

**Feeding behaviour of growing pigs:
Effects of the social and physical environment**

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'What is the use of a book,' thought Alice,
'without pictures or conversations?'

Alice's Adventures in Wonderland
Lewis Carroll (1865)

Til Jørgen

Abstract

This thesis examines in detail the feeding pattern of growing pigs and investigates how different components of the social and physical environment affect the feeding behaviour and production performance of the animals. Using a computerized single-space feeding system, currently used by most breeding companies in their selection programmes, four experiments were carried out looking at effects of the following factors: Group size, feeder design, trough space and individual housing.

Decreasing the accessibility of the food, either indirectly by increasing pig:trough ratio or directly by fitting an enclosed race in front of the trough, modifies the feeding behaviour of the animals in the direction of fewer, but longer visits to the trough.

Increasing the social constraint, either directly by increasing the group size or indirectly by offering low levels of protection from other pigs whilst feeding, increases the rate of eating. All pigs succeeded in adapting to the constraint placed on their feeding behaviour and adjusted to the lack of feeding space, as there were no significant effects of social and physical environment on production performance. No correlations were found between social behaviour (aggression level and rank) and any of the feeding behaviour and production variables.

A change in the social environment from group to individual housing resulted in only a small increase in feeder visits, regardless of the feeding pattern displayed by the pig whilst group housed. However, this had significant effects on the daily food intake of those animals with few, long visits, and suggests that these pigs were disadvantaged in terms of daily food intake rather than number of feeder visits when group housed.

The general discussion considers various criteria used in the literature to define 'a meal', briefly discusses the validity of such classifications of visits to the trough, and elaborates on the relationship between food accessibility and feeding pattern. The effects on feeding rate are placed in the context of competition and preferred rate of eating. A large number of additional environmental factors and their influence on feeding behaviour is reviewed.

Declaration

I hereby declare that this thesis has been composed by me, and that it is a recount of my own work. The results presented here have not previously been submitted for any degree or qualification.

Birte Lindstrøm Nielsen

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List of Abbreviations

approx.	approximately
d	day
DE	digestible energy
df	degrees of freedom
DFI	daily food intake
DUV	duration of visit
FIV	feed intake per visit
FO	feeder occupation
FR	feeding rate
g	gram
hr	hour
kg	kilogram
MAFF	Ministry of Agriculture, Fisheries and Food
min	minutes
MJ	megaJoules
NDV	number of daily feeder visits
no.	number
ns	not significant
p	probability
pers. comm.	personal communication
RI	Rank Index
s.e.	standard error
s	seconds
sec	seconds
s.e.d.	standard error of the difference
s.d.	standard deviation
sig.	significant
SOAFD	Scottish Office Agriculture & Fisheries Dept.
S _p	sum of p-values
vs	versus

Chapter 1

General Introduction

"...experimental feedings [were carried out] in which one head was fed to satiation (first head) before the other head was fed. The second head generally did eat...after the first head had become satiated."

From a study of the feeding behaviour of a two-headed snake (Andreadis and Burghardt, 1993)

1.1. Introduction

This thesis considers the feeding behaviour of growing domestic pigs (*Sus scrofa*). This covers only a tiny part of the subject area of feeding behaviour, which embraces a substantial body of work, and the term itself has been used to describe a range of food related activities. Some authors define feeding behaviour as simply 'eating' and as such describe it by daily food intake alone (Chesters and Quarterman, 1970). Others view it as the means by which an animal achieves a desired or optimal nutrient intake, and the feeding behaviour may consist of choices that the animal has to make between two or more different types of feed (Kyriazakis *et al.*, 1990). The food choices of wild animals roaming freely in an environment where food quality and quantity vary can be described as one extreme of this situation. The feeding behaviour of animals in their natural environment will often be referred to as foraging (e.g. Hauser, 1993). Assessments of this behaviour in the wild may be carried out using radiotelemetry (Doncaster, 1993), whereas more specific studies, such as estimation of feeding motivation usually takes place in more controlled environments making use of techniques such as operant conditioning and second order schedules (Day *et al.*, 1995).

For the purpose of this thesis, feeding behaviour will be defined as those activities that are involved in obtaining and ingesting food (McFarland, 1987). The feeding behaviour of domestic animals can be studied in controlled conditions, which is very useful for testing or clarifying specific theories. Also, the experimental situation can be made to resemble the environment on the farm, which is highly relevant for the pig industry. The feeding behaviour of growing pigs can be described in terms of visits to the feeding trough, time spent feeding and feed intake per visit. These variables and their interactions will be discussed in detail in section 1.3.1. Feeding behaviour and feeding pattern will be used synonymously, although pattern will tend to refer to changes over time of specific variables. The rest of this chapter will describe aspects relating to the feeding behaviour of growing pigs, from which this project arose and which were central to its further development.

Each of the four experiments presented in this thesis (Chapters 2-5) contain in their introductions a number of references to the literature currently available on the specific topic of each chapter. Additionally, the General Discussion (Chapter 6) considers the combined findings of this thesis, and places them in

the context of experimental results obtained by others. Thus, the following sections do not contain comprehensive reviews of the literature concerning feeding behaviour, but aim to give an overview of the scope and shortcomings of the experimental results currently available, including an examination of factors relating to individual characteristics of the animal, which will not be further investigated in the present study.

1.2. Background

In the United Kingdom, the genetic selection for breeding stock in pigs is carried out by a small number of large commercial breeding companies, from which the farmer may buy boars and gilts. Pig breeding programmes are based almost exclusively on production values, and only few behavioural aspects are included in some selection indices. An example would be 'mothering ability' for the dam-line selection, which is measured crudely by variables such as numbers of teats and piglet survival. There are three main reasons for not including behavioural traits in selection indices: Firstly, most behaviours are at present defined as economically unimportant traits, and as such would not be weighted very highly in an index designed to optimize economic performance. Secondly, the behaviour of animals is relatively difficult to both measure and parameterize. Finally, the long-term effects of direct selection for behavioural aspects are largely unknown.

One of the housing methods used previously by breeding companies consisted of individual penning of the animals on test; a method, which consequently involved laborious measures of food intake. In most companies this has now been superseded by group housing and the use of computerized feed intake recording systems. The Hunday FIRE feeder (Figure 1.1) is an example of such a system. Changing the selection environment from individual to group housing, which resembles that found on most farms, is one of the important benefits gained from these systems. However, all feed intake recorders currently on the market are single-spaced, allowing only one animal to feed at any one time. This is unlike the feeding systems seen on most pig farms, where groups of growing pigs have access to multi-space feeding troughs. It was this difference between the selection environment and the commercial pig farms which initially launched the project presented here.

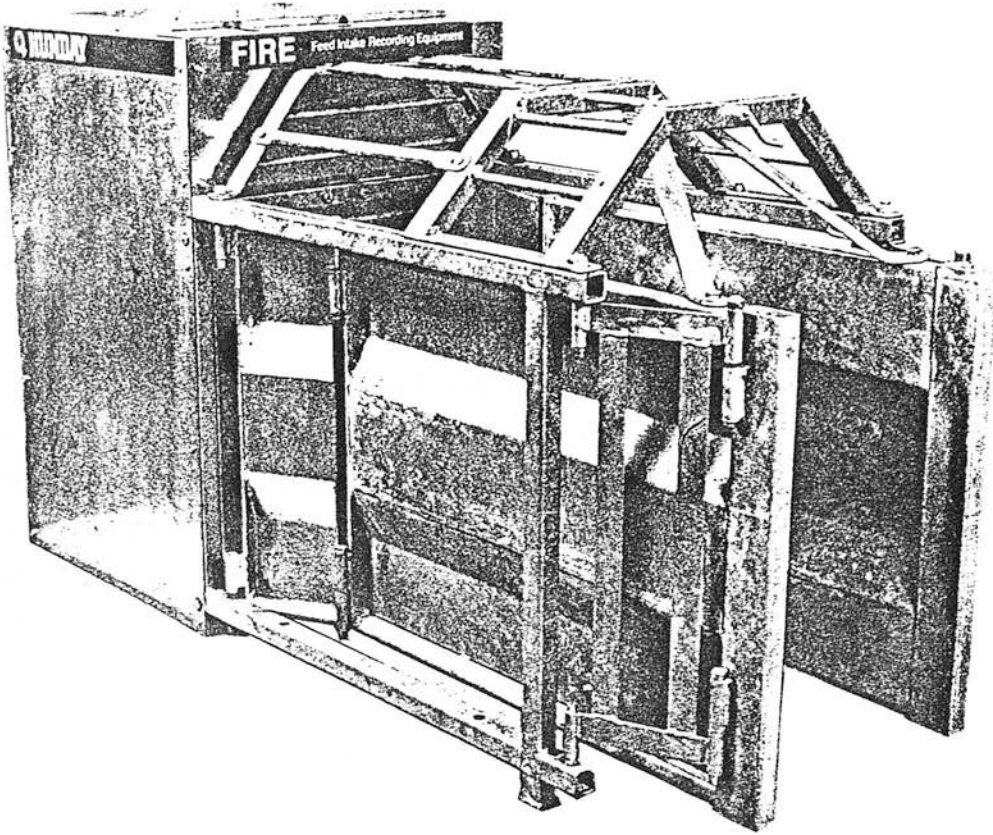


Figure 1.1. The FIRE (Feed Intake Recording Equipment) feeder produced by Hunday Electronics Ltd in Newcastle-upon-Tyne, UK. This feeder was used in all of the experiments presented in this thesis, and is currently installed by all major pig breeding companies in the United Kingdom. An example of the data file obtained automatically from this type of feeder is given in Appendix A.

1.3. Aims and objectives

This project arose from the perceived problem that the direct selection on performance parameters by breeding companies could lead to an indirect selection for correlated behavioural responses, some of which may be undesirable (Figure 1.2). However, both behaviour and performance of the individual are influenced by the environment in which the animal is kept. This environment consists of various components, which can be used to describe both physical and social aspects, and these are represented in Figure 1.2. The physical environment consists of components such as space allocation and the number of feeding spaces, whereas the social environment involves factors such as the size and composition of the group. Other aspects, such as nutritional or pathogenic components, will not be investigated in the following. The social environment may be non-existent, if the pig is kept in isolation, or very limited if

the pig is individually penned without tactile or even visual contact to other pigs. There will be interactions and confounding effects between these two environments. Indeed it is quite difficult to alter only one of the two when studying group housed pigs. Increasing the group size, for example, will affect both the social and the physical environment, even if the size of the pen is augmented proportionately.

In order to predict the long-term consequences of a given selection environment, it is necessary to understand both the nature and extent to which the environment affects the behaviour and performance of the individual. This thesis investigates the influence of a range of environmental factors on the feeding behaviour of growing pigs using a computerized single-spaced feed intake recording system. The aims and objectives of this thesis are as follows:

- To investigate in detail the feeding behaviour of growing pigs.
- To determine the extent of environmental influences on feeding behaviour.
- To disentangle the relative importance of the social and physical environment for the expression of feeding behaviour in growing pigs.

1.3.1. Measurements, derivations and definitions

The daily food intake of most free feeding animals is a summation of discrete bursts of feeding behaviour interspersed with periods where no food is ingested. According to Le Magnen (1985, p. 48)

"John Brobeck (1955) was the first to point out that the cumulative intake of foods in a feeding pattern was the product of meal size and frequency and that a study of feeding must involve these two different parameters."

In the following, the unit of measure used to describe a burst of feeding behaviour will be "visit to the feeder", where the feeder refers to the computerized feed intake recorders (FIRE; Figure 1.1) used in all the experiments presented here, and to the four-space trough feeder used in Chapter 3. A visit is the recording of an animal gaining access to followed by withdrawal from the feed trough. In the computerized single-space feeders the difference between pre- and post-visit trough weight is stored automatically in a

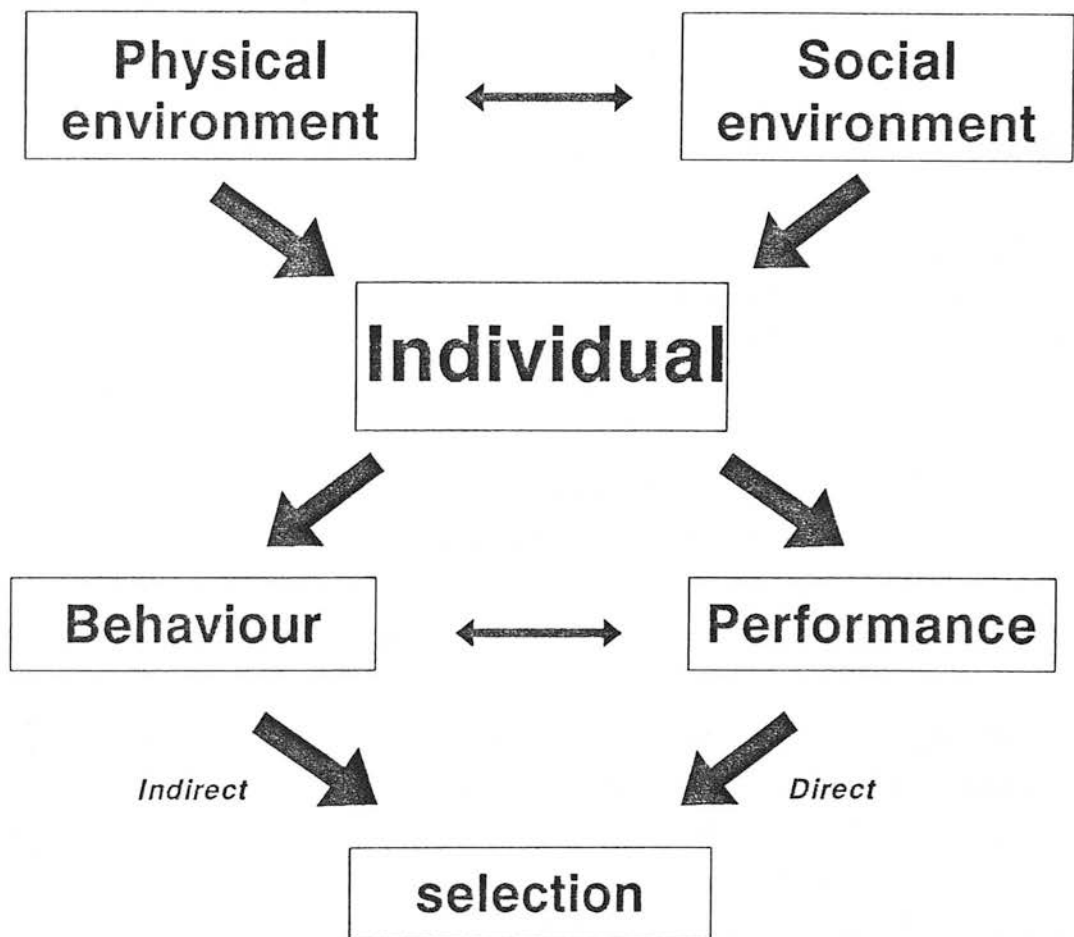


Figure 1.2. Schematic illustration of the breeder's predicament: The environment in which an animal is kept can be described by two components, the physical and the social environment, which are represented here. These environmental components influence both the behaviour and the performance of the individual, and the direct selection on performance parameters could lead to an indirect selection for correlated behavioural responses, some of which may be undesirable.

data file together with the number of the pig's uniquely coded ear-transponder, as well as the time and the duration of the visit (see Appendix A). The term 'visit' will hereafter refer to the behavioural actions described above.

Three base variables are measured by the computerized feeders (see Appendix A), from which can be derived all other parameters used to describe the feeding behaviour of an animal offered a given food. These three base variables are: Number of Daily Visits (NDV), Food Intake per Visit (FIV), and Duration of Visit (DUV). Using the base measurements, the daily food intake (DFI) of an individual pig can be derived as follows:

$$\text{DFI (g/day)} = \text{NDV (visits/day)} * \text{FIV (g/visit)} \quad (\text{eq. 1})$$

Similar daily intake levels of a given food can be achieved by various combinations of feeding frequency (i.e. NDV) and feed intake per visit (FIV). Likewise, changes in the daily food intake of an animal will come about through changes in the relative values of NDV and FIV.

The speed with which the food is ingested (Feeding Rate (FR)) can be calculated when the duration of the visit (DUV) is known:

$$\text{FR (g/min)} = \text{FIV (g/visit)}/\text{DUV (min/visit)} \quad (\text{eq. 2})$$

Calculating the feeding rate this way, however, introduces a high level of variation, as very short visits, where only, say, a mouthful has been removed from the trough, often result in substantially elevated values. To prevent such bias in the data, individual feeding rates are calculated on a daily basis using the proportional relationship between daily food intake and total daily feeding time (Feeder Occupation (FO)). Feeder occupation can be derived from the third pairwise combination of the three base variables as follows:

$$\text{FO (min/day)} = \text{NDV (visits/day)} * \text{DUV (min/visit)} \quad (\text{eq. 3})$$

These equations are written this way purely as a result of the measurements obtained by the computerized feeders, and no implicit causal relationship should be deduced. For example, daily food intake may as likely dictate as be dictated by number of daily feeder visits. Daily food intake is at present the only information from the computerized feeders systematically used by breeding

companies, and this one measure may disguise a number of different feeding strategies. Breaking down daily food intake into its component behaviours could reveal a greater underlying variation between individuals; a variation which may be important to future selection programmes.

The parameters described above are the components which make up the feeding pattern of growing pigs, and it is the environmental effects on these variables and their inter-relations, which will be reported here.

1.3.2. Computerized feed intake recorders

In recent years an increasing number of computerized feeder designs have become available (e.g. Slader and Gregory, 1988; De Haer *et al.*, 1992). Various research groups have utilised these feeders to monitor the feeding behaviour (Young and Lawrence, 1994) as well as measuring individual feed intake (De Haer and Merks, 1992) of group housed pigs.

At least three types of computerized feeders using individual ear-transponders are widely used: The IVOG-station (HokoFarm, Marknesse, Holland), ACEMA-48 (Société ACEMO, Pontivy-Cedex, France), and the FIRE feeder (Hunday Electronics Ltd, Newcastle upon Tyne, UK). They all use dry, pelleted feed, and differ mainly in the design of the entrance, with the IVOG-station fitted with a head-guard, the FIRE feeder offering slightly more protection of the feeding pig with a full length, open-ended race, whereas the ACEMA-48 has a fully enclosed race. In all the feeders the pig has to reverse out, as there is no front exit, as is often seen in electronic sow-feeders. The IVOG-station has been used in the work by De Haer (1992), mainly to estimate genetic correlations between growth and feeding pattern, especially residual feed consumption (De Haer *et al.*, 1993). FIRE feeders, which were used in all the experiments presented in the following chapters, are currently installed by all the major breeding companies in the United Kingdom. ACEMA-48 is used in a similar way by the French testing stations (Labroue *et al.*, 1994).

Another type of feeder is the Hillsborough dry-wet feeder which, strictly speaking, does not fit under the heading of this section as this feeder is not computerized. It has been used mainly for experimental purposes (Walker, 1991; Morrow and Walker, 1994a,b), and is not manufactured commercially

(Norman Walker, 1995; pers. comm.). This feeder uses non-pelleted feed, and supplies both food and water, with no other source of water available in the experiments in which it has been used (e.g. Walker, 1991). Feed is obtained following presses to a lever in the trough, which dispenses approximately 5g of food each time it is pressed by the feeding pig. The food intake is estimated on a group basis, and no individual feeding pattern parameters can be obtained from these feeders. This feeder type has been used mainly in comparison with other feeder designs and to estimate environmental effects on production parameters (Morrow and Walker, 1994a,b; Walker, 1991).

All of the feeder designs mentioned above are single-spaced, allowing only one animal to feed at any one time. This is mainly due to economic constraints in the production of multi-space computerized feeders. There are computerized multi-space feeders available for dairy cows (HokoFarm, Marknesse, Holland), where all cows in a group can feed from several feeding troughs, or, alternatively, access can be reduced to only one feeder for certain cows. Similar systems are not, to my knowledge, currently available for pigs.

From the above descriptions it may be appreciated that differences in feeder design can complicate comparisons across different experimental units. It is therefore important to bear this in mind when different feeders designs are referred to in following.

1.4. Feeding behaviour in relation to group housed growing pigs

There is a paucity of literature available on feeding behaviour of group housed growing mammals. In most experimental studies of feeding behaviour the animals used are not growing, and they are not housed in groups. The use of adult animals is most widespread in the feeding behaviour experiments carried out on rats. This is mainly due to these studies being investigations into questions relating to topics such as diurnal rhythms (Sanford and Peacock, 1991), sensory control of feeding behaviour (Yang *et al.*, 1992), or nutritional preferences (Enns and Grinker, 1983), where the use of growing animals may introduce a level of variation which is undesirable for the purpose of the experiment in question. The lack of group housing experiments arises from a number of technical and procedural problems, which have to be overcome in order to study individual animals within a group. For instance, relatively cheap

alternatives to computerized feeders can be used for individually housed animals, because no individual identification is necessary. The main issue, however, is the interactions between animals kept in a group environment which introduces an additional level of variation, the extent of which it may be difficult to estimate. Also, the total number of experimental animals necessary is often greater when studying groups as opposed to individuals. These experiments may still have substantial relevance to the feeding behaviour of group housed growing pigs, and have, as such, been referred to extensively in this thesis. However, when reference is made to work on rats, it should be kept in mind, that these animals most likely are adult, single-caged individuals.

An increasing number of experiments are being carried out, which study various aspects of feeding in dry (non-lactating) sows using so-called electronic sow-feeders (Edwards and Riley, 1986; Eddison, 1992; Bressers *et al.*, 1993). These investigations use adult animals, and they also use restricted feeding regimes, where individual sows are rationed according to live-weight and stage of gestation. As growing pigs are usually fed *ad libitum*, this makes comparisons between these two types of experimental animal of limited value.

A large body of work concerning feeding behaviour has been carried out using rats as the experimental animals. The rat, being a nocturnal animal, eats most of its food during the dark period, which is different from the diurnal circadian rhythm found in pigs. However, both species consume their food in discrete meals (Auffray and Marcilloux, 1980; Bigelow and Houpt, 1988; Collier *et al.*, 1972), and both species show a bimodal distribution of feeding activity (Kersten *et al.*, 1980; De Haer and Merks, 1992) with high levels of feeding behaviour displayed at the beginning and towards the end of the active period. Some experiments using pigs do not, however, find two distinct peaks in the daily feeding activity (Gonyou *et al.*, 1992; Young and Lawrence, 1994). The pig and the rat will be the two main species referred to in this thesis, although the discussion of feeding behaviour in general may be applied to a broader range of animals.

1.4.1. Influence of animal characteristics on feeding behaviour

The feeding behaviour of an animal in a given environment is dependent on various individual characteristics of the animal in question. In the experiments

presented in the next four chapters, interactions between environmental factors and individual characteristics of the animal, such as breed and sex, were kept to a minimum by using only entire male pigs from the same breeding stock and by choosing animals at a constant initial live-weight. As comparisons will be made to other experiments using animals which may differ with regard to one or more characteristics, the following section considers how these differences may affect the reported results.

Breed, gender, and physiological state

Labroue *et al.* (1994) found that Large White pigs visited the feeder twice as often as pigs of the French Landrace breed (approx. 20 vs 10 visits/day; respectively). De Haer and De Vries (1993) found Great Yorkshire pigs to have more visits, less feed intake per visit, and shorter visits than pigs of Dutch Landrace (Table 1.1). Differences have also been found in the feeding behaviour of males, females and castrates (Table 1.1). These differences cannot be attributed directly to differences in growth rate between the three sexes, as similar growth rates and daily food intakes were obtained by the Dutch Landrace Boars and the Yorkshire gilts presented in Table 1.1 (663 vs 651 g/d and 1868 vs 1862 g/d; respectively), although their feeding patterns differed with respect to a number of variables. Across breeds, boars eat less frequent and more per visit than gilts (De Haer and De Vries, 1993), and castrates spend longer eating, and eat more, both per visit and per day, than boars (Labroue *et al.*, 1994).

Very little information on feeding behaviour is available concerning indigenous breeds, such as the Chinese Meishan, which has been subjected to radically different selection pressures than the main European breeds. Wangsness *et al.* (1980) present comparative data from Yorkshire and Ossabaw pigs, the latter described only as a genetically obese feral strain of pig. The two breeds differed in level of body fat (Ossabaw having approximately double the proportion of fat compared to Yorkshire) and in body size (51 vs 29 kg live-weight at 16 weeks). It is therefore not possible to disentangle the factors which caused the differences observed in the feeding behaviour of these animals. The obese breed had a lower feeding rate than the lean breed (7.2 vs 14.8 g/min; respectively). Labroue *et al.* (1994) reported a weekly increase in feeding rate of just over 3g/min, most likely as a direct consequence of the concomitant increase in size of the animals (+50 kg over 9 weeks). Taking into account the

Table 1.1. Effects of sex and breed of the animal on various feeding behaviour parameters.

