	32.0	32.9	32.6	0.5	
Fat tissue %	38.6	36.5	36.4	0.8	**
Subcutaneous fat %	25.4	23.9	23.6	0.8	*
Other fat tissue %	13.2	12.7	12.8	0.3	

a SEM, pooled standard error of the mean.
b Probabilities: *** = $P < 0.001$; ** = $P < 0.01$; * = $P < 0.05$.
c Means.
d Different ($P < 0.01$) variances between Treatment 1 and Treatments 2+3. Between brackets standard errors. Student test was used to test differences of means between Treatment 1 and Treatments 2+3.
e PEI, energy intake for production (energy intake corrected for energy requirements for maintenance (0.719 MJ ME x body weight$^{0.63}$ (kg), ARC, 1981).
f Protein and lipid depositions were estimated per pig from daily gain and PEI according to De Greef (1992).
g Variances of the growths between Treatment 1 and Treatments 2+3 had a tendency ($P < 0.10$) to differ.
h EC, energy conversion (energy intake (MJ ME)/gain (kg)), EC for production (PEI (MJ ME)/gain (kg)).

Energy intake, performance and carcass traits

The means and variances of daily energy intake and daily PEI in Treatment 1 were higher ($P < 0.01$) than in the restricted treatments (Table 3): twice as much for the standard deviations of energy intake and PEI. After 70 kg BW, the pigs in Treatment 1 had a higher ($P < 0.05$) growth than the pigs in the restricted treatments (Figure 1). The variance in growth of the pigs in Treatment 1 tended to be higher ($P < 0.10$) than for the restricted pigs in Treatments 2 and 3 (Table 3). The coefficients of variation for growth between Treatment 1 and the restricted treatments were similar, 9.9 and 10.3%, respectively.

In the restricted treatments feed consumption of some pigs exceeded feed allowance. These pigs that had eaten their feed allowance sometimes interrupted the meals of those still offered feed. Furthermore, De Haer and Merks (1992) found that individual housing reduced the standard deviation of feed intake by 30% compared with group housing. Variations in growth were not reported. Using individually housed pigs, Affentranger (1994) reported a 87% reduction of the standard deviation of feed intake and a coefficient of variation for growth of 6% in restrictively fed pigs. Therefore, the higher variations in energy intake and growth may result from the combination of restriction of individual feed intake and group housing.

The pigs in Treatment 1 had a higher ($P < 0.01$) mean and variance of the estimated lipid deposition than the pigs in Treatments 2 and 3 (Table 3). This may be due to the high mean and variance of the PEI in Treatment 1, because the extra energy intake above the level corresponding to maximum daily protein deposition was deposited as lipid.

The mean estimated protein deposition in Treatment 1 was higher ($P < 0.05$) than in Treatments 2 and 3. This indicates that on average the maximum daily protein deposition was not reached in the restricted treatments. The pigs in the restricted treatments were given energy for maintenance and a fixed amount of PEI. The maintenance requirement for energy increases with increasing BW more than the maintenance requirements for amino acid (Fuller et al., 1989; Wang and Fuller, 1990). Therefore, the amino acid supply for growth increased with BW. Furthermore, the minimum ratio between lipid and protein depositions increases with BW (De Greef, 1992; Bikker, 1994; Quiniou et al., 1995). Therefore, in the restricted treatments, energy intake, more likely than amino acid intake may have been too low for some pigs to reach the maximum daily protein deposition at the end of the fattening period.

In order to reach the level of maximum protein deposition, it may be better to calculate the PEI from growth and energy conversion ratio for production during the previous weeks.

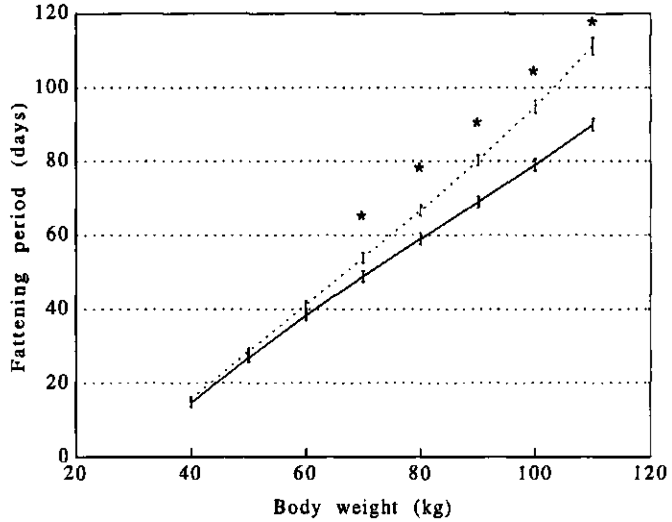

Fig. 1. Relationships between fattening duration and body weight for Treatment 1 (—) and Treatments 2 + 3 (---), (* difference ($P < 0.05$) in number of fattening days within body weight)

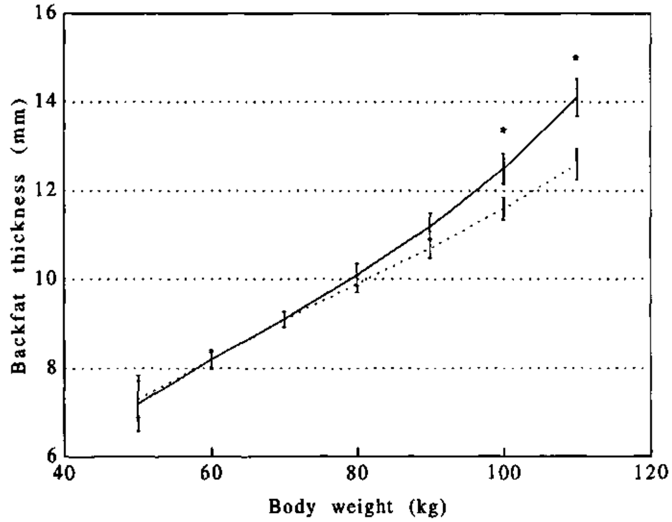

Fig. 2. Relationships between backfat thickness and body weight for Treatment 1 (—) and Treatments 2 + 3 (---), (* difference ($P < 0.05$) in backfat thickness within body weight)

The energy conversion ratio did not differ ($P > 0.10$) between Treatment 1 and Treatments 2 and 3. The pigs in the restricted treatments converted the production energy with a higher efficiency to leaner growth than in Treatment 1. However, the pigs in Treatment 1 grew faster, and, therefore, had a lower total demand for maintenance to reach slaughter weight than the pigs in the restricted treatments. Using individually housed castrated males, Campbell and Taverner (1988) also found no improvement of the feed conversion ratio of restrictively fed pigs (80% of *ad libitum*). However, Affentranger (1994) and Leymaster and Mersmann (1991) reported a decrease in feed conversion ratio of 6 and 10%, respectively, in restricted pigs. It may be assumed that in the latter studies the better production energy conversion ratio was not totally offset by a higher total energy demand for maintenance.

The main objective of imposing feeding strategies to fattening pigs is to optimize growth and carcass quality. The analyses of carcass traits showed that the pigs in the restricted treatments had a higher percentage ($P < 0.01$) of lean meat tissue and a lower percentage ($P < 0.01$) of fat tissue in the carcass than the pigs in Treatment 1 (Table 3). Especially, the percentages of ham and subcutaneous fat tissue in the carcass in the restricted treatments were improved ($P < 0.05$). At the end of the fattening period, backfat thickness in Treatment 1 was higher ($P < 0.05$) than in the restricted treatments (Figure 2).

The results of carcass dissection confirm the lower estimated lipid deposition and energy conversion ratio for production. The higher lean meat tissue percentage and lower backfat thickness in Treatment 2 and 3 are in agreement with the results of Leymaster and Mersmann (1991), and Affentranger (1994).

In conclusion, feed restriction reduced both mean and variation in energy intake and mean growth. Moreover, the energy conversion ratio for production was improved by feed restriction. This was associated with an increase in carcass lean meat tissue percentage of 2.6 units. Further improvements in both performance and carcass traits may be reached when the PEI of the individual pig is based on growth performance during the previous weeks.

References

Affentranger, P., 1994. Mast- und Schlachtleistung sowie Fleisch- und Fettqualität dreier Schweinetypen bei unterschiedlichen Fütterungsintensitäten. PhD Thesis, Eidgenössischen Technischen Hochschule Zurich, 119 pp.

ARC, 1981. The nutrient requirements of pigs. Technical review by an ARC Working Party. Farnham Royal, Slough, Commonwealth Agricultural Bureaux, 307 pp.

Bergström, P.J. and Kroeske, D., 1968. Methods of carcass assessment in research on carcass quality in the Netherlands. I. Description of methods. Report C-123, IVO, Zeist, The Netherlands and Proceedings of the 9th Annual Meeting of the EAAP, Dublin.

Bikker, P., 1994. Protein and lipid accretion in body components of growing pigs. PhD Thesis, Agricultural University, Wageningen, 203 pp.

Campbell, R.G. and Taverner, M.R., 1988. Genotype and sex effects on the relation between energy intake and protein deposition in growing pigs. J. Anim. Sci., 66: 676-686.

Cole, D.J.A., Hardy B. and Lewis, D., 1972. Nutrient density of pigs diets. In: D.J.A. Cole (Ed.), Pig production, Butterworths, London, p. 243-257.

Cöp, W.A.G., 1974. Protein and fat deposition in pigs in relation to body weight gain and feeding level. Communications Agricultural University, Wageningen, 18:1-78.

CVB, 1994. Veevoedertabel, gegevens over chemische samenstelling, verteerbaarheid en voederwaarde van voedermiddelen. Centraal Voederbureau, Lelystad.

De Greef, K.H., 1992. Prediction of production, nutrition induced tissue partitioning in growing pigs. PhD Thesis, Agricultural University, Wageningen, 117 pp.

De Haer, L.C.M. and Merks, J.W.M., 1992. Patterns of daily feed intake in growing pigs. Anim. Prod., 54:95-104.

De Haer, L.C.M., Merks, J.W.M., Kooper, H.G., Buiting, G.A.J. and Van Hattum, J.A., 1992. A note on the IVOG®- station: a feeding station to record the individual feed intake of group housed growing pigs. Anim. Prod., 54:160-162.

Fuller, M.F., McWilliam, R., Wang, T.C. and Giles, L.R., 1989. The optimum dietary amino acid pattern for growing pigs. 2. Requirements for maintenance and for tissue protein accretion. Br. J. Nutr., 62:255-267.

Kanis, E., 1988. Effect of average daily food intake on production performance in growing pigs. Anim. Prod., 46:111-122.

Kanis, E. and Koops, W.J., 1990. Daily gain, food intake and food efficiency in pigs during the growing period. Anim. Prod., 50:353-364.

Labroue, F., Guéblez, R., Sellier, P. and Meunier-Salaün, M.C., 1994. Feeding behaviour of group-housed Large White and Landrace pigs in French central test stations. Livest. Prod. Sci., 40:303-312.

Lambooij, E. and Merks, J.W.M., 1989. Technique and injection place of electronic identification numbers in pigs. IVO B-Report 335, Zeist, 12 pp.

Leymaster, K.A. and Mersmann, H.J., 1991. Effect of limited feed intake on growth of subcutaneous adipose tissue layers and on carcass composition in swine. J. Anim. Sci, 69:2837-2843.

Moughan, P.J., Smith, W.C. and Pearson, G., 1987. Description and validation of a model simulating growth in the pig (20-90 kg liveweight). NZ J. Agric. Res., 30:481-489.

Quiniou, N., Noblet, J., Van Milgen, J. and Dourmad, J.-Y., 1995. Effect of energy intake on performance, nutrient and tissue gain and protein and energy utilization in growing boars. Anim. Sci, 61:133-143.

Ramaekers, P.J.L., Huiskes, J.H.,Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C. and Swinkels, J.W.G.M., 1995. Estimating individual body weights of group-housed growing-finishing pigs using a forelegs weighing system. Comput. Electron. Agric., 13:1-12.

Rundgren, M., 1988. Growing pig performance. PhD Thesis, Swedish University of Agricultural Sciences, Uppsala.

SAS Institute Inc., 1989. SAS/SAS® Users Guide, version 6, Fourth Edition, Volume 2., Cary NC, 846 pp.

Snedecor, G.W. and Cochran, W.G., 1980. Statistical methods. The Iowa State University Press, Iowa, 507 pp.

Sterrenburg, P. and Ouwerkerk, E.N.J., 1986. Rekenmodel voor de bepaling van de thermische behaaglijkszone van varkens (BEZOVA). Report 78, IMAG, Wageningen, 21 pp.

Tess, M.W., Dickerson, G.E., Nienaber, J.A. and Ferrell, C.L., 1986. Growth, development and body composition in three genetic stocks of swine. J. Anim. Sci, 62:968-979.

Tullis, J.B., 1981. Protein growth in pigs. PhD Thesis, University of Edinburgh, 183 pp.

Walstra, P. 1980. Growth and carcass composition from birth to maturity in relation to feeding level and sex in dutch landrace pigs. PhD Thesis, Agricultural University, Wageningen, 207 pp.

Wang, T.C. and M.F. Fuller, 1990. The effect of plane of nutrition on the optimum dietary amino acid pattern for growing pigs. Anim. Prod., 50:155-164.

Whittemore, C.T. and Fawcett, R.H., 1976. Theoretical aspects of a flexible model simulate protein and lipid growth in pigs. Anim. Prod., 22:87-96.

Zhang, W., Huiskes, J.H. and Ramaekers, P.J.L., 1993. Serial ultrasonic measurements of backfat thickness in growing-finishing pigs I. Location determination of serial ultrasonic measurements. Pigs News and Information, 14(4):173N-176N.

Chapter 4

Effectiveness of a pair-gain feeding strategy for individually fed group-housed finishing pigs

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Abstract

In total, 48 crossbred barrows and 12 gilts were used to examine the effectiveness of a pair-gain feeding strategy for individually fed group-housed barrows. In a pair-gain feeding strategy, barrows are individually restricted to a feeding level at which their growth is similar to the mean growth of *ad libitum* fed gilts. The aims of this feeding strategy is to deliver animals in a compartment in one batch, and to improve carcass traits of the barrows. At 29.8 ± .4 kg body weight (BW), barrows were assigned to either the pair-gain treatment or the *ad libitum* treatment. All pigs had free access to feed up to 60 kg BW. The experimental period was from 60 to 110 kg BW. The twelve group fed gilts and 24 individually fed barrows (12 per pen) were also given free access to feed throughout the experimental period. The remaining 24 barrows (12 per pen) were put on a pair-gain feeding strategy. The barrows in the pair-gain treatment had a similar growth as the gilts. The *ad libitum* fed barrows had both a higher ($P < .05$) growth and a higher energy conversion ratio for production than the barrows in the pair-gain treatment. The energy conversion ratio, backfat thickness and lean meat tissue percentage were similar ($P > .10$) for the two treatments. In conclusion, the pair-gain feeding strategy proved to be effective in achieving similar growth between barrows and gilts. The energy conversion ratio and carcass traits of the barrows, however, were not improved.

Introduction

In the Netherlands, farmers use the all-in all-out management system in rooms for 80 to 100 growing-finishing pigs. Although a group of feeder pigs are put on as one batch, differences in growth among room mates make it necessary to deliver pigs in two or three batches. Farmers use this strategy to market pigs within the weight range where the highest price per kg carcass weight is paid (Giesen et al., 1988).

In *ad libitum* feeding systems, part of the variation in growth among room mates results from differences between barrows and gilts. Barrows with free access to feed have a higher voluntary energy intake and, therefore, a higher growth than gilts (Campbell, 1988; Kanis, 1988; Cole and Chad, 1989; Affentranger, 1994; Thomke et al., 1995). In addition to growth, the high feed intake is also associated with a low lean meat tissue percentage of *ad libitum* fed barrows,(Walstra, 1980; Leymaster and Mersmann, 1991; Affentranger, 1994; Thomke et al., 1995). Ramaekers et al. (1996) reported that the individual energy intake of group-housed barrows can be controlled by using feeding stations. Furthermore, feed restriction improved the carcass lean meat tissue percentage.

With a pair-gain feeding strategy, barrows are individually fed to a feeding level at which their growth is similar to the mean growth of *ad libitum* fed gilts. The aims of this feeding strategy is to deliver pigs in one batch and to improve carcass traits of the barrows. In this study, the effectiveness of a pair-gain feeding strategy was examined for individually fed group-housed barrows.

Materials and Methods

Animals and treatments

In total, 48 crossbred barrows (BW 29.8 ± .4 kg) and 12 crossbred gilts (BW 29.5 ± .8 kg) were used. Pigs were allotted to the respective treatments on the basis of BW and litter origin. From 30 to 60 kg BW, all pigs had free access to feed. For each pig the experimental period was from 60 kg to 110 kg BW. The 12 gilts and 24 of the 48 barrows were fed *ad libitum* in the experimental period. The other 24 barrows were fed accordingly a pair-gain feeding strategy.

In the pair-gain feeding strategy, the feed allowance of the barrows was BW dependent and was determined on a weekly basis. Barrows of which the BW was up to 3 kg higher than the mean BW of the gilts were pair-gain fed. The increment of 3 kg above the mean BW of the gilts was arbitrarily chosen. For the pair-gain fed barrows, the daily energy allowance for the subsequent week was calculated as the sum of the energy requirement for maintenance and production. Maintenance was computed as .719 MJ ME x $BW(kg)^{.63}$ (ARC, 1981). The energy requirement for production was computed as the estimated cumulative growth of the gilts times the cumulative energy conversion for production of the barrow. The cumulative growth of the gilts was calculated from 50 kg BW onwards. For each barrow the cumulative energy conversion for production was computed using the cumulative energy intake of production (energy intake minus energy intake for maintenance; PEI) divided by the cumulative growth from 50 kg onwards of the barrow.

Barrows with BW lower than the mean BW of the gilts were offered feed *ad libitum* in the subsequent week. For barrows that weighed more than the mean BW of the gilts + 3 kg, the daily energy allowance in the subsequent week was calculated as the mean daily energy intake per pig in the previous week increased with an amount of feed to compensate for the extra maintenance requirement.

During the experiment, the mean BW of the gilts was calculated weekly from the individual BW. After the first delivery of gilts, the BW of the delivered gilts were extrapolated per gilt in the subsequent weeks using equation [1]. Following this procedure it was avoided that the mean BW and the cumulative growth of the gilts plateaued or decreased.

$$BW\_e = BW\_d + G \times D \qquad [1]$$

where:

BW_e = estimated BW,

BW_d = BW on the day of delivery,

G = growth in the 14 days preliminary to the day of delivery,

D = number of days after delivery.

Body weight was measured weekly on Thursday between 9:00 and 10:00 h using a weighing scale (Welvaarts W2000, Den Dungen, The Netherlands). Backfat thickness was scanned ultrasonically (Renco Lean-Meater, Renco Corporation, Minnesota, USA) on the days of weighing. Backfat thickness was measured on the back at a point marked by a tattoo (Zhang et al., 1993a).

Housing and Feeding

The pigs were kept in five 6.0 m x 2.2 m pens (12 pigs per pen). The pens had partially solid, warm-water heated, floors and tri-bar metal slats. The room, in which the pens were situated, had a computer-controlled heating and mechanical ventilation system. At the beginning of the growing-finishing period, room temperature was set at 24°C. During the first week, room temperature was gradually decreased from 24 to 22°C. Thereafter, room temperature was decreased with .6°C per week to a minimum of 18°C.

The pens with barrows were equipped with IVOG® feeding stations. The feeding station consisted of a single space feeder, placed on a load cell, and an antenna (De Haer et al., 1992;

Ramaekers et al., 1996). Feed intake per visit was calculated after every visit to the feeder and recorded together with an electronic identification number. A transponder, (Tiris, Texas Instruments, Almelo, The Netherlands) injected in the earbase, was used as electronic identification device (Lambooij and Merks, 1989).

The pen with the gilts was equipped with a single space feeder. Feed intake of the gilts was measured weekly as a mean per pen.

All pigs were offered a finishing diet containing 13.1 MJ ME and .71% apparent ileal digestible lysine per kg and had free access to water from a nipple adjacent to the feeder.

Delivery strategy, slaughter procedure and carcass analysis

Pigs that had attained a BW of 105 kg or above on the day of weighing were slaughtered 5 days later. The pigs were killed by exsanguination after electrical stunning. The carcass was scalded, scraped and split longitudinally. In both treatments, 15 randomly selected barrows were dissected into trimmed major cuts according to the Dutch standard dissection method (Bergström and Kroeske, 1968). All cuts were weighed. Lean meat tissue was defined as the weight of trimmed ham and other trimmed lean meat tissue joints, *i.e.*, shoulder, cutlets and meat scraps. The fat tissue was defined as the weight of subcutaneous fat tissue and other fat tissue. Subcutaneous fat tissue was trimmed from back, ham, loin and shoulder, lower jaw, flare and kidney. The other fat tissue consisted of belly and breast-tip.

Computations

The daily energy intake per pig was calculated using the ME content of the diets. Protein and lipid depositions were estimated from the daily energy intake for production and the daily gain (De Greef, 1992).

Statistical analysis

The contrast of interest was the pair-gain treatment vs the *ad libitum* treatment. Treatment effects on performance and carcass traits were assessed by analysis of variance using GLM model [2] (SAS, 1989). The individual pig was the experimental unit.

$$Y_{ij} = \mu + T_i + \beta_1 W110_{ij} + \beta_2 BF60_{ij} + e_{ij} \qquad [2]$$

where:

Y_{ij} = variable,

μ = overall mean,

T_i = Treatment (i = *ad libitum* and pair-gain treatment),

$W110_{ij}$ = Covariable, deviation of the final BW from the mean final BW (for performance traits) or mean carcass weight (for carcass traits),

$BF60_{ij}$ = Covariable, deviation of backfat thickness from the mean backfat thickness at 60 kg BW,

e_{ij} = residual error

Results and discussion

Data of one gilt and three barrows in the pair-gain treatment were not included in the analyses. This was due to health problems and equipment malfunctioning. In the analyses, data of 45 barrows and 11 gilts were used.

In the experimental period, the gilts had a daily energy intake of 26.9 MJ ME, a growth of 736 g per day and an energy conversion ratio of 37.7 MJ ME per kg gain.

The experimental period of the pair-gain treatment contained in total 194 pig weeks for the 21 barrows. In 91 weeks, 13 barrows were pair-gain fed. In 56 weeks, 11 barrows had free access to feed. In 47 weeks, 5 barrows were restricted according the feeding scheme for pigs that were more than 3 kg heavier than the mean BW of the gilts.

After a week of adaptation to the pair gain feeding strategy, the growth of the pair-gain fed barrows was similar to that of the gilts during weeks 2 to 7 (Figure 1). In week 8, the growth of the gilts declined more than that of the pair-gain fed barrows. The *ad libitum* fed barrows were on a higher ($P < .05$) level of growth than the barrows in the pair-gain treatment.

The daily energy intake, PEI, growth, energy conversion ratio for production and estimated daily lipid deposition of the *ad libitum* fed barrows were higher ($P < .05$) than that of the barrows in the pair-gain treatment (Table 1). The estimated daily protein depositions were similar ($P > .10$) for the two treatments.

Table 1. Least square means of performance and carcass traits of the *ad libitum* and pair-gain treatments.

	Barrows *ad libitum*	Barrows pair-gain	SEM[a]	*ad libitum* vs pair-gain feeding[a]	Covariable backfat thickness at initial body weight[b]
Performance					
Number of pigs	24	21			
Initial body weight (kg)[c]	61.0	60.4	0.3		
Final body weight (kg)[c]	109.9	110.1	0.5		
Initial backfat thickness (mm)[c]	8.6	8.6	0.2		
Final backfat thickness (mm)[c]	15.5	15.0	0.8		
Energy intake (MJ ME/d)	34.2	31.4	0.7	**	
PEI (MJ ME/d)[d]	22.4	19.6	0.6	**	
Growth (g/d)	816	760	17	*	
EC (MJ ME/ kg gain)[d]	42.3	41.5	0.7		y = 41.9 (0.7) + 1.5 (0.3) x d_bft60; R-sqr = 0.45; rsd = 3.1
EC for production (MJ ME/kg gain)[d]	27.5	25.8	0.5	*	y = 26.8 (0.6) + 1.3 (0.3) x d_bft60; R-sqr = 0.43; rsd = 2.6
Estimated lipid deposition (g/d)[e]	313	264	13	**	y = 290 (13) + 18 (6) x d_bft60; R-sqr = 0.27; rsd = 61
Estimated protein deposition (g/d)[e]	109	107	4		y = 108 (4) - 8 (2) x d_bft60; R-sqr = 0.46; rsd = 17
Carcass traits					
Number of pigs	15	15			
Carcass weight (kg)[c]	88.7	87.1	0.4		
Lean meat tissue %	53.8	54.0	0.8		y = 53.9 (0.4) - 1.61 (0.2) x d_bft60; R-sqr = 0.39; rsd = 3.0
Ham %	21.8	21.7	0.4		y = 21.8 (0.4) - 0.71(0.2) x d_bft60; R-sqr = 0.34; rsd = 1.7
Other lean meat tissue %	32.0	32.3	0.4		y = 32.1 (0.5) + 0.89 (0.2) x d_bft60; R-sqr = 0.36 rsd = 1.7
Fat tissue %	38.8	38.5	0.8		y = 38.6 (0.8) +1.68 (0.4) x d_bft60; R-sqr = 0.39; rsd = 3.2
Subcutaneus fat %	25.4	24.9	0.8		y = 25.2 (0.8) + 1.60 (0.2) x d_bft60; R-sqr = 0.41; rsd = 2.9
Other fat tissue %	13.3	13.6	0.3		

a SEM, pooled standard error of mean; Probabilities: ** = P < .01; * = P < .05.

b d_bft60 = the deviation of the mean backfat thickness at 60 kg ; R-sqr = coefficient of determination; rsd = residual standard deviation; SE between brackets.

c MEANS.

d PEI, energy intake for production (energy intake corrected for energy requirements for maintenance (.719 MJ ME x body weight$^{0.63}$ (kg), ARC, 1981); EC, energy conversion ratio (energy intake (MJ ME)/ gain (kg)), EC for production (PEI (MJ ME) / gain (kg)).

e Protein and lipid depositions were estimated per pig from daily gain and PEI according De Greef (1992).

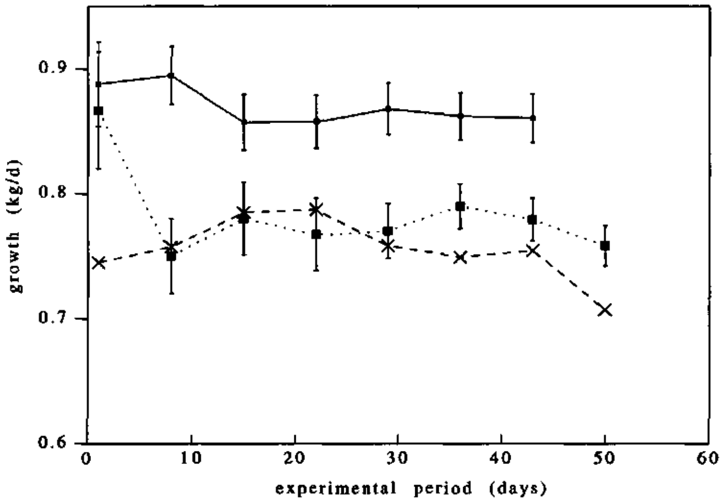

Fig. 1. Cumulative growth of the gilts (X), pair-gain (■) and *ad libitum* (▪) treatments from the start of the experiment to the first delivery of a pig in a treatment.

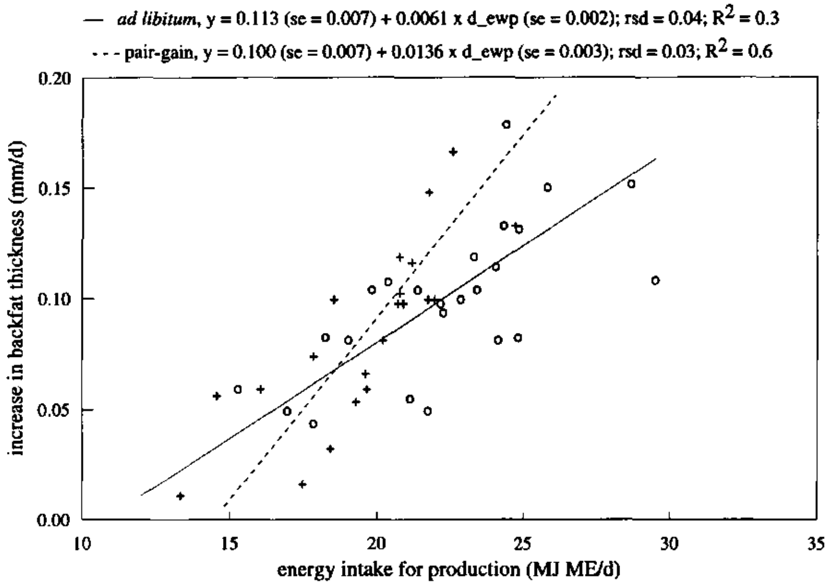

Fig. 2. Relationship between increase in backfat thickness and the energy intake for production (d_ewp is difference to the mean energy intake for production per treatment) pair-gain (+) and *ad libitum* (o) treatments.

The barrows in the pair-gain treatment had lower energy conversion ratios for production than the *ad libitum* fed barrows. However, the *ad libitum* fed barrows grew faster and had, therefore, a lower total demand for maintenance to reach slaughter weight. Therefore, the total energy conversion ratios were similar ($P > .10$) for the two treatments. Campbell (1988), Rao and McCracken (1992), Bikker (1994) and Ramaekers et al. (1996) also reported no differences in energy conversion ratio in restrictively and *ad libitum* fed pigs.

The mean daily energy intake of the barrows in the pair-gain treatment was 92% of the energy intake of the *ad libitum* fed barrows. The pair-gain feeding strategy improved the energy conversion ratio for production. This improvement was associated with a decrease in the estimated daily lipid deposition of barrows in the pair-gain treatment, whereas the estimated daily protein deposition was similar to that of the *ad libitum* fed barrows (Table 1). From an economic point of view it is preferable that the maximum protein deposition is reached (De Vries and Kanis, 1992).

Carcass traits and the backfat thickness on the day of delivery were similar ($P > .10$) for the pair-gain and *ad libitum* treatments (Table 1). These findings are not in line with the observed improvement in energy conversion for production of the barrows in the pair-gain treatment. Rao and McCracken (1992) with boars and Bikker (1994) with gilts found that energy restriction of 10 and 5%, respectively, did not affect the chemical carcass composition. It may be that the energy restriction in the pair-gain treatment was not severe enough to improve the backfat thickness and lean meat tissue percentage in the carcass. Ramaekers et al. (1996) found in a similar study an improvement of the carcass lean meat tissue percentage of 2.6 units in barrows fed 80% of *ad libitum*.

In the barrows of the pair-gain treatment, the increase in backfat thickness per unit of energy intake (MJ ME/d) was higher ($P < .05$) than in the *ad libitum* fed barrows (Figure 2). Rao and McCracken (1992), Bikker (1994), and Thomke et al. (1995) reported that *ad libitum* fed pigs deposit more lipid in the lean meat tissue and in the offal than restrictively fed pigs. This suggests that the higher estimated lipid deposition in the *ad libitum* fed pigs has also occurred in tissue parts other than fat tissue.

McLaren et al. (1989), with barrows and gilts, and Zhang et al. (1993b), with barrows, reported that ultrasonic measures of backfat thickness at 74 and 60 kg BW had a correlation of .4 and .8, respectively, with backfat thickness in the carcass at about 100 kg BW. Our results and the results of Bikker (1994) suggest that variation in backfat thickness does not decrease from 60 to 110 kg BW when restricting pigs at levels that allow maximum protein deposition. In both treatments variance in backfat thickness at 60 kg BW explained about 40% of the variance in lean meat tissue percentage (Table 1). This means that part of the variation in lean meat tissue was already present at the start of the experimental period. Regardless the carry-over effect of the variation in lean mean tissue, Bikker (1994) and Ramaekers et al. (1996) reported that with an energy intake restriction of 20 % or above the lean meat tissue percentage in the carcass can be improved. However, this may result in lower growth of the barrows than that of the gilts.