Feeding variable ⁺ (unit)	NDV (visits/day)	FIV (g/visit)	DUV (min/visit)	FR (g/min)
De Haer and De Vries (1993):				
Dutch Landrace				
Boars	15.4	155	4.9	33.2
Gilts	15.9	151	4.6	31.5
Yorkshire				
Boars	18.8	134	3.3	37.9
Gilts	21.7	109	3.0	36.9
Labroue <i>et al.</i> (1993):				
French Landrace				
Boars	13.6	196	5.2	37.3
Castrates	11.7	222	6.9	32.3
Large White				
Boars	26.2	146	3.5	40.1
Castrates	23.6	183	4.7	37.0

⁺ NDV=Number of daily visits; FIV=Feed intake per visit; DUV=Duration of visit; FR=Feeding rate.

live-weight differences of the lean and obese pigs, the increased feeding rate seen by the lean Yorkshire pigs could be attributed to the difference in size at a given age. The obese pigs also ate more per metabolic kg of live-weight than the lean, which was achieved through an increased meal size, as no differences were found in meal frequency. The authors state 'it is not clear whether [this] hyperphagia is a cause...or result of the obese state'. For comparison, some feeding behaviour data adapted from Auffray and Marcilloux (1983) regarding Large-White and Chinese pig breeds at a similar live-weight are presented in Table 1.2.

A study of the genetically obese Zucker rat may reveal more about the true differences in feeding behaviour between fat and lean animals, as obese and lean individuals can be obtained from the same litter. These animals have been widely used to investigate the physiological control of adipose tissue growth (e.g. Vasselli and Maggio, 1990), especially in relation to obesity studies in humans. These rats have been found to differ in their feeding behaviour, with obese animals initiating fewer, but larger meals than their lean counterparts (Castonguay *et al.*, 1982; Enns and Grinker, 1983). This may be analogous to

the feeding behaviour of castrated Large White pigs, where the higher daily food intake is obtained through a proportionately greater increase in feed intake per visit than the corresponding decrease in feeding frequency (Table 1.1; Labroue *et al.*, 1993).

Other differences in physiological state which may influence feeding behaviour, such as oestrous, stage of parturition, or lactational status, will not be reviewed here, as they are of only limited relevance to the feeding behaviour of growing pigs.

Early experience

The influence of early experience on feeding behaviour consists of at least two factors: The effects of the early social environment (e.g. maternal influence, presence or absence of conspecifics), and effects of early nutritional environment (e.g. neophobia, food preferences).

The literature concerning the influence of early social experience on the feeding behaviour of pigs is very scarce. Most work in this area has been concerned with ruminants under grazing conditions (Ortegarayes and Provenza, 1993), and has predominantly examined interactions between mother and young, and the level of maternal influence on the feeding behaviour and food choice of the offspring (Mirza and Provenza, 1992, 1994; Provenza *et al.*, 1993). These investigations may not be directly relevant to the ontogeny of pig feeding behaviour, but it is possible that the pre-weaning environment of piglets to some extent affects their feeding behaviour post-weaning (see below).

Table 1.2. Feeding behaviour variables from Large-White and Chinese pig breeds (adapted from Auffray and Marcilloux, 1983).

	Large-White	Chinese
n	2	2
Live-weight (kg)	177	172
Daily food intake (kg)	3.8	3.3
Number of meals	3.3	4.1
Duration of meal (min)	17	13
Meal size (g)	1184	858
Feeding rate (g/min)	70	68
Daily feeding time (min)	55	48

The study of food avoidance has been most thoroughly examined in rats (e.g. Rozin, 1968; Gustavson and Gustavson, 1982), whose efficiency in learning from post-ingestive consequences most likely arise from the inability of this species to vomit. Individual differences have been found in the feeding pattern of rats in response to the introduction of a novel food (Brunton, 1995), and Forkman (1991) found evidence of social facilitation in gerbils when presented with novel, but not with familiar food.

Early experience for pigs, in terms of the pre-weaning environment, consists of both social and nutritional aspects. Amount of creep feeding has been found to correspond poorly to the growth of the pig post-weaning (Appleby *et al.*, 1992; Fraser *et al.*, 1994) although anecdotal evidence from China suggests that feeding water hyacinth to piglets immediately prior to weaning results in subsequent higher intakes of this food (Kilgour, 1978). Campbell (1976) found that pigs weaned from sows given a flavoured diet would eat significantly more of a weaner diet with similar flavour than pigs with no previous experience of the flavour. Ermer *et al.* (1994) found that weaner pigs had a preference for feeds containing spray-dried porcine plasma as opposed to dried skimmed milk. They found no significant differences in daily food intake, meal size or meal frequency between pigs offered the two diets separately. The rôle of other factors such as age at weaning (Boe, 1993) in the development of feeding behaviour is still unclear.

Prior experience with certain types of feed can influence the feed uptake through physiological changes, as pigs which have previously been fed bulky feeds will have a larger gut capacity and, as a result of this adaptation, be able to eat more of a bulky food, than pigs with no previous experience of bulk (Kyriazakis and Emmans, 1995).

Age

Age may be an inappropriate concept when dealing with growing animals, as this measure is highly correlated with other parameters, such as live-weight and stage of maturity. Many of the feeding behaviour parameters has been found to change significantly with time (Bampton, 1991; Labroue *et al.*, 1994), and these changes may be a direct result of the age-dependent changes in body size. Also, an increase in age will gradually change the physiological state of the animal as it changes from growing to mature. So although the feeding pattern of pigs is modified with age, from frequent visits to the trough by newly weaned pigs

(Bigelow and Houpt, 1988) to few, large meals ingested by sows (Auffray and Marcilloux, 1980) it is not possible to disentangle the simultaneous effects of increases in live-weight, degree of maturity and level of experience.

1.5. Experimental outline

The following chapters contain the design and results of four experiments investigating the effects of the social and physical environment on the feeding behaviour of growing pigs. As mentioned earlier, all four experiments make use of a computerized feed intake recording system (FIRE, Hunday Electronics Ltd, UK). In Chapter 2 changes in the social environment are investigated by looking at the effects of differences in group size, each group sharing a FIRE feeder. Chapter 3 investigates parts of the physical environment by looking at effects of pig:trough ratio comparing the single-spaced FIRE feeder to a four-space feeding trough using groups of ten pigs. Chapter 4 determines the effects of feeder design, fitting three different types of entrance design to the FIRE feeder, thereby offering different levels of protection to the feeding pig. The last experiment, presented in Chapter 5, examines the influence of the social environment, by housing pigs individually which have previously been group housed. Finally, the general discussion in Chapter 6 brings together the results of these four experiments to form a concerted theory regarding environmental influences on the feeding behaviour of growing pigs, discussing the findings with reference to the current literature.

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Chapter 2

Effect of group size on feeding behaviour, social behaviour, and performance of growing pigs using single-space feeders *

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2.1. Abstract

Use of computerized feed intake recording (CFIR) equipment allows automatic recording of individual feed intake of animals kept in groups. However, current CFIR systems have only one feeding space per social group which may lead to increased competition for access to the feeder. The importance of this competitive behaviour as a source of genotype x environment interaction is unclear. The present experiment examined the effect of increased competition around a single-space feeder on individual performance and behaviour by manipulating the number of pigs per feeder. One hundred and fifty male crossbred pigs were penned at 34 ± 0.3 kg (mean \pm s.e.) in groups of 5, 10, 15, or 20 for 29 days with one single-space computerized feeder per pen and 1.06 m²/pig. Pigs kept in groups of twenty made fewer but longer visits to the feeder and ate more and faster than pigs kept in the smaller groups (7.1 vs 14.3 visits/day, $p < 0.01$; 6.91 vs 4.64 min/visit, $p < 0.05$; 214 vs 119 g/visit, $p < 0.05$; 31.6 vs 25.9 g/min, $p < 0.05$; means of group size 20 vs means of group size 5, 10, and 15, respectively). No differences were found between group sizes in daily food intake, daily live-weight gain and feed conversion ratio (overall means: 1490 g/day, 725 g/day and 2.09 g/g, respectively). Mean number of aggressive interactions initiated and won were significantly lower for the two largest group sizes on the day of grouping. A rank index based on pairwise aggressive interactions was not correlated to any of the production or feeding behaviour variables. No significant effect of group size was found on mean number of attempts to displace other pigs from the feeder. The change in feeding pattern in the largest groups appears to represent an adaptation to the constraint placed on their feeding behaviour and they succeed in adjusting to the lack of feeding space as there were no significant differences between groups in production variables. A correlation between performance and social behaviour may have been disguised by environmental factors such as space allowance and straw provision or, alternatively, aggression and growth may be independent characteristics.

Key words: *pigs, computerized feed intake recording, group size, feeding behaviour, social behaviour, performance*

2.2. Introduction

Many genetic selection programmes for pigs have been based on systems of testing which involve measurement of feed intake from animals kept in individual pens. The intake of individually housed animals is obtained by manual weighing of feed offered and refused; a method which is labour intensive. Individual penning is expensive and this housing method differs from that found on most commercial farms where growing pigs are housed in groups. The selection of pigs in an environment different from the one in which they are to be kept may be responsible for any discrepancy there may be between performance results achieved by pig breeders and those obtained commercially (Merks, 1989).

The development of computerized feeding systems has the potential to resolve these problems. Computerized food intake recording (CFIR) systems allow individuals to be selected on their individual food intake whilst being kept in a social environment (Young and Lawrence, 1994). However, current CFIR systems provide only one feeding space per group of animals which may lead to increased competition for access to the feeder, both in comparison to the former individual feeding system used in selection programmes and to the housing situation on farms where more than one feeding space may be available per group of animals (Webb *et al.*, 1990). The importance of this competitive behaviour as a source of genotype x environment interaction is at present unclear (Webb, 1989). For example pigs, that perform well in a CFIR system, may be behaviourally different from pigs that perform less well resulting in an indirect selection for certain behavioural traits, such as aggression.

A large number of experiments have been carried out with various combinations of group size, feeding space and stocking density to investigate the effect of social competition on the performance of growing pigs. Most authors found that increasing group size does not appear to have any adverse effect on performance when the animals are given ample space and *ad libitum* feeding (e.g. Randolph *et al.*, 1981; Kornegay and Notter, 1984; McConnell *et al.*, 1987). When the space allowance per pig is reduced, or the access to food somehow restricted, adverse effects on performance are first seen in the larger groups (Petersen and Nielsen, 1977; Hanrahan, 1983; Petherick, 1983). However, the results are not always unambiguous. In many of the experiments pens of the

same size have been used to test different group sizes, thereby confounding the effects of group size and group density (e.g. O'Grady, 1983; Suss *et al.*, 1985). Hunt *et al.* (1985) found that group size did not have any significant effect on daily food intake, daily gain or feed conversion ratio. The three group sizes used (10, 15, and 20 animals per group) were kept at increasing stocking density close to or below the recommended minimum for pigs of that weight (MAFF, 1984). Consequently, the lack of effect of group size/stocking density on performance could be due to a general lack of space resulting in all the pigs growing sub-optimally. In an investigation of different group sizes using single-space feeders Walker (1991) tested groups of 10, 20, and 30 pigs with a constant space allowance of 0.6 m²/animal. He found that pigs kept in groups of ten had a lower daily food intake but a better food conversion efficiency than pigs kept in groups of 20 or 30, resulting in no differences in average daily live-weight gain between groups. As expected the number of pigs queuing at the feeder increased with larger group sizes.

Few data are available concerning the effect of group size on the social behaviour of growing pigs and the findings reported are often of an anecdotal character. Some authors found that group size did not affect behaviour adversely (Suss *et al.*, 1985; Mortensen, 1988); others found that incidents of tail biting were more common in large groups (Petersen and Nielsen, 1977). Olsson and Hederström (1989) found that growth rate of the biters rather than the bitten pigs was adversely affected and they suggest that tail biting is due to competition at feeding which, in turn, is affected by group size and number of pigs per feed dispenser. Hsia *et al.* (1988) found that environmental temperature affected aggression levels in large groups of pigs, and Hansen and Hagelsø (1980) note that stability of the social hierarchy may decrease with increasing group size.

The present experiment was designed to investigate the effect of increased competition around a single-space feeder on individual performance and behaviour by manipulating the number of pigs per feeder whilst maintaining a constant stocking density.

2.3. Material and methods

Animals

One hundred and fifty crossbred (Large White x Landrace) entire male pigs (initial live-weight 33.8 ± 4.1 kg; mean \pm s.d.) were used. Three replicates were carried out, each using 50 animals allocated to one of four different group sizes: 5, 10, 15, or 20 pigs per group. The variation in initial live-weight within each group was kept as low as possible ($s.d._{\max} = 5.1$ kg), and pigs were selected from at least two different pens on the farm to ensure a minimum of familiarity within each group. Number of litter mates within a group never exceeded two for the groups of five, and four for all other group sizes. To guarantee a supply of experimental animals of similar weight from the farm's stock the start of each group on the experiment was lagged by one week.

Housing

The animals were kept in a naturally ventilated room. The top half of two adjacent walls consisted of wooden slats through which natural light could enter. During the course of the experiment, natural light levels gradually increased from 12 to 18 hours. In an attempt to counterbalance this change in the light period and to ensure sufficient light for video recording, artificial lights were switched on at 05.00 hr and off at 20.00 hr during the whole experimental period. The average temperatures measured hourly (Autolog, Remonsys Ltd, Somerset, UK) inside and outside the kennels were 16 ± 0.2 °C and 11 ± 0.2 °C respectively (means \pm s.e.).

Each pen contained an insulated kennel, a dunging area with 1, 2, 2, and 3 waterbowl(s) for group size 5, 10, 15, and 20, respectively, and one single-space computerized feeder (FIRE, Feed Intake Recording Equipment, Hunday Electronics Ltd, UK). The size of the pen was kept in proportion to the number of pigs in it, thus keeping the group density the same (1.06 m²/pig) for all groups. The shape of the pens were designed to be as similar as possible, thus avoiding the pens being disproportioned (e.g. deep and narrow) as the group size increased. Also, the distance from the feeder entrance to the opposing pen-side was approximately the same for all four pen sizes and at least 1.5 m. The front of the pens consisted of meshed boards whereas the sides were fully sheeted to eliminate physical contact between pigs in adjacent pens.

The feeders consisted of a race, the width of which could be adjusted to ensure that only one pig at a time could enter the feeder, and a fibreglass feed trough mounted in a frame with its weight bearing on a load cell. Each pig was provided with a uniquely coded ear-tag transponder. The pigs gained access to the feed trough by pushing upon a top hinged door mounted on the race. The electronic system detected the door opening and recorded the weight of the trough immediately prior to pig entry. At the same time the identification circuit recorded the pig's transponder number. When the pig had finished feeding the electronic system detected the door closure and again recorded the weight of the trough. The difference between pre- and post-visit trough weight was stored in a data file together with the pig's transponder number, the time and the duration of the visit. Between each visit the weight of the trough was checked by the electronic system: if below a preset minimum (empty trough weight + 500g), the door was briefly locked and the trough topped up with feed (approx. 1 kg) from a hopper above.

Experimental procedure

Each group was kept in the pens for 29 days during which period the animals were weighed weekly (Table 2.1). Between 09.00 and 10.00 hr the pens were cleaned and fresh straw provided five days a week; the hoppers were re-filled at the same time every day. The feed used was a commercial pelleted grower diet (Ultra Grade 320, Dalgety Agriculture Ltd, Bristol, UK) of the following composition per kg fresh: 195g protein, 55g oil, 60g ash, 47g fibre, and 13.4 MJ DE.

On the first day of the experimental period (Day 1) the race leading to the feeder trough was left wide open to encourage the pigs to enter the feeder. On Day 2 the race was narrowed to avoid more than one pig entering the feeder, whether or not all the animals had made a visit to the feeder. If an animal had not visited the feeder by the end of Day 2 a stockperson would place a few, fresh food pellets on the floor immediately outside the trough, put the animal inside the race and keep it there for a short amount of time (<5 min). If pigs had not started eating on Day 3 of the experiment they would have been removed from the trial.

The behaviour of the animals was recorded using time-lapse video equipment. The camera was mounted on a rail attached to the wall, allowing the camera to

Table 2.1. Experimental procedures used for each group.

Day	Experimental procedure:
0	Pigs weighed in home pen.
1+	Pigs spray marked in home pen and transferred to experimental pen at 13.00 hr. Video recording 13.00 to 20.00 hr.
2+	Video recording 05.00 to 09.00 hr.
8	Pigs weighed.
15	Pigs weighed.
22	Pigs weighed.
28	Pigs spray marked, straw given at 10.00 hr; Video recording 10.00 to 20.00 hr.
29	Video recording 05.00 to 09.00 hr. Pigs weighed and removed from experimental pen.

+ No video recording of group size 5 replicate 1 due to power cut.

be positioned in front of each pen up to 3 metres above the ground. Each group was recorded four times during the experimental period (Table 2.1) The time-lapse video recorder was programmed to record at 4.6 x real time. Prior to video recording on Days 1 and 28 the animals were numbered consecutively using a durable marker spray (Spray Brand, Ritchey Tagg Ltd, Ripon, UK) to ensure easy identification on the video tapes. The markings were still visible for the recording on the following morning. In a pilot trial the provision of straw had been shown to result in a bout of increased activity, and so the pen to be recorded on Day 28 was given straw at 10.00 hr precisely to make sure that a comparison between groups was valid.

The video tapes were watched and a time sampling protocol used to record the position (inside or outside kennel) and posture (stand, sit, or lie) of each individual pig in the group every 10 minutes. When pigs were in the kennel and not visible on the video recording it was assumed they were lying inactive. In addition, the following behavioural categories were recorded when they occurred: -

i) Aggression (Bite, threat, push, knock with head, chase or fight another pig): All pairwise aggressive interactions were scored and the identity of the two pigs involved were noted. In addition, the pig that initiated the aggressive encounter and, where possible, the pig that won the aggressive encounter were identified.

ii) Displacements (Stand in front of the entrance to the feeder, nose, push or bite the pig in the feeder): All attempts by one pig to displace another pig from the feeder were scored together with the identity of the pigs involved and the outcome of the displacement (i.e. whether successful or not).

iii) Mounting (Mount or attempting to mount another pig): All occurrences of one pig mounting another were recorded, together with the identity of the individuals involved.

Statistical methods

The data were analysed using GENSTAT (Version 5; Lawes Agricultural Trust, 1990) and MINITAB (Release 9; Minitab Inc., 1992).

The data on feeding behaviour and the performance data were analysed using analysis of covariance. The model tested the effects of group size between pens, adjusting for differences in initial live-weight. Significant effects were examined further using a model which compared groups of twenty to the other group sizes as this was found to give a better description of the data than a linear model. Data from the first week of the experiment, in which the pigs became accustomed to the feeders, were excluded from the analyses. Trends over time were tested for using the linear effect of day as treatment in an analysis of variance. The means of Days 8-28 of the experimental period for each individual animal were used in these analyses, thus avoiding repeated measures.

The time samples were converted into proportion of time spent in various activities by each group of pigs. These data were checked for normality, and effects of group size on level of activity were tested for using analysis of variance.

The aggressive interactions between pairs were used to establish the dominance rank of the individuals within each group. For each pair, using only interactions with an outcome, the pig with most frequent wins was identified as the dominant of the two. As the hierarchy is not necessarily linear, and as not all dyads were represented in all groups (i.e. not every pig fight every other pig) a dominance rank index was calculated. Various methods were examined, but found to correlate highly and hence one of the simplest calculations were chosen (Lee *et al.*, 1982):

$$RI_A = \frac{1}{2}(D-S+N+1)$$

where RI_A = dominance rank index of animal A
 D = number dominated by animal A
 S = number dominating animal A
 N = group size

This formula results in $RI_A = N$ if animal A is dominant to all other pigs in the group, and $RI_A = 1$ if animal A is subordinate to all other pigs in the group. Pigs with no aggressive interactions, and therefore no apparent established dominance relationships are given values midway between the two extremes $((N+1)/2)$.

Spearman Rank Correlation tests were used on a subset of variables to determine the consistency of ordering within each group of pigs. Under the null hypothesis that the ordering of two variables are independent the p-value from the test is uniformly distributed on (0,1), i.e. any p-value between 0 and 1 would be equally likely. The sum of the p-values (S_p) from the m groups gives a test statistic whose null distribution is approximately Normal ($m/2, m/12$) and only 5% would be greater than $m/2 + 1.645(m/12)^{0.5}$. Thus the null hypothesis was rejected if: -

$$S_p > \frac{1}{2}m + 1.645(m/12)^{0.5} \quad \text{for correlations} < 0$$

$$S_p < \frac{1}{2}m - 1.645(m/12)^{0.5} \quad \text{for correlations} > 0$$

where m is the number of groups and S_p is the sum of p-values for m number of groups. For $m=12$, the threshold of significance ($p < 0.05$) for these equations are therefore $S_p > 7.645$ and $S_p < 4.355$, respectively. Other tests for within-group consistency of ordering exist, but a test based on S_p was chosen because it gives equal weighting to all the groups, independent of size.

Number of aggressive interactions initiated and won and number of feeder displacements were analysed using a two-way analysis of variance with group size and day as treatments, as well as test of Spearman Rank Correlations. Sexual behaviour (number of mounts) was also analysed using the above two-way analysis of variance, and the effect of group size on the proportion of pigs seen mounting was tested for using Kruskal-Wallis k-sample test.

2.4. Results

Twelve minor incidents of illness were recorded during the whole experimental period. One pig died from a twisted gut and one pig was removed from the trial due to an anal prolapse. No pigs were removed from the trial as a result of not learning how to use the feeder.

Feeding pattern

Some feeder visits were recorded where no food apparently had been consumed. Almost 70% of these non-feeding feeder visits lasted less than 15 seconds and they represented 11.0% of all visits, a proportion which was constant across group sizes.

Significant time trends were found in an analysis of variance which used effect of day on trial as treatment. Four of the variables measured showed significant ($p < 0.001$) linear changes with days on trial, all of which were independent of group size. Feeding rate, daily food intake, and number of daily feeder visits increased on average by 6.3 g/min, 399 g/day, and 2.52 visits/day, respectively, over the 21 days, whereas the mean duration of feeder visits decreased by 1.26 min/visit.

The feeding behaviour and performance results are presented as overall means over 21 days (Days 8-28) for the different group sizes in Table 2.2. The group size in which the pigs were kept influenced all the feeding behaviour variables, with pigs kept in groups of twenty making fewer ($p < 0.01$) but longer ($p < 0.05$) visits to the feeder, than pigs kept in the smaller groups. These two variables did not, however, counteract each other, as the pigs kept in groups of twenty still spent less total time in the feeder ($p < 0.05$). Pigs in group size twenty also ate more per visit ($p < 0.05$), and they ate faster ($p < 0.05$) than pigs kept in the smaller groups. Number of visits per day was negatively correlated with

duration of visit in the Spearman Rank test ($S_p=11.56$; $p<0.001$) and feed intake per visit ($S_p=11.74$; $p<0.001$), both of which were positively correlated ($S_p=0.67$; $p<0.001$). Feeding rate was correlated negatively to feeder occupation ($S_p=11.92$; $p<0.001$). However, this may be an artifact of the three previously mentioned correlations, as feeding rate is calculated from feed intake per visit and duration of visit, and feeder occupation is calculated from number of daily visits and duration of visit.

Table 2.2. Mean feeding and production variables for the different group sizes. The means of the three pens per treatment are from days 8-28 of the experimental period, and all are adjusted for differences in initial live-weight.

Group size	5	10	15	20	20 vs rest ⁺		
					residual s.d.	F	sig.
Feeding variables:							
Feeder visits per day	15.9	13.6	13.4	7.1	7.70	18.03	**
Duration of visit (min)	4.28	5.01	4.62	6.91	3.80	7.85	*
Food intake per visit (g)	96.2	134.5	126.5	214.4	109.32	15.84	*
Feeding rate (g/min)	23.8	26.9	27.0	31.6	7.03	12.42	*
Feeder occupation (min/pig/day)	63.3	61.4	53.5	48.1	15.63	8.88	*
Production variables:							
Food intake ⁺⁺ (g/day)	1456	1609	1416	1495	488.4	<1	ns
Live-weight gain (g/day)	695	762	714	721	265.6	<1	ns
Food conversion ratio	2.16	2.13	2.01	2.10	0.324	<1	ns

⁺ Comparison of group size 20 with other group sizes ($df=1,5$).

⁺⁺ Calculated as the mean of individual daily food intakes; it is not necessarily equal to the product of number of feeder visits and food intake per visit presented in the table.

* $p<0.05$; ** $p<0.01$; ns = not significant.

The circadian pattern of feeder occupation differed between group sizes (Figure 2.1). The groups of five never exceeded a feeder occupation of 30 min/hour, and only at the peak in the afternoon did the groups of ten occupy the feeder over 50 min/hour. In contrast, the groups of fifteen and twenty used the feeder 60-100% of the time (36-60 min/hour) for almost all of the light period (Figure 2.1). All group sizes had the same proportion of their feeder visits at the morning peak, which was influenced to a large extent by the cleaning of the pens, whereas feeding in the afternoon was distributed over a longer time period for groups of fifteen and twenty, and the groups of twenty fed proportionately more during the night than the smaller groups (Figure 2.2).