Implications

The present study shows that a pair-gain feeding strategy using feeding stations proved to be effective. Feed intake of the barrows had to be restricted for about 10% to achieve similar growth of barrows and gilts. However, a pair-gain feeding strategy implemented at 60 kg BW did not improve the energy conversion ratio and carcass traits of the barrows.

References

Affentranger, P., 1994. Mast- und Schlachtleistung sowie Fleisch- und Fettqualität dreier Schweinetypen bei unterschiedlichen Fütterungsintensitäten. Ph.D. Thesis, Eidgenössischen Technischen Hochschule, Zurich, 119 pp.

ARC, 1981. The nutrient requirements of pigs. Technical review by an ARC Working Party. Farnham Royal, Slough, Commonwealth Agricultural Bureaux, 307 pp.

Bergström, P.J. and Kroeske D., 1968. Methods of carcass assessment in research on carcass quality in the Netherlands. I. Description of methods. Report C-123, IVO, Zeist, The Netherlands and Proceedings of the 9th Annual Meeting of the EAAP, Dublin.

Bikker, P., 1994. Protein and lipid accretion in body components of growing pigs. Ph.D. Thesis, Agricultural University, Wageningen, 203 pp.

Campbell, R.G., 1988. Nutritional constraints to lean tissue accretion in farm animals. Nutr. Res. Rev., 1:233-253.

Cole, D.J.A. and Chad, S.A., 1989. Voluntary food intake of growing pigs. In: Forbes, J.M., Varley, M.A. and Lawerence, T.L.J. (eds) The Voluntary Food Intake of Pigs, An Occasional Publication of the British Society of Animal Production, 13:61-70.

De Greef, K.H., 1992. Prediction of production, nutrition induced tissue partitioning in growing pigs. Ph.D. Thesis, Agricultural University, Wageningen, 117 pp.

De Haer, L.C.M., Merks, J.W.M., Kooper,H.G., Buiting, G.A.J. and Van Hattum J.A., 1992. A note on the IVOG®-station: a feeding station to record the individual feed intake of group housed growing pigs. Anim. Prod., 54:160-162.

De Vries, A.G. and Kanis, E., 1992. A growth model to estimate economic values for food intake capacity in pigs. Anim. Prod., 55:241-246.

Giesen, G.W.J., Baltussen, W.H.M. and Oenema J., 1988. Optimalisering van het afleveren van mestvarkens. Landbouw-Economisch Instituut, publikation 3.139, Den Hague, The Netherlands.

Kanis, E., 1988. Effect of average daily food intake on production performance in growing pigs. Anim. Prod., 46:111-122.

Lambooij, E. and Merks, J.W.M., 1989. Technique and injection place of electronic identification numbers in pigs. IVO B-report 335, Zeist, The Netherlands, 12 pp.

Leymaster, K.A. and Mersmann, H.J., 1991. Effect of limited feed intake on growth of subcutaneous adipose tissue layers and on carcass composition in swine. J. Anim. Sci, 69:2837-2843.

McLaren, D.G., McKeith, F.M. and Novakofski, J., 1989. Prediction carcass characteristics at market weight from serial real-time ultrasound measures of backfat and loin eye area in the growing pig. J. Anim. Sci., 67:1657-1667.

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A. and Van der Peet-Schwering, C.M.C., 1996. Performance and carcass traits of individual pigs housed in groups as affected by ad libitum and restricted feeding. Livest. Prod. Sci. (in press).

Rao, D.S. and McCracken, K.J., 1992. Energy: protein interactions in growing boars of high genetic potential for lean growth. 2. Effects on chemical composition of gain and whole-body protein turn-over. Anim. Prod., 54:83-93.

SAS Institute Inc., 1989. SAS/SAS® Users Guide, version 6, Fourth Edition, Volume 2., Cary NC, 846 pp.

Thomke, S., Alaviuhkola, T., Madsen, A., Sundstøl, F., Mortensen, H.P., Vangen, O. and Andersson K., 1995. Dietary energy and protein for growing pigs. 2. Protein and fat accretion and organ weights of animals slaughtered at 20, 50, 80 and 110 kg live weight. Acta. Agric. Scand. Sect. A, Anim. Sci., 45:54-63.

Walstra, P., 1980. Growth and carcass composition from birth to maturity in relation to feeding level and sex in dutch landrace pigs. Ph.D. Thesis, Agricultural University Wageningen, 207 pp.

Zhang, W., Huiskes, J.H. and Ramaekers, P.J.L., 1993a. Serial ultrasonic measurements of backfat thickness in growing-finishing pigs I. Location determination of serial ultrasonic measurements. Pigs News and Information, 14:173N-176N.

Zhang, W., Huiskes, J.H. and Ramaekers, P.J.L., 1993b. Serial ultrasonic measurements of backfat thickness in growing-finishing pigs II. Relationship with carcass traits. Pigs News and Information, 14:177N-180N.

Chapter 5

Effect of feed restriction on eating traits of group-housed finishing pigs

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Abstract

In two experiments, 120 crossbred barrows (29.7 ± .2 kg BW) were used to examine the effect of feed restriction on eating traits of barrows. Eating traits per pig were determined using transponders and an electronic feeding station equipped with an antenna. In both experiments, a control group of 24 barrows (12 per pen) had free access to a high (H) energy diet (13.1 MJ ME/kg and .71% apparent ileal digestible lysine). From 55.9 ± .7 to 110.2 ± .6 kg BW in Exp. 1, the daily energy allowance of 48 barrows was restricted to 18 MJ ME per day above maintenance using diet H, and a low (L) energy diet (12.5 MJ ME/kg and .67% apparent ileal digestible lysine), respectively, for 24 barrows each (12 per pen). From 55.5 ± .7 to 110 ± .5 kg BW in Exp. 2, 24 barrows (12 per pen) were restricted to a feeding level at which their growth was similar to the mean growth of a group of 12 reference gilts (29.5 ± .8 kg BW). The gilts had free access to feed using diet H. In both experiments, feed restriction increased (P < .05) the number and duration of visits to the feeder and of the visits without feed intake. The restrictively fed barrows consumed about 88% of the feed in fewer (P < .01) large meals than *ad libitum* fed barrows. Energy density had no effect on the eating traits. Furthermore, feed restriction changed the circadian feed intake patterns. It was concluded that feed restriction increased feeder visiting time and number of visits and of number of meals per day. This increase was related to the number of visits to the feeder in which no feed was consumed.

Introduction

Feeding stations in combination with automatic weighing enables the use of body weight (BW) dependent feeding schemes for individual pigs housed in groups (Berberich, 1988; Slader and Gregory, 1988; Ramaekers et al., 1995). Using body weight dependent feeding schemes, the individual feed intake of pigs can be restricted in order to improve performance and carcass traits (Ramaekers et al., 1996ab).

Feed restriction of groups-housed pigs has shown to alter animal behaviour (Hammel and Hurnik, 1987). Verstegen et al. (1982) found in a metabolism study that feed restriction increased the heat production associated with activity with 20%. Restrictively fed pigs stood more, and were more restless and aggressive (Graves et al., 1978), nibbled more on penmates

(Robert et al., 1991) and spended less time lying (Day et al., 1995) than *ad libitum* fed pigs. Although animal behaviour is changed, it is not known whether restricted feeding alters the traits associated with feed intake (eating traits). In this study the effect of individual feed restriction was examined on eating traits of group-housed barrows.

Materials and Methods

Animals and Designs

In two experiments, 120 crossbred barrows (29.7 ± .2 kg BW) and 12 gilts (29.5 ± .8 kg BW) of a combination of Large White sire line and a rotation crossbred sow line (Dutch Landrace, Dutch Large White sow line and Finnish Landrace) were used.

In both experiments, the barrows were allotted to the treatments on the basis of BW and litter origin at the start of a preliminary period of 36 days. In the preliminary period, all pigs had free access to a starter diet containing 12.7 MJ ME per kg and .82 % apparent ileal digestible lysine.

The experimental period was from 55.9 ± .7 to 110.2 ± .6 kg BW in Exp. 1, and from 55.5 ± .7 to 110.0 ± .5 kg BW in Exp. 2.

In Exp. 1, 72 barrows were used in two replicates of 36 pigs each. The pigs in the control treatment were maintained with free access to a high energy diet (H) containing 13.1 MJ ME per kg and .71% apparent ileal digestible lysine. The daily energy allowance of the restricted pigs was 18 MJ ME per day above maintenance using diet H and a low (L) energy diet (12.5 MJ ME/kg and .67% apparent ileal digestible lysine). The maintenance requirement was computed as .719 MJ ME x $BW(kg)^{.63}$ (ARC, 1981).

In Exp. 2, 12 gilts and 48 barrows were used. The gilts were used as a reference group and were fed *ad libitum* using diet H. The control treatment had free access to diet H. In the restricted treatment, the barrows with a BW that was heavier than the mean BW of the gilts were restricted using diet H (Ramaekers et al., 1996b). Barrows with a BW that was lighter than the mean BW of the gilts were offered feed *ad libitum*.

In both experiments, feed allowances were computed weekly after measuring BW.

Housing and equipment

In both experiments, the pigs were kept with 12 pigs per pen (6.0 m x 2.2 m). The pens had partially solid, warm-water heated, floors and tri-bar metal slats. The pens with barrows were equipped with IVOG® feeding stations. The feeding station consisted of a single space feeder, placed on a load cell, and an antenna (De Haer et al., 1992). Feed intake per visit was calculated after each visit to the feeder. Furthermore, the initial and final times of each visit to the feeder were recorded. A transponder, (Tiris, Texas Instruments, Almelo, The Netherlands) injected in the earbase, was used as an electronic identification device (Lambooij and Merks, 1989).

In the restricted treatments of both experiments, the remaining feed allowance of a restrictively fed barrow was estimated every 10 seconds during each visit. When a pig had eaten its daily ration, the operating flap in the feeder was blocked for the rest of the day. Furthermore, the operating flaps of the feeders were blocked every 30 seconds for 25 seconds during each visit over the restriction period to minimize the amount of ort in the feeder. On each day, a new eating period started at 00:00 hour.

In Exp. 2, the pen with the gilts was equipped with a single space feeder. Eating traits of the gilts were not recorded.

In both experiments, all pigs had free access to water from a nipple adjacent to the feeder. The room was illuminated with daylight and artificial lights from 8:00 to 16:00 h.

Eating traits

The mean eating traits per pig per day were calculated using the data of the recordings of the feeding station from one week after the start of the experimental period to the day on which the first pig in a pen was delivered. A visit of a pig to the feeder started when the transponder was recognized by the antenna of the feeding station and ended when the transponder of the pig was not recognized by the antenna for 25 seconds or when another pig was recognized by the antenna. The duration time of a visit was calculated as the difference between the time of the first and last recognition of the pig. For grouping visits into meals, a meal criterion of 5 minutes was used (De Haer and Merks, 1992). Successive visits of the same pig with an interval less than 5 minutes were grouped into the same meal. The daily feeder visiting time is the sum of the duration of all visits of a pig on a day.

The eating traits were computed from all visits. This means that the data of both the visits with and without feed intake were used. Large meals per pig per day that had a major contribution to the pig's daily feed intake were selected from the meals using the Linda-index (De Haer and Merks, 1992).

The following eating traits were calculated from all the visits. Thus from visits with and without feed intake:
feed intake (kg/d),
number of visits per day,
number of meals per day, and
feeder visiting time (min/d).

From the visits in which feed was consumed the following eating traits were computed:
feed intake per visit (g),
feed intake per meal (g),
time per visit (min),
time per meal (min),
rate of feed intake (g/min), and
ratio between number of meals and number of visits.

The following large meals eating traits were computed:
feed intake in large meals (kg/d),
feed intake per large meal (g),
feeder visiting time in large meals (min),
number of large meals per day,
time per large meal (min),
rate of feed intake in large meals (g/min),
fraction of feed intake per day in large meals,
fraction of large meals per day, and
fraction time per day in large meals.

Statistical analysis

In Exp. 1, the contrasts of interest were the *ad libitum* treatment vs the two restricted treatments and the restricted H treatment vs the restricted L treatment. In Exp. 2, The contrast of interest was the *ad libitum* treatment vs the restricted treatment.

In both experiments, the homogeneity of variance between the *ad libitum* and restricted treatments was tested (Snedecor and Cochran, 1980). Eating traits with similar ($P > .10$) variances were assessed by analysis of variance using GLM model [1] (SAS, 1989), otherwise a Student test was used. The pig was the experimental unit.

$$Y_{ijk} = \mu + T_i + R_j + T_i \times R_j + e_{ijk} \quad [1]$$

where:

Y_{ijk} = variable,

μ = overall mean,

T_i = treatment (Exp 1, i = 1, 2 or 3; Exp 2, i= 1 or 2),

R_j = replicate (Exp. 1, j = 1 or 2),

e_{ijk} = residual error.

Results

In Exp. 2, data of three barrows in the restricted treatment were not included in the analyses. This was due to equipment malfunctioning.

In both experiments, mean and within treatment variances in feed intake of the restricted treatments were smaller ($P < .05$) than those of the *ad libitum* treatments (Tables 1 and 2). In Exp. 1, energy density had no effect ($P > .10$) on the feed intake of the two restricted treatments.

In both experiments, the applied restriction of feed intake was associated with changes of the feeder visiting time, the number of visits, and the number of meals per day (Tables 1 and 2). Feeder visiting time of the restrictively fed pigs was 8 to 19 min/day longer ($P < .05$) than that of the *ad libitum* fed pigs. Restrictively fed pigs had 20 to 50% more ($P < .01$) visits per day to the feeder, and about 30% more ($P < .05$) meals per day than their *ad libitum* fed counterparts.

The differences in feeder visiting time, number of visits per day and number of meals per day between the restricted and *ad libitum* treatments were mainly due to the occurrence of visits to the feeder without feed intake. In both experiments, the number of visits per day and number of meals per day with feed intake of the restricted treatments were similar to those of the *ad libitum* treatments. In Exp. 1, feeder visiting time in the visits with feed intake was similar between the restrictively fed pigs and the *ad libitum* fed pigs. In Exp. 2, the feeder

Table 1. Feed intake and eating traits of the *ad libitum* and restrictively fed barrows in Exp. 1.

	Ad libitum [a] H [b]		Restricted H		Restricted L		*Ad libitum* vs Restricted (H+L)	
	mean	sd	mean	sd	mean	sd	mean	variances [c]
number of pigs	24		24		24			
feed intake per day (kg)	2.9	0.4	2.3	0.2	2.4	0.2	***	***
feed intake per day in large meals (kg)	2.6	0.4	2.0	0.1	2.1	0.2	***	***
feeder visiting time (min/d)	65	15	76	12	73	16	*	
feeder visiting time without feed intake (min/d)	1	0.5	6	3	4	3	***	***
feeder visiting time with feed intake (min/d)	64	15	69	10	69	14		
number of visits per day	17	11	22	9	20	9		
number of visits without feed intake per day	2	1	11	5	9	5	***	***
number of visits with feed intake per day	15	10	12	4	11	5		***
number of meals per day	8.5	2.4	11.7	2.7	11.1	3.4	***	
number of meals without feed intake per day	0.7	0.3	3.5	1.2	3.6	1.3	***	***
number of meals with feed intake per day	7.7	2.3	8.2	2.4	7.5	2.6		
time per visit (min)	6.3	3.6	8.0	2.4	8.5	3.0	*	*
time per meal (min)	9.6	4.0	10.1	2.5	10.9	3.4		
feed intake per visit (g)	294	174	274	81	309	112		**
feed intake per meal (g)	439	161	346	87	390	116	*	**
rate of feed intake (g/min)	47	9	35	5	37	7	***	**
feeder visiting time in large meals (min/d)	58	14	59	9	60	13		
feed intake per large meal (g)	582	191	621	134	639	133		*
number of large meals per day	5.3	1.5	4.2	1.2	4.1	1.2	***	
time per large meal (min)	12.7	5.0	17.6	3.6	17.7	4.8	***	
rate of feed intake in large meals (g/min)	48	10	35	5	37	7	***	**
fraction of feed intake per day in large meals	0.91	0.03	0.87	0.02	0.88	0.02	***	
ratio between number of meals and number of visits	0.67	0.23	0.78	0.09	0.78	0.08	*	***
fraction of large meals per day	0.69	0.08	0.51	0.06	0.56	0.07	***	
fraction time per day in large meals	0.91	0.03	0.85	0.03	0.87	0.03	***	

a *Ad libitum*, free acces to feed, Restricted, daily feed allowances 18 MJ ME above maintenance

b H, energy density = 13.1 MJ ME/kg; L, energy density = 12.5 MJ ME/kg.

c Different ($P < .05$) within treatment variances between *ad libitum* treatment vs restricted treatments. Student test was used to test differences of means between *ad libitum* treatment vs restricted treatments. Probabilities: *** = $P < .001$; ** = $P < .01$; * = $P < .05$.