Performance

Despite the differences between group sizes in feeding pattern the animals achieved the same level of performance as there were no differences between groups in daily food intake, daily live-weight gain and food conversion ratio (Table 2.2). This result is expressed in Figure 2.3 where feed intake per visit is plotted against number of visits per day for each individual animal ($n=148$). The overall mean of daily food intake is drawn as an isoline ($x*y=1490\text{g/day}$) and pigs kept in groups of 20 cluster around the steep part of the curve with their mean number of daily feeder visits being 7.1 ± 1.11 compared to 14.3 ± 1.28 (means \pm s.e.) for the smaller group sizes. In the Spearman Rank test daily live-weight gain was positively correlated with daily food intake ($S_p=0.07$; $p<0.001$) and negatively correlated with food conversion ratio ($S_p=10.73$; $p<0.001$).

Time samples

No effect of group size was found on the synchrony of activity on both Days 1 and 28, and both days showed similar levels of activity (Proportion of time standing: 0.22 vs 0.24 (s.e.=0.02); lying: 0.78 vs 0.75 (s.e.=0.02); Day 1 and 28, respectively). On both days all groups had a high activity level immediately after the initial grouping of the pigs at 13.00 hr (Day 1) and after provision of fresh straw at 10.00 hr (Day 28). A higher proportion of time was spent in the kennel on Day 1 than Day 28 (0.64 vs 0.38 (s.e.=0.03); $p<0.001$) and less time was spent lying in the dunging area (0.13 vs 0.38 (s.e.=0.04); $p<0.01$), leading to no difference in total proportion of inactivity between the two days.

Aggression

There was a significant decrease on Day 1 in mean number of aggressive interactions both initiated and won when group size increased from ten to

fifteen (Table 2.3). There was an overall difference in level of aggression between Days 1 and 28 (1.86 vs 1.42 (s.e.=0.10) aggressive interactions initiated/pig/hour, 1.53 vs 0.95 (s.e.=0.08) aggressive interactions won/pig/hour; $p < 0.001$), and a significant Day x Group interaction was found ($p < 0.001$) as the difference in aggression between groups had disappeared by Day 28 (Table 2.3). Number of aggressive interactions initiated did not correlate to any of the performance or feeding behaviour variables. On both Day 1 and Day 28 the Spearman Rank test showed a positive correlation between number of aggressive interactions initiated and number of aggressive interactions won ($S_p = 0.70$ and 0.07 , respectively; both $p < 0.001$). The causal relationship between these two variables cannot be identified.

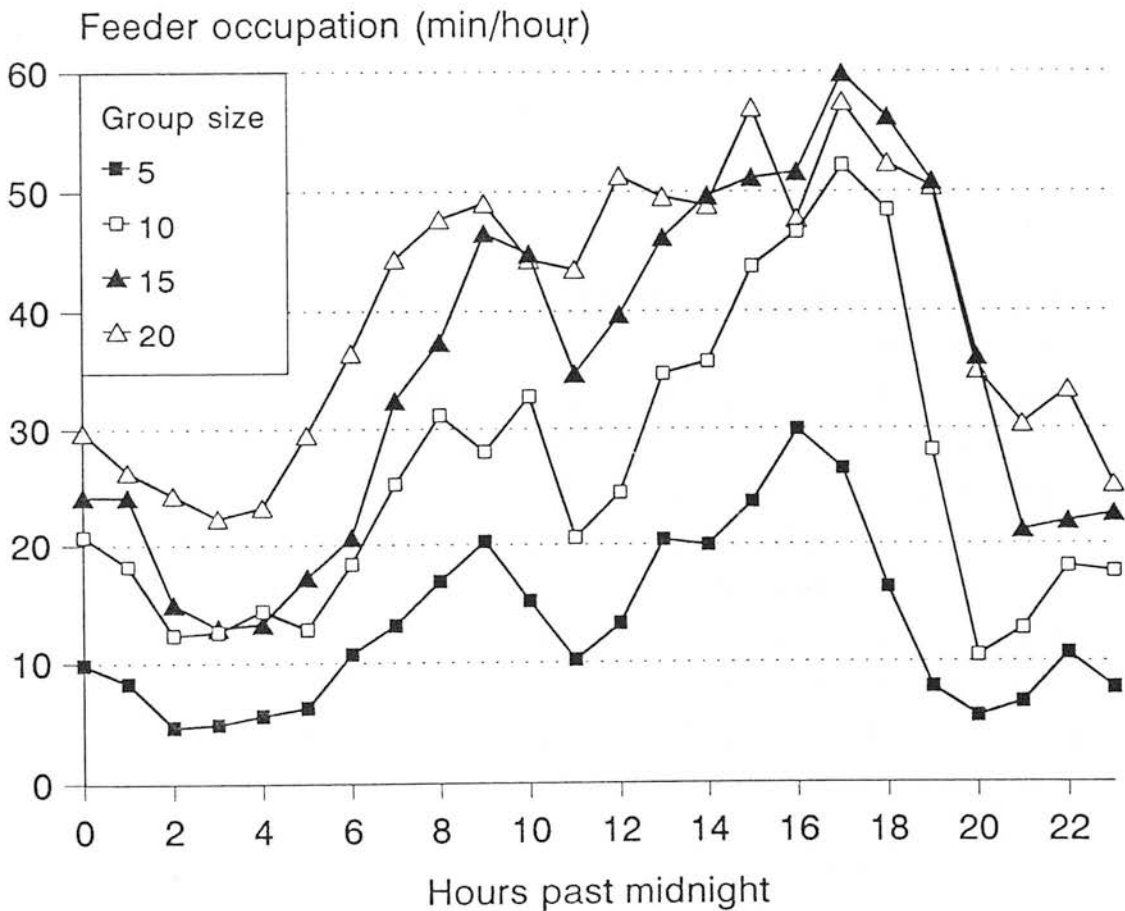


Figure 2.1. Hourly feeder occupation (min/hour) by the four group sizes.

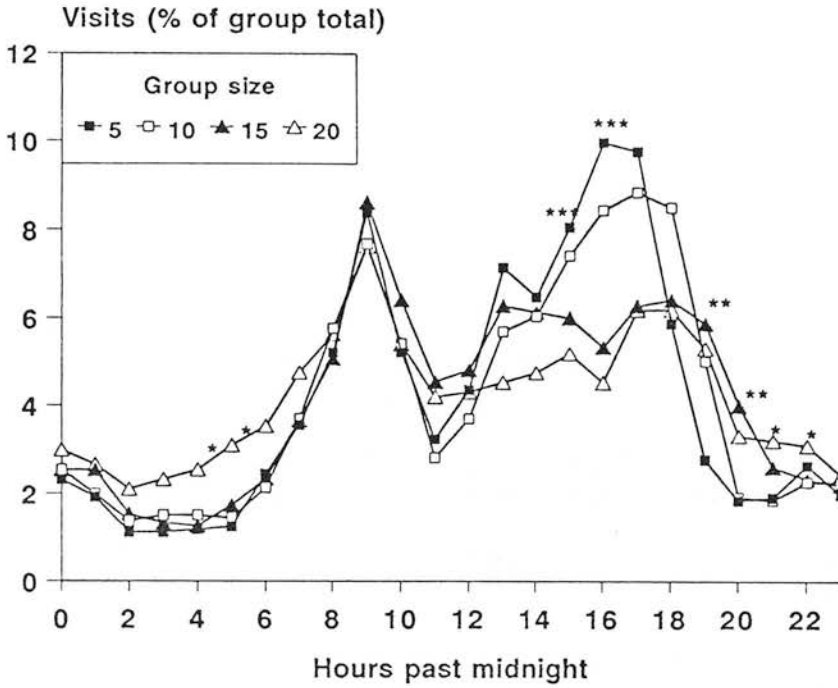


Figure 2.2. Proportional distribution of feeder visits over the 24 hr (% of group total) for the four group sizes. Asterisks indicate significance levels at times where analysis of variance showed that group sizes differed.

Displacements

No difference between group sizes was found in number of displacements attempted per pig on either Day 1 or Day 28, but group size did significantly affect displacement success rate on Day 1 (Table 2.3). Overall, more displacements were attempted per animal per hour (1.50 vs 1.15 (s.e.=0.07); $p < 0.001$) and proportionately more displacements were successful on Day 1 than on Day 28 (0.23 vs 0.14 (s.e.=0.013); $p < 0.001$). On Day 1 number of displacements attempted correlated positively with number of attempted displacements received ($S_p = 1.72$; $p < 0.001$). This reflects the behavioural pattern observed around the feeder where a displaced pig will often attempt to promptly displace the feeding pig in order to regain access to the trough. The strength of this correlation is supported by the highly significant regression of proportional number of attempted displacements received on Day 1 ($DisR_{day1}$) on proportional number of displacements attempted ($DisA_{day1}$), where $DisR_{day1} = (0.95 \pm .003)DisA_{day1}$ ($p < 0.001$; $R^2 = 51.6\%$). This indicates, that for every displacement a pig attempts it is likely to get 0.95 attempts back. On Day 28 number of displacements attempted correlated negatively to feed intake per visit ($S_p = 8.98$; $p < 0.01$).

Table 2.3. Mean number of hourly aggressive interactions initiated and won, displacements attempted and successful, displacement success rate, and mounting on Days 1 and 28 by pigs in the four different group sizes.

	Day	Group size				s.e.	sig.++
		5+	10	15	20		
Aggressive interactions							
- initiated/pig/hour	1	2.97 ^a	2.67 ^a	1.51 ^b	1.45 ^b	0.38	*
	28	1.45	1.63	1.97	0.83	0.44	ns
- won/pig/hour	1	2.56 ^a	2.18 ^a	1.21 ^b	1.19 ^b	0.26	**
	28	1.15	1.00	1.22	0.64	0.34	ns
Displacements							
- attempted/pig/hour	1	0.95	1.83	1.52	1.47	0.51	ns
	28	0.37	0.91	1.24	1.25	0.55	ns
- successful/pig/hour	1	0.29	0.47	0.24	0.34	0.14	ns
	28	0.04	0.16	0.27	0.07	0.13	ns
- success rate (%)	1	45.8 ^a	29.1 ^b	15.9 ^c	24.6 ^{bc}	5.3	*
	28	37.9	14.3	19.3	7.1	10.5	ns
Mounts/pig/hour	1	0.00	0.06	0.07	0.10	0.08	ns
	28	0.03	0.27	0.20	0.10	0.10	ns

+ Means for Day 1 includes estimates of missing values.

++ Two-way analysis of variance testing for effects of group size and day.

a,b,c Within rows means followed by different superscripts are significantly different ($p < 0.05$).

Rank

Using Spearman Rank tests no correlations were found between the Rank Index (RI) and any of the other variables.

Sexual behaviour

Very few incidents of mounting were registered, and they were performed by a relatively small number of individuals. There was a significant overall increase in mounting from Day 1 to Day 28 (0.07 vs 0.16 (s.e. = 0.03) mounts/pig/hour; $p < 0.05$). There was no effect of group size on the frequency of mounting, nor was there any significant difference between the actual and the expected number of pigs seen mounting for each group size (Kruskal-Wallis: $H_{adj} = 5.53$; $df = 3$; ns).

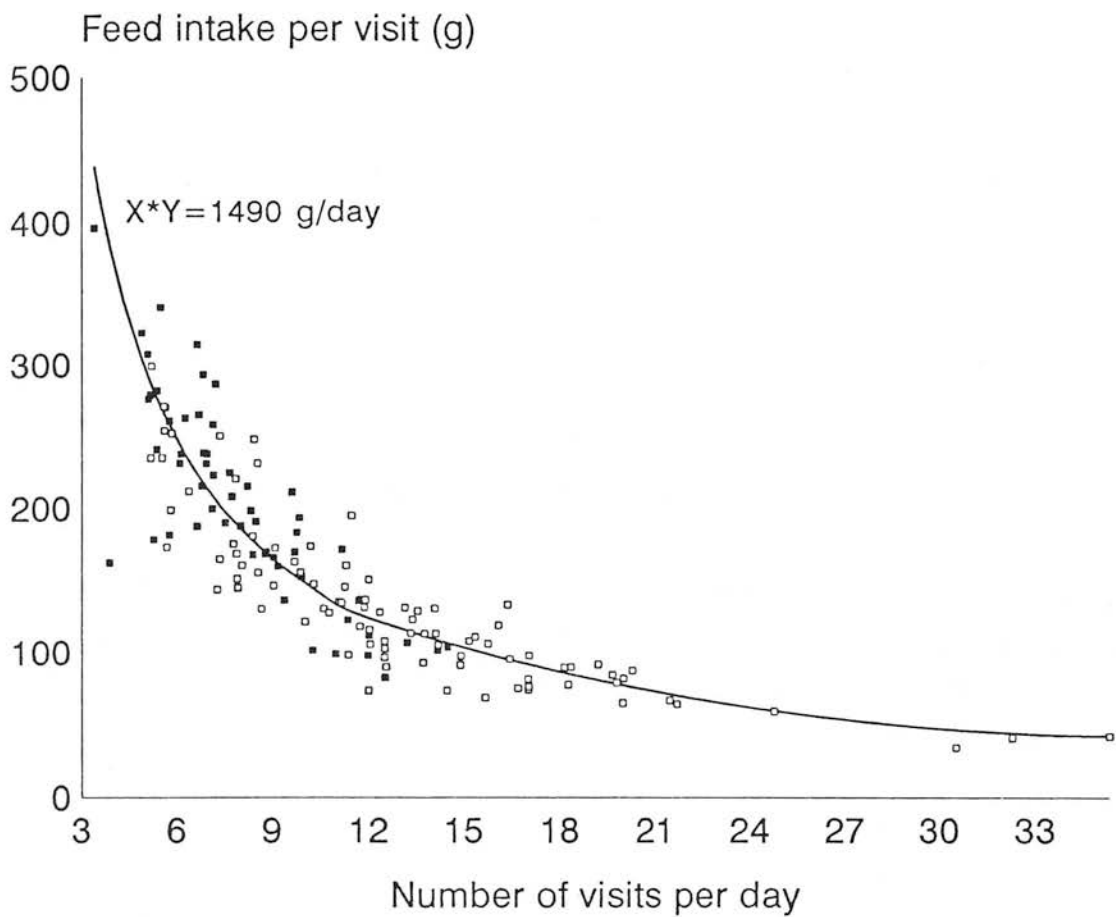


Figure 2.3. Mean feed intake per visit plotted against mean number of visits per day for each individual animal (n=148). Pigs kept in groups of twenty are indicated by solid squares. The isoline represents combinations of x and y resulting in a daily food intake of 1490 g/day (the overall mean).

2.5. Discussion

The feeding behaviour results found in the present experiment correspond in magnitude to those found by Labroue *et al.* (1994), and also by De Haer and Merks (1992) and De Haer and De Vries (1993) who used eight pigs per group with access to computerized single-space feed intake recorders. De Haer (1992) compared the group housed pigs to individually housed animals and found that pigs kept individually had more frequent, but shorter, visits to the feeder, and ate less per visit than pigs kept in groups of eight. Thus animals kept individually, and therefore free of any social constraint, display a feeding pattern that contrasts with that observed in the groups.

Individually housed pigs have been found to have an improved production in terms of a higher daily food intake (Gonyou *et al.*, 1992), a higher growth rate (De Haer and De Vries, 1993) and a better feed conversion ratio (Petersen, 1976) compared to group housed pigs. This would appear to indicate that the feeding pattern displayed by individually housed animals results in an improved production. However, De Haer and De Vries (1993) did not find differences in daily food intake between individual and group housed pigs, and the improved growth may have been due to other factors such as different levels of activity.

It may be, however, that the feeding pattern expressed by individually penned animals is the preferred pattern, and the difference in feeding pattern seen when pigs are group housed represents an adaptation to constraints placed on their feeding behaviour. Whilst individually kept animals have many, small 'meals', group housed pigs achieve the same daily food intake, but adapt to the social environment by changing their feeding pattern to have fewer, larger 'meals' (see Figure 2.3). Similar changes in feeding pattern have been found in rats when accessibility to food is decreased (Levitsky, 1974). The constraint on feeding behaviour may not only be an effect of social competition but consists in part of an un-willingness of the pigs to feed at night due to the circadian rhythm of the animals (i.e. inherent photoperiodicity), together with a preference of group housed animals to feed at the same time, resulting in the peaks seen in feeding activity.

In the current experiment there appears to be a threshold effect for all the feeding behaviour variables measured, with the pigs kept in groups of twenty differing significantly from pigs kept in groups of fifteen or less. This difference in feeding behaviour seen in the groups of twenty (fewer, but longer visits, with more eaten and faster) indicate that when group size reaches a certain level, an additional change in feeding behaviour is necessary in order to achieve the desired level of food intake. The different feeding pattern displayed by pigs kept in the groups of twenty enabled these animals to consume food at a similar level to that of the other groups, as all group sizes showed similar daily food intakes and live-weight gains.

The adaptation of feeding behaviour to achieve a desired daily intake is only possible within certain limits. In the present experiment the daily feeding time

averaged around one hour per pig. In theory, this gives a maximum of 24 pigs per group to allow sufficient feeding time for all individuals. This, however, would require a complete change to the circadian rhythm of the animals, with half the feeding activity becoming nocturnal. Walker (1991) found that groups of 30 animals occupied the feeder 92% of the time, and the biphasic eating pattern usually displayed by group housed pigs disappeared as the animals were feeding through the night. This would suggest that although these pigs were succeeding in adapting to the lack of feeding space, they did so by displaying behaviour not normally seen in diurnal animals. In addition, the almost continuous occupation of the feeder is an indication that the pig to feeder ratio (30:1) had reached its maximum for single-space feeders without adverse effects on performance. This is also expressed in considerably higher feeding rates for pigs in the groups of 30 (53 g/min vs 28 g/min; group size 30 vs 10, respectively; N. Walker, 1994; pers. comm.). In the present experiment pigs kept in groups of twenty ate significantly faster than pigs in the smaller groups and consequently had a shorter daily feeder occupation. This is another indication of the constraint placed on the pigs in the groups of twenty, and this is supported by findings that provision of an additional single-space feeder to a group of twenty pigs increased the total time spent feeding from 44 to 51 min/pig/day (Morrow and Walker, 1994).

Petherick (1983) concluded that larger group sizes appear to have higher levels of general activity, with a consequent higher number of encounters between individuals and higher aggression, which leads to a reduction in performance. This is in agreement with Bryant and Ewbank (1972), Randolph *et al.* (1981) and Hsia (1984), but not with the results from the present experiment. Mendl *et al.* (1993) found less agonistic behaviour per animal in large groups of sows (n=37) compared to groups of five, and in the present experiment pigs in the two largest group sizes had a lower individual level of aggression on mixing day (Day 1) than pigs kept in groups of five or ten. This unexpected result may partly be an artifact of the unit of measure, as space allowance increased proportionately with group size, whereas the number of possible dyads increased geometrically ($n(n-1)/2$) with group size. From the video recordings it became clear that within a group of animals, independent of group size, only a small (<3) number of pairs would be engaged in agonistic encounters at any one time. This would result in the larger group sizes having a smaller proportion of pigs displaying agonistic behaviour at any one time, which could be due to a disproportional lack of space in the larger groups in which to

simultaneously carry out certain aggressive behaviours. A high stocking density has been found to leave insufficient room for intense fighting in both pigs (Moss, 1978) and dairy cows (Arave and Albright, 1981). Appleby and Jenner (1993) point out that sub-group size and local stocking density are important aspects of how animals perceive group size.

A positive correlation has been found between social rank and performance (McBride *et al.*, 1964; Hansen *et al.*, 1982; Benkov, 1989) especially when there is restricted access to feed, apparently due to the effects of higher competition. Beilharz and Cox (1967) also found positive significant correlations between dominance value and production traits. They note, however, that the causal relationship between dominance value and live-weight is not clear. In the present experiment no relationship was found between position in the hierarchy and any of the feeding behaviour or performance variables. Vargas *et al.* (1987) found that daily gain correlated positively with frequency of aggression but not with social rank. None of the different variables measuring aggression in the present experiment showed any significant correlation with feeding behaviour or performance. McBride *et al.* (1964) state that social behaviour has a minimum effect on productivity when husbandry conditions are optimal, and they found that social rank accounted for only 13% of the total variation in growth. It may be that the space allowance, straw provision and general high level of management in the present study has disguised or eliminated any correlation between dominance rank and performance (Hansen and Hagelsø, 1980). It may also be that no correlation is found because, as Meese and Ewbank (1973) notes, social rank inadequately expresses an animals rôle in the group (see also Bernstein, 1981).

Meyer *et al.* (1984) found a reduction in aggression if straw was available, whereas Kelley *et al.* (1980) found that provision of straw had no significant effect on aggressive behaviour in *ad libitum* fed growing pigs. Provision of straw has been found to have a significant effect in reducing the occurrence of tail biting (Van Putten, 1969), and no tail biting occurred during the present experiment. Some tail biting may have been expected due to the increased competition around the feeder in the largest groups (Olsson and Hederström, 1989) and attempted displacements often involved biting or rubbing on the tail of the feeding pig. De Haer (1992), using single-space feeders and no provision of straw, reported that 5% of the group housed animals died as a consequence of tail-bites and up to 15% experienced tail-biting.

The causal relationship between attempted displacements and feed intake per visit on Day 28 is difficult to determine. It could be an effect of pigs with a low feed intake per visit having a higher number of daily feeder visits and therefore are more likely to attempt to displace other pigs from the feeder. Or it could be that pigs, who attempt a lot of displacements, have a desire to feed at peak times and hence an inflexibility in their feeding schedule, are more likely to be displaced, or at least disturbed, by attempted displacements and therefore have less feed intake per visit. The lack of any significant correlations between displacements and rank, aggression, or production variables supports the suggestion that position in the hierarchy is a poor predictor of both feeding behaviour and performance. The high proportion (0.7) of very short (<15 sec) non-feeding feeder visits, may to some extent reflect the level of attempted feeder displacements.

The use of entire males was expected to result in relatively high levels of aggression as well as some amount of sexual behaviour in the form of mounting. Although more mounting was seen at the end as compared to the beginning of the experiment, this behaviour was displayed by only a few individuals and did not correlate with any of the performance or behaviour variables. The difference between Day 1 and Day 28 could be attributed to general differences in behaviours displayed on those two days, with more aggression taking place on Day 1 leaving less time for other activities, rather than degree of sexual maturation. On rare occasions mounting was seen as a means to displace another pig in the feeder.

In summary, group housed growing pigs modify their feeding behaviour when group size reaches twenty as a response to the increased competition. They adapt to the social environment and the decreased accessibility of the food by eating less frequent, more at a time, and quicker. Although this results in a similar daily intake, growth rate, and feed conversion for all group sizes, the higher feeding rate and consequently lower feeder occupation by pigs in the largest groups are indications that they are under some social constraint. Independent of group size no significant correlations were found between performance of the animals and neither dominance rank order nor level of aggression. A possible correlation may have been disguised by other factors such as straw provision or space allowance, or, alternatively, growth and aggression may be independent characteristics.

2.6. Acknowledgements

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2.8. Kurzfassung

Nielsen, B.L., Lawrence, A.B. und Whittemore, C.T., 1995. *Auswirkungen der Gruppengröße auf Freßverhalten, Sozialverhalten und Mastleistung von Schweinen bei Gebrauch eines Einzelfreßapparates. Livest. Prod. Sci., (eingereicht).* Der Gebrauch von computergesteuerten Futteraufnahmemessgeräten (CFAMG) erlaubt die automatische Erfassung der Futteraufnahme von in Gruppen gehaltenen Einzeltieren. Derzeitige CFAMG haben jedoch nur einen Freßplatz für jede soziale Gruppe, was zu erhöhter Konkurrenz um den Zugang zum Futterspender führen kann. Die Bedeutung dieses Konkurrenzverhaltens als Ursprung einer Genotyp-Umwelt Interaktion ist unklar. Einhunderd- und fünfzig unkastrierte männliche Kreuzungstiere wurden ab einem Gewicht von 34 ± 0.3 kg (Mittelwert \pm s.e.) für 29 Tage in Gruppen von 5, 10, 15 bzw. 20 Tieren gehalten, mit einem computergesteuerten Futterspender je Gruppe bei einem Platzangebot von $1.06 \text{ m}^2/\text{Tier}$. Tiere in 20er Gruppen suchten den Futterspender weniger häufig auf, blieben dort jedoch länger und fraßen mehr und schneller als Tiere, die in kleineren Gruppen gehalten wurden (7.1 vs 14.3 Besuche/Tag, $p < 0.01$; 6.91 vs 4.64 min/Besuch, $p < 0.05$; 214 vs 119 g/Besuch, $p < 0.05$; 31.6 vs 25.9 g/min, $p < 0.05$; Mittelwerte der Gruppengröße 20 vs Gruppengrößen 5, 10 und 15). Die Gruppengröße hatte keinen Einfluß auf tägliche Futteraufnahme, Tageszunahmen und Futtermittelverwertung (Mittelwerte: 1490 g/Tag, 725 g/Tag bzw. 2.09 kg/kg). Durchschnittliche Anzahl angefangener und gewonnener aggressiver Interaktionen am Tag des Zusammenstellens waren signifikant niedriger für die Gruppengrößen 15 und 20. Ein Rangindex beruhend auf paarweisen aggressiven Interaktionen war mit keiner der Produktions- und Fütterungsvariablen korreliert. Ein signifikanter Effekt von Gruppengröße auf durchschnittliche Anzahl der Verdrängungsversuche anderer Schweine vom Futterautomaten wurde nicht gefunden. Die Änderung des Freßmusters in den größeren Gruppen scheint eine Anpassung an die Einschränkung des Freßverhaltens zu sein. Diese Anpassung an das verringerte Freßplatzangebot ist erfolgreich, da es was Leistungsparameter betrifft keine signifikanten Unterschiede zwischen Gruppen gab. Es ist denkbar, daß eine Korrelation zwischen Leistung und Sozialverhalten von Umweltfaktoren wie Platzangebot und Bereitstellung von Stroh überlagert wurde. Andererseits könnten Aggression und Wachstum auch voneinander unabhängige Merkmale sein.