Table 2. Feed intake and eating traits of the *ad libitum* and restrictively fed barrows in Exp. 2.

	Ad libitum [a]		Restricted		*Ad libitum* vs Restricted	
	mean	sd	mean	sd	mean	variances [b]
number of pigs	24		21			
feed intake per day (kg)	2.5	0.3	2.3	0.2	**	*
feed intake per day in large meals (kg)	2.3	0.3	2.0	0.2	***	***
feeder visiting time (min/d)	65	14	84	15	***	
feeder visiting time without feed intake (min/d)	0.5	0.2	3.0	2.0	***	***
feeder visiting time with feed intake (min/d)	64	13	81	14	***	
number of visits per day	9.3	2.1	13.8	4.7	***	
number of visits without feed intake per day	1.0	0.4	5.6	3.0	***	***
number of visits with feed intake per day	8.2	2.0	8.2	2.0		
number of meals per day	6.7	1.3	8.6	2.6	***	
number of meals without feed intake per day	0.5	0.3	1.9	1.4	***	***
number of meals with feed intake per day	6.2	1.3	6.7	1.4		
time per visit (min)	9.0	3.0	11.3	2.8	*	
time per meal (min)	11.3	3.3	13.2	3.0	*	
feed intake per visit (g)	366	118	333	86		
feed intake per meal (g)	454	127	389	85	*	
rate of feed intake (g/min)	42	9	30	5	***	*
feeder visiting time in large meals (min/d)	58	13	69	13	**	
feed intake per large meal (g)	574	127	639	144		
number of large meals per day	4.4	0.8	3.6	0.8	**	
time per large meal (min)	14.2	3.8	21.1	5.4	***	*
rate of feed intake in large meals (g/min)	42	9	31	5	***	*
fraction of feed intake per day in large meals	0.91	0.03	0.88	0.03	***	
ratio between number of meals and number of visits	0.79	0.09	0.85	0.07	*	
fraction of large meals per day	0.72	0.08	0.55	0.11	***	
fraction time per day in large meals	0.91	0.03	0.85	0.04	***	

a *Ad libitum*, free acces to feed, energy density = 13.1 MJ ME/kg, Restricted, pair-gain feeding, energy density =13.1 MJ ME/kg.

b Different ($P < .05$) within treatment variances between *ad libitum* treatment vs restricted treatment. Student test was used to test differences between treatments means.
Probabilities: *** = $P < .001$; ** = $P < .01$; * = $P < .05$.

visiting time of the restrictively fed pigs was higher (P <.01) than that of the *ad libitum* fed pigs.

In both experiments, the rate of feed intake of the restrictively fed pigs was about 25% lower (P < .001) than that of the *ad libitum* fed pigs. This difference in rate of feed intake resulted from a low feed intake and a high feeder visiting time of the restrictively fed pigs.

The results of the large meals are presented in Tables 1 and 2. Although, in both experiments, the fraction of feed intake in large meals in restrictively fed pigs was only numerically lower than that of the *ad libitum* fed pigs, the fraction of large meals per day of the restrictively fed pigs was about 0.15 lower (P < .001) than that of the *ad libitum* fed pigs.

In Figure 1, the daily patterns of feed intake, feeder visiting time, and number of large meals are presented per pen for both experiments. In the *ad libitum* treatments, the eating trait patterns had two peaks, a small one in the morning and a large one in the afternoon. In the restricted treatments, the patterns of the feed intake and feeder visiting time were different from those of the *ad libitum* treatments. As soon as a new feeding period started at 0:00 h, the restrictively fed pigs started to eat. Towards the end of the day feed intake and visiting time per hour declined. The pattern of the number of large meals per hour of the restrictively fed pigs was similar to that of the *ad libitum* fed pigs.

In Figure 2, the data on the mean feed intake per large meal are presented per hour during the day for both experiments. In the *ad libitum* treatments, the hourly feed intake per large meal remained almost at the same level throughout the day. There was only a slight increase in the feed intake per meal between 17:00 and 20:00 h. In the restricted treatments, the hourly feed intake per large meal declined during the day. At the start of the eating period, the hourly feed intake per large meal of the restrictively fed pigs was higher than that of the *ad libitum* fed pigs. This was reversed at the end of the eating period.

Discussion

Feed restriction is used to improve performance and carcass traits of barrows. As expected, the mean and variances of feed intake were decreased (P < .05) by feed restriction (Tables 1 and 2).

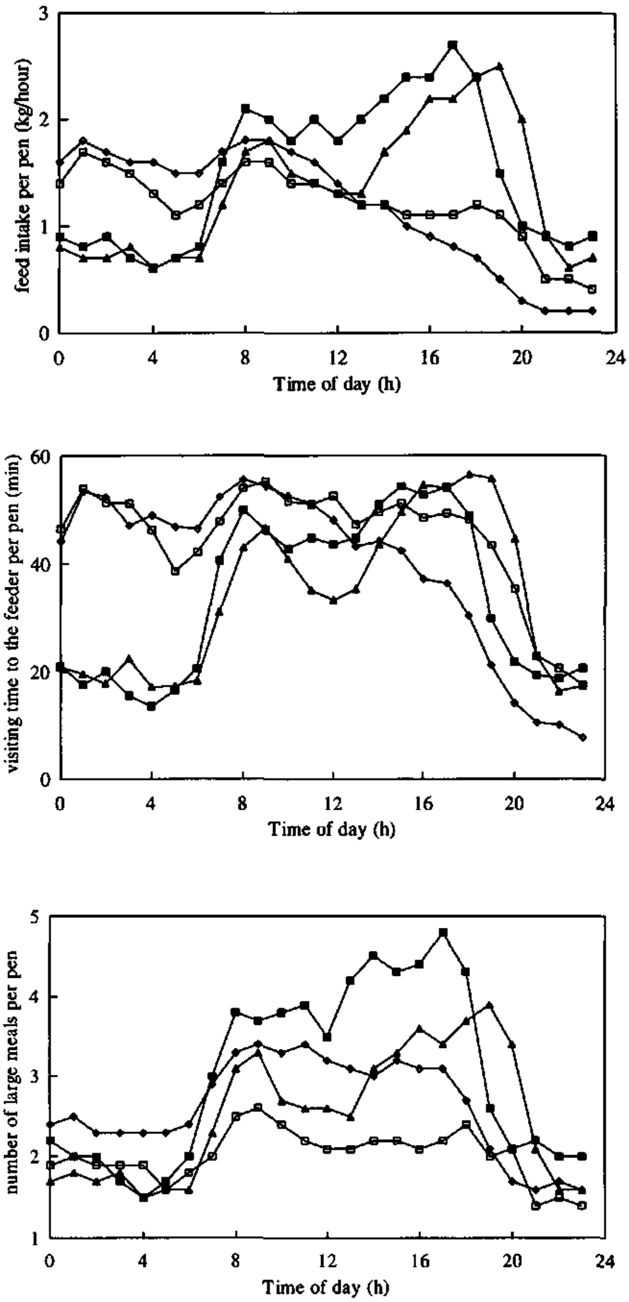

Fig. 1. Mean feed intake, feeder visiting time and number of large meals per h for the *ad libitum* (■, Exp. 1, n = 24; ▲, Exp. 2, n = 24) and the restrictively fed (◇, Exp. 1, n = 48; □, Exp. 2, n = 21) pigs.

Eating traits and animal behaviour

Feed restriction increased daily feeder visiting time and frequency of feeder visits due to more visits without feed intake and a low rate of feed intake in visits with feed intake (Tables 1 and 2).

The high number of visits and feeder visiting time of visits without feed intake in the restricted treatments suggest that the restrictively fed pigs were more restless around the feeder. An overall restless behaviour of restrictively fed pigs was reported in several studies (Graves et al., 1978; Hammel and Hurnik, 1987 ; Day et al., 1995). Using climate respiration units, Verstegen et al. (1982) found that feed restriction was associated with an increase of activity related heat production. The increased activity caused by feed restriction may demand extra feed energy requirements at the expense of the energy available for growth.

The low rate of feed intake in the visits with feed intake in the restricted treatments was probably due to the procedure of feed restriction. Every 30 seconds the operating flap of the feeder was blocked for 25 seconds to minimize the possibility of feed orts in the trough. In pigs given free access to feed, Morrow and Walker (1994) found that reducing the dispensing rate of the operating flap from 5.3 to 2.7 g per press decreased the rate of feed intake with about 37%. Nielsen et al. (1995) reported that in *ad libitum* fed pigs, 20 pigs instead of 10 pigs per feeder increased the rate of feed intake with about 17%. In both studies, total feed intake was not affected. Therefore, the effect of feed restriction on the eating traits of group-housed pigs not only depends on the amount of feed allowance. It may also depend on the procedure of restriction of access to feed, the dispensing rate of the feeder, and the number of pigs per feeder.

Eating patterns

In the *ad libitum* treatments, the circadian patterns of feed intake and feeder visiting time (Figure 1) were similar to patterns found by De Haer and Merks (1992) and Nielsen et al. (1995). The *ad libitum* fed pigs seem to have a preference for eating in the late afternoon (16:00 - 18:00 h) when the feeder is occupied during nearly 90% of the time. The amplitude of feed intake and feeder visiting time in the present study (12 pigs per pen) were more pronounced than those in the study (8 pigs per pen) of De Haer and Merks (1992). This may be due to the number of pigs per feeder. Nielsen et al. (1995) found that the amplitude of feeder visiting time was about 15 min per h higher when pigs were housed in groups of 20 instead of 10.

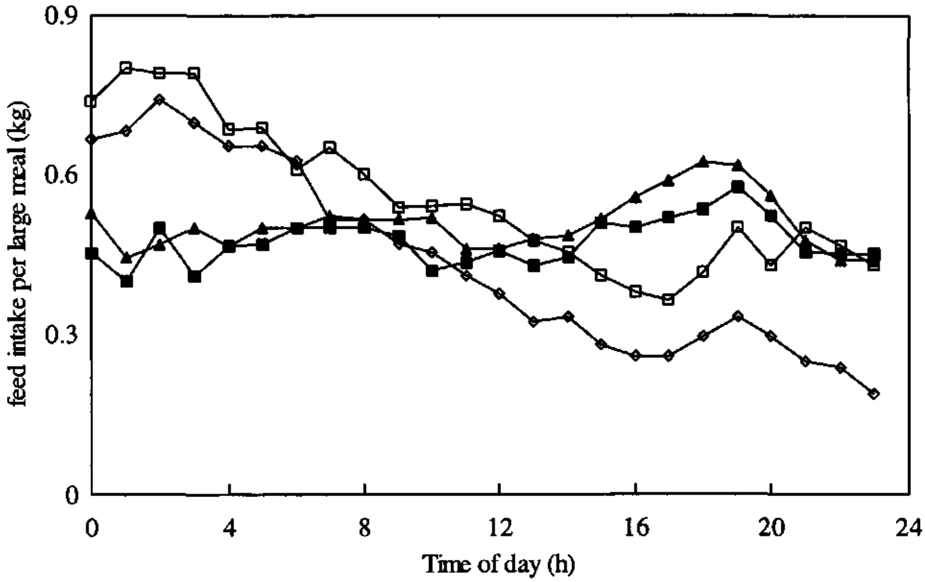

Fig. 2. Mean feed intake per large meal per h for the *ad libitum* (■, Exp. 1, n = 24; ▲, Exp. 2, n = 24) and the restrictively fed (◇, Exp. 1, n = 48; □, Exp. 2, n = 21) pigs.

Feed restriction changed the patterns of feed intake and feeder visiting time dramatically (Figures 1 and 2). As soon as a new feeding period started, the restricted pigs started to eat. Between 0:00 and 12:00 h the feeders in the restricted treatments were occupied for nearly 80 to 90% of the time. Furthermore, the pigs in the restricted treatments consumed their feed allowance in fewer large meals than the *ad libitum* fed pigs (Tables 1 and 2) and the amount of feed consumed per large meal decreased towards the end of the day (Figure 2).

The high and low feed intake per large meal in the restricted treatments at the beginning and end of a new eating period, respectively, suggest that the patterns of eating traits are strongly affected by the sensation of hunger.

The pattern of eating traits may be altered by creating more eating periods during the day. Hammel and Hurnik (1987) reported that feed intake and feeder visiting time were not affected when pigs were allowed free access to feed every 4 h for 20 minutes. However, their results show that the time restricted pigs did consume the same amount of feed in fewer large meals than the *ad libitum* fed pigs. This suggests that the sensation of hunger was still present even though these pigs consumed the same amount of feed than the *ad libitum* fed pigs. Dividing the daily feed intake allowances over more than one eating period per day in restrictively fed pigs may alter the pattern of eating traits, but it also may increase the occurrence of aggressive behaviour and queuing around the feeder at the start of each eating period.

Implications

Feed restriction clearly changes the eating traits of group-housed pigs. Feed restriction increased the daily feeder visiting time and the number of visits per day resulting from a high occurrence of visits to the feeder without feed intake. The increased activity around the feeder may increase energy demands for maintenance at the expense of energy available for growth.

References

ARC, 1981. The nutrient requirements of pigs. Technical review by an ARC Working Party. Farnham Royal, Slough, Commonwealth Agricultural Bureaux, 307 pp.

Berberich, R., 1988. Die automatische Wägung wachsender Schweine als element der rechnergestützten Prozeßsteuerung. PhD thesis, University Gießen, Germany, 196 pp.

Day, J.E.L., Kyriazakis, I., and Lawrence, A.B., 1995. The effect of food deprivation on the expression of foraging and exploratory behaviour of growing pigs. Appl. Anim. Behav. Sci., 42:193-206.

De Haer, L.C.M., Merks, J.W.M., Kooper, H.G., Buiting, G.A.J. and Van Hattum, J.A., 1992. A note on the IVOG®-station: a feeding station to record the individual feed intake of group housed growing pigs. Anim. Prod., 54:160-162.

De Haer, L.C.M. and Merks, J.W.M., 1992. Patterns of daily feed intake in growing pigs. Anim. Prod., 54:95-104.

Graves, H.B., Graves, K.L. and Sherrit G.W., 1978. Social behavior and growth of pigs following mixing during the growing-finishing period. App. Anim. Eth., 4:169-180.

Hammell, K.L., and Hurnik, J.F., 1987. Fixed-interval conditioned feed intake in swine and cattle. Can. J. Anim. Sci, 67:319-325.

Lambooij, E. and Merks, J.W.M., 1989. Technique and injection place of electronic identification numbers in pigs. IVO B-report 335, Zeist, The Netherlands, 12 pp.

Morrow, A.T.S., and Walker, N., 1994. Behavioural and production responses of finishing pigs to increasing workload to obtain food ad libitum from hopper feeders. Anim. Prod., 59:125-129.

Nielsen, B.L., 1995. Feeding behaviour of growing pigs: Effects of the social and physical environment. PhD Thesis, The University of Edinburgh, 123 pp.

Ramaekers, P.J.L., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C. and Swinkels, J.W.G.M.,

1995. Estimating individual body weights of group-housed growing-finishing pigs using a forelegs weighing system. Comput. Electron. Agric., 13:1-12.

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A. and Van der Peet-Schwering, C.M.C., 1996a. Performance and carcass traits of individual pigs housed in groups as affected by ad libitum and restricted feeding. Livest. Prod. Sci. (in press).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A. and Van der Peet-Schwering, C.M.C., 1996b. Effectiveness of a pair-gain feeding strategy for individually fed group-housed finishing pigs (submitted).

Robert, S., Matte, J.J. and Girard, C.L., 1991. Effect of feeding regimen on behavior of growing-finishing pigs supplemented or not supplemented with folic acid. J. Anim. Sci, 69:4428-4436.

SAS Institute Inc., 1989. SAS/SAS® Users Guide, version 6, Fourth Edition, Volume 2., Cary NC, 846 pp.