2.9. Résumé

Nielsen, B.L., Lawrence, A.B. et Whittemore, C.T., 1995. *Effets de la taille du groupe sur le comportement alimentaire, le comportement social et les performances de croissance des porcs dans des systèmes d'alimentation à auges monoplaces. Livest. Prod. Sci., (soumis).* L'utilisation de systèmes informatisés enregistrant la consommation alimentaire (SIEC) permet de relever automatiquement la consommation alimentaire individuelle d'animaux logés collectivement. Toutefois, les SIEC courants n'ont qu'une auge par groupe social, ce qui peut amener à une compétition accrue pour l'accès à la nourriture. L'importance de ce comportement compétitif comme origine d'une interaction génotype x environnement est peu claire. Cent cinquante porcs mâles croisés, ont été logés à $34 \pm 0,3$ Kg (moyen \pm ds) en groupes de 5, 10, 15 ou 20 pendant 29 jours avec une seule auge monoplace informatisée par loge et $1,06 \text{ m}^2$ par animal. Les porcs en groupes de 20 ont effectué moins de visites mais d'une durée plus longue avec une consommation plus importante et plus rapide que les porcs en groupes plus petits (7,1 contre 14,3 visites/jour, $p < 0,05$; 31,6 contre 25,9 g/min, $p < 0,05$; moyennes des groupes de 20 contre moyennes des groupes de 5, 10 et 15 respectivement). La consommation quotidienne d'aliments, le gain de poids vif journalier et le rapport consommation/gain de poids étaient comparables pour tous les groupes (moyennes générales: 1490 g/jour, 725 g/jour et 2,09 g/g respectivement). Le nombre moyen d'interactions agressives suscitées et réussies était significativement plus bas dans les deux groupes les plus importants le jour de mise en groupes. Un classement par ordre numérique d'interactions agressives entre paires n'était corrélé avec aucune des paramètres de croissance ou de comportement alimentaire. La taille du groupe n'influçait pas significativement le nombre moyen de tentatives visant à écarter d'autres porcs de l'auge. Le changement dans le comportement alimentaire des groupes les plus importants paraît représenter une adaptation à la contrainte sociale, ils ont réussi à s'accommoder au manque d'espace à l'auge puisqu'il n'y avait pas de différences significatives de croissance entre les groupes. Une corrélation entre les performances et le comportement social peut avoir été masquée par des facteurs environnementaux tels que l'espace alloué et la fourniture de paille ou bien, l'agressivité et la croissance sont peut-être des caractéristiques distinctes.

Chapter 3

Feeding behaviour of growing pigs using single or multi-space feeders *

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3.1. Abstract

Most studies of the feeding behaviour of group housed growing pigs have used computerized single-space feeders, which result in a pig:trough ratio which differs from that found on commercial pig farms, where multi-space feeding troughs are used. The present experiment compared the feeding patterns of group housed, growing pigs given access to either a computerized single-space feeder or a four-space feeding trough. Eighty cross-bred entire male pigs (initial live-weight 32.3 ± 0.62 kg; mean \pm s.e.) were allocated to groups of ten, and each group given access to one of the two feeder types. The feeding behaviour was measured automatically from the single-space feeders, and determined for the four-space trough treatment from video tapes, where feeder visits were counted and timed, combined with daily weights of the food eaten per group. Pigs given access to a four-space trough visited the feeder much more frequently (84.5 vs 14.3 visits/day; s.e.d.=5.3; $p < 0.001$), and for shorter durations (0.67 vs 4.67 min/visit; s.e.d.=0.36; $p < 0.001$), eating only a little per visit (24 vs 149 g/visit; s.e.d.=14; $p < 0.001$) compared to pigs kept in the groups given access to a computerized single-space feeder. High levels of allelomimetic feeding was shown by pigs using the four-space trough with 61% of all visits initiated whilst one or more pigs were already feeding. Also, a higher proportion of visits were made adjacent to a feeding pig, than would have been expected by chance (.59 vs .50; $p < 0.001$). No significant differences were found between treatments in the rate of feeding or daily feeder occupation. The differences in feeding pattern did not result in differences in production variables in terms of daily food intake, daily live-weight gain, and feed conversion ratio. A bout analysis was applied to the data using frequency distributions of length of intervals between visits. For pigs using the four-space trough visits could justifiably be collapsed into feeding bouts, whereas this was not the case for visits displayed by pigs using the single-space feeder. Pigs using the four-space trough showed a high frequency (0.64) of changes between troughs within each feeding bout. This may represent exploratory or sampling behaviour, which may aid the pig to ultimately obtain a nutrient sufficient diet should many different food items be available. Comparing feeding bouts from the four-space feeders to visits from the single-space feeders revealed no differences between the two types of feeders, indicating that single-space feeders constrain the feeding pattern mainly in terms of preventing changes between trough-spaces within bursts of feeding.

Key words: *trough space, feeder type, feeding behaviour, pigs*

3.2. Introduction

The feeding behaviour of group housed pigs have been investigated using single-space computerized feeders (De Haer *et al.*, 1992; Labroue *et al.*, 1994; Nielsen, 1995). This type of feeder is used by many breeding companies to enable accurate and automatic measurements of production parameters for use in selection programmes (Webb *et al.*, 1990), whilst at the same time keeping the animals in groups, as they are on commercial pig farms. However, the feeder type most commonly used on farms is a multi-space feeder, allowing several animals to feed simultaneously. Differences in the pig:trough ratio may contribute to any discrepancy there may be between performance results achieved by pig breeding companies and those obtained commercially (Merks, 1989). Some investigations have compared single and multi-space feeders, but they have exclusively looked at the production performance of growing pigs using these two types of feeders. Walker and Overton (1989) tested groups of 18 pigs from 30 to 80 kg comparing a single-space feeder to a conventional feeder providing sufficient feeding space for six animals to feed simultaneously, and they found no significant differences in the performance of the animals. Similar results have been obtained by Albar and Granier (1989) and Hansen *et al.* (1982), and for feedlot beef cattle by Gonyou and Stricklin (1981).

The pig:trough ratio can be adjusted by altering either the number of pigs or the number of feeder spaces or both. Using two single-space feeders as opposed to one for groups of twenty pigs has been found to increase the daily food intake, but have no significant effects on growth rate and feed conversion efficiency (Morrow and Walker, 1994). This finding may be compared to results from Walker (1991) who found that pigs kept in groups of ten had a lower daily food intake but a better food conversion efficiency than pigs kept in groups of 20 or 30, resulting in no differences in average daily live-weight gain between groups. Thus a pig:trough ratio of 20:2 may not have the same effect as a ratio of 10:1.

The present experiment was carried out to investigate the effects on feeding behaviour and production performance of providing either a computerized single-space feeder or a four-space trough to groups of growing pigs. The two types of feeders used differed in more than one aspect (i.e. design and trough number). However, the experimental set-up was intended to simulated the two

situations found in the selection environment and on the commercial pig farm, respectively.

3.3. Material and methods

Animals

Eighty crossbred (Large White x Landrace) entire male pigs (initial live-weight 32.3 ± 0.62 kg; mean \pm s.e.) were used. Two replicates were carried out, each using 40 animals allocated in groups of ten to one of two treatments: one computerized single-space feeder per group, or one four-space trough per group. The variation in initial live-weight within each group was kept as low as possible (s.e._{max} = 1.7 kg), and pigs were selected from at least two different pens on the farm to ensure a minimum of familiarity within each group. In order to guarantee a supply of experimental animals of similar weight from the farm's stock the initial grouping of the four pens within each replicate was lagged in time so that two groups (one from each treatment) were penned on a Tuesday and Thursday respectively, and the two remaining groups were penned in the same manner the following week.

Housing

The experiment was carried out in a naturally ventilated room. The top half of two adjacent walls consisted of wooden slats through which natural light could enter. During the course of the experiment, natural light levels gradually decreased from 14.5 to 10 hours. In an attempt to counterbalance this change in the light period and to ensure sufficient light for video recording, artificial lights were switched on at 05.00 hr and off at 20.00 hr during the whole experimental period. The average temperatures measured hourly inside and outside the kennels were 15.1 ± 0.7 °C and 11.4 ± 0.7 °C respectively (means \pm s.e.).

Each pen contained an insulated kennel (0.36 m²/pig), a dunging area (1.05 m²/pig) with two water-bowls and either one single-space computerized feeder (FIRE, Feed Intake Recording Equipment, Hunday Electronics Ltd, UK) or one four-space feeding trough (ACO Polymer Products Ltd, Shefford, UK) dependent on treatment. The front of the pens consisted of meshed boards whereas the sides were fully sheeted to eliminate physical contact between pigs in adjacent pens.

The single-space feeders consisted of a race, the width of which could be adjusted to ensure that only one pig at a time could enter the feeder, and a fibreglass feed trough mounted in a frame with its weight bearing on a load cell. Each pig was provided with a uniquely coded ear-tag transponder. The pigs gained access to the feed trough by pushing upon a top hinged door mounted on the race. The electronic system detected the door opening and recorded the weight of the trough immediately prior to pig entry. At the same time the identification circuit recorded the pig's transponder number. When the pig had finished feeding the electronic system detected the door closure and again recorded the weight of the trough. The difference between pre- and post-visit trough weight was stored in a data file together with the pig's transponder number, the time and the duration of the visit. Between each visit the weight of the trough was checked by the electronic system: if below a preset minimum (empty trough weight + 500g), the door was briefly locked and the trough topped up with feed (approx. 1 kg) from a hopper above.

Experimental procedure

Each group was kept in the pens for 29 days during which period the animals were weighed weekly. Between 08.00 and 09.00 hr the pens were cleaned and fresh straw provided five days a week. Pilot studies had shown the provision of straw to result in a bout of increased activity, and straw was therefore given at 09.00 hr exactly to make sure that a comparison between groups was valid. The hoppers were re-filled at the same time every day. The four-space troughs were emptied using a vacuum-cleaner to ensure that all of the refusals were measured. Any contamination of the refusal was removed and the remaining refusal was put back into the four-space trough, to ensure no differences between treatments with regard to freshness of the food. The feed used was a commercial pelleted grower diet (Ultra Grade 320, Dalgety Agriculture Ltd, Bristol, UK) of the following composition per kg fresh: 195g protein, 55g oil, 60g ash, 47g fibre, and 13.4 MJ DE.

On the first day of the experimental period (Day 1, which is the day of initial penning for all groups) the race leading to the feeder trough on the single-space feeders was left wide open to encourage the pigs to enter the feeder. On Day 2 the race was narrowed to avoid more than one pig entering the feeder, whether or not all the animals had made a visit to the feeder. If an animal had not visited the feeder by the end of Day 2 a stockperson would place a few, fresh food pellets on the floor immediately outside the trough, put the animal inside

the race and keep it there for a short amount of time (3-5 min). If pigs had not started eating on Day 3 of the experiment they would have been removed from the trial.

The feeding behaviour of the animals on the four-space trough treatment was recorded using time-lapse video equipment. The camera was mounted on a rail attached to the wall, allowing the camera to be positioned in front of each pen up to 3 metres above the ground. Each group was recorded twice during the experimental period (Days 15 and 23) between 09.00 hr and 20.00 hr. The time-lapse video recorder was programmed to record at 4.6 x real time. Prior to video recording on Days 15 and 23 the animals were marked with unique number codes using a durable marker spray (Spray Brand, Ritchey Tagg Ltd, Ripon, UK) to ensure easy identification on the video tapes.

The video tapes were watched and all visits to the four-space feeding trough recorded, logging the pig identity, time the visit commenced (hour, minute, second), trough-space chosen (1 to 4), number of other pigs feeding (0 to 3) when visit commenced, number of pigs feeding from trough-spaces adjacent to the trough-space chosen (0 to 2), and time the visit was terminated. If a visit was interrupted for less than 5 seconds and the visit was continued from the same trough-space, this was logged as one visit. All changes of trough-space, independent of the change-over time, were recorded as separate visits. In order to allow comparisons between single and multi-space feeders over the 24-hr period, and to estimate feed intake per visit for pigs using the four space feeders, values comprising 24 hours were derived from the data obtained from the 9.00-20.00 hr period. The individual values for feeding frequency were increased proportionately to the overall ratio measured in the single-space feeders between the 9.00-20.00 hr period and 24 hours.

Statistical methods

Performance data from the first week of the experiment, in which the pigs became accustomed to the feeders, were excluded from the analyses. Overall means of the experimental period for each individual animal were used in the analyses, thus preventing repeated measures. Means from Days 15 and 23 were used for pigs using the four-space trough, and for pigs using the single-space feeders means from Days 15 to 21 were used, due to some loss of data towards the end of the experimental period. The data were analysed using GENSTAT (Version 5; Lawes Agricultural Trust, 1990). The data on feeding behaviour



and the performance data were analysed by analysis of variance using groups as block-structure and number of trough spaces per group as treatment.

To determine the feeding bout-criterion for each individual animal a bout analysis was carried out using a non-linear (so-called 'broken-stick') model fitted to the log-transformed frequency per second of the inter-visit intervals (see Sibly *et al.*, 1990). The bout analysis consisted of a series of calculations which fitted two regression lines to the data; sequentially fitting one line to an increasing proportion of the whole data-set, with the second line being fitted to the remaining data points. The sums of the mean squared errors of the two fitted lines were calculated, and the data were divided at the inter-visit interval which resulted in the minimum sum of mean square errors. The resulting two lines were fitted as a broken-stick and the point of inflection chosen as the bout criterion. This analysis was performed for each individual separately. Visits separated by intervals less or equal to the bout criterion were collapsed into feeding bouts for subsequent analysis.

3.4. Results

Three pigs were removed from the trial; two as a result of not learning how to use the feeder, and one due to a spinal abscess. One of the computerized single-space feeders developed a fault leading to the loss of all data from one of the four groups allocated to this treatment.

The results are presented in Table 3.1. Pigs given access to a four-space trough displayed a feeding pattern which differed significantly and substantially from that seen in pigs using the single-space feeders. They visited the feeder more frequently ($p < 0.001$), and for shorter durations ($p < 0.001$), eating only a little per visit ($p < 0.001$) compared to pigs kept in the groups given access to a computerized single-space feeder. No significant differences were found between treatments in the rate of feeding or time spent feeding (i.e. feeder occupation). The differences in feeding pattern did not result in differences in production variables in terms of daily food intake, daily live-weight gain, and feed conversion ratio.

Table 3.1. Feeding behaviour and performance variables for group housed growing pigs given access to either a single-space or a four-space feeder (Means over 2 and 7 days respectively). Figures in italics are means of estimated values (see section 3.3).

Feeder type	4-space	1-space	s.e.d.	p <
Number of pigs	40	28		
Number of groups	4	3		
Means per pig:				
No. of visits (9.00-20.00 hr)	53.5	9.2	3.36	0.001
No. of visits per day	<i>84.5</i>	14.3	5.32	0.001
Feed intake (g/visit)	24	149	13.6	0.001
Duration (min/visit)	0.67	4.67	0.360	0.001
Feeding rate (g/min)	38.6	33.1	5.41	ns
Feeder occupation (min; 9.00-20.00 hr)	31.0	37.7	3.15	ns
Feeder occupation (min/day)	<i>49.0</i>	59.0	4.96	ns
Initial live-weight (kg)	32.9	31.6	3.65	ns
Daily food intake (g/day)	1760	1766	158.1	ns
Daily live-weight gain (g/day)	810	813	48.6	ns
Feed conversion ratio (g/g)	2.25	2.23	0.111	ns

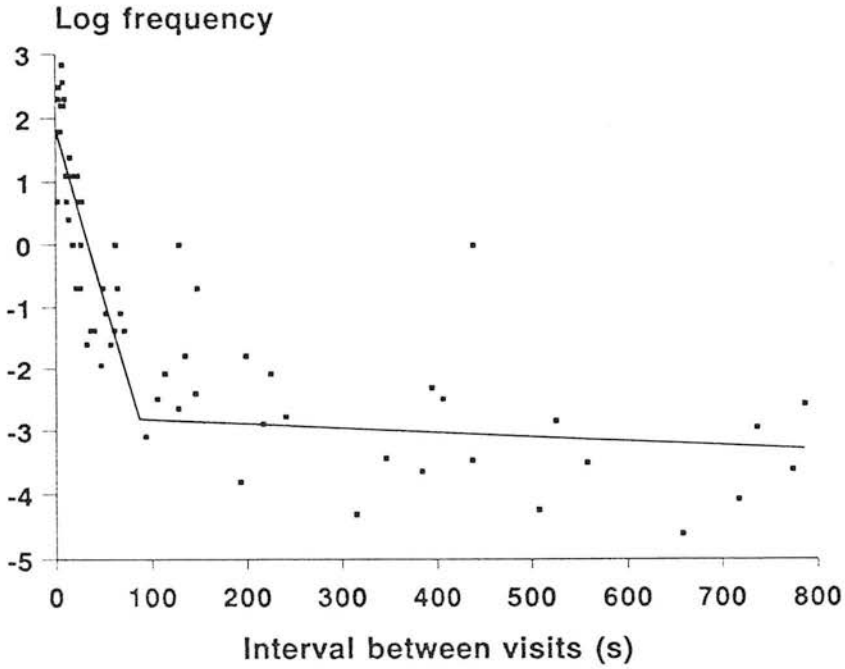
For the pigs using the four-space feeder, a high level of allelomimetic feeding was seen with 2607 out of 4278 visits (61%) made when one or more pigs were already feeding. Differences were found in the overall distribution of visits to the four trough-spaces ($\chi^2=15.1$; $df=3$; $p<0.01$). However, it was not possible for the pigs to choose between all four trough-spaces at all times due to other pigs feeding. Choosing only visits which were commenced when no other pig was feeding, revealed a higher number of visits to the two end trough-spaces as compared to the two middle trough-spaces (1007 vs 664 visits, respectively; $\chi^2=70.4$; $df=1$; $p<0.001$). Visits commenced when three trough-spaces were already occupied (i.e. leaving only one trough-space available) showed no differences between end and middle trough-spaces in the last trough-space available (151 vs 123 visits, respectively; $\chi^2=2.86$; $df=1$; ns). In situations when one pig was already feeding, a higher number of visits were made to trough-spaces next to the feeding pig than to non-adjacent trough-spaces (905 vs 620 visits, respectively). If the choice of trough-space of the first feeding pig is distributed according to visits commenced when the feeding trough is unoccupied (60.3% of visits made to spaces at the ends of the trough), and the second pig were to choose its trough-space at random (i.e. independent of whether it is adjacent to the feeding pig) it results in a slightly lower probability

of feeding next to another pig (0.47), than if both pigs were to chose at random (0.50). However, when only one other pig is feeding the actual proportion of visits made adjacent to the feeding pig is 0.59, which is significantly higher than the random probability (905 adjacent vs 620 non-adjacent visits; $\chi^2=53.3$; $df=1$; $p<0.001$).

Using the logarithm of the frequencies of interval length, the use of a two-process model (i.e. fitting two linear models to the data subdivided into two portions) was justified for the feeding patterns displayed by the pigs given access to a four-space trough. For all 40 pigs on this treatment the broken-stick model gave a significantly better fit than a linear model as measured by the reduction in residual errors (all p -values <0.05). However, the broken-stick model could not justifiably be applied to the feeding data obtained from the computerized single-space feeders. For 6 out of 28 pigs fitting a broken stick model did not significantly reduce the residual error compared to a linear model, and thus a single line was sufficient to describe the feeding patterns observed. Feeding data from another three pigs produced negative bout criteria, and the remaining 19 pigs showed a much wider range of criteria (93 to 2571 seconds) compared to those obtained from pigs using the four-space trough (19 to 442 seconds). It was therefore decided not to apply the bout analysis to the data accumulated by the computerized single-space feeders, and individual bout criteria were calculated only for the pigs using the four-space feeding trough. This criterion indicates the length of interval between visits which, according to the model, separates within-bout intervals from between-bout intervals. An example of one such bout criterion can be seen in Figure 3.1a, indicated by the point of intercept between the two lines fitted to the data when split into two portions; the left-hand portion representing a 'fast' process (or within-bout intervals) and the right-hand portion representing a 'slow' process (or between-bout intervals). In order to allow comparison with results previously published, Figure 3.1b shows the log survivorship curve for the same pig. Figure 3.2a,b show an equivalent example for a pig using the computerized single-space feeder.

The results of the bout analysis are presented in Table 3.2. When visits to the four-space feeding trough was summarized according to individual bout criteria, no differences were found between the feeding patterns of pigs using the two types of feeders. Figure 3.3 shows the number of trough-space changes within a bout as a function of number of visits within a bout for the 40 pigs allocated to the four-space trough treatment. The equation for the fitted line is $y=0.64(x-1)$ (s.d.=0.015; $p<0.001$; $R^2=90.3\%$), where the slope indicates the proportion of trough-space changes made out of number of trough-space changes possible.

a)



b)

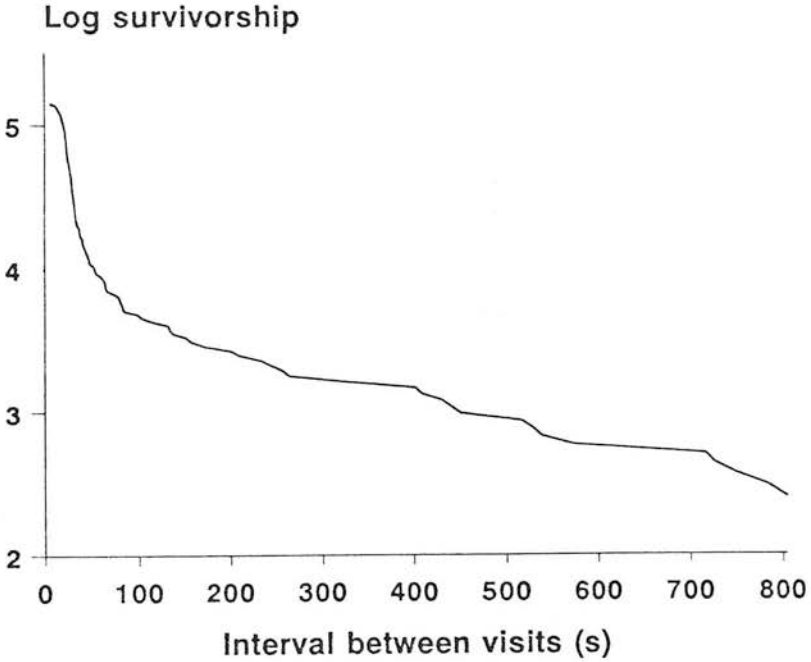
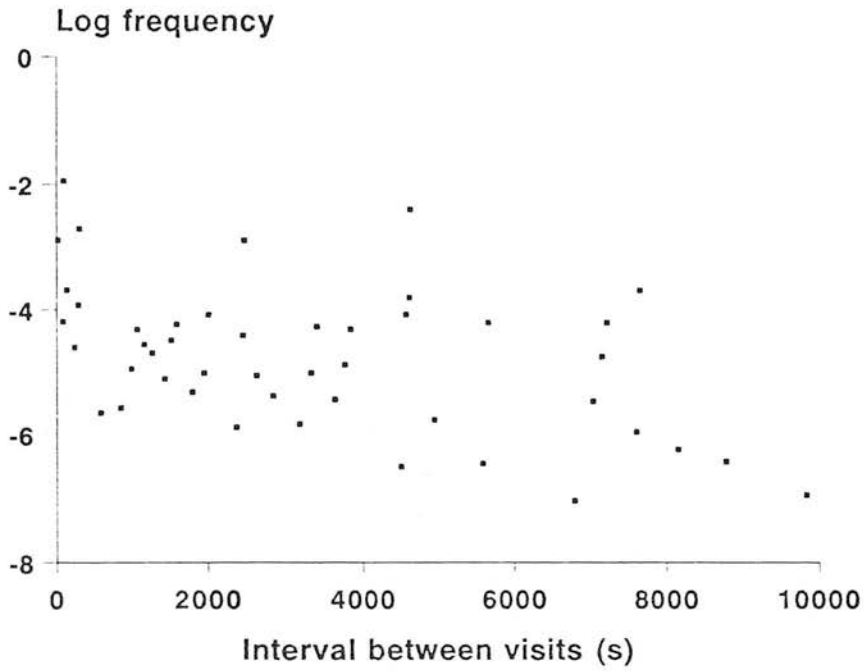


Figure 3.1. Distribution of between-visit intervals for one individual pig from a group using the four-space feeder: a) the frequency distribution on a log scale (see Sibly *et al.*, 1990), and b) the same data plotted as a log survivorship curve. For clarity, only intervals up to 800 seconds are shown.

a)



b)

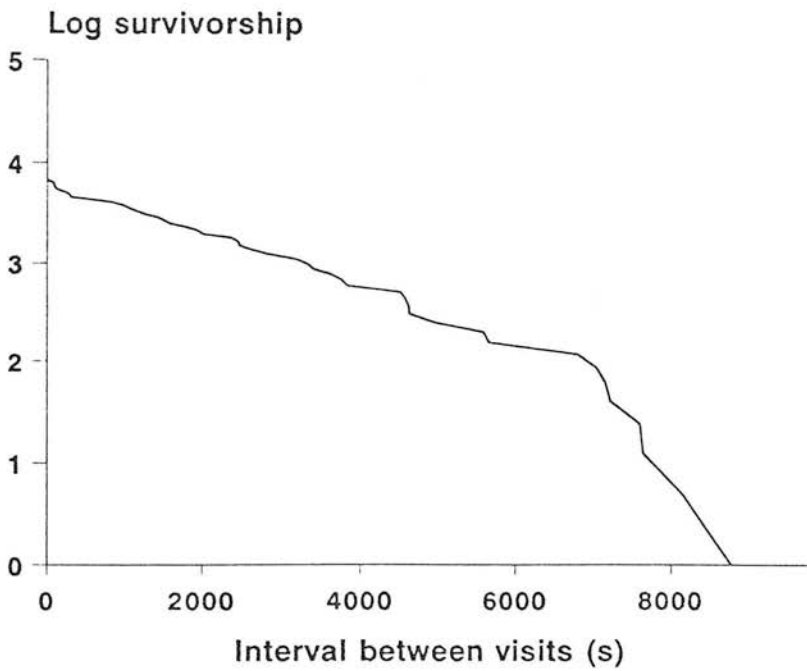


Figure 3.2. Distribution of between-visit intervals for one individual pig from a group using the single-space feeder: a) the frequency distribution on a log scale (see Sibly *et al.*, 1990), and b) the same data plotted as a log survivorship curve.