Slader, R.W. and Gregory, A.M.S., 1988. An automatic feeding and weighing system for ad libitum fed pigs. Comput. Electron. Agric., 3:157-170.

Snedecor, G.W. and Cochran, W.G., 1980. Statistical methods. The Iowa State University Press, Iowa, 507 pp.

Verstegen, M.W.A., Hel, van de W., Brandsma, H.A. and Kanis, E., 1982. Heat production in groups of growing pigs as affected by weight and feeding level. Proc. 9th Symp. Energy metabolism of farm animals, Lillehammer, Norway. EAAP publ. no 29, p 218-221.

Chapter 6

Eating traits in relation to performance and carcass traits of ad libitum and restrictively fed group-housed finishing pigs

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Abstract

In two experiments, 120 crossbred barrows (29.7 ± .2 kg BW) were used to examine whether there is a relation between eating traits, and performance and carcass traits in *ad libitum* and restrictively fed group-housed pigs. Eating traits per pig were determined using transponders and an electronic feeding station equipped with an antenna. In both experiments, a control group of 24 barrows (12 per pen) had free access to a high (H) energy diet (13.1 MJ ME/kg and .71% apparent ileal digestible lysine). From 55.9 ± .7 to 110.2 ± .6 kg BW in Exp. 1, the energy allowance of 48 barrows was restricted to 18 MJ ME per day above maintenance using diet H, and a low (L) energy diet (12.5 MJ ME/kg and .67% apparent ileal digestible lysine), respectively, for 24 barrows each (12 per pen). From 55.5 ± .7 to 110.0 ± .5 kg BW in Exp. 2, 24 barrows (12 per pen) were restricted to a feeding level at which their growth was similar to the mean growth of a group of 12 reference gilts (29.5 ± .8 kg BW). The gilts had free access to feed (diet H). Daily energy intake of the *ad libitum* and restrictively fed pigs was correlated with growth and lean meat tissue percentage. In the *ad libitum* treatments, daily energy intake was correlated with daily feeder visiting time, time per meal and feed intake per meal, but not with number of meals per day and rate of feed intake. Thirty percent of the variance in lean meat tissue percentage of the *ad libitum* fed pigs was related to daily energy intake and number of meals per day. In the restricted treatments, number of meals per day was correlated with energy intake, but not with lean meat tissue percentage. In conclusion, number of meals per day explained part of the variation of lean meat tissue percentage in *ad libitum*, but not in restrictively fed group-housed pigs.

Introduction

In practice, feed restriction is applied to improve performance and carcass traits of barrows. In individually housed barrows, restricting feed intake improved the carcass traits and reduced the variation of carcass traits (Affentranger, 1994). Individual feed restriction of group-housed pigs also improved carcass traits, but the variation of carcass traits was not reduced (Ramaekers et al. 1996a).

In *ad libitum* fed pigs, De Haer et al. (1993) and Labroue et al. (1994) found that part of the variation in performance and carcass traits may be related to variation in eating traits.

Ramaekers et al. (1996c) found that restricting the individual feed intake of group-housed pigs decreased the variation of feed intake, but not the between animal variation of daily feeder visiting time and number of meals per day.

In the present study it was examined whether there is a relationship between eating traits, and performance and carcass traits in group-housed *ad libitum* and restrictively fed pigs.

Materials and Methods

Animals and Designs

In two experiments, 120 crossbred barrows (29.7 ± .2 kg BW) and 12 gilts (29.5 ± .8 kg BW) of a combination of Large White sire line and a rotation crossbred sow line (Dutch Landrace, Dutch Large White sow line and Finnish Landrace) were used.

In both experiments, the barrows were allotted to one of two treatments on the basis of BW and litter origin at the start of a preliminary period of 36 days. In the preliminary period, all pigs had free access to a starter diet containing 12.7 MJ ME per kg and .82 % apparent ileal digestible lysine.

The experimental period was from 55.9 ± .7 to 110.2 ± .6 kg BW in Exp. 1, and from 55.5 ± .7 to 110.0 ± .5 kg BW in Exp. 2.

In Exp, 1, 72 barrows were used in two replicates of 36 pigs each. Each replicate had three treatments of 12 pigs. The pigs in the control treatment (*Ad libitum* I) had free access to a high energy diet (H) containing 13.1 MJ ME and .71% apparent ileal digestible lysine per kg. The energy allowance of the restricted pigs (Restricted H and Restricted L) was 18 MJ ME per day above maintenance using diet H and a low (L) energy diet (12.5 MJ ME and .67% apparent ileal digestible lysine/kg). The maintenance requirement was computed as .719 MJ ME x $BW(kg)^{.63}$ (ARC, 1981).

In Exp. 2, 12 gilts and 48 barrows were used and they were all fed diet H. The gilts were used as a reference group and were fed *ad libitum*. The 24 barrows in the control treatment (*Ad libitum* II) had free access to feed. In the restricted treatment (Restricted II), the barrows with a BW that was heavier than the mean BW of the gilts were restricted (Ramaekers et al., 1996b). Barrows with a BW that was less than the mean BW of the gilts were offered feed *ad libitum*.

In both experiments, BW was measured weekly. Thereafter, feed allowances were computed.

Housing and equipment

In both experiments, the pigs were housed with 12 pigs per pen (6.0 m x 2.2 m). The pens had partially solid, warm water heated, floors and tri-bar metal slats. The pens with barrows were equipped with IVOG® feeding stations. The feeding station consisted of a single space feeder, placed on a load cell, and an antenna (De Haer et al., 1992). Feed intake per visit was calculated after every visit to the feeder. Furthermore, the initial and final times of each visit to the feeder were recorded. A transponder, (Tiris, Texas Instruments, Almelo, The Netherlands) injected in the earbase, was used as an electronic identification device (Lambooij and Merks, 1989).

In both experiments, the remaining feed allowance of a restrictively fed barrow was estimated every 10 seconds during each visit. When a pig had eaten its daily ration, the operating flap in the feeder was blocked for the rest of the day. Furthermore, the operating flaps of the feeders were blocked every 30 seconds for 25 seconds during each visit over the restriction period to minimize the amount of ort in the feeder. On each day, a new eating period started at 00:00 h.

In Exp. 2, the pen with the gilts was equipped with a single space feeder. Only, the mean growth of the gilts was used to compute feed allowances of the restrictively fed barrows (Ramaekers et al., 1996b).

In both experiments, all pigs had free access to water from a nipple adjacent to the feeder. The room was illuminated with day-light and artificial lights from 8:00 to 16:00 h.

Eating traits

The mean eating traits per pig were calculated using the data from one week after the start of the experimental period to the day on which the first pig in a pen was delivered. Visits with no feed intake were not included in the calculations of eating traits. The following eating traits were computed for each barrow according to De Haer and Merks (1992):

feed intake (kg/d),
feeder visiting time (min/d),
number of meals per day,
feed intake per meal (g),
visiting time per meal (min),
rate of feed intake (g/min).

Measurements

Body weight was measured weekly on Thursday between 9.00 and 10.00 h using a weighing scale (Welvaarts W2000, Den Dungen, The Netherlands). At the end of the experimental period, backfat thickness was scanned ultrasonically (Renco Lean-Meater, Renco Corporation, Minnesota, USA) according to Zhang et al. (1993). In Exp. 1 and 2, 16 and 15 pigs per treatment, respectively, were randomly selected for carcass dissection. The right half-carcass (including feet and head) of the selected pigs were dissected into trimmed major cuts according to the Dutch standard dissection method (Bergström and Kroeske, 1968). All cuts were weighed. Lean meat tissue was defined as the weight of trimmed ham, trimmed shoulder, trimmed cutlets and meat scraps.

Statistical analysis

Correlations between eating traits, and performance (growth and energy conversion ratio) and carcass traits (backfat thickness and lean meat tissue percentage) were estimated after correction for body weight and backfat thickness at the start of the experimental period (SAS, 1989).

Results

In Exp. 2, data of three barrows in the restricted treatment were not included in the analyses. This was due to equipment malfunctioning.

In Table 1, the performance and eating traits of the *ad libitum* and restrictively fed pigs that were used in the statistical analysis are presented for both experiments. For a complete presentation of the data is referred to related articles of Ramaekers et al. (1996abc).

In both experiments, energy intake and growth in the restricted treatments were lower than in the *ad libitum* treatments. Energy conversion ratios were similar among treatments. In Exp. 1, lean meat tissue percentage in the restrictively fed pigs was about 2.6 units higher than in the *ad libitum* fed pigs. In Exp. 2, backfat thickness and lean meat tissue percentage were similar for the two treatments.

In both experiments, feed intake per meal and rate of feed intake in the restricted treatments were about 15 and 26 %, respectively, lower than in the *ad libitum* treatments. In Exp. 2, feeder visiting time in the restricted treatment was about 26 % longer than in the *ad libitum* treatment. In both experiments, number of meals per day and time per meal were similar among treatments.

Table 1. Performance, carcass traits and eating traits of the *ad libitum* and restricted barrows in experiments 1 and 2.

Exp. 1	*Ad libitum* I		Restricted	Restricted	
Level of feeding	H		H	L	
Energy density (MJ ME/kg)	13.1		13.1	12.5	
Number of pigs	24		24	24	
	MEAN	SD	MEAN	MEAN	SD[a]
Initial body weight (kg)	57.5	5.0	57.5	52.8	5.5
Final body weight (kg)	112.4	3.6	110.1	108.2	3.7
Energy intake (MJ ME/d)	37.5	4.0	30.2	29.2	2.5
Growth (g/d)	958	102	764	723	77
EC (MJ ME/ kg gain[b]	39.1	2.5	39.6	40.8	2.6
Final backfat thickness (mm)	14.3	2.1	12.3	12.3	2.1
Lean meat tissue %[c]	53.4	3.4	56.0	56.1	3.4
Feeder visiting time (min/d)	64	15	69	69	12
Number of meals per day	7.7	2.3	8.2	7.5	2.5
Time per meal (min)	9.6	4.0	10.1	10.9	3.0
Feed intake per meal (g)	439	161	346	390	101
Rate of feed intake (g/min)	47	9	35	37	6

Exp. 2				
Level of feeding	*Ad libitum* II		Restricted II	
Energy density (MJ ME/kg)	13.1		13.1	
Number of pigs	24		21	
	MEAN	SD	MEAN	SD
Initial body weight (kg)	54.9	5.4	55.8	4.7
Final body weight (kg)	109.9	3.7	110.1	2.3
Energy intake (MJ ME/d)	33.6	3.0	30.6	2.3
Growth (g/d)	821	86	755	83
EC (MJ ME/ kg gain)	41.2	3.4	40.8	3.7
Final backfat thickness (mm)	15.5	2.6	15.0	3.9
Lean meat tissue %	53.8	3.9	54.0	3.7
Feeder visiting time (min/d)	64	13	81	14
Number of meals per day	6.2	1.3	6.7	1.4
Time per meal (min)	11.3	3.3	13.2	3.0
Feed intake per meal (g)	454	127	389	85
Rate of feed intake (g/min)	42	9	30	5

a Pooled SD of treatments Restricted H and Restricted L.

b EC, energy conversion (energy intake (MJ ME)/growth (kg).

c *Ad libitum* I, Restricted H and Restricted L, n = 16; *Ad libitum* II and Restricted II, n = 15

In Exp. 1, energy density in the two restricted treatments had no effect on performance and eating traits. Therefore, the data of the two restricted treatments of Exp. 1 were analysed as one treatment (Restricted H+L).

In Table 2, the correlation coefficients between eating traits and, respectively, performance and carcass traits are presented. In the *ad libitum* treatments of both experiments, energy intake was positively correlated with growth and backfat thickness, and negatively with lean meat tissue percentage. No correlation was found between energy intake and energy conversion ratio. The positive correlations between energy intake, and feeder visiting time, time per meal and feed intake per meal were associated with a positive and negative correlation of these eating traits with growth and lean meat tissue percentage, respectively. Number of meals per day and rate of feed intake were not correlated with energy intake. Of these two eating traits, number of meals per day was positively correlated with lean meat tissue percentage (Figure 1). No correlation was found between number of meals per day and the performance traits.

In the restricted treatments of both experiments, the correlations between energy intake, and the performance and carcass traits were similar to those found in the *ad libitum* treatments. Moreover, feeder visiting time was positively correlated with energy intake. In contrast to the *ad libitum* treatments, number of meals per day was positively correlated with energy intake in restrictively fed pigs. The other eating traits were not correlated with energy intake.

In Exp. 1, feeder visiting time and number of meals per day were correlated with growth. These were also associated with energy intake. Furthermore, feeder visiting time was correlated with backfat thickness. None of the eating traits were correlated with lean meat tissue percentage. This is illustrated for number of meals per day in Figure 1.

In Exp. 2, the positive correlation between energy intake and feeder visiting time was associated with positive and negative correlations of these two traits with lean meat tissue percentage and backfat thickness, respectively. Time per meal and the rate of feed intake were correlated with the carcass traits. The number of meals per day was not correlated with any of the performance and carcass traits (Figure 1).

Table 2. Correlations between eating traits and performance and carcass traits of the *ad libitum* and restrictively fed barrows in experiments 1 and 2.

Exp. 1

	Ad libitum I					Restricted H+L				
	EI[a]	G	EC	BF	LT[b]	EI	G	EC	BF	LT
Energy intake (MJ ME/d)		0.83**	0.13	0.59**	-0.42		0.74**	-0.17	0.39*	-0.24
Feeder visiting time (min/d)	0.51*	0.52*	-0.12	0.39	-0.19	0.43*	0.29*	-0.03	0.37*	-0.09
Number of meals per day	-0.25	-0.20	-0.03	0.07	0.47	0.48*	0.40*	-0.13	0.14	0.08
Time per meal (min)	0.44*	0.36	0.05	0.20	-0.51*	-0.20	-0.20	0.11	0.04	-0.08
Feed intake per meal (g)	0.48*	0.32	0.18	0.13	-0.60*	-0.29	-0.26	0.12	-0.12	0.02
Rate of feed intake (g/min)	-0.12	-0.31	0.37	-0.19	-0.09	-0.17	-0.11	0.01	-0.20	-0.01

Exp. 2

	Ad libitum II					Restricted II				
	EI	G	EC	BF	LT	EI	G	EC	BF	LT
Energy intake (MJ ME/d)		0.65**	0.23	0.32	-0.79**		0.65**	-0.09	0.39	-0.41
Feeder visiting time (min/d)	0.37	0.25	0.09	0.08	-0.44	0.41	-0.12	0.49*	0.74***	-0.55*
Number of meals per day	0.05	0.15	-0.16	-0.46*	0.56*	0.39	0.26	-0.04	0.08	0.18
Time per meal (min)	0.24	0.04	0.22	0.44*	-0.69**	0.14	-0.22	0.40	0.64**	-0.58*
Feed intake per meal (g)	0.33	0.11	0.22	0.49*	-0.73**	0.21	0.10	0.00	0.13	-0.42
Rate of feed intake (g/min)	0.09	0.12	-0.08	0.02	0.06	0.03	0.41	-0.56*	-0.63**	0.34

a EI = energy intake (MJ ME/d); G = growth (g/d); EC = energy conversion (MJ ME/kg growth); BF = final backfat thickness; LT = lean meat tissue %

b LT; *Ad libitum* I, n = 16; Restricted H+L, n = 32; *Ad libitum* II, n = 15; Restricted II, n = 15.

* P < .05; ** P < .01; *** P < .001

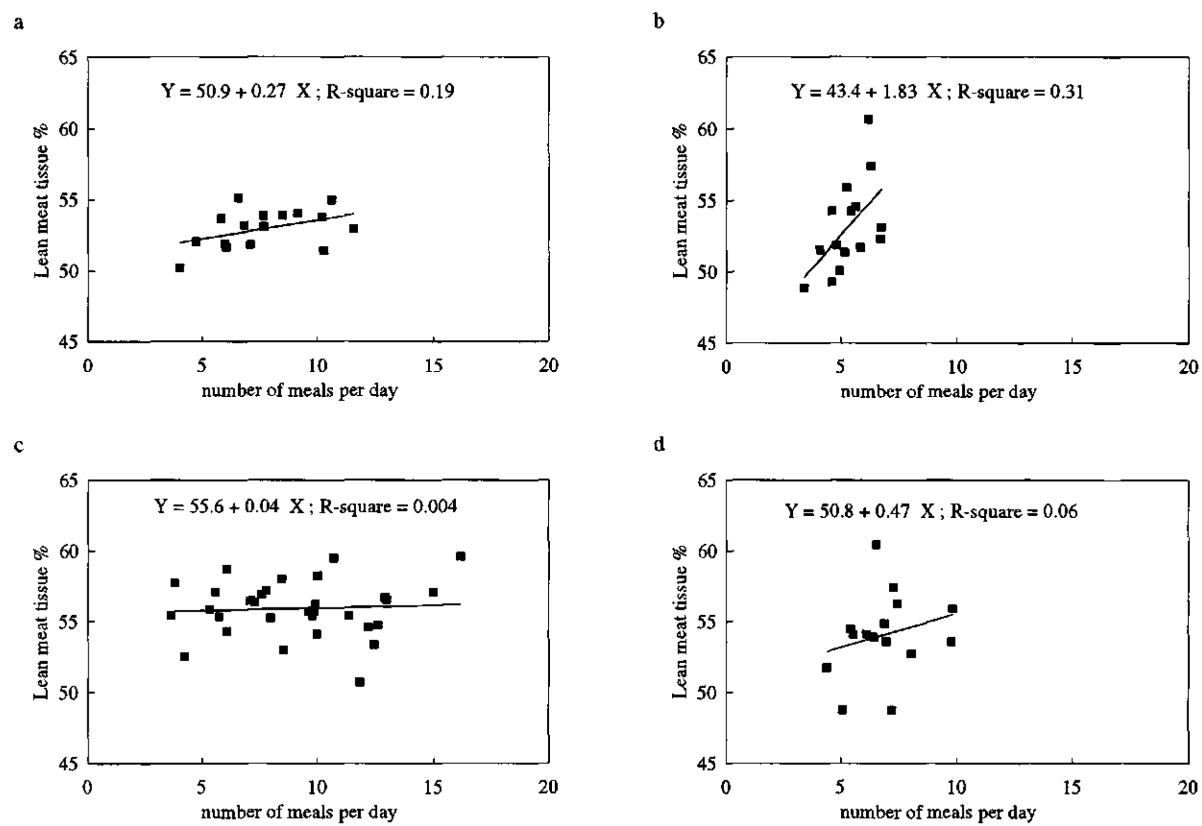

Fig. 1. Lean meat tissue percentage in pigs with different number of meals per day for the treatments *Ad libitum* I (a), *Ad libitum* II (b), Restricted H+L (c) and Restricted II (d).

Discussion

Energy intake

In the *ad libitum* fed pigs, energy intake was correlated with both growth and lean meat tissue percentage (Table 2). These findings confirm the results of De Haer et al. (1993) and Labroue et al. (1994). Feeder visiting, time per meal and feed intake per meal were correlated with energy intake. Therefore, it may be that the observed correlations between these eating traits and the performance and carcass traits are, at least partly, due to their relation with energy intake.

Meal eaters and nibblers

The number of meals per day and the rate of feed intake were not clearly associated with the energy intake of the *ad libitum* fed pigs (Table 2). The number of meals per day of a pig was related to it's lean meat tissue percentage. De Haer et al. (1993) also found a relationship between number of meals per day and carcass traits.

Thirty percent of the variance in lean meat tissue percentage was related to the daily energy intake and the number of meals per day (Equation 1).

$$LT = 59.8 - 0.25\ (\pm 0.08) \times DEI + 0.36\ (\pm 0.19) \times NMD;\ R^2 = .30 \qquad [1]$$

where:

LT = lean meat tissue percentage,

DEI = daily energy intake (MJ ME/d),

NMD = number of meals per day.

Pigs with a high number of meals per day (nibblers) are leaner than pigs with a low number of meals per day (meal eaters), when corrected for daily energy intake (equation 1). It was found that the efficiency of amino acid utilisation was improved in pigs that received two or more meals instead of one meal per day (Batterham and Barley, 1989; Partridge et al., 1985; Batterham and O'Neill, 1978).

Based on the increased efficiency of amino acid utilisation with the high number of meals, one would expect that nibblers have a higher growth than meal eaters. However, number of meals per day was not related to growth at the same energy intake. In a study of De Haer et al. (1993), the relation between various eating traits and performance was examined. One of the eating traits, residual feed intake, was defined as feed intake minus the predicted feed intake based on metabolic body weight and level of production (growth and lean meat tissue percentage). De Haer et al. (1993) found a positive correlation (r = .45) between number of meals and residual feed intake. This suggest that nibblers have a higher energy demand (maintenance) for activities associated with feeding than meals eaters. More meals per day on one hand may result in higher efficiency of amino acid utilisation. On the other hand, more meals per day may increase the energy demand for maintenance. This may explain the lack of relation between number of meals per day and growth.

From equation 1 it can be deducted that number of meals per day can be considered an animal specific trait. This agrees with the study of De Haer and De Vries (1993), where a heritability (h^2) of .45 was estimated for number of meals per day.

Feed restriction

In the restrictively fed pigs, lean meat tissue percentage was related with energy intake, but not with number of meals per day (Table 2). In contrast to the *ad libitum* fed pigs, number of meals per day was positively correlated with energy intake. This means that the restrictively fed pigs with the highest feed intake had the most meals per day. After correcting number of meals per day for energy intake it was not possible to distinguish nibblers and meal eaters among the restrictively fed pigs.

Conclusions

Number of meals per day together with daily energy intake explained part of the variance in lean meat tissue percentage of group-housed *ad libitum* fed pigs. Nibblers, pigs with a high number of meals per day, had a higher lean meat tissue percentage than the meal eaters. In the restricted treatments, number of meals per day was correlated with energy intake, but not with lean meat tissue percentage. In group-housed restrictively fed pigs, it was not possible to identify nibblers due to the relation between number of meals per day and energy intake.

References

Affentranger, P. 1994. Mast- und Schlachtleistung sowie Fleisch- und Fettqualität dreier Schweinetypen bei unterschiedlichen Fütterungsintensitäten. Ph.D. Thesis, Eidgenössischen Technischen Hochschule, Zurich, 119 pp.

ARC, 1981. The nutrient requirements of pigs. Technical review by an ARC Working Party. Farnham Royal, Slough, Commonwealth Agricultural Bureaux, 307 pp. Batterham, E.S. and O'Neill, G.H., 1978. The effect of frequency of feeding on the response by growing pigs to supplements of free lysine. Br. J. Nutr., 39:265-270.

Batterham, E.S. and Bayley, H.S., 1989. Effect of frequency of feeding of diets containing free or protein-bound lysine on the oxidation of [^{14}C]lysine or [^{14}C]phenylalanine by growing pigs. Br. J. Nutr., 62:647-655.

Bergström, P.J. and Kroeske, D., 1968. Methods of carcass assessment in research on carcass quality in the Netherlands. I. Description of methods. Report C-123, IVO, Zeist, The Netherlands and Proceedings of the 9th Annual Meeting of the EAAP, Dublin.

De Haer, L.C.M., Merks, J.W.M., Kooper, H.G., Buiting, G.A.J., and Van Hattum, J.A., 1992. A note on the IVOG®-station: a feeding station to record the individual feed intake of group housed growing pigs. Anim. Prod., 54:160-162.

De Haer, L.C.M. and Merks, J.W.M., 1992. Patterns of daily feed intake in growing pigs. Anim. Prod., 54:95-104.

De Haer, L.C.M., Luiting, P., and Aarts, H.L.M., 1993. Relations among individual (residual) feed intake, growth performance and feed intake pattern of growing pigs in group housing. Livest. Prod. Sc., 36:233-253.

De Haer, L.C.M., and De Vries, A.G., 1993. Effects of genotype and sex on the feed intake pattern of group housed growing pigs. Livest. Prod. Sci., 36:223-232.

Labroue, F., Guéblez, R., Sellier, P., and Meunier-Salaün, M.C., 1994. Feeding behaviour of group-housed Large White and Landrace pigs in French central test stations. Livest. Prod. Sci., 40:303-312.

Lambooij, E. and Merks, J.W.M., 1989. Technique and injection place of electronic identification numbers in pigs. IVO B-report 335, Zeist, The Netherlands, 12 pp.

Partridge, I.G., Low, A.G., and Keal, H.D., 1985. A note on the effect of feeding frequency on nitrogen use in growing boars given diets with varying levels of free lysine. Anim. Prod., 40:375-377.

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996a. Performance and carcass traits of individual pigs housed in groups as affected by ad libitum and restricted feeding. Livest. Prod. Sci. (in press).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996b. Effectiveness of a pair-gain feeding strategy for individually fed group-housed finishing pigs (submitted).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996c. Effect of feed restriction on eating traits of group-housed finishing pigs (submitted).

SAS Institute Inc., 1989. SAS/SAS® Users Guide, version 6, Fourth Edition, Volume 2., Cary NC, 846 pp.

Zhang, W., Huiskes, J.H., and Ramaekers, P.J.L., 1993. Serial ultrasonic measurements of backfat thickness in growing-finishing pigs I. Location determination of serial ultrasonic measurements. Pigs News and Information, 14:173N-176N.

GENERAL DISCUSSION

Introduction

The developments in computerized feeding stations and automatic weighing devices make it possible to apply feeding strategies on individual pigs housed in groups. In this thesis, a forelegs weighing system for group-housed pigs was developed and validated (chapter 2). In two subsequent experiments, body weight (BW) dependent feeding strategies were used to improve performance and carcass traits (chapters 3 and 4). Because the applied feeding strategies affected the eating traits (chapter 5), the relationship between eating traits and performance and carcass traits were studied in both *ad libitum* and restrictively fed pigs (chapter 6). In this general discussion, the focus will be on the possibilities of the use of a forelegs weighing system and a computerized feeding station in research or practice. In the second part, it will be discussed whether the eating and performance traits in the growing period (28 - 55 kg BW) provide information about the subsequent performance in the finishing period (55 - 110 kg BW) and the carcass traits of the pig.

Forelegs weighing system

Forelegs weighing systems are suitable to measure automatically BW of individual pigs (chapters 1 and 2) without isolating the individual pig from it's penmates. The forelegs weighing system enabled us to determine BW of growing-finishing pigs with an average error of 2.5 % (chapter 2). Using a general equation, over and underestimations of BW were systematic within pig. For research, the accuracy of BW estimation can be further improved by adjusting the general equation for individual pigs with for example data on BW collected at the beginning and end of the growing-finishing or experimental period.

Forelegs weighing, compared with weekly manually weighing outside the pen, has the advantage that it measures automatically several forelegs weights of a pig per day and that it has a low manual labour demand. Animals are normally (manually) weighed once weekly using a balance. The variation in gain between weeks within animals may result in differences in gain. It may also be related to differences in gut fill and bladder fill, and/or to weighing errors. Our results show that the pig's BW may vary within a range of 1.5 % of the mean BW during a day (chapter 2). Therefore, the time of day at which BW is determined may be important. Another disadvantage of manual weighing outside the pen is that it may interfere with the aim of the design of the experiment (Schrama et al., 1993; Ekkel et al., 1995). Using forelegs weighing, these disadvantages of manual weighing can be avoided.

The forelegs weighing system proved to be a useful research tool. Ramaekers et al. (1996) used the forelegs weighing system to measure growth depressions over short periods (4 to 5 days) to quantify the effect of diseases on production. With the occurrence of an outbreak in influenza disease, an average growth depression of 65% was observed over 4 days (Figure 1). At the begin of the outbreak in influenza disease, the pig did not consume any feed. Therefore, no forelegs weights were recorded. The results show that the pig's weight decreased with about 8% during the period of illness.

In practice, the pig's BW is an important trait. For monitoring growth performance and, if necessary, adjusting feeding strategies, BW must be measured with sufficient accuracy during the growing-finishing period. With restricted feeding, an underestimation of BW with 10 kg will lead to a growth depression of about 40 g/d due to the fact that about 80 g feed for production will be used for maintenance.

Furthermore, BW is used to determine the settings of the climate computer (Van 't Klooster, 1994) and the day of delivery to the slaughter house (Jørgensen, 1993). Ramaekers et al. (1995) concluded that at the present time, implementation of forelegs weighing balances in every pen (10 pigs/pen) is economically not feasible. It was suggested that a forelegs weighing balance in one pen per compartment could be an on-farm alternative. When the mean BW of one pen is known, the mean BW of other pens can be estimated (Ahlschwede and Jones, 1993). Furthermore, when the initial BW and the weekly feed intake of a pen is known, the mean BW per pen can also be estimated within 2% of the true BW using the growth model TMV (Van der Peet-Schwering et al., 1994; Ramaekers, unpublished data). It can be concluded that the forelegs weighing system is a valuable tool to collect BW of group-housed pigs both for research institutes and commercial farms.

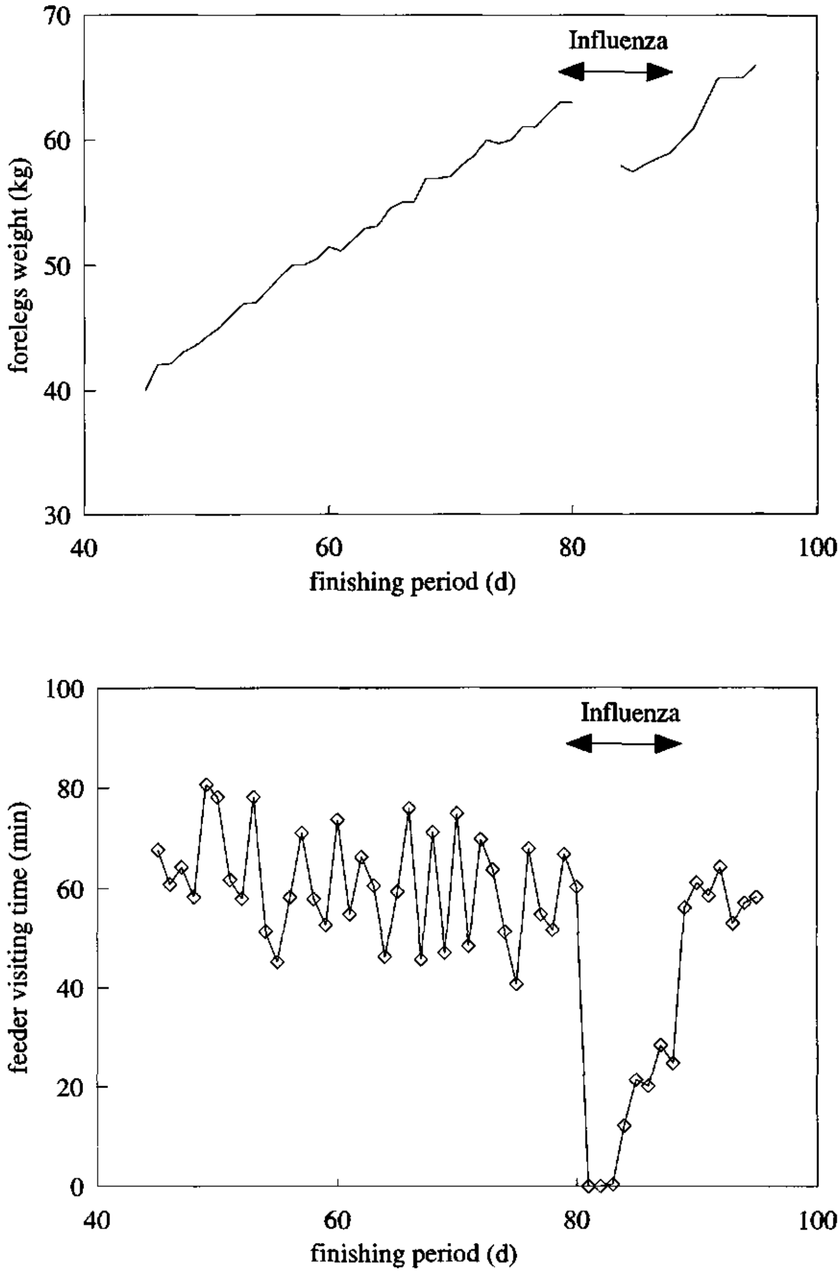

Fig. 1. Forelegs weight (—) and feeder visiting time (◊) of a pig during the finishing period in relationship with the incidence of influenza.