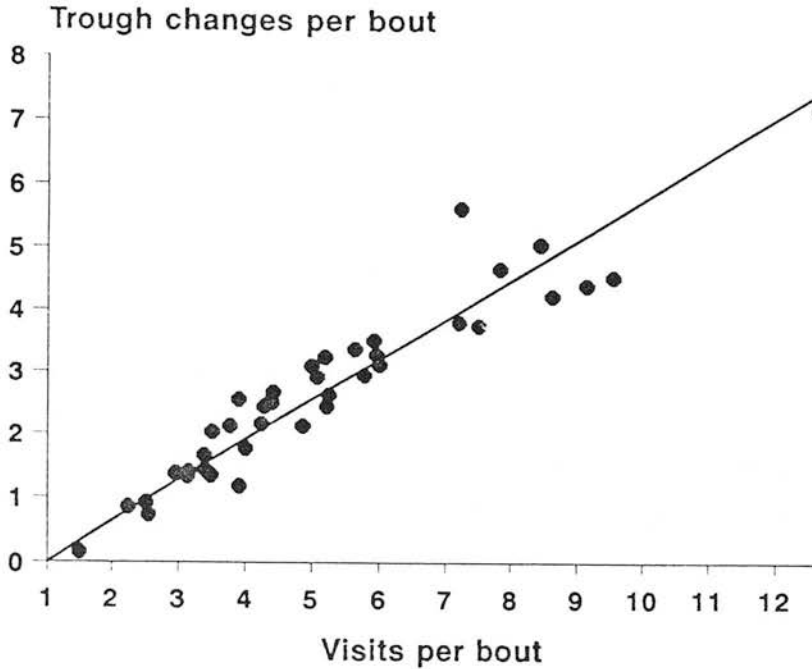


Figure 3.3. The mean number of trough-space changes within feeding bouts plotted against the mean number of visits per bout for each of the 40 animals using the four-space trough. The slope of the regression line is 0.64 ± 0.015 (\pm s.d.), equivalent to the proportion of trough-space changes made out of the number possible.

Table 3.2. Feeding behaviour variables for group housed growing pigs given access to either a single-space or a four-space feeder after application of individual bout criteria. Figures in italics are means of estimated values (see section 3.3).

Feeder type	4-space	1-space ⁺	s.e.d.	p <
No. of bouts (9.00-20.00 hr)	12.0	9.2	1.49	ns
No. of bouts per day	<i>19.0</i>	14.3	2.37	ns
Feed intake (g/bout)	<i>110</i>	149	14.2	ns
Duration (min/bout)	4.71	4.67	0.901	ns

⁺ Pigs using the single-space feeders did not display a feeding behaviour which could justifiably be divided into bouts (i.e. their feeding pattern was a single process; see Sibly *et al.*, 1990). Bouts therefore equal visits for pigs on that treatment.

3.5. Discussion

Although the feeding behaviour of the pigs differed substantially between feeder-types, no significant differences were found in the daily food intake and live-weight gain of these animals. The feeding pattern of the pigs using a four-space trough is very similar to that found in individually housed animals (De Haer and Merks, 1992; De Haer and De Vries, 1993). It had previously been assumed, that the difference in feeding pattern between individually and group housed animals was due to the differences in the social environment in terms of less competition and social interactions. However, the pigs in the present experiment were all kept in groups of ten, and thus the effects of the social environment, over and above that imposed by differences in pig:trough ratio, were similar for treatments. This is also reflected in the similar rates of feeding, as we have previously found (Nielsen *et al.*, 1995a) that increasing the group size, and thereby the social constraint, can lead to significant increases in the feeding rate. The differences in the design of the two types of feeders may have influenced the feeding patterns observed, as the computerized single-space feeder had a race leading up to the feeding trough in order to prevent more than one pig accessing the trough at any one time. This increase in protection of the feeding pig and concurrent decrease in the accessibility of the feed may have influenced the feeding behaviour of the animals. In previous work (Nielsen *et al.*, 1995b) we compared single-spaced feeders with and without a race, and found no significant differences in the feeding frequency of the groups of ten pigs using the two feeder types. Therefore, the difference in pig:trough ratio between the two feeders is most likely the main cause of the observed differences in feeding pattern.

In the present experiment it was found that the feeding behaviour displayed by pigs using the computerized single-space feeders could not justifiably be divided into bouts. In the work by De Haer and Merks (1992) and Labroue *et al.* (1994) log survivorship functions were used to determine the point of division between inter and intra-meal intervals, and the average value (5 and 2 min; respectively) were subsequently applied to all animals, in order to enable comparisons of meals across breed, sex, and housing system. The differences found between number of visits and number of bouts when using this method has been variable, but significant (14 visits vs 9 bouts, De Haer and Merks, 1992; 19 visits vs 7 bouts, Labroue *et al.*, 1994). In comparison, applying meal criteria of 2 or 5 minutes to the data from the present experiment resulted in only small

differences between number of visits and bouts (14.3 visits vs 12.8 and 11.9 bouts; respectively). Although the variation of the meal-criteria used in the literature often is small, Slater (1974) points out, that the use of one overall bout-criterion ignores individual differences in the feeding pattern.

It may be that a three-process model, as suggested by Machlis (1977) and later by Berdoy (1993), would describe better the feeding behaviour of pigs using the computerized single-space feeders. Some of the bout criteria which arose from the preliminary bout analysis of this data were substantially higher (e.g. 42 min) than values reported in the literature, and this could be an indication that other processes, such as 'super-bouts' were operating.

It has previously been suggested (Nielsen *et al.*, 1995c), that the feeding pattern displayed by individually housed animals (i.e. frequent visits eating very little) is the pattern preferred by the animals, and that group housed pigs display a pattern which is an adaptation to the social constraints. Pigeons and rats show a preference for a feeding schedule of small, frequent rewards as opposed to larger and less frequent rewards even if the latter yields more energy per time unit (Todorov, 1973; Logan, 1965). The present experiment has shown, that a decrease in the pig:trough ratio from 10:1 to 10:4 appears to reduce the competition around the feeding trough sufficiently to allow the animals to express a less constrained feeding pattern, similar to that seen in individually housed animals. The four-space trough allowed simultaneous feeding to occur, and the animals feeding from this type of trough showed high levels of allelomimetic feeding. It is difficult to determine whether the observed preference for feeding-spaces adjacent to another feeding pig is an indication of social facilitation. From the video recordings it appeared that a pig would prefer to change to a trough-space which had just been vacated by another feeding pig. No formal test of this behaviour was carried out, but such a strategy would be sensible, as the previously feeding pig may have found, and left, some 'nutritious' food. This may also be one explanation to the clear preference of pigs to feed next to, rather than away from other feeding pigs. The frequent trough-space changes within a bout displayed by these pigs are suggestive of sampling or exploratory behaviour, although the same feed was available in all four trough compartments. Growing pigs given a choice of two foods will eat some of both, even when both foods are limiting to different degrees (Kyriazakis *et al.*, 1990). The high frequency of trough-space changes may be analogous to the feeding behaviour of wild or feral pigs, to whom often

a multitude of food items are simultaneously available, and frequent sampling of the different foods would ultimately aid the pig to obtain a diet of optimal nutrient composition (Dardaillon, 1989; Sjarmidi *et al.*, 1991).

It can be concluded from the present experiment that the use of single-space computerized feeders does give rise to a substantially different feeding pattern compared to that of pigs using a multi-space trough. However, no differences were found between feeder-types in the production variables of the animals. Also, the feeder visits displayed by animals with access to a four-space trough could be collapsed into bouts of feeding, and the frequency and size of these feeding bouts did not differ significantly from the feeder visits measured by the single-space feeders. This would indicate, that although the single-space feeders prevent allelomimetic feeding, they constrain the feeding pattern mainly in terms of preventing changes between trough-spaces, or sampling behaviour, within bursts of feeding.

3.6. Acknowledgements

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Chapter 4

Effects of single-space feeder design on feeding behaviour and performance of growing pigs *

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4.1. Abstract

Computerized feed intake recording (CFIR) systems of various designs are used by research centres and breeding companies to monitor the individual food intake of pigs kept in groups. In the present experiment three feeder designs are compared in order to estimate the effect on performance and feeding behaviour. Ninety entire male pigs (34 ± 0.6 kg; mean \pm s.e.) were allocated in 3 replicates to pens of ten pigs; each pen containing one of three different feeder entrance designs: Low (head-guard), Medium (full length standard race), and High (enclosed pneumatic race) protection against disturbance of the feeding pig. No significant differences were found between treatments in daily food intake, daily live-weight gain, feed conversion ratio, number of visits per day and daily feeder occupation. Pigs with access to an enclosed race had longer visits than pigs on the two other treatments, and they also ate more per visit (4.8, 4.8, and 6.2 (s.e.d.=0.4) min/visit; 172, 157, and 202 (s.e.d.=11) g/visit; means of Low, Medium, and High protection, respectively). The enclosed race was not only the most protective, it was also the most difficult to enter, and this decreased accessibility of the food may have given rise to the changed feeding pattern displayed by pigs using this type of race. Access to a feeder with Low protection resulted in a faster rate of eating (36.9, 33.2, and 32.8 (s.e.d.=0.8) g/min; means of Low, Medium, and High protection, respectively) indicative of a more forced feeding behaviour.

Key words: *single-space feeder design, feeding behaviour, pigs*

4.2. Introduction

In recent years computerized feeders have been widely used to monitor the feeding behaviour of group housed pigs (Young and Lawrence, 1994) and to measure individual feed intake (De Haer and Merks, 1992). Various such feeders have been designed (e.g. Slader and Gregory, 1988; De Haer *et al.*, 1992), and at present most, if not all, such feeders are single-spaced, allowing only one animal to feed at any one time (Webb *et al.*, 1990). They differ mainly in the design of the entrance and, more specifically, the level of protection offered to the feeding pig. The IVOG-station (HokoFarm, Marknesse, Holland) as used by De Haer *et al.* (1992) has an open entrance with only a head-guard to prevent two animals feeding at once. FIRE feeders (Hunday Electronics Ltd, Newcastle upon Tyne, UK) as used by Nielsen *et al.* (1995), have an adjustable race leading to the feed trough, whereas ACEMA-48 (Société ACEMO, Pontivy-Cedex, France) used in some of the French testing stations (Labroue *et al.*, 1994) has a full length race with an entrance door preventing the feeding pig from being disturbed by other group members. These differences have been found to affect the feeding pattern of growing pigs with increasing protection leading to fewer but longer feeder visits (Molenaar, unpublished; quoted by De Haer, 1992; Morrow and Walker, 1994). However, none of these studies compared more than two entrance designs. It is therefore at present difficult to estimate the full effect of feeder design on both performance and behaviour and difficult to compare results obtained from different types of feeders. Computerized single-space feeders are used by many breeding companies in the performance testing of pigs, and the influence of feeder design on feed intake and feeding behaviour may be crucial to the accurate estimation of performance traits used in the selection programme.

The aim of the present experiment was to fully investigate the effect of single-space feeder entrance design on the performance and feeding behaviour of growing pigs by using designs offering three levels of protection.

4.3. Material and methods

Ninety crossbred entire male pigs were used with a mean initial live-weight of 34.4 (s.d.=5.03) kg. Three replicates were carried out, each using 30 animals allocated in groups of 10 to one of three different entrance designs (Figure 4.1):

Low (head-guard), Medium (standard full length race), and High (enclosed pneumatic race) protection against disturbance of the feeding pig by pen-mates.

The animals were kept in a naturally ventilated room. The top half of two adjacent walls consisted of wooden slats through which natural light could enter. During the course of the experiment the natural light gradually decreased from 17.5 to 13 hours per day. In an attempt to counterbalance this change in the light period, artificial lights were switched on at 05.00 hr and off at 20.00 hr during the whole experimental period. The mean ambient temperature range was 11 to 17 °C.

Each pen (1.3 m²/pig) consisted of an insulated kennel, a dunging area with two water bowls and one single-space computerized feeder (FIRE, Feed Intake Recording Equipment, Hunday Electronics Ltd, Newcastle upon Tyne, UK) fitted with one of the three entrance designs. All feeders were equipped with a fibreglass feed trough mounted in a frame with its weight bearing on a load cell. Each pig was provided with a uniquely coded ear-tag transponder. The pigs gained access to the feed trough by pushing upon a top hinged door mounted on a frame in front of the trough. The electronic system detected the door opening and recorded the weight of the trough immediately prior to pig entry. At the same time the identification circuit recorded the pig's transponder number. When the pig had finished feeding the electronic system detected the door closure and again recorded the weight of the trough. The difference between pre- and post-visit trough weight was stored in a data file together with the pig's transponder number, the time and the duration of the visit. Between each visit the weight of the trough was checked by the electronic system: if below a preset minimum (empty trough weight + 500g), the door was briefly locked and the trough topped up with feed (approx. 1 kg) from a hopper above.

Each group was kept in the pens for 29 days during which period the animals were weighed weekly. Between 09.00 and 10.00 hr the pens were cleaned and fresh straw provided five days a week; the hoppers were re-filled at the same time every day. The feed used was a commercial pelleted grower diet (Ultra Grade 320, Dalgety Agriculture Ltd, Bristol, UK) of the following composition per kg fresh: 195g protein, 55g oil, 60g ash, 47g fibre, and 13.4 MJ DE.

On the first day of the experimental period (Day 1) for treatments Medium and High the race was left wide open to encourage the pigs to enter the feeder. On

Day 2 the race was narrowed to prevent more than one pig entering the feeder, whether or not all the animals had made a visit to the feeder. If an animal had not visited the feeder by the end of Day 2 a stockperson would place a few, fresh food pellets on the floor immediately outside the trough, put the animal inside the race and keep it there for a short amount of time (3 to 5 min). If a pig had not started eating on Day 3 of the experiment it was removed from the trial.

The data were analysed using analysis of covariance in GENSTAT (Version 5; Lawes Agricultural Trust, 1990) fitting racetype as treatment within replicate and adjusting for differences in initial live-weight. Mean values over Days 18 to 28 for each individual animal were used in order to preclude repeated measures.

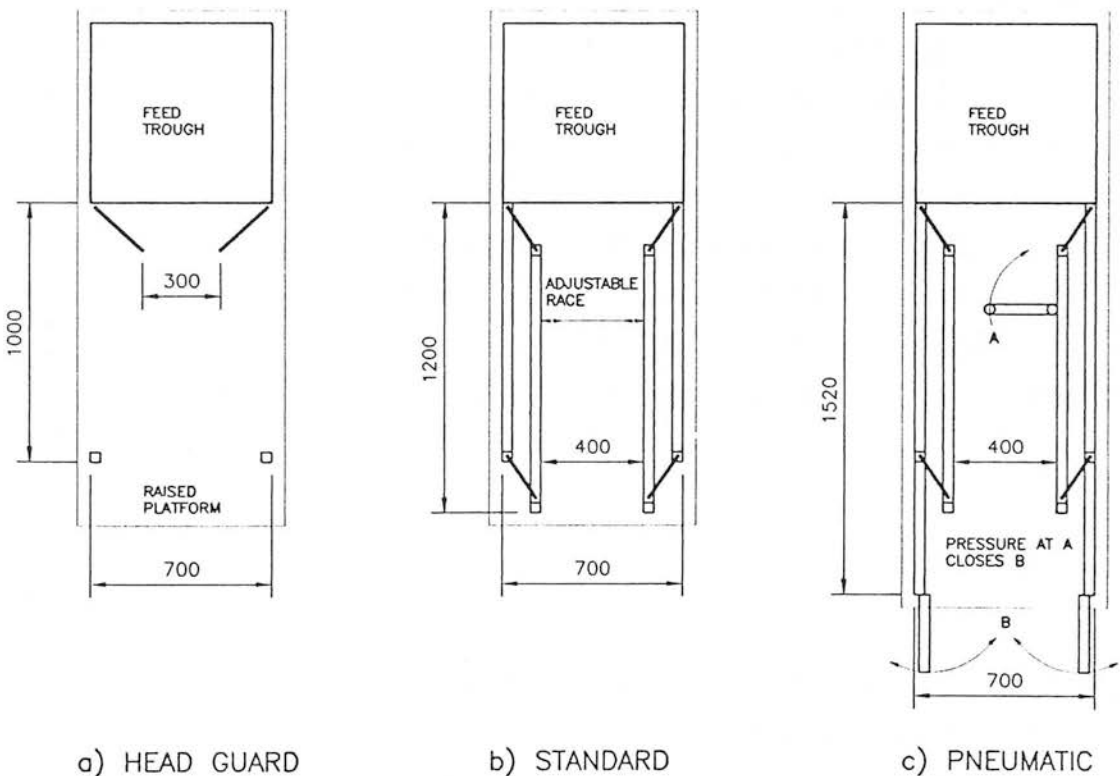


Figure 4.1. Plan view diagram of the three feeder designs used; a) Head guard (Low), b) Standard (Medium), and c) Pneumatic (High). Measurements in mm.

4.4. Results

The enclosed race with the pneumatic door had more functional problems than the other designs, but pigs had to be removed from all of the treatments as a result of not learning to use the feeder (2, 3, and 3 pigs removed from treatment Low, Medium and High respectively). A further three pigs were removed due to illness. In order to completely eliminate any potential effect of learning difficulties and feeder failures only feeding data means over days 18 to 28 were included in the analyses. On allocation of the animals to the different treatments an attempt was made to minimize the within-group variation in initial live-weight. As the supply of male pigs from the farm stock was inconsistent this resulted in a greater between-group variation in live-weight and in slightly heavier pigs being allocated to treatment Low (Table 4.1). All means have been adjusted for differences in initial live-weight although this difference between treatments was not significant.

The results are presented in Table 4.1. No significant differences were found between treatments in daily food intake, daily live-weight gain, and feed conversion ratio. Pigs on treatment High had significantly longer ($p < 0.05$) visits to the feeder, and they ate more per visit ($p < 0.05$) than pigs on the two other treatments. Pigs on treatment Low ate faster ($p < 0.05$) than pigs on the other treatments. No differences were found between treatments in daily feeder occupation. Feeder visits where no food had been eaten were most frequent on treatment Medium and least frequent on treatment High ($p < 0.001$). The circadian pattern of feeder occupation was similar for all treatments (Figure 4.2).

4.5. Discussion

The results are in agreement with the findings of Molenaar (unpublished; quoted by De Haer, 1992) who is reported to have found, that number of visits to the feeder and rate of feed intake were higher and meal sizes were smaller with feeders equipped with a head-guard (low protection) than feeders offering full protection. This would indicate, that pigs using a feeder offering low protection may be more disturbed by other pigs whilst feeding, resulting in a

Table 4.1. Performance and feeding behaviour of group housed pigs provided with one of three different kinds of feeder design. Means over Days 18-28 (except live-weights).

Treatment (Entrance design)	Low (Head-guard)	Medium (Standard)	High (Pneumatic)	s.e.d.
n	28	27	24	
Initial live-weight ⁺	38.0	31.5	33.1	3.7
Final live-weight	61.4	53.8	54.1	4.6
Daily food intake (g/d)	2055	1941	1889	130
Daily live-weight gain (g/d)	794	810	773	35
Feed conversion ratio (g/g)	2.59	2.40	2.45	0.07
Number of visits per day	13.26	13.98	10.39	1.89
Duration (min/visit)	4.82 ^a	4.81 ^a	6.21 ^b	0.37
Feed intake (g/visit)	172 ^a	157 ^a	202 ^b	11
Feeding rate (g/min)	36.9 ^a	33.2 ^b	32.8 ^b	0.8
Feeder occupation (min/d)	57.1	60.6	59.4	4.3
Non-feeding feeder visits per day	0.79 ^b	1.08 ^a	0.41 ^c	0.09

⁺ All subsequent means (except final live-weight) are adjusted for differences in initial live-weight.

^{a,b,c} Within rows means followed by different superscripts are significantly different ($p < 0.05$).

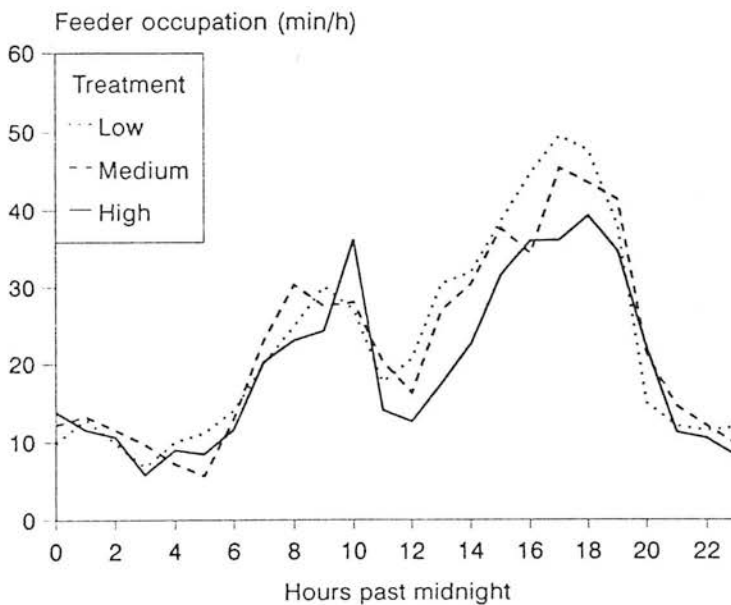


Figure 4.2. Circadian pattern of feeder occupation for three different feeder entrance designs.

more forced feeding pattern with smaller meals eaten more rapidly. This effect on feeding rate was also found by Nielsen and Lawrence (1993), when group size reached twenty. The increase in feeding rate could also be due to a larger food spillage from this type of design, as indicated by the slightly worse (non-significant) feed conversion ratio by pigs given access to this type of feeder, but very little spillage was observed from any of the three feeder designs and, furthermore, the trough section of all three feeders were identical.

In the present experiment there was a small, but non-significant, decrease in daily feeder visits when the feeders were fitted with an enclosed race (treatment High). Morrow and Walker (1994) found the number of feeder visits almost halved in groups with access to a feeder with a full length open race compared to a feeder with a head-guard, but no such reduction was found in the present experiment. This difference in results may be, at least partly, explained by the different feeder designs used in the two experiments. In Morrow and Walker's work the feeding trough contained separate food and water dispensers operated by the pig. This was the only source of water available in the pen, a factor which may have elevated the number of visits overall. Rats have been found to alter their feeding pattern when required to press a bar for food (Kissileff, 1970) and the operant-type feeder used by Morrow and Walker (1994) may have contributed to the differences in results between that and the present experiment. Also, the race was fitted with a bar over the rump of the feeding pig to prevent it from being mounted by other pigs, which may have protected the pig more than the full length race used in the present experiment.

In previous work (Nielsen and Lawrence, 1993) we found that increasing the competition around the feeder by increasing the number of pigs per feeder resulted in fewer and longer feeder visits only when group size reached 20 pigs. Individually penned animals, on the other hand, have significantly shorter and more frequent feeder visits than group housed pigs (De Haer and Merks, 1992; De Haer and De Vries, 1993). The increased protection offered by the fully enclosed race was expected to eliminate disturbance of the feeding pig and hence simulate the single housing situation. However, the feeding behaviour displayed by pigs using this type of race did not resemble the feeding pattern of individually kept animals, but was more similar to that observed in large groups. The fully enclosed race was not only the most protective, it was also the most difficult to enter. In rats, meal frequency has been found to decrease and meal size increase with decreasing accessibility of the food (Levitsky, 1974). It is

therefore likely that although a fully enclosed feeding space protects the feeding animal from disturbance it simultaneously makes the trough less accessible resulting in similar changes in feeding pattern to those seen with increased competition.

Although racetype had no effect on the performance of the animals, we cannot eliminate the possibility that racetype may have affected the ranking of the pigs according to performance. As opposed to the pneumatic race, the use of a standard race does not decrease the accessibility of the food below that already imposed by the social environment, and, furthermore, the standard race appears to prevent the increase in feeding rate seen in pigs using the low protection feeder.

4.6. Acknowledgements

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Chapter 5

Effect of individual housing on the feeding behaviour of previously group housed growing pigs *

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5.1. Abstract

The feeding behaviour of individually housed growing pigs differs significantly from that of group housed animals, with individual penning resulting in shorter, more frequent visits to the feeding trough (De Haer and Merks (1992); *Anim. Prod.*, **54**: 95-104). Substituting group housing by a single housing environment was therefore expected to substantially increase the number of visits to the feeding trough. Three groups of ten cross-bred entire male pigs (initial live-weight 29.3 ± 0.6 kg; mean \pm s.e.) were housed for 14 days (Period 1) with access to one computerized single-space feeder per group. Four pigs were chosen from each group; two pigs showing a high feeding frequency (H pigs: 18.9 ± 2.0 visits/day; mean \pm s.e.; n=6) and two pigs showing a low feeding frequency (L pigs: 9.5 ± 0.8 visits/day; mean \pm s.e.; n=6). L pigs also had a higher feed intake per visit (137 vs 82 g/visit; s.e.d.=8; $p < 0.001$), but a lower daily food intake (1246 vs 1477 g/d; s.e.d.=84; $p < 0.05$) than H pigs. On Day 15, H and L pigs were moved to individual pens identical to the group pens for a period of 14 days (Period 2). This individual housing resulted in only a small increase in the frequency of feeder visits (2.8 ± 0.8 visits/day), irrespective of the feeding frequency displayed by the pigs during Period 1. This relatively small increase in number of daily feeder visits resulted in a significant increase ($p < 0.05$) in daily food intake, leading to no differences between pigs in daily food intake once individually penned. Pigs showing a low number of daily feeder visits when group housed may have been constrained in terms of daily food intake as a result of the displayed feeding pattern. In addition, it may be that the feeding pattern of growing pigs is less flexible than expected, and that pigs, which have been constrained in their food intake, make only small modifications to their feeding pattern, sufficient to compensate for the previous constraint. It is likely that growing pigs will adhere to a feeding pattern that has provided them with sufficient food in the past, even when a change in the environment allows for more extreme modifications.

Key words: *pigs, housing, feeding behaviour, computerized single-space feeders*

5.2. Introduction

Differences between growing pigs kept in individual and group housing have been found in both behaviour and production performance. De Haer (1992) used groups of eight pigs with access to computerized single-space feed intake recorders, and compared the feeding behaviour of these group housed pigs to that of individually housed animals. She found that pigs kept individually had shorter and more frequent visits to the feeder, and that they ate less per visit than pigs kept in groups of eight. Individually housed pigs have been found to have an improved production in terms of a higher daily food intake (Gonyou *et al.*, 1992), a higher growth rate (De Haer and De Vries, 1993), even on restricted feeding (Patterson, 1985), and a better feed conversion ratio (Petersen, 1976) compared to group housed pigs. This would appear to indicate that the feeding pattern displayed by individually housed animals results in an improved production. However, De Haer and De Vries (1993) did not find differences in daily food intake between individual and group housed pigs, and the improved growth may have been due to other factors such as different levels of activity.

Rats have been found to prefer a relatively large number of small meals (Johnson *et al.*, 1993), and it may be that the feeding pattern expressed by individually penned animals is the preferred pattern, and the difference in feeding pattern seen when pigs are group housed represents an adaptation to the social constraints placed on their feeding behaviour. Group housed pigs achieve the same daily food intake as individually kept animals, but adapt to the social environment by changing their feeding pattern to have fewer, larger 'meals'. Nielsen *et al.* (1995a) found that increasing the group size to twenty animals exacerbated this change in feeding pattern with pigs kept in groups of twenty having fewer and shorter visits than pigs kept in groups of five, ten, or fifteen. Similar changes in feeding pattern have been found in rats when accessibility to food is decreased (Levitsky, 1974). It could therefore be expected, that housing previously group housed animals individually will lead to a change in feeding behaviour towards a higher number of feeder visits.

Within group housed animals there is some degree of variation between individuals with regard to feeding pattern. This variation could be partly genetic, but may also be attributed to effects of the social environment and the higher pig:trough ratio in the group housing situation, where not all pigs can

feed simultaneously. Pigs which display a low feeding frequency, and which therefore deviate most from individually housed animals in their feeding pattern, may be more constrained by the group environment than pigs with a higher feeding frequency. The variation in feeding frequency seen in group housed pigs is negatively correlated to the amount of food eaten per feeder visit, and no differences have been found in daily food intake or growth rate between animals with different feeding patterns (Nielsen, 1995). This experiment was designed to investigate the nature of this individual variation in feeding pattern observed in group housed animals, as well as consider the effect of social environment by examining the effect of individual housing on the feeding behaviour of pigs previously kept in groups.

5.3. Material and methods

Animals and housing

Thirty entire male pigs (Landrace x Large White) with an initial live-weight of 29.3 ± 0.6 kg (mean \pm s.e.) were used. Three replicates were carried out in sequence, each using one group of ten pigs initially penned together. Each pen was equipped with an insulated kennel, two water-bowls, and one computerized single-space feeder (FIRE, Hunday Electronics Ltd, Newcastle upon Tyne, UK), and each pen had a space allowance of $1.3 \text{ m}^2/\text{pig}$. The front of the pens consisted of meshed boards whereas the sides were fully sheeted to eliminate physical contact between pigs in adjacent pens. Between 08.00 and 09.00 hr the pens were cleaned and fresh straw provided three days a week; the hoppers were re-filled at the same time every other day. The feed used was a commercial pelleted grower diet (Ultra Lean 320, Dalgety Agriculture Ltd, Bristol, UK) of the following composition per kg fresh weight: 200g protein, 50g oil, 60g ash, 48g fibre, and 13.5 MJ DE.

The animals were kept in a naturally ventilated room. The top half of two adjacent walls consisted of wooden slats through which natural light could enter. During the course of the experiment, natural light levels gradually decreased from 13 to 7 hours. In an attempt to counterbalance this change in the light period and to ensure sufficient light for video recording, artificial lights were switched on at 05.00 hr and off at 20.00 hr during the whole experimental period. The average temperatures measured hourly by electronic temperature probes (Autolog, Remonsys Ltd, Somerset, UK) during the final two replicates

were 5.1 ± 0.09 °C and 4.0 ± 0.08 °C inside and outside the kennels, respectively (means \pm s.e.).

The feeders consisted of a race, the width of which could be adjusted to ensure that only one pig at a time could enter the feeder, and a fibreglass feed trough tautly mounted in a frame with its weight bearing on a load cell. Each pig was provided with a uniquely coded ear-tag transponder. The pigs gained access to the feed trough by pushing upon a top hinged door mounted on the race. The electronics detected the door opening and recorded the weight of the trough immediately prior to opening. At the same time the identification circuit recorded the pig's transponder number. When the pig had finished feeding the electronics detected the door closure and again recorded the weight of the trough. The difference between pre- and post-visit trough weight was stored in a data file together with the pig's transponder number, the time and the duration of the visit. Between each visit the weight of the trough was checked by the electronics: if below a preset minimum (empty trough weight + 500g), the door was briefly locked and the trough topped up with feed (approx. 1 kg) from a hopper above.

Experimental procedure

On the first day of the experimental period for each replicate (Day 1) the race leading to the feeder trough was left wide open to encourage the pigs to enter the feeder. On Day 2 the race was narrowed to prevent more than one pig entering the feeder, whether or not all the animals had made a visit to the feeder. If an animal had not visited the feeder by the end of Day 2 a stockperson would place a few, fresh food pellets on the floor immediately outside the trough, put the animal inside the race and keep it there for a short amount of time (<5 min). If pigs had not started eating on Day 3 of the experiment they were removed from the trial.

After 14 days (Period 1) four pigs were chosen from each replicate group: two showing a low number of daily feeder visits (L pigs) and two showing a high number of daily feeder visits (H pigs). These animals (n=12) were housed individually for a subsequent 14 days (Period 2) in pens identical to the group pens. The animals were weighed every 3-4 days during all of the experimental period.

Behavioural recordings

The behaviour of the animals was recorded using time-lapse video equipment. The camera was mounted on a rail attached to the wall, allowing the camera to be positioned in front of each pen up to 3 metres above the ground. The time-lapse video recorder was programmed to record at 4.6 x real time. All recordings were continuous between 09.00 and 20.00 hr. In Period 1 all three groups were recorded on Day 11; in Period 2 the individually housed animals were recorded once each in random order between Days 22 to 25. Prior to video recording in Period 1 the animals were numbered consecutively using a durable marker spray (Spray Brand, Ritchey Tagg Ltd, Ripon, UK) to ensure easy identification on the video tapes. In a pilot trial the provision of straw had been shown to result in a bout of increased activity, and so the pen to be recorded was given straw at 09.00 hr precisely to ensure that comparisons between groups and between individuals were valid.

A time sampling procedure was used to record behaviour from the video tapes. The following variables were recorded at 10 min intervals for each of the 12 pigs in the two periods: position (i.e. whether inside or outside kennel), posture, and behavioural activity (Table 5.1). In addition, the following behavioural categories were recorded for all animals in Period 1 as and when they occurred:

- 1) Aggression (bite, threat, push, knock with head, chase or fight another pig): All pairwise aggressive interactions were scored and the identity of the two pigs involved were noted. In addition, the pig that initiated the aggressive encounter and, where possible, the pig that won the aggressive encounter were identified.

- 2) Displacements (stand in front of the entrance to the feeder, nose, push or bite the pig in the feeder): All attempts by one pig to displace another pig from the feeder were scored together with the identity of the pigs involved and the outcome of the displacement (i.e. whether successful or not).

Statistical analyses

The time samples were converted into proportion of time spent in various activities by each pig in the two Periods, checked for normality, and analysed by oneway analyses of variance. Individual means of performance and feeding

behaviour variables from Days 4-14 (Period 1) and Days 18-28 (Period 2) were also analysed by analysis of variance using GENSTAT (Version 5; Lawes Agricultural Trust, 1990). In the ANOVA model, effects of feeding frequency level (i.e. L and H pigs) were tested between pigs and effects of Period (i.e. housing environment) were tested within pig having removed the overall effect of replicate.

The aggressive interactions between pairs in Period 1 were used to establish individual dominance ranks within each group. The following dominance rank index (RI) was used (Lee *et al.*, 1982):

$$RI_A = \frac{1}{2}(D-S+N+1)$$

where RI_A = dominance rank index of animal A
 D = number dominated by animal A
 S = number dominating animal A
 N = group size

This formula results in $RI_A = N$ if animal A is dominant to all other pigs in the group, and $RI_A = 1$ if animal A is subordinate to all other pigs in the group. Pigs with no aggressive interactions, and therefore no apparent established dominance relationships are given values midway between the two extremes $((N+1)/2)$.

Table 5.1. Description of the behavioural categories used in the time sampling procedure.

Behavioural category ⁺	Description of activities
Feed	Standing in feeder apparently chewing or ingesting food from the trough.
Drink	Drinking from or nosing the inside of a water-bowl
Root ⁺⁺	Manipulating the floor, straw, or any of the pen fixtures with the snout, including nosing and sniffing.
Social behaviour ⁺⁺	All interactions with pen-mates (nosing, sniffing, fighting, biting, mounting, etc.)
Alert ⁺⁺	Pig motionless with ears erect and eyes open.
Move	Pig in motion (walking or running) without being engaged in any other behavioural activity.

⁺ When a pig was in the kennel and not visible on the video recording it was assumed that the pig was lying inactive.
⁺⁺ These categories were observed infrequently when pigs were lying down, and were only included in the analysis when performed whilst standing.

Within-group correlations between feeding frequency and dominance rank (RI), number of aggressive interactions initiated, and number of feeder displacements attempted, respectively, were analysed using the Spearman Rank Test.

5.4. Results

Two pigs were removed from the trial as a result of not learning to use the feeder (replicates 1 and 3, respectively).

In the group housing environment (Period 1) L and H pigs differed not only in the number of daily feeder visits on the basis of which they chosen but, as expected, with regard to other feeding behaviour variables as well (Table 5.2): H pigs spent less time per visit ($p < 0.05$), and had a lower feed intake per visit ($p < 0.001$) than L pigs. This lower feed intake per visit did not completely counteract the higher number of daily visits as H pigs had a higher daily food intake ($p < 0.05$) than the L pigs in Period 1.

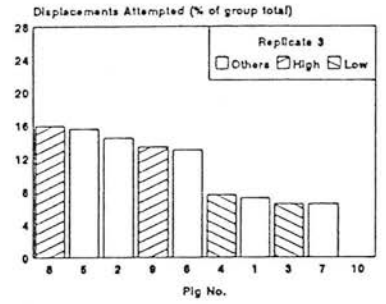
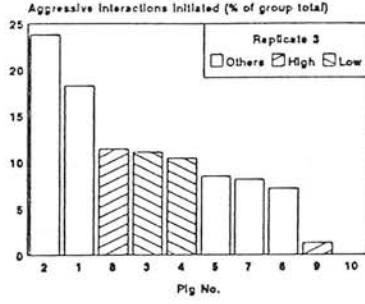
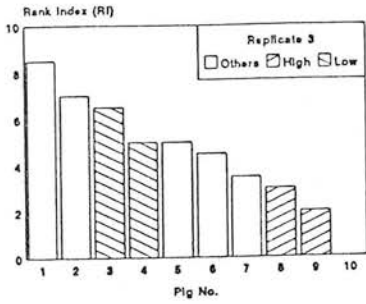
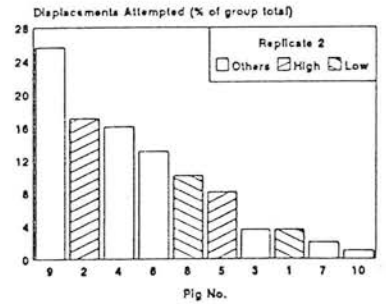
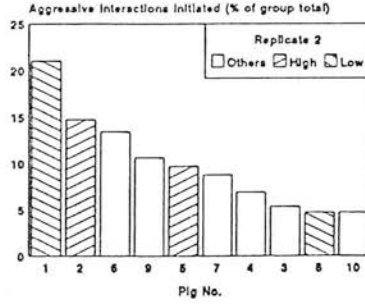
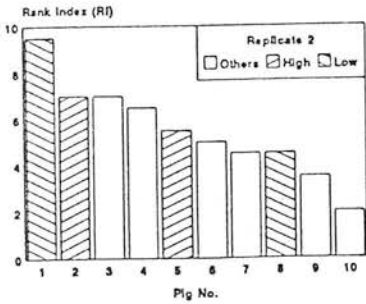
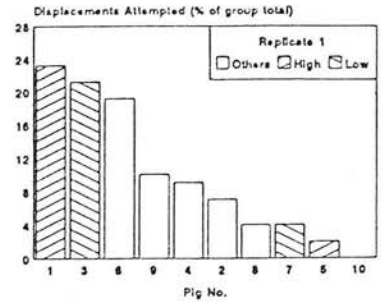
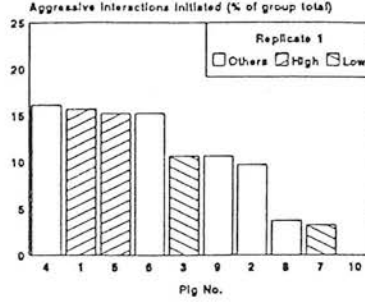
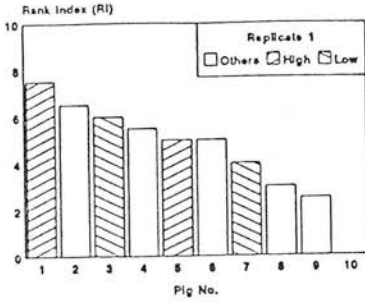
No significant within-group correlations were found in Period 1 between feeding frequency and dominance rank index (RI), aggressive interactions initiated, and displacements attempted (maximum Spearman Correlation = -0.67; $n = 9$; ns). To further explore the relationship between feeding pattern and social behaviour, the animals were numbered within groups according to the dominance rank index (RI) and ordered according to their individual values or levels of RI, aggression and attempted displacements (Figures 5.1a-c). The position of the L and H pigs within groups did not appear to be a systematic effect of rank, level of aggression or displacement attempts.

The difference between L and H pigs in number of daily feeder visits was unchanged following the individual penning (Figure 5.2) as both L and H pigs increased their number of daily feeder visits by 2.8 ± 0.8 visits/day in Period 2 ($p < 0.05$). This increase in feeder visits was equivalent to an increase of 32% for the L pigs in Period 2, as opposed to 13% for the H pigs. There was a significant increase ($p < 0.05$) in daily food intake for Period 2 versus Period 1 of 38% for the L pigs and 10% for the H pigs, and no significant difference in daily food intake was found between L and H pigs in Period 2. Daily live-weight gain increased significantly in Period 2 (Table 5.2; $p < 0.05$) but there was no significant difference between L and H pigs in this measure.

Table 5.2. Mean feeding behaviour and production variables for L and H pigs in the two housing conditions. For variables where Period had a significant effect the s.e.d. between L and H pigs, and the significance level are given separately for each Period.

	Period	L pigs	H pigs	s.e.d. L/H	p< L/H	s.e.d Period	p< Period
n		6	6				
Initial live-weight (kg)		29.4	29.3	0.95	ns		
Number of daily feeder visits	1	9.5	18.9	1.3	0.001	1.0	0.05
	2	12.5	21.4	2.4	0.01		
Duration of visit (min)	1	5.4	3.2	0.7	0.05	0.3	ns
	2	5.2	3.5				
Feed intake per visit (g)	1	137	82	5	0.001	12	ns
	2	130	82				
Feeding rate (g/min)	1	26.0	26.4	2.5	ns	1.3	ns
	2	27.1	23.0				
Feeder occupation (min/day)	1	49.5	55.8	7.4	ns	4.6	0.05
	2	62.4	69.4	13.5	ns		
Daily food intake (g/day)	1	1246	1477	84	0.05	94	0.05
	2	1581	1623	149	ns		
Daily live-weight gain (g/day)	1	684	698	47	ns	48	0.05
	2	869	758	66	ns		
Feed conversion ratio (g/g)	1	1.88	2.12	0.09	0.01	0.14	ns
	2	1.82	2.16				

In both housing systems, H pigs displayed similar bimodal patterns of feeding with a small peak around 09.00 hr, when the pens were cleaned out and the pigs aroused, and a second larger peak in the late afternoon (Figure 5.3). The peak at 09.00 hr for the H pigs was slightly higher in Period 2 than in Period 1, reflecting that the feeder is always available when a pig is individually housed. The L pigs did not have a peak in the morning in Period 1 and they also showed a tendency to peak slightly later than the H pigs in the afternoon (Figure 5.3), indicating that they did not succeed in getting access to the feeder at these times. In Period 2, the L pigs showed a slight modification to their circadian feeding pattern compared to Period 1 (Figure 5.3). They displayed a morning peak, reflecting the lack of competition, and the distribution in Period 2 was more similar to that seen by the H pigs in both Periods. For both L and H pigs, the increased number of visits during Period 2 took place primarily during the afternoon in the hours prior to the peak displayed in Period 1.



(a)

(b)

(c)

Figures 5.1a-c. Within-group histograms of pigs plotted in order of: a) rank index (RI); b) aggressive interactions initiated (% of group total); and c) displacements attempted (% of group total), with L and H pigs indicated by hatched bars.

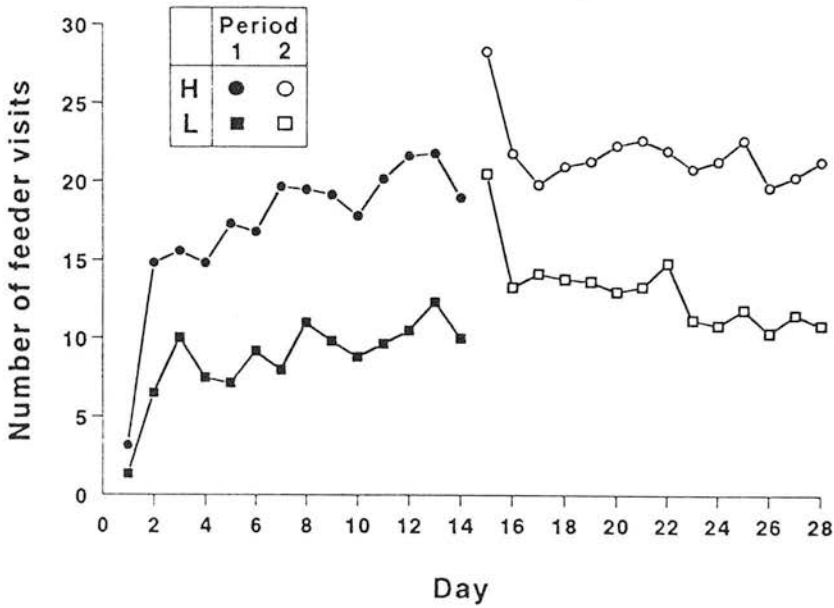


Figure 5.2. Mean number of daily feeder visits displayed by H pigs and L pigs over the whole experimental period. Day 15 is the day of individual housing.

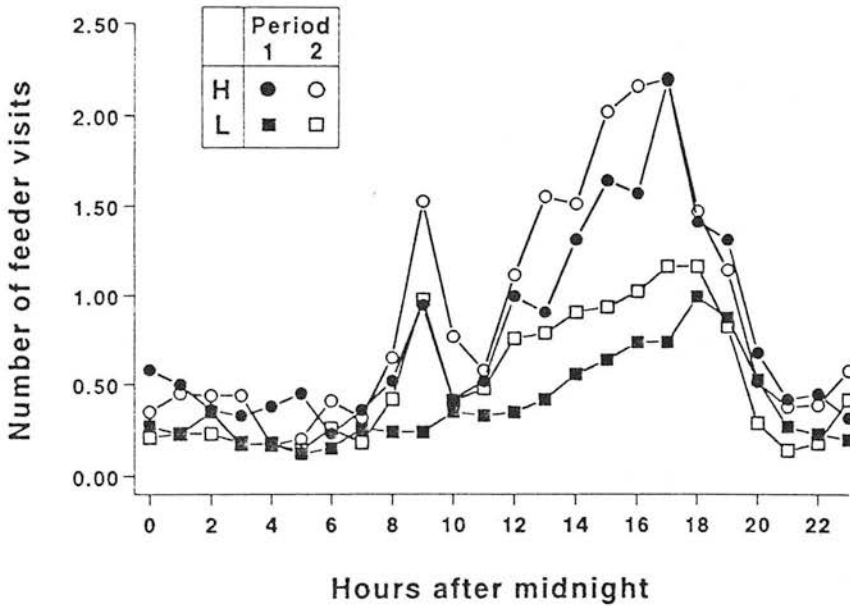


Figure 5.3. Distribution of feeder visits over the 24-hours for H pigs and L pigs in Periods 1 and 2.

The time-sampling results are shown in Table 5.3. No significant differences between L and H pigs were found in percentage time spent in different behavioural activities. In Period 2, where no social behaviour was possible, more rooting was observed ($p < 0.05$). Although there were significant differences between Periods in feeder occupation as measured by the computerized single-space feeders (Table 5.2), this difference was not apparent when the time sampling method was used.

5.5. Discussion

The individual housing resulted in only a small increase in the frequency of feeder visits which resulted in a significant increase in daily food intake, irrespective of the feeding frequency displayed by the pigs whilst group housed, in turn leading to no differences between pigs in daily food intake once individually penned.

The feeding behaviour of individually housed growing pigs has been found to differ significantly from that of group housed animals, with individual penning resulting in shorter, more frequent visits to the trough (De Haer, 1992). De Haer and Merks (1992) found the difference between individually and group housed animals to be around 44 visits/day (58 vs 14 visits/day). Substituting the group housing by a single housing environment had therefore been expected to substantially increase the number of visits to the feeding trough, but in the present experiment, individual housing of previously group housed pigs resulted in only a small increase in feeding frequency. It had also been expected that L pigs would increase their number of feeder visits in Period 2 to reach the level of the H pigs as a result of the individual housing and lack of competition around the feeder. However, this did not happen, as the increment in feeding frequency was of the same magnitude for both types of pigs.

De Haer and Merks (1992) used individually housed pigs that had no previous group housed experience with the single-space feeders (Jan Merks, 1995; pers. comm). This may have resulted in a feeding behaviour being displayed, which reflects more the feeding pattern preferred by the animals. Nielsen *et al.* (1995b) found that if group housed growing pigs were given access to a four-space trough they displayed a feeding pattern similar to that of the individually penned animals observed by De Haer and Merks (1992). The initial period of

group housing used in the present experiment, involving competition around the single-space feeder, may have altered the feeding pattern in such a way, that when individually housed, the animals continued to display visits of the same duration and eat at the same rate, as when group housed. The only modification of the feeding pattern made by both H and L pigs was a small increase in feeding frequency, which was sufficient to counteract the slight depression in feed intake in the group housed situation. Rats have also been found to augment their food intake initially by increasing the meal frequency following exposure to low temperatures (Portet, 1981), exogenous administration of insulin (Steffens, 1970), or dilution of the diet with bulk (Le Magnen, 1969). When the food intake of rats is temporarily reduced by intragastric feeding, the reduction is achieved by a decrease in the number of daily meals (Thomas and Mayer, 1978). This would suggest, that feeding frequency is used in the initial short term regulation of daily food intake. In rats, changes in meal size may occur in the longer term following environmental constraints on feed intake (Portet, 1981). During the period of individual housing in the present experiment, all pigs reached a steady-state of feeding frequency within two days, and no sign of variation from that initial level was present at the end of the period.

Table 5.3. Comparison between housing method (Period 1 and 2) and feeding frequency category (L and H) of percentage of time spent in different activities.

	Housing method			Feeding frequency		
	Period 1	Period 2	s.e.d.	L pigs	H pigs	s.e.d.
Lying	77.9	76.2	1.85	78.8	75.3	2.72
Sitting ⁺	0.4	0.9	0.29	0.6	0.7	0.21
Feeding	5.6	5.5	0.85	5.8	5.3	0.63
Rooting	6.4 ^a	11.6 ^b	1.71	8.1	9.9	2.53
Social behaviour	5.4	-	-	4.7	6.2	1.43
Other	4.3	6.0	0.87	4.6	5.7	0.70

⁺ A significant interaction between housing method and feeding frequency category was found for this variable ($p=0.046$).

^{a,b} Within housing or feeding pattern category, means with different superscript are significantly different ($p<0.05$).

Most of the social behaviour displayed in Period 1 consisted of nosing and rooting other pigs. In Period 2, where no social behaviour was possible, more rooting was directed towards other substrates, leading to no difference between Periods in the total amount of rooting behaviour. It has previously been shown, that removal of a substrate such as straw can result in an increased level of interactions with pen-mates, sometimes leading to outbreaks of tail biting (Van Putten, 1969; Hansen and Hagelsø, 1980). However, no previous reports have indicated that removal of pen-mates can lead to an apparent replacement manipulation of other substrates.

The discrepancy between the time sampling procedure and the more accurate measurements obtained from the computerized feeder in terms of feeding frequency emphasizes the invalidity of the former method to measure infrequent behaviours.

The depression in food intake during group housing was most distinct in pigs with a low number of daily feeder visits, and these animals also displayed a feeding pattern most divergent from that observed in individually housed pigs (De Haer and Merks, 1992; De Haer and De Vries, 1993). These findings suggest that pigs with a low feeding frequency when group housed were disadvantaged in terms of daily food intake as a result of the feeding pattern displayed. The results also indicate that the feeding pattern of growing pigs may be less flexible than expected, and that pigs, which have been constrained in their food intake, make only small modifications to their feeding pattern, sufficient to compensate for the previous constraint. It is possible, that growing pigs will adhere to a feeding pattern that have provided them with sufficient food in the past, even when a change in the environment allows for more extreme modifications.

5.6. Acknowledgements

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Chapter 6

General Discussion

The Double-Door Effect

*Double doors are justified
because they're comfortably wide.
Therefore you only half undo 'em;
and therefore nothing can get through 'em.*

Piet Hein (1966)

6.1. Introduction

It has been shown in the preceding chapters that the feeding behaviour of growing pigs is influenced by a number of environmental factors of both social and physical character. Feeding behaviour has been described here in terms of three base variables (number of daily feeder visits (NDV), feed intake per visit (FIV), and duration of visit (DUV)), as measured by the computerized feed intake recorders used in the preceding experiments, as well as their derivations (daily food intake (DFI), feeding rate (FR), and feeder occupation (FO)). The relationship between these variables have been described in detail in the general introduction of this thesis (Chapter 1), and the equations are repeated here only for ease of reference in relation to the rest of this chapter:

$$\text{DFI (g/day)} = \text{NDV (visits/day)} * \text{FIV (g/visit)} \quad (\text{eq. 1})$$

$$\text{FR (g/min)} = \text{FIV (g/visit)/DUV (min/visit)} \quad (\text{eq. 2})$$

$$\text{FO (min/day)} = \text{NDV (visits/day)} * \text{DUV (min/visit)} \quad (\text{eq. 3})$$

In the following sections, these parameters and their interactions will be discussed, bringing together the results from the four experiments covered by this thesis and discussing the findings with reference to the current literature. Also, the individual components of the social and physical environment will be discussed in this context in order to form a concerted theory regarding environmental influences on the feeding behaviour of growing pigs. Visits to the feeder, as a unit of measure used to describe feeding behaviour, will be compared to other methods of summarizing feeding behaviour (e.g. meals, bouts). Overlaps between the different sections will occur, but generally the effects will be discussed under the subject heading which has been influenced most by the factor or variable in question. Some of the results of particular importance for the pig breeding industry are highlighted, and the conclusions bring together the major findings of the four experiments within the context of the current literature.

6.2. Environmental effects on feeding behaviour

The various components of feeding behaviour are highly correlated, as has become evident from the previous chapters and from the equations on the preceding page, and they will therefore not be dealt with separately. The subsequent three sections will collectively cover most aspects of feeding behaviour, as well as discuss the usefulness of various meal definitions and their application.

6.2.1. Meal definitions and meal size

In the General Introduction of this thesis, the feeding behaviour of pigs, and a number of other species, was described as bursts of feeding interspersed with periods where no food is ingested. The way in which feeding behaviour is distributed across time depends on the size of the unit with which the feeding behaviour is measured (e.g. bite of food, visit to trough). In order to describe the observed behaviour in the most biologically meaningful way, it may be appropriate to collapse feeding activity into behavioural bouts through some systematic and objective method.

Various measures of feeding behaviour have been subjected to different methods of bout analysis with varying results. One method used is the log survivorship curve, which describes the probability of an event occurring relative to the time elapsed since the last event (Lehner, 1979). This method has been applied to a wide range of data, but is intrinsically difficult to use and, being a decay curve, the points are not independent of each other. Sibly *et al.* (1990) developed a method which uses the logarithm of the frequencies (per unit time) of between-visits intervals. These intervals are considered to be generated by either a fast process (operating within bouts) or a slow process (operating between bouts), both processes assumed to be Poisson processes, and no assumptions are made about the underlying control mechanisms. Broadly speaking, by plotting the log frequencies per unit time against the inter-visit intervals, a broken-stick model can be fitted if two processes are occurring, and the bout criterion (i.e. the interval length which divides within-bout intervals from between-bout intervals) is the interval at the point of inflection on the broken-stick fitted. Berdoy (1993) has since developed a three-process model,

first suggested by Machlis (1977), which incorporates two break-points, dividing bouts and super-bouts respectively.

In Chapter 3, a bout analysis was attempted on feeding data from both single-space computerized feeders and from multi-space feeding troughs. It was found that, using the method developed by Sibly *et al.* (1990), a two-process model (i.e. fitting a broken stick) was justified for the feeding patterns displayed by the pigs given access to a four-space feeding trough. However, this type of model could not justifiably be applied to the feeding data obtained from the single-space feeders. Most published results regarding feeding behaviour of growing pigs using single-space feeders, have incorporated some form of bout criterion in order to collapse visits to the feeder into so-called meals. A bout criterion of 5 minutes was used by De Haer and Merks (1992), and 2 minutes was used by Labroue *et al.* (1994). Both used log survivorship curves to estimate individual criteria, and both applied one average value to all pigs. As described in Chapter 3, both found substantial decreases in the number of feeding events when visits were collapsed into meals, whereas this was not the case for the data used in Chapter 3, even when bout criteria of 2 and 5 minutes were applied arbitrarily (14.3 visits vs 12.8 and 11.9 bouts; respectively). The bout analysis did, however, aid the description of the feeding behaviour of pigs given access to a four-space trough. The large number of visits displayed by these animals could be collapsed into feeding bouts, and these bouts did not differ in size or frequency from the visits displayed by the pigs using the single-space feeder. This would indicate that, although single-space feeders prevent allelomimetic feeding, they constrain the feeding pattern mainly in terms of preventing changes between trough-spaces within bursts of feeding. I therefore conclude that visit to the feeder, as a unit of measure, is an appropriate way to describe the feeding behaviour of growing pigs using single-space feeders. Although bout analyses may on occasions be usefully applied in order to summarize feeding behaviour, it should be applied with caution.

The size of a meal, however one defines it, is dependent on the physical characteristics of the food offered, and may be affected by the size of the stomach. One theory regarding the physiological control of meal size relates to inhibitory signals from gastrointestinal sites to the central nervous system (i.e. a satiety feedback), suggesting that these signals may be due to osmo-receptors, gastric distension or hormonal changes (Haupt, 1985). For the purpose of this section it is not important whether this theory is appropriate or whether or not

the lateral hypothalamus plays a major rôle for the temporal distribution of spontaneous meals (Kissileff, 1970), and no attempt is made to review here the vast number of investigations into the physiological control of food intake. What is important, however, are the physiological constraints on feeding behaviour, which may limit the range within which the animal can express its feeding pattern.

Rats with free access to food normally eat 10-15 meals per day of approximately 1.5g each (Johnson *et al.*, 1993). De Castro (1981) found in free-feeding rats that the interval between two meals (i.e. the period from the start of one meal to the start of the next) was not governed by the size of the preceding meal, but that the actual amount in the stomach at the end of the meal was the controlling factor*. Rats can be forced to reduce their feeding frequency to one meal of 20-25g per day, whereas, at the other extreme, they seem unwilling to eat meals smaller than 0.5g, or to eat more than 30 meals per day (Johnson *et al.*, 1993). Adult pigs can eat their daily food intake in one substantial meal (Barnett *et al.*, 1992; Terlouw and Lawrence, 1993), which is also the normal method used for the restricted feeding of dry sows on most farms. Adult pigs fed *ad libitum* will eat their daily food intake in only 3-4 meals (Auffray and Marcilloux, 1980), spending approximately 100 min per day eating a pelleted, fibrous diet (Brouns *et al.*, 1994). Growing pigs are usually fed *ad libitum*, and no work has been found to date which specifically addresses the maximum meal size of growing pigs. Pigs with previous experience of bulky feeds are able to consume more of a high fibre diet through enlargements of the gastro-intestinal tract (Kyriazakis and Emmans, 1995).

Rats have been found to prefer a relatively large number of small meals (Johnson *et al.*, 1993). The feeding behaviour observed in individually housed pigs by De Haer (1992) resembles the feeding pattern found in pigs given access to a four-space feeder (Chapter 3), with a high feeding frequency and eating only a little at each visit to the feeding trough. Both environmental conditions place limited social or physical constraints on the expression of feeding behaviour, and it appears that many, small meals are the preferred pattern of intake for growing pigs.

*This may offer a likely explanation of the discrepancy in the literature regarding prandial correlations, i.e. the relationship between meal size and the time to or since the next meal (e.g. Collier *et al.*, 1972: no prandial correlations; De Castro, 1975: significant prandial correlations).

6.2.2. Feeding rate

In the experiments presented here, feeding rate was found to be greatest in the largest group size (n=20) and when the protective race was removed from the feeder. No differences in feeding rate were found when access to four troughs without protection was offered, compared to the single-space feeder with a protective race, to groups of equal size (n=10). No changes in the feeding rate occurred when pigs were moved from a group of ten into individual pens.

Feeding rate was found to increase during the course of the experiment presented in Chapter 2 (approx. +2g/min per week), and similar results have been found by Labroue *et al.* (1994), and Bigelow and Houpt (1988). In humans, eating rate increases with body size, level of obesity, hunger and food preference (Hill and McCutcheon, 1984). Terlouw and Lawrence (1993) found that pregnant sows fed a high level of food showed an increase in feeding rate over parities (130g/min to 200g/min from parity 1 to 3), whereas low-fed sows showed a consistent high rate of eating (approx. 230g/min; parities 1 to 3). Such high feeding rates found in food restricted pregnant sows most likely reflect the increased and persistent feeding motivation of these animals (Terlouw *et al.*, 1991).

Over and above changes with time or age, the feeding rate of individual animals in a given environment appear to be a relatively stable characteristic (Figure 6.1a,b; Whishaw *et al.*, 1992; Auffray and Marcilloux, 1983). Some authors find that the size of a meal cannot be accurately estimated from the meal duration (De Castro, 1975; Morrison, 1980; Castonguay *et al.*, 1986), however, variation in feeding rate between individuals is often ignored. There are inconsistent results reported in the literature regarding changes in the feeding rate within a meal (No change: Auffray and Marcilloux, 1983; decrease: Whishaw *et al.*, 1992), but this within-meal variation is relatively small and will generally have little or no influence on the overall feeding rate of an individual (Le Magnen, 1985).

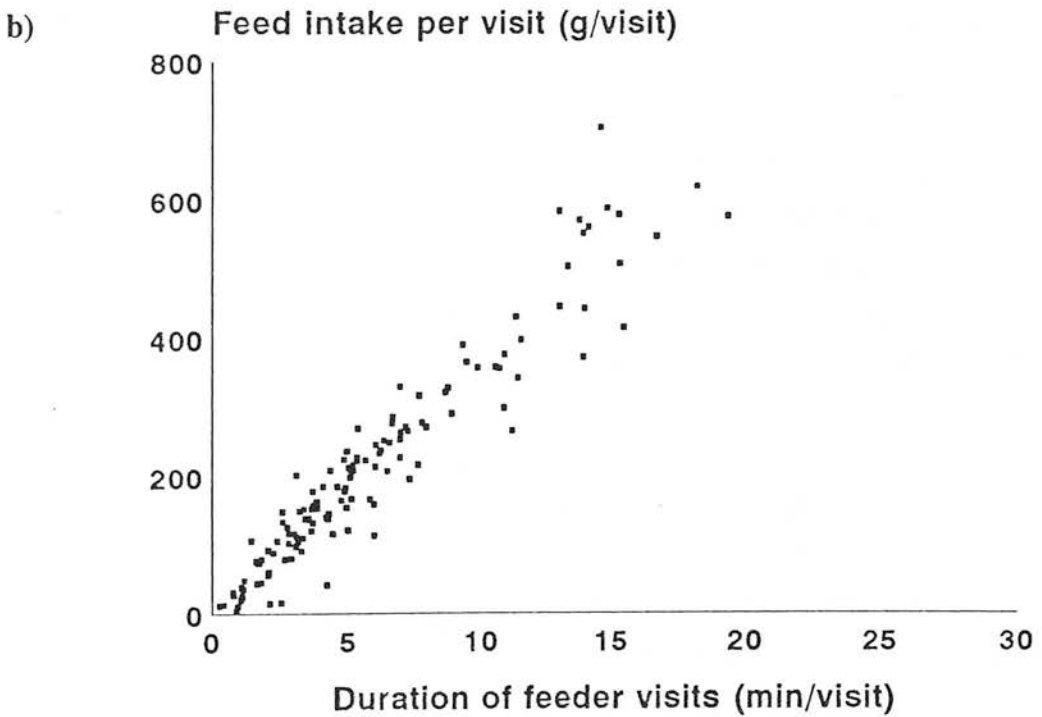
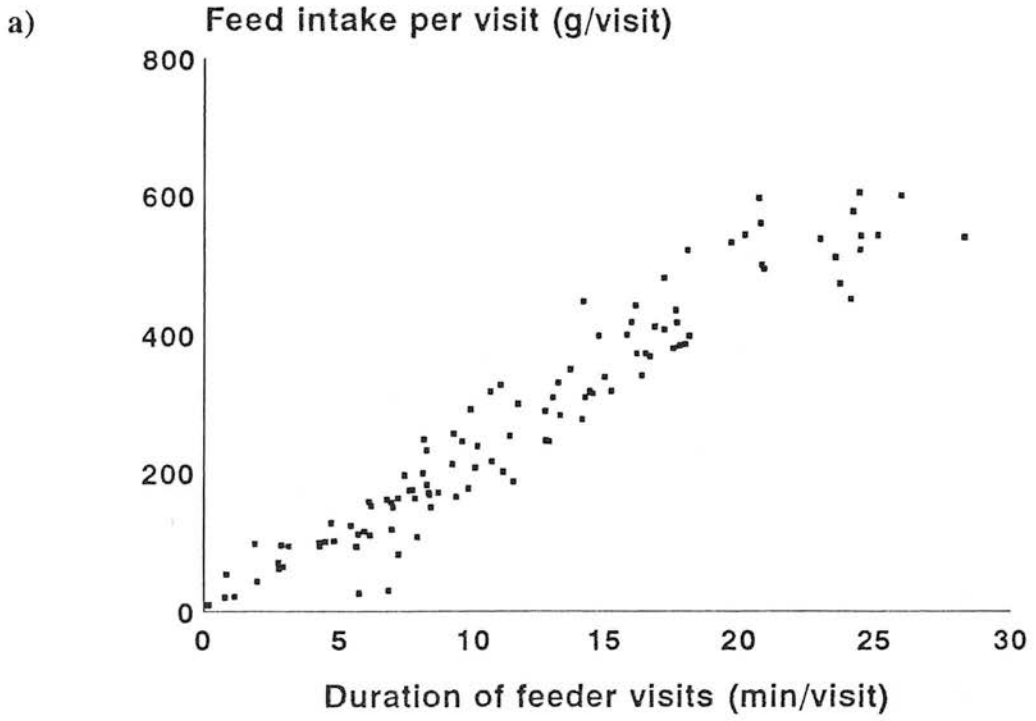


Figure 6.1a,b. Example of constancy of feeding rate within individuals over a limited time period. The slope (FR) of the regression line of feed intake per visit (FIV) on duration of visit (DUV) is analogous to equation 2. Two pigs are plotted with a mean feeding rate of a) 23.2 g/min ($R^2=0.92$) and b) 35.7 g/min ($R^2=0.91$), respectively.

Feeding rate has a relatively limited range within animals, presumably due to factors such as mouth-size and saliva production rate. The evidence presented above describes the constancy of feeding rate within an individual (Figure 6.1a,b), and the augmented rate of feeding resulting from increased social constraint and higher feeding motivation. I therefore suggest that, within an animal's limited range, there appears to be a preferred rate of eating. This preferred feeding rate may differ from the actual feeding rate, when environmental constraints force the animal to eat faster in order to obtain a sufficient level of daily food intake. Thus, the preferred feeding rate is the rate adopted by the animal when feeding in conditions which place little or no constraints on the feeding behaviour of the animal. If, however, changes in the environment result in constraining conditions, say, the number of animals per feeder increases to a level which limits the total daily feeder occupation for the animal to below the desired daily feeding time of that animal, then the animal has to eat faster on average in order to get its desired food intake per day. If the feeding rate reaches the maximum for the individual, and insufficient time is available for the animal in which to eat, inevitably the daily food intake will decrease. Changes in the feeding rate can therefore be used by an *ad libitum* fed animal to increase food intake in situations where the animal is under some form of environmental constraint. At the other extreme, when rats are given increasing amounts of food through catheters, the oral food intake is depressed in a dose-dependent manner, but feeding rate is decreased only at the highest levels of parenteral feeding (Meguid *et al.*, 1991), suggesting an unwillingness to digress below a given rate of intake and supporting the theory of a preferred feeding rate.

Whishaw *et al.* (1992) found that the feeding rate of rats offered the same type of food was influenced by environment, circadian rhythm and food deprivation experience. Rats would eat faster in an open, illuminated environment than in dark, enclosed conditions. Eating rate also increased at the time of day when the animals are most likely to eat, i.e. the beginning and end of the active period; presumably due to a higher motivation to feed. This also agrees with the observed increase in feeding rate by rats fed below their *ad libitum* intake; when the rats were returned to unrestricted feeding, their rate of eating decreased, although this recovery was only partial as they still ate faster than their initial pre-deprivation rate. Presatiation has also been found to result in reduced rates of eating (Cooper and Francis, 1993). Whishaw *et al.* (1992) suggest that augmented feeding rate is used by the rats as a means to optimize

food intake in conditions with a perceived high predation risk and to enhance food intake at normal eating times. Significant genetic variation in feeding rate has been found in *Drosophila melanogaster*, a species where larval competition for food is of a so-called 'scramble type', and the competitive ability is expressed in efficient food consumption at the fastest rate (Joshi and Mueller, 1988). The demonstration that flexibility in the feeding rate of an animal can be beneficial, complements the proposition that an animal has a preferred rate of eating. The above information suggests that a period of environmental constraint can have long-term consequences for the rate of eating, as if the preferred rate has been shifted upwards as a result of the animal experiencing restricted feeding.

Various attempts have been made to predict the feeding rate of different species in different environments. Minagawa and Murano (1993) expressed feeding rate of crabs as a function of prey density ($FR = FR_{\max}(1 - e^{-k \cdot \text{prey density}})$). Maximum eating rate in cattle was predicted by Taylor *et al.* (1987) as a function of degree of maturity (u) and incisor arcade breadth (D) ($FR_{\max} = 0.53 \cdot (u_D)^3 \cdot (D_{\text{adult}})^2$). Other attempts have included expression of feeding rate as a discontinuous asymptotic function of bite weight (Laca *et al.*, 1994). The preferred rate of eating of a given animal may be determined by degree of maturity combined with nutritional and physical aspects of the food offered.

From the results of the four experiments presented in this thesis together with findings reported in the literature it is suggested that, at a given age, an animal has a preferred rate of ingestion and that environmental constraints may force the animal to deviate from its preferred feeding rate in order to sustain a given level of daily food intake.

6.2.3. Daily food intake

Daily food intake can be viewed as the parameter which directly connects feeding behaviour and production performance. This subject heading therefore covers both aspects of daily food intake.

In all but one experiment (Chapter 5) no effects of environmental factors were found on any of the production parameters measured. It had been expected that some of the extreme treatments, such as keeping pigs in groups of twenty

with access to only one feeding trough, would affect production performance. However, all pigs appeared to adapt successfully to the constraints placed on their feeding behaviour.

The exception was reported in the experiment which examined the effects of the social environment by moving previously group housed pigs into individual pens (Chapter 5). It was found that pigs which displayed a relatively low number of feeder visits in the group housed period had a lower daily food intake than pigs with a high number of daily feeder visits. This difference subsequently disappeared as the pigs were moved to individual housing. Such a relationship between number of daily feeder visits and daily food intake was not found in any of the other experiments.

The relationship between daily food intake and number of daily feeder visits is highly dependent on the third parameter in equation 1, feed intake per visit. In order to investigate this relationship, equation 1 was log-transformed into a linear model as follows:

$$\ln(\text{DFI}) = \ln(\text{NDV}) + \ln(\text{FIV}) \quad (\text{eq. 1})$$

All of the four experiments had included groups of ten pigs given access to a standard computerized single-space feeder. In Table 6.1, these twelve groups from across the four experiments are presented together. Figure 6.2a-c shows the three parameters from equation 1 plotted against each other, using data from the individual pigs from the twelve groups across the four experiments. It can be seen that separately, $\ln(\text{NDV})$ and $\ln(\text{FIV})$ are poor predictors of $\ln(\text{DFI})$ (Figure 6.2a,b), whereas their correlation coefficient is .86 ($R^2=74\%$; Figure 6.2c).

To test for any overall relationship between daily food intake and number of daily feeder visits, a linear model was used which fitted the effects of $\ln(\text{NDV})$ within these twelve inter-experimental, but comparable groups ($n=113$). The regression model

$$\ln(\text{DFI}) = \text{constant} + \text{group} + \ln(\text{NDV})$$

accounted for 36.5% of the variation and was highly significant ($df=12,100$; $p<0.001$). However, this was due to a significant effect of group ($df=11,100$;

$p < 0.001$) whereas the $\ln(\text{NDV})$ parameter was nearly, but not significant ($df=1,100$; $p=0.058$). Others have found significant correlations between feeding frequency and production parameters (Cohn *et al.*, 1962; De Haer, 1992). De Haer *et al.* (1993) found a significant positive relationship between number of daily feeder visits and daily food intake ($r=0.38$; for comparison, the overall correlation between DFI and NDV for the 113 pigs from groups of ten across the four experiments was 0.19). After correcting for differences in level of daily food intake, significant correlations of number of daily feeder visits were found to lean percentage (positive) and daily gain (negative) in growing pigs kept in groups of eight with access to a single-space computerized feeder. A higher level of intake in pigs with higher feeding frequencies may be an artefact of food spillage, if each visit to the trough results in an amount of food being spilled. However, the computerized single-space feeders used by De Haer *et al.* (1993; IVOG-station) and in the experiments presented in this thesis (FIRE feeders) result in very little spillage. In order to address the question regarding the degree to which daily food intake depends on feeding frequency, and as the results presented above are divergent, it may be useful to investigate further the individual differences in feeding pattern and their consequences for the daily food intake.

Table 6.1. Comparative feeding behaviour and performance data (Mean (s.e.); $n=3$) from the four experiments, which each included three groups of initially ten pigs given access to a single-space computerized feeder.

Experiment presented in Chapter	2	3	4	5*
Total number of pigs	30	28	27	28
Number of groups (n)	3	3	3	3
Initial live-weight (kg)	33.9 (1.7)	30.2 (2.8)	31.6 (1.7)	29.4 (0.6)
Daily live-weight gain (g/d)	763 (52)	793 (56)	788 (35)	715 (15)
Daily food intake (g/d)	1611 (92)	1766 (188)	1876 (44)	1559 (44)
Feed conversion ratio	2.13 (.04)	2.23 (.14)	2.38 (.05)	2.20 (.07)
Number of daily feeder visits	13.7 (1.2)	14.3 (2.1)	13.8 (1.0)	15.4 (2.1)
Duration of visits (min/visit)	4.96 (.53)	4.67 (.46)	4.75 (.60)	4.17 (.59)
Feed intake per visit (g/visit)	133 (1)	149 (17)	148 (17)	110 (12)
Feeding rate (g/min)	26.9 (2.0)	30.9 (2.8)	32.1 (0.8)	26.8 (1.1)
Feeder occupation (min/d)	61.4 (2.2)	59.0 (2.8)	60.1 (3.8)	58.5 (1.1)

* Mean of 11 days; other experiments mean of 21 days.

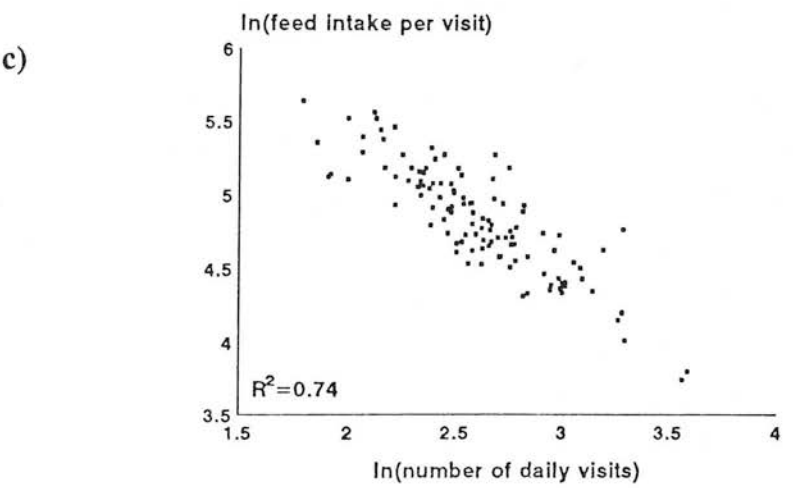
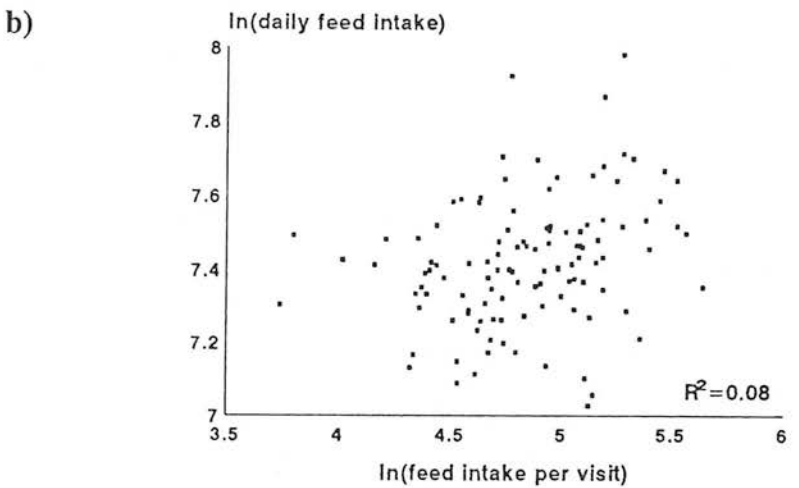
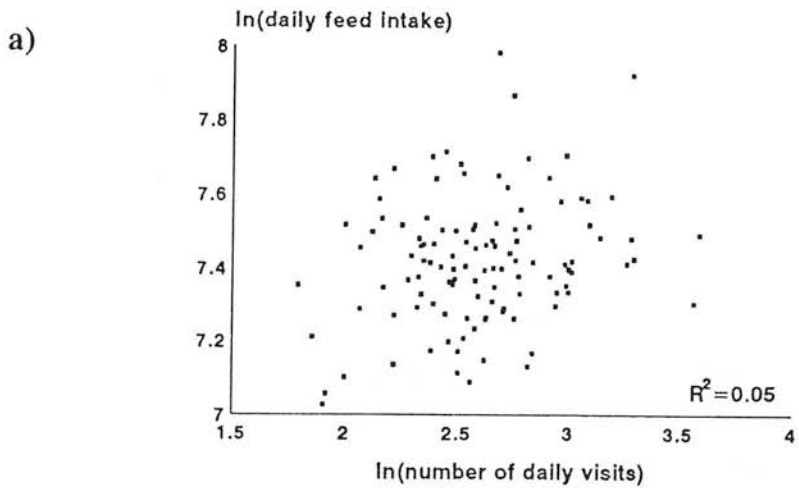


Figure 6.2a-c. Ln(DFI), ln(NDV), and ln(FIV) plotted against each other. Data from twelve groups of initially ten pigs (see text for details). Overall R^2 values presented.

The daily food intake of an animal is achieved through a combination of number of daily feeder visits and feed intake per visit. As has previously been shown, the same level of intake can be obtained by various combinations of these two parameters. An example of this is given in Figure 6.3. Both pigs were kept in the same group of twenty in the experiment presented in Chapter 2, and it is clear from the spread of the points for each pig, that the pig with a low number of daily feeder visits (pig A) displayed a much higher variation in feed intake per visit than pig B, which visited the feeder much more frequently. Pig B, in turn, had a higher variation in the feeding frequency than pig A. Both pigs varied their feeding pattern along the isoline of equal daily food intake. From Figure 6.3 it can be seen, that even small changes in the number of feeder visits made a lot of difference to the daily food intake for pig A, whereas it had hardly any consequences for pig B. It appears, that a visit for pig A had much more importance for the daily food intake than a visit for pig B. It may be, that pigs with high number of visits are the most flexible in their feeding pattern, simply because each visit becomes less crucial for sustaining a given level of food intake. The previously described indications of a positive relationship between daily food intake and number of daily feeder visits may be a result of pigs with a low number of feeder visits failing to gain access to the feeder frequently enough to achieve a sufficient daily food intake.

This method (Figure 6.3) of presenting daily food intake emphasises the individual variation which is concealed when an animal is described in terms of daily food intake alone. De Haer (1992), who investigated the relevance of eating pattern for selection of growing pigs, predicts that adding information relating to feeder occupation and number of daily feeder visits to a selection index based on production parameters will not significantly increase genetic progress. However, as genetic progress is measured in terms of optimizing economical traits, it may be that the variation between individuals in feeding patterns can be utilised for developing breeding stock more suited for certain environments, or more able to adapt to changing conditions.

No relationship was found between daily food intake and dominance rank in the experiment which compared different group sizes (Chapter 2). This particular aspect of daily food intake will be discussed in section 6.2.4.

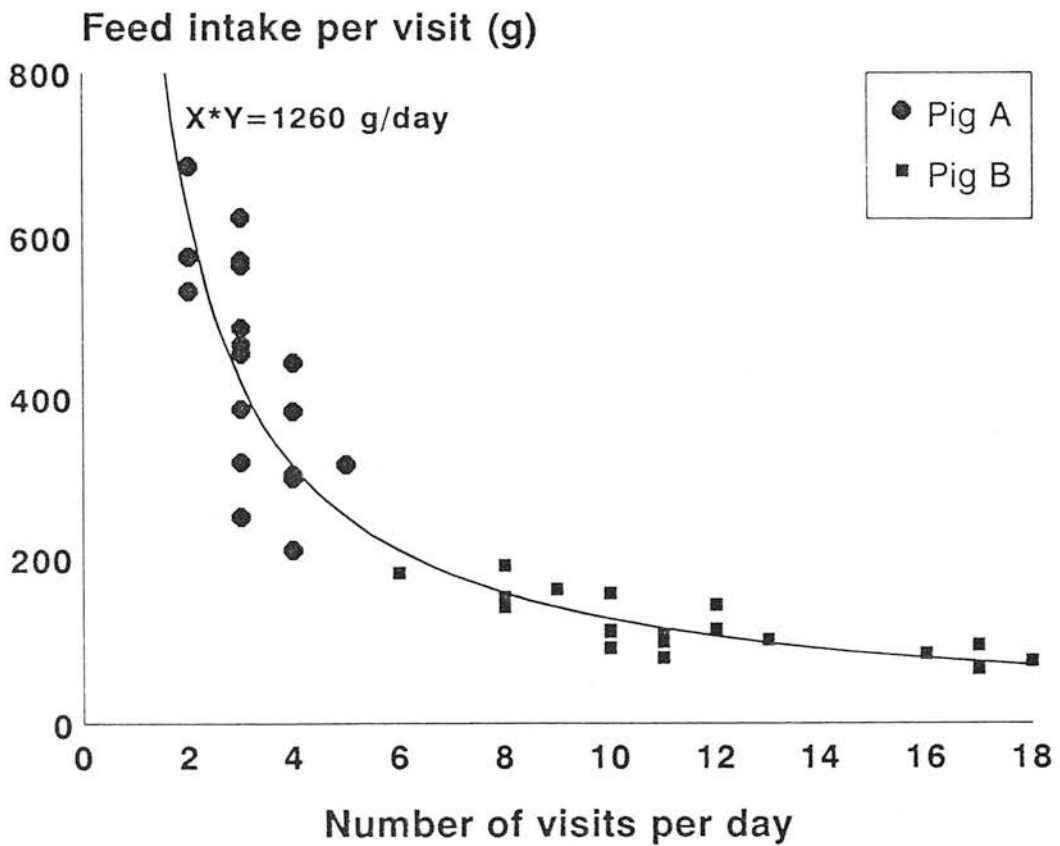


Figure 6.3. Number of daily feeder visits (NDV; recorded over 21 days) plotted against mean feed intake per visit (FIV) for two pigs of similar size housed within a group of twenty. Both pigs had similar levels of daily food intake (1255 and 1264g/d, pig A and B respectively), and the pictured isline represents all combinations of NDV and FIV resulting in a daily intake of 1260g (Data from Chapter 2).

6.2.4. Social constraints

For growing pigs kept in groups, the social environment impinges on almost every action performed by the individual animals. In the following, the effects of being in a group as compared to being housed individually will be discussed, as well as the nature and extent of the social influence on individuals within a group. In addition, parts of the physical environment which may interact with the social environment will be considered.

Individual versus group housing

Although a substantial body of literature exists on the feeding behaviour of individually housed rats, there is a paucity of investigations into the feeding

behaviour of group housed animals and, as such, very little comparative research has been carried out. Most comparisons of individual and group housed pigs have focussed on the production performance of the animals. In her thesis, Lydia de Haer (1992) compared group housed ($n=8$) with individually housed pigs and found substantial differences in the feeding behaviour of these animals. Individually housed animals obtained their daily food intake by a large number of small meals whereas group housed pigs ate less frequent, but larger meals. This would appear to indicate that placing growing pigs within a social environment leads to a modification of their feeding behaviour in the direction of fewer and larger meals. In the experiment presented in Chapter 5, the feeding behaviour of group housed pigs did not substantially change after the pigs had been moved to individual housing. It was concluded that the feeding pattern of growing pigs appeared to be highly dependent on the previous experience of the animals. A feeding pattern similar to that of the individually housed animals in the work by De Haer (1992) was found, when group housed pigs were given access to a four-space feeding trough (Chapter 3; many visits with a low feed intake per visit). These combined findings indicate that a low feeding frequency is not a result of the social environment *per se*, but is mainly attributable to increases in the pig:trough ratio.

Similar rates of feeding were found in Chapter 3 with both single and multi-space feeders, whereas increasing the group size from five to twenty (Chapter 2) resulted in significant increases in the feeding rate. A comparable increase in the rate of feeding could be seen when the protective race in front of the single-space feeder was replaced by a head-guard (Chapter 4). Combining these results enables a separation of the otherwise confounded effects of social and physical environment. The effects of the social environment, over and above the variation in pig:trough ratio, appear to be an increased urgency or pressure placed on the feeding behaviour which is expressed in a faster rate of feeding. This suggests that changes in the environment which result in an increased feeding rate of the animals may be of a tension enhancing (i.e. stressful) nature, and that changes in the feeding rate may be used as an index of the social pressure imposed by a change in the given environment.

Allelomimetic feeding

Group housed pigs given access to a single-space feeder have no opportunity to feed simultaneously, but do show the bimodal feeding pattern also observed in

individually housed animals (Chapter 2; De Haer and Merks, 1992). In Chapter 3, pigs feeding from a multi-space trough displayed a high level of simultaneous or allelomimetic feeding (61% of all visits), and they also showed a preference for troughs directly adjacent to troughs occupied by another feeding pig. Meunier-Salaün and Faure (1984) found that hens preferred to feed side by side rather than apart in spite of increased aggression, but Savory and MacLeod (1980) found that only feeding activity and not food intake was enhanced by the social environment of chickens. No measurements of individual feed intake were possible from the multi-space troughs used in Chapter 3, and no formal test could be carried out to determine whether this type of allelomimetic feeding is an indication of social facilitation, which has previously been reported in growing pigs (Hsia and Wood-Gush, 1984).

Dominance rank

In the experiment presented in Chapter 2, no relationship was found between either aggression or position in the hierarchy and any of the feeding behaviour or performance variables. A number of experiments have reported positive correlations between social rank and performance (McBride *et al.*, 1964; Beilharz and Cox, 1967; Hansen *et al.*, 1982) especially when access to feed has been restricted. The causal relationship between dominance value and production performance (e.g. live-weight) is not clear, and some of the reported correlations are weak. For example, McBride *et al.* (1964) found that social rank accounted for only 13% of the total variation in growth. Some data suggest that dominant individuals may spend more time defending their food rather than eating it (Brouns and Edwards, 1994). Also, dominance assessed in a non-feeding situation may show little correlation with that displayed in a feeding context. McBride *et al.* (1964) note that social behaviour has a minimum effect on productivity when husbandry conditions are optimal. It may be that other factors, such as the high space allowance and straw provision used throughout the experiments presented here, have disguised or eliminated any significant correlation between dominance rank and performance (Hansen and Hagelsø, 1980). It may also be that no correlation is found because social rank does not adequately express the rôle of an animal within a group (Meese and Ewbank, 1973; Bernstein, 1981).

6.2.5. Food accessibility

The accessibility of the food can be reduced through increases in the pig:trough ratio, or through modifications to the design of the feeder by making it more difficult to access the trough, or by introducing some form of arbitrary response (e.g. bar-pressing) in order to obtain food. These will be discussed in turn in the following.

Pig:trough ratio

The relationship between number of animals and number of feeding troughs can be modified through changes to one or both parameters. In Chapter 2, comparisons were made between groups of 5, 10, 15, and 20 given access to one single-space feeder, whereas Chapter 3 investigated groups of ten pigs feeding from either a single-space feeder or a four-space trough. Changes in the group size confounds the effects of altering the pig:trough ratio with differences in the social constraints of the animals. In section 6.2.4 it was argued that the increased feeding rate displayed by pigs in the groups of twenty was a result of the social constraint placed on these animals rather than due to differences in the pig:trough ratio. Pigs kept in groups of twenty also visited the feeder less often, but ate more per visit, than pigs in the smaller groups. This in itself does not necessarily alter the daily food intake, if the increase in feed intake per visit is proportional to the decrease in number of daily feeder visits, which was the case for these animals. The change in feeding pattern does indicate, however, that it was easier for these animals to stay in the feeder than to gain access, and the pattern therefore shifted towards fewer, but longer visits. In a situation where the food is highly accessible, as was the case for the pigs in Chapter 3 given access to a four-space trough, the feeding pattern changes in the opposite direction with a high frequency of short visits. Thus, a decrease in the pig:trough ratio from 20:1 to 10:1 and from 10:1 to 10:4 leads to substantial and uni-directional differences in feeding patterns.

Morrow and Walker (1994a) provided groups of twenty pigs with either one or two single-space feeders. The frequency of visits per pig increased significantly when two feeders were present (23.3 vs 30.3 visits/day). This reduction in pig:trough ratio from 20:1 to 20:2 can be directly compared to the reduction from 20:1 to 10:1 obtained by Walker (1991), who used the same experimental set-up, but did not find differences between the two group sizes in the number

of visits. This is an indication of the interactive effects of group size and pig:trough ratio.

In both Chapters 2 and 3, daily food intake was found to be unaffected by changes in pig:trough ratio, and within a certain range this appears to be the case for group housed pigs (Walker and Overton, 1989). There is, however, some disagreement in the literature with regard to this. Morrow and Walker (1994a) found that the daily food intake was significantly increased when access to two feeders were offered (20:2 vs 20:1), indicating that, on average, the pigs were constrained when only one feeder was present per twenty animals and also that the increase in meal frequency was not offset by a concomitant proportional decrease in meal size. Walker (1991), on the other hand, found a significant increase in daily food intake when pig:trough ratio increased from 10:1 to 20:1.

Feeder design

In the literature on feeding behaviour a multitude of feeder designs have been used to measure components of the feeding pattern of various species. The way in which different feeders reduce the accessibility of the food can be divided into two main groups: Feeders which make it difficult to gain access to the food (e.g. by placing a door in front of the trough), and feeders which makes it difficult to retain access to the food (e.g. intermittent bar-presses required). Some feeders incorporate both kinds of reduced accessibility.

The experiment presented in Chapter 4 was designed to investigate the effects of altering the level of protection given to the feeding pig, but the different types of feeder entrance design also varied the ease with which pigs could gain access to the trough. Fitting an enclosed race in front of the trough led to longer visits, which corresponds to the change in feeding pattern seen in the groups of twenty relative to the smaller groups in Chapter 2. Similar results were obtained by Morrow and Walker (1994b).

Another way of limiting the accessibility of the food is to introduce a so-called procurement cost. So far most studies of feeding behaviour have been carried out on rats, and most of the equipment used has been operant, i.e. the rat has to press a panel one or more times in order to get access to pre-set amounts of food. Using this type of feeding apparatus there is a minimum procurement cost of one press per reinforcement (delivery of food) which is often regarded as

'no cost'. However, Kaufman and Collier (1983) found a drop in meal frequency by half when one bar-press was required in order to obtain food compared to the free-feeding situation, and Kissileff (1970) found an increase in the number of short pauses in feeding when rats were required to press a bar for food (one press per pellet) compared to feeding from a feeder, which delivered a pellet each time one was removed (no arbitrary response required). Levitsky (1974) found that the normal pattern of predominantly nocturnal feeding in rats disappeared with just minor reductions in the food accessibility (opening a door or pressing a bar once).

Johnson *et al.* (1984) tested two types of cost required for the animal to be able to feed: A procurement cost, consisting of a number of bar-presses the rat needed to perform in order to gain access to the food, and a consumption cost, consisting of a number of bar-presses required to receive a pre-set, small amount of food (i.e. the reinforcement). Increasing the procurement cost resulted in larger, but less frequent meals, equivalent to the response seen when accessibility is decreased through increased pig:trough ratio. Increasing the consumption cost, however, resulted in smaller and more frequent meals. Clifton *et al.* (1984) found that imposing a constraint on the rate of feeding in rats also resulted in an increased feeding frequency and smaller meals. It may be that a consumption cost is not equivalent to a decrease in food accessibility, but may act as an artificial reduction in the feeding rate. Lucas and Timberlake (1988) found that even small delays (16 and 32 sec) in the delivery of pellets resulted in substantial reductions in meal size and a concomitant increase in meal frequency, and that longer delays produced no further changes in average meal size. The normal time required by a rat to consume one 100 mg pellet ranged between 8 and 12 sec. This relatively large effect of apparently small changes in the possible feeding rate may partly explain why Collier *et al.* (1972) found no effect on meal size of increasing the bar-pressing:reinforcement rate (i.e. consumption cost) from 1:1 to 240:1, if the feeding behaviour was already affected at the 1:1 ratio.

Morrow and Walker (1994a) used an experimental set-up, which differed in a number of aspects from the experiments presented in previous chapters. For example, they used a constant lighting schedule to enable 24-hr video-recording, and their feeding trough contained separate food and water dispensers operated by the pig (This was the only source of water available in the pen, a factor which may have elevated the number of visits overall). This food dispenser may

explain some of the differences in feeding frequency of pigs kept in groups of twenty found by Morrow and Walker (1994a; 23.3 visits/day) and the experiment presented in Chapter 2 (7.1 visits/day), if the food dispenser operated by the pig effectively introduced a consumption cost, as described above.

In summary, the results of the present work are in agreement with the literature, in that meal frequency decreases and meal size increases as a function of decreasing feed accessibility in terms of procurement cost (Levitsky, 1974; Kaufman and Collier, 1983; Johnson and Collier, 1994). Alternatively, if the animal has to pay a consumption cost, either in form of bar-presses or as an artificial reduction of the animal's feeding rate, then meal frequency increases and the meals are smaller (Johnson *et al.*, 1984, 1993; Lucas and Timberlake, 1988). No effects equivalent to that of a consumption cost were found in the experiments presented here, but the feeders used by Morrow and Walker (1994a,b) may impose such a cost through the food dispenser placed in the trough.

6.2.6. Other environmental factors

Components of the environment, other than the social and physical aspects covered by the experiments presented in this thesis, may influence the feeding behaviour of growing pigs. The subsequent two sections contain brief discussions of a limited number of additional environmental aspects, in order to introduce these into the context of the present work.

Ambient light and temperature

Both rats and pigs display a clear periodicity in their activity levels with around 70% of the daily food intake being consumed during the active phase (Montgomery *et al.*, 1978; Kersten *et al.*, 1980). In some animals, if kept under constant temperature and lighting conditions, the 24 hour periodicity may drift from the norm, indicating that a circadian rhythm is achieved through daily adjustments of an innate rhythm (McFarland, 1987). The circadian rhythm of rats can be altered by changing the lighting schedule (Kersten *et al.*, 1980), and under continuous light conditions the circadian feeding cycle is slightly longer than 24 hours (Rosenwasser *et al.*, 1981).

In the experiments presented in this thesis, the lighting schedule used was dictated by the variation in natural light which could enter the experimental room. Thus all trials had an artificial light period of around 15 hours, from 05.00 hr (GMT) in the morning to 20.00 hr (GMT) at night. No apparent differences were found in the experimental results which could be attributed to the seasonal differences in natural lighting. However, such seasonal light changes are highly correlated with the concomitant temperature changes.

Ferguson *et al.* (1994) suggest that it is unlikely that potentially fast-growing pigs will be able to reach their potential when kept at temperatures above 20 °C, especially when offered feeds of high nutrient density. Lowering the ambient temperature increases the heat demand of the animals, and Ingram and Legge (1974) found a sustained increase in intake when changing the ambient temperature for growing pigs from 25 °C to 5 °C. Nienaber *et al.* (1991) found that the usual age/time dependent decrease in meal frequency and increase in meal size disappeared when group housed pigs were kept under cool (13 °C) and severe cold stress (5 °C) conditions, as compared to under thermoneutral conditions (21 °C). No significant differences were found in feed intake or final live-weight.

The experiments presented here were carried out in a building with natural ventilation and where ambient temperatures could not be controlled. The conditions therefore changed according to daily and seasonal variations, and the animals had access to insulated kennels within the pens, and straw was always available to use for thermoregulation. The overall