Feeding stations

The IVOG® feeding station is an excellent tool to monitor feed intake and eating traits of individually *ad libitum* fed pigs housed in groups (chapters 3 and 4; De Haer, 1992). Collecting data using feeding stations makes it possible to monitor the feed intake of each pig in a pen. This can provide valuable information for breeding (De Haer and De Vries, 1993; Labroue et al., 1994), for the development of growth models (Van der Peet-Schwering et al., 1994) and for estimations of nutrient (*e.g.* amino acids) requirements of pigs. In addition to feed intake, the IVOG® feeding station also provides data about the eating behaviour of each pig in a pen.

In addition to monitoring the feed intake of individual pigs housed in groups, feeding stations can be used to control the feed intake of individual pigs towards preset goals for production. Our results show that with the use of feeding stations and BW dependent feeding schemes, the variation in energy intake among pigs can be reduced (chapters 3 and 4). However, this reduction in the variation in energy intake among pigs was lower than found in individual housed pigs (Affentranger, 1994). The observed difference may be due to the applied procedure for feed restriction. We restricted the pigs using one feeding period per day. The feeding period started at 00:00 h and ended at the time at which pigs had eaten their assigned amount of feed. With this feeding strategy, some pigs had eaten their feed allowances before noon. These pigs had to wait until midnight before a new feeding period started. The increased number of meals without feed intake suggest that the restriction period was too long for some pigs. More feeding periods could be used to achieve a better distribution of the feed intake during the day. Ramaekers (unpublished results) found in *ad libitum* fed pigs that the interval between large meals within a day was about 4 hours. With 4 to 5 large meals per pig per day (chapter 5), 4 to 5 feeding periods per day would meet the pig's expectation. However, more feeding periods may result in more abnormal behaviour, *i.e.*, rooting or nibbling on penmates, around each new feeding period (Robert et al., 1991). Therefore, two or three feeding periods per day seems to be the best compromise. It may be that with more feeding periods, the number of meals without feed intake will decrease.

For applied research, the IVOG® station has shown to be a valuable device. Ramaekers et al. (1996), using IVOG® feeding and drinking stations, developed signalling systems based on eating and drinking traits. The signalling allowed for detection of disorders in eating and drinking behaviour of *ad libitum* fed pigs housed in groups using electronic identification.

Feeding and drinking disorders may be indicative of health problems of the pig or malfunctioning of the feed and (or) water supply. Ramaekers et al. (1996) found that both signalling systems detected pigs with influenza one to two days earlier than a visual health control. These results suggest that feed or water intake related disorders can be detected by measuring eating and drinking behaviour. Early detection of diseases or disorders in feed supply may lead to lower losses in production and consequently an increase in marginal return.

In combination with climatic conditions data, the feeding station can provide information about the relationship between room temperature and eating traits. During times of hot weather the pigs delay their feed intake towards cooler periods of the day (Figure 2). These data suggest that with restricted feeding, pigs should be fed early in the morning and late in the evening. Moreover, the pigs should be offered more feed in the morning than in the evening.

The results of the performance and carcass traits in chapters 3 and 4 show the limited potential of the IVOG® system for individual feed restriction of group-housed pigs in practice. The number of pigs per feeder is limited to a maximum of 15 pigs (Ramaekers et al, 1996), due to the long daily feeder visiting time per pig especially in the growing period (about 80 min per pig per day). Feed restriction increased feeder visiting time per pig. Therefore, IVOG® feeding stations are economically not applicable on commercial farms. However, cheaper devices supplied with an antenna, a dispensing rate counter, and a dispenser blocking mechanism could be implemented on farms to be used for practical purposes.

The results in chapter 6 showed that eating traits were related to performance and carcass traits. Daily eating time and number of visits per day could be used to distinguish lean growers from fat growers, and to restrict the fat growers. The feed restriction system could be combined with the eating disorders signalling system and forelegs weighing.

In future research, the feeding stations can be used in choice feeding experiments. Using more feeding stations per pen and different feeds, the ratio between the feeds during the growing-finishing can be determined. Moreover, the preference of feeds within a day can be examined. In behaviour studies, the feeding stations could be used to determine the hierarchy of dominance among penmates.

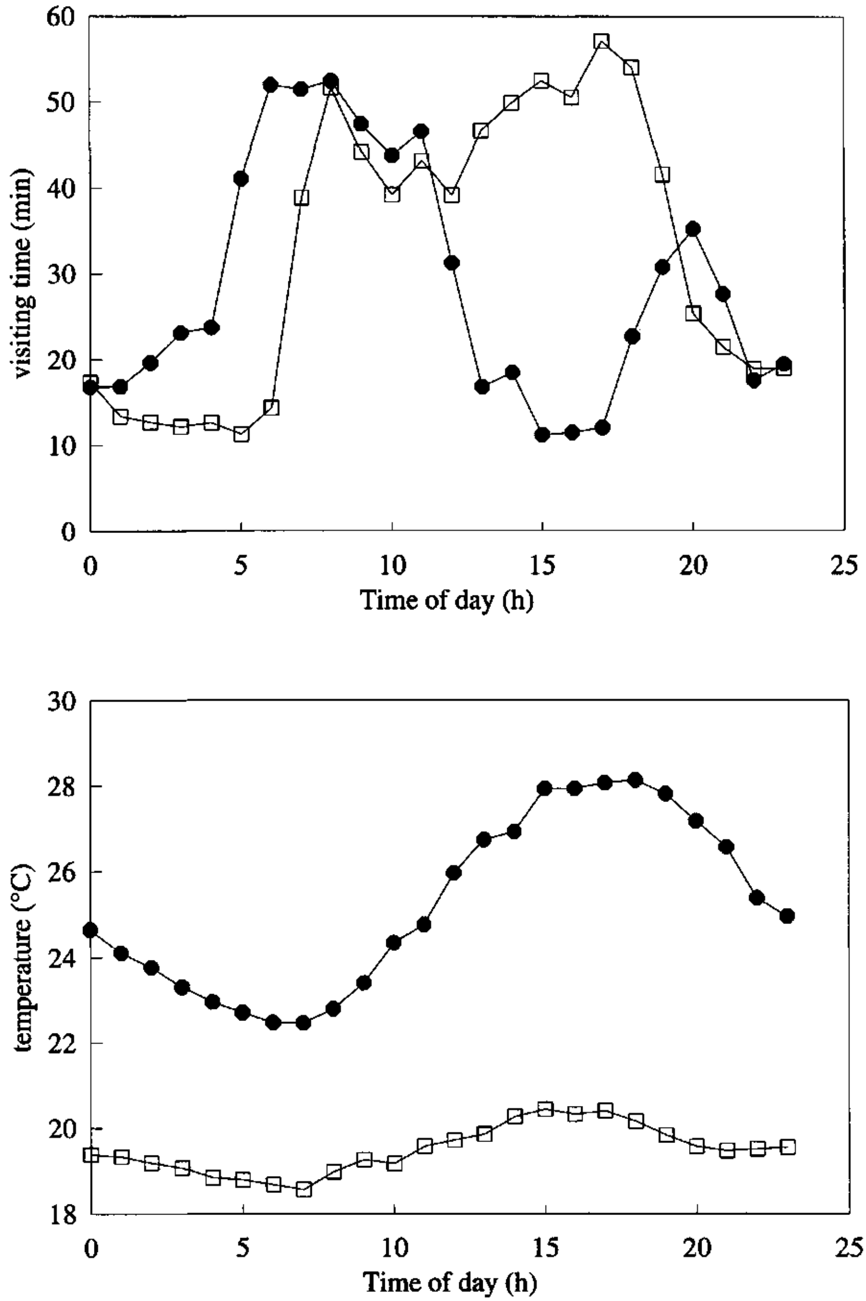

Fig. 2. Feeder visiting time (●, hot period; □, thermoneutral period) and room temperature (●, hot period; □, thermoneutral period) during the day.

Carcass traits at slaughter are related to traits in the growing period

The results in chapter 4 show that variance in backfat thickness at the beginning of the experimental period explained about 40% of the variance in energy conversion ratio and in carcass traits between pigs at the end of the finishing period. This suggest that part of the variance in performance of the pigs in the preliminary period (28-55 kg BW) is related to the variance in performance of these animals in the subsequent finishing period (55-110 kg BW). In Table 1, performance and eating traits in the preliminary period of the *ad libitum* fed pigs of Exp. 1 and 2 are related to the performance and carcass traits in the finishing period (unpublished results). In the preliminary period, energy intake was related to growth and feeder visiting time. The energy intake in the preliminary period was positively related to energy intake and to energy conversion ratio in the finishing period. Moreover, energy intake was negatively related to lean meat tissue percentage. Energy conversion ratio in the preliminary period was positively and negatively related to energy conversion ratio in the finishing period and to lean meat tissue percentage, respectively. Number of meals per day in the preliminary period was positively related to lean meat tissue percentage, but not to growth in the finishing period.

Table 1. Correlations between performance and eating traits in the preliminary period with the performance and carcass traits in the finishing period of the *ad libitum* fed barrows in Exp. 1 and 2.

	Finishing period (55 -110 kg BW)				
	EIP[ab]	EI	G	EC	LT
Preliminary period (28 - 55 kg BW)					
Energy intake (MJ ME/d)		0.50***	0.05	0.58***	-0.46*
Growth (g/d)	0.88***	0.40**	0.14	0.34*	-0.21*
EC (MJ ME/kg growth)	0.10	0.07	-0.21	0.44**	-0.47*
Feeder visiting time (min/d)	0.36*	0.26	0.17	0.10	-0.40*
Number of meals per day	0.01	-0.28	-0.11	-0.20	0.56**

a EIP = energy intake preliminary period (MJ ME/d); EI = energy intake (MJ ME/d) G = growth (g/d); EC = energy conversion ratio (MJ ME/kg growth); LT = lean meat tissue %.

b EIP, EI, G, EC, number of pigs = 48; LT, number of pigs = 31.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

The lean meat tissue percentage of the carcass is partly determined by energy intake, energy conversion ratio and number of meals per day in the preliminary period (Equation 1). Also, feeder visiting time and number of meals per day in the preliminary period determine lean meat tissue percentage (Equation 2). It should be emphasized that these relations are determined using *ad libitum* fed barrows. With feed restriction or other genders these relations may change. In contrast to energy intake and energy conversion, feeder visiting time and number of meals per day can be determined using an electronic transponder and a single space feeder equipped with an antenna. Both equations show that part of variance in lean meat tissue percentage can be explained by variance in performance and eating traits in the growing period.

$$LT = 75.9\ (\pm 9.4) - 0.36\ (\pm 0.19) \times DEI_I - 0.68\ (\pm 0.27) \times EC_I + 0.65\ (\pm 0.23) \times NMD_I\ ;\ R^2 = .54 \quad [1]$$

$$LT = 50.1\ (\pm 5.5) - 0.05\ (\pm 0.05) \times TD_I + 0.75\ (\pm 0.29) \times NMD_I\ ;\ R^2 = .34 \quad [2]$$

LT	=	lean meat tissue percentage,
DEI_I	=	daily energy intake (MJ ME/d)in the preliminary period,
EC_I	=	energy conversion ratio (energy intake (MJ ME)/growth (kg) in the preliminary period,
NMD_I	=	number of meals per day in the preliminary period,
TD_I	=	feeder visiting time in the preliminary period.

Our results confirm the findings of Bikker et al. (1996) that energy intake level in the growing period (20-45 kg BW) affected the backfat thickness at the end of the subsequent finishing period (85 kg BW) regardless of the feeding regime in the latter period. The results suggest that restricting pigs that have a high energy intake in only a few number of meals per day (meal eaters) during the growing period may improve their energy conversion ratio and lean meat tissue percentage.

Restriction of daily energy intake seems of value only when pigs with a high energy intake, and pigs with many (nibblers) and few meals per day could be distinguished in an early stage of the growing-finishing period. The repeatabilities of daily energy intake, and number of meals per day and daily feeder visiting time in the preliminary period were, respectively, 0.35, 0.51 and 0.53 (Ramaekers, unpublished data, computed according De Haer and Merks, 1992). For example, number of meals per day per pig has to be measured for about 10 to 14 days in order to distinguish whether a pig is a nibbler or a meal eater.

Reducing variance in energy intake in the finishing period did not decrease variance in performance and in carcass traits (chapter 3). Results in chapters 4 and 6, and equations 1 and 2 show that part of the variance in performance in the finishing period and lean tissue percentage can be explained by variance in traits that are not related to energy intake and by carry-over effects from the growing period. Therefore, to improve uniformity of, for example, lean tissue percentage of pigs at slaughter, control of energy intake should be applied from the beginning of the growing-finishing period using feed intake and eating traits data.

Final conclusions

Feeding stations and forelegs weighing devices can be used to monitor and automatically control feed intake, eating traits and BW of individual pigs housed in groups. Furthermore, growth and growth composition can be influenced using feeding stations and weight dependent feeding schemes. Reduction in variance in energy intake in the finishing period as we used in our experiments did not result in clear reductions of variance in performance and carcass traits. Control of feed intake should be applied from the beginning of the growing-finishing period to improve uniformity in performance and carcass traits. Implementation of body weight dependent feeding strategies at 60 kg will only give partly the desired result.

Using feeding stations and forelegs weighing devices, other areas of research under practical conditions (group-housing) can be explored. These studies can help to improve both performance and efficiency of utilisation of nutrient in growing-finishing pigs.

On commercial farms, electronic identification and forelegs weighing may be applied as management tools for controlling the production of growing-finishing pigs.

References

Affentranger, P., 1994. Mast- und Schlachtleistung sowie Fleisch- und Fettqualität dreier Schweinetypen bei unterschiedlichen Fütterungsintensitäten. Ph.D. Thesis, Eidgenössischen Technischen Hochschule, Zurich, 119 pp.

Ahlschwede, W.T. and Jones, D.D., 1993. Producer ability to estimate market pig weight. In Johnson, R.K. (editor). *Nebraska Swine report 1993, pp 12-13.*

Bikker, P., Verstegen, M.W.A., Kemp, B. and Bosch, M.W., 1996. Performance and body composition of finishing gilts (45 to 85 kilograms) as affected by energy intake and nutrition in earlier life: I. Growth of the body and body components. J. Anim. Sci., 1996, 74:806-816.

De Haer, L.C.M., 1992. Relevance of eating pattern for selection of growing pigs. PhD Thesis, Agricultural University, Wageningen, 159 pp.

De Haer, L.C.M. and Merks, J.W.M., 1992. Patterns of daily feed intake in growing pigs. Anim. Prod., 54:95-104.

De Haer, L.C.M. and De Vries, A.G., 1993. Effects of genotype and sex on the feed intake pattern of group housed growing pigs. Livest. Prod. Sci., 36:223-232.

Ekkel, E.D., Van Doorn, C.E.A., Hessing, M.J.C. and Tielen, M.J.M., 1995. The specific-stress-free housing system has positive effects on productivity, health, and welfare of pigs. J. Anim. Sci., 73:1544-1551.

Jørgensen, E., 1993. The influence of weighing precision on delivery decisions in slaughter pig production. Acta Agric. Scand. Sect. A. Anim. Sci., 43:181-189.

Labroue, F., Guéblez, R., Sellier, P. and Meunier-Salaün, M.C., 1994. Feeding behaviour of group-housed Large White and Landrace pigs in French central test stations. Livest. Prod. Sci., 40:303-312.

Ramaekers, P.J.L., Huiskes, J.H. and Vesseur, P.C., 1995. Automatische bepaling van het individuele lichaamsgewicht van vleesvarkens in het hok met een voorhandweger. Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.123, 30 pp.

Ramaekers, P.J.L., Huiskes, J.H., Vesseur, P.C., Binnendijk, G.P. and Vermeer, H.M., 1996. Signaleren van afwijkingen in het eet- en drinkgedrag bij vleesvarkens. Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.142, 22 pp.

Robert, S., Matte, J.J. and Girard, C.L., 1991. Effect of feeding regimen on behavior of growing-finishing pigs supplemented or not supplemented with folic acid. J. Anim. Sci, 69:4428-4436.

Schrama, J.W., Del Bario, A.S., Verstegen, M.W.A., Brandsma, H.A. and Van der Hel, W., 1993. Alteration of energy metabolism in pigs fed at three levels after transport in relation to physical activity. In C.R. Boon and E. Collins (Editors), Proceedings of the Fourth International Symposium on Livestock Environment, Coventry, American Society of Agricultural Engineers (ASAE), St Joseph, Michigan., pp 570-577.

Van der Peet-Schwering, C.M.C., Vos, H.P.J.M., Van der Peet, G.F.V., Verstegen, M.W.A., Kanis, E., Smits, C.H.M., De Vries, A.G. and Lenis, N.P., 1994. Informatiemodel Technisch Model Varkensvoeding (TMV). Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.117, 126 pp.

Van 't Klooster, C.E., 1994. Implementation of natural ventilation in pig houses. PhD Thesis, Agricultural University, Wageningen, 153 pp.

SUMMARY

Summary

Electronic identification provides the opportunity to monitor data of individual pigs housed in groups. Feed intake and body weight (BW) can be monitored using a feeding station and a balance, respectively. Moreover, a forelegs weighing system can be used to estimate the daily individual BW of group-housed pigs without human interference. The main objective of this thesis was to examine whether it is possible to control individual daily growth and carcass composition in group-housed pigs using feeding stations.

In chapter 1, weighing devices for automatic weighing of individual pigs housed in groups were reviewed. In chapter 2, a *forelegs* weighing system for group-housed pigs was developed and validated. A pig has to stand at least 2 minutes on the weighing balance to obtain a reliable forelegs weight. Using a general equation for barrows and gilts, the deviation of the estimated BW was less than 5% of the measured BW for 95% ± 2.2 of the weighing days. It was concluded that forelegs weighing is a suitable method to estimate the individual BW of growing-finishing pigs housed in groups.

In two experiments, *BW and rate of gain dependent feeding strategies* in the finishing period (55 - 110 kg BW) were examined in relation to performance and carcass traits (chapters 3 and 4). In Exp. 1 (chapter 3), the daily energy allowance of barrows was restricted to 18 MJ ME per day above maintenance. The restrictively and *ad libitum* fed pigs had a mean daily energy intake of 29.7 and 37.5 MJ ME, respectively. In Exp. 2 (chapter 4), barrows were restricted to a feeding level at which their growth was similar to the mean growth of a group of *ad libitum* fed gilts. The mean daily energy intake of the gilts, and the restrictively and *ad libitum* fed barrows was 26.9, 31.4 and 34.2 MJ ME, respectively. In Exp. 1, the restrictively fed barrows had a lean meat tissue percentage that was 2.6 units higher than that of the *ad libitum* fed counterparts. In Exp. 2, the restrictively fed barrows had a similar growth as the *ad libitum* fed gilts. Feed restriction of the barrows gave no improvement of the lean meat tissue percentage compared with the *ad libitum* fed barrows.

In both experiments, feed restriction decreased the between animal variance in energy intake, but not in energy conversion ratio, growth or lean meat tissue percentage. The results in chapter 4 showed that variance in backfat thickness at the beginning of the experimental period explained about 40% of the variance in carcass traits between pigs at the end of the finishing period.

In chapter 6, it was shown that *eating traits* of pigs affect performance and carcass traits independently of energy intake. In the *ad libitum* fed pigs, number of meals per day together with daily energy intake explained part of the variance in lean meat tissue percentage. At the same level of feed intake, nibblers, pigs with a high number of small meals per day, had a higher lean meat tissue percentage than meal eaters, pigs with a low number of large meals per day.

In both experiments, feed restriction increased the number of visits per day to the feeder (chapter 5). This was mainly due to an increase in the number of the visits in which no feed was consumed. Furthermore, feed restriction changed the circadian feed intake patterns. In the restrictively fed pigs, it was not possible to identify nibblers due to the relation between number of meals per day and energy intake (chapter 6).

In *conclusion*, feeding stations and forelegs weighing devices can be used to control individual daily growth and carcass traits of group-housed pigs. However, the variance in performance and carcass composition was not only related to variance in energy intake. In *ad libitum* fed pigs, variance in lean meat tissue percentage was related to the variance in performance in the growing period and to the variance in number of meals per day. Using feeding stations and forelegs weighing devices, other areas of research under practical conditions (group-housing) can be explored. In addition to research, electronic identification systems and forelegs weighing can be applied on commercial farms as a management tool for controlling the production system of growing-finishing pigs.

SAMENVATTING

Samenvatting

Met elektronische identificatie is het mogelijk individuele gegevens van in groepen gehuisveste vleesvarkens te verzamelen. Voeropname en lichaamsgewicht (LG) kunnen worden geregistreerd met respectievelijk een voerstation en een weegplateau. Een voorhandweegsysteem kan gebruikt worden om automatisch dagelijks individuele gewichten te bepalen van in groepen gehuisveste vleesvarkens. De belangrijkste doelstelling van dit proefschrift was het onderzoeken of voerstations gebruikt kunnen worden voor het sturen van de dagelijkse groei en karkassamenstelling van in groepen gehuisveste vleesvarkens.

In hoofdstuk 1 zijn in een literatuuroverzicht de mogelijkheden onderzocht voor het automatisch bepalen van het individuele LG van in groepen gehuisveste vleesvarkens. De ontwikkeling en validatie van een voorhandweegsysteem zijn beschreven in hoofstuk 2. Voor het bepalen van een betrouwbaar voorhandgewicht dient een vleesvarken tenminste 2 minuten op de weegschaal te staan. Met één algemene formule voor borgen en zeugjes kon uit het voorhandgewicht het LG bepaald worden met een afwijking van minder dan 5% ten opzichte van het gemeten LG op 95% ± 2,2 van de dagen. Geconcludeerd werd dat voorhandweging een bruikbare methode is voor het bepalen van het individuele LG van in groepen gehuisveste vleesvarkens.

In twee experimenten, werden de effecten van LG afhankelijke voerstrategieën in het gewichtstraject van 55 tot 110 kg LG onderzocht op de technische resultaten en op de karkaskenmerken (hoofdstukken 3 en 4). In experiment 1 (hoofdstuk 3) werd de dagelijkse voergift per borg beperkt tot 18 MJ ME boven de energiebehoefte voor onderhoud. De beperkt en onbeperkt gevoerde vleesvarkens hadden een gemiddelde dagelijkse energieopname van respectievelijk 29,7 and 37,5 MJ ME. In experiment 2 (hoofstuk 4) werden de borgen individueel beperkt op een voerniveau waarop de groei van de borgen gelijk was aan de gemiddelde groei van een groep onbeperkt gevoerde zeugjes. De gemiddelde dagelijkse energieopnames van de zeugjes en van de beperkt en onbeperkt gevoerde borgen waren respectievelijk 26,9, 31,4 and 34,2 MJ ME.

Het vleespercentage van de beperkt gevoerde borgen in experiment 1 was 2,6 procent hoger dan van de onbeperkt gevoerde borgen. In experiment 2 hadden de beperkt gevoerde borgen en de onbeperkt gevoerde zeugjes een vergelijkbare gemiddelde groei per dag. De vleespercentages van de beperkt en onbeperkt gevoerde borgen in experiment 2 waren ver-

gelijkbaar. In beide experimenten verminderde de variantie in de energieopname, maar niet de variantie in de energie conversie, groei of vleespercentage.

Uit de resultaten in hoofdstuk 4 bleek dat de spekdikte aan het begin van de experimentele periode reeds 40 % van de variantie in karkaskenmerken tussen vleesvarkens aan het eind van de experimentele periode verklaarde.

In hoofdstuk 6 is gevonden dat de eetkenmerken van de borgen onafhankelijk van de energieopname invloed hadden op de technische resultaten en op de karkaskenmerken. Bij de onbeperkt gevoerde vleesvarkens verklaarden het aantal maaltijden per dag en de energieopname per dag een deel van de variantie in het vleespercentage. Bij een gelijke energieopname hadden 'nibblers', varkens met veel kleine maaltijden per dag, een hoger vleespercentage dan 'meal eaters', vleesvarkens met weinig grote maaltijden per dag. In beide experimenten brachten de beperkt gevoerde borgen meer bezoeken per dag aan het voerstation dan de onbeperkt gevoerde vleesvarkens (hoofdstuk 5). Dit verschil in bezoekfrequentie aan het voerstation werd hoofdzakelijk veroorzaakt door het aantal bezoeken waarin geen voer werd opgenomen. Verder hadden de beperkt gevoerde borgen een ander voeropnamepatroon gedurende de dag dan de onbeperkt gevoerde borgen. Door de relatie tussen het aantal maaltijden per dag en de energieopname per dag was het niet mogelijk om bij de beperkt gevoerde borgen de 'nibblers' te onderscheiden van de 'meal eaters' (hoofdstuk 6).

Geconcludeerd werd dat voerstations en voorhandweging gebruikt kunnen worden voor het individueel sturen van de groei en karkaskenmerken van in groepen gehuisveste vleesvarkens. De variantie in de technische resultaten en karkaskenmerken was echter niet alleen gerelateerd aan de variantie in energieopname. De variantie in het vleespercentage van de onbeperkt gevoerde vleesvarkens was ook gerelateerd aan de variantie in de technische resultaten in het gewichtstraject 28-55 kg en aan de variantie in het aantal maaltijden per dag. In het praktijkonderzoek kunnen voerstations en voorhandweging ook voor andere onderzoeks-doeleinden worden gebruikt. Als ondersteuning van het management op praktijkbedrijven zijn er voor elektronische dierherkenning en voorhandweging toepassingsmogelijkheden.

List of publications

Refereed Scientific Papers

Ramaekers, P.J.L., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C. and Swinkels, J.W.G.M., 1995. Estimating individual body weights of group-housed growing-finishing pigs using a forelegs weighing system. Comput. Electron. Agric., 13:1-12.

Ramaekers, P.J.L., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C., Swinkels, J.W.G.M. and Van der Peet-Schwering, C.M.C., 1995. Modern techniques for automatic determination of individual body weight of growing-finishing pigs housed in groups. Übers. Tierernähr., 23:215-228.

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996. Performance and carcass traits of individual pigs housed in groups as affected by ad libitum and restricted feeding. Livest. Prod. Sci. (in press).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996. Effectiveness of a pair-gain feeding strategy for individually group-housed finishing fed pigs (submitted for publication).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996. Effect of feed restriction on eating traits of group-housed finishing barrows (submitted for publication).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996. Eating traits in relation to performance and carcass traits of group-housed ad libitum and restrictively fed finishing pigs (submitted for publication).

Zhang, W., Huiskes, J.H. and P.J.L. Ramaekers, 1993. Serial ultrasonic measurements of backfat thickness in growing-finishing pigs I. Location determination of serial ultrasonic measurements. Pigs News and Information 14:173N-176N.

Zhang, W., Huiskes, J.H. and P.J.L. Ramaekers, 1993. Serial ultrasonic measurements of backfat thickness in growing-finishing pigs II. Relation with carcass traits. Pigs News and Information 14:177N-180N.

Conference Presentations

Ramaekers, P.J.L, Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C. en Swinkels, J.W.G.M., 1994. Bepaling van het lichaamsgewicht van in groepen gehouden vleesvarkens met een voorhandweegsysteem, om naar lichaamsgewicht te kunnen voeren. In: Scheurs, V.V.A.M. en Boekholt, H.A. (eds). Proceedings van de 19e studiedag Nederlandstalige voedingsonderzoekers, 6 april 1994, Wageningen, pp 37-38.

Huiskes, J.H. and Ramaekers, P.J.L., 1994 The use of electronic identification in management on breeding and fattening pig farms. In: Proc. Rassegna Suinicola 1994, Reggio-Emilia.

Ramaekers, P.J.L., Huiskes,J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C. and Swinkels, J.W.G.M., 1994. Use of daily eating time and eating frequency as indicators for abnormal low feed intake of group housed fattening pigs. 45th EAAP meeting, 4-8 september 1994, Edinburg, Schotland, p 334 (abstr.).

Ramaekers, P.J.L., Huiskes,J.H., Verstegen, M.W.A., Den Hartog, L.A., Vesseur, P.C. and Swinkels, J.W.G.M., 1994. Estimation of body weight of fattening pigs using a forelegs weighing system. 45th EAAP meeting, 4-8 september 1994, Edinburgh, Scotland, p 335 (abstr.).

Ramaekers, P.J.L., Huiskes, J.H., Den Hartog, L.A., Swinkels, J.W.G.M. and Verstegen, M.W.A., 1995. Signaling abnormal low feed consumption of individual pigs housed in groups using feeder visiting time. J. Anim. Sci., 73 (Suppl. 1): 246 (abstr.).

Ramaekers, P.J.L., Swinkels, J.W.G.M., Huiskes, J.H., Verstegen, M.W.A., Den Hartog, L.A., and Van der Peet-Schwering, C.M.C., 1996. Restricting feed intake of individually fed, group-housed barrows affects eating behavior. J. Anim. Sci., 74 (Suppl. 1): 188 (abstr.).

Research Reports

Ramaekers, P.J.L., Huiskes, J.H. and Vesseur, P.C., 1995. Automatische bepaling van het individuele lichaamsgewicht van vleesvarkens in het hok met een voorhandweger. Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.123, 30 pp.

Ramaekers, P.J.L., Huiskes, J.H., Vesseur, P.C., Binnendijk, G.P. and Vermeer, H.M., 1996. Signaleren van afwijkingen in het eet- en drinkgedrag bij vleesvarkens. Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.142, 22 pp.

Zhang, W., Huiskes, J.H. and Ramaekers, P.J.L., 1993. Ultrasone meting van spekdikte bij groeiende vleesvarkens en latere classificatieresultaten. Research Institute for Pig Husbandry, Rosmalen, The Netherlands, report P 1.104, 18 pp.

Other Publications

Ramaekers, P., 1992. Electronische dierherkenning:toekomstmuziek of nachtmerrie. Varkens, 11:72-74.

Ramaekers, P., 1992. Het oog van de meester krijgt hulp. Hokofarm Nieuws nr 3.

Ramaekers, P., 1993. Automatische gewichtsbepaling in het hok. Varkens, 9 augustus 1993:34-36.

Ramaekers, P. en Huiskes, J., 1994. Automatisch wegen van vleesvarkens in het hok. Praktijkonderzoek Varkenshouderij, 6:18-20.

Ramaekers, P.J.L. en Huiskes, J.H., 1995. Voorhandweging vleesvarkens biedt praktische voordelen. Veehouder Nu, 4:14-15.

Ramaekers, P. en Ammerlaan, T., 1995. Voorspelling van de groei van vleesvarkens. Varkens, 24 oktober 1995, 28-29.

Van Paassen, T. en Ramaekers, P., 1995. Ieder varken heeft z'n eigen dorst. Boederij/ Varkenshouderij, 16:18-19.

Havermans, M. en Ramaekers, P, 1996. Antennesysteem signaleert afwijkingen in het eet- en drinkgedrag. Praktijkonderzoek Varkenshouderij, 2:20.

Curriculum vitae

Peter Johannes Lambertus Ramaekers werd op 7 juni 1961 geboren in Horst (Limburg). In 1979 behaalde hij het HAVO diploma aan het Boschveldcollege te Venray. In september 1979 begon hij met de studie Landbouw aan de Hogere Agrarische Scholen van de KNBTB te 's-Hertogenbosch. Deze studie werd in juni 1983 afgesloten met als hoofdvak Varkenshouderij.

Na het vervullen van de militaire dienst werd in augustus 1984 gestart met de Hoger Kadercursus pluimvee- en varkenshouderij aan het Opleidingscentrum voor Dierveredeling te Almelo. Na zijn afstuderen trad hij in maart 1985 in dienst als voorlichter varkenshouderij bij het Consulentschap voor de Varkens- en Pluimveehouderij van het Ministerie van Landbouw en Visserij.

In september 1989 werd deze baan opgezegd en om te beginnen met de studie Zoötechniek, oriëntatie Veevoeding, aan de Landbouwuniversiteit te Wageningen.

In januari 1992 werd deze studie afgerond met als afstudeervakken: veevoeding en veehouderij, waarbij het diploma met lof werd behaald.

In maart 1992 trad hij in dienst bij het Proefstation voor de Varkenshouderij te Rosmalen als onderzoeker elektronische dierherkenning. Het onderzoek beschreven in dit proefschrift was onderdeel van het project "De waarde van injecteerbare transponders op bedrijfsniveau in de vleesvarkenshouderij".

Per 1 mei 1996 werkt hij als nutritionist bij de FNM-sektie VVM te Twello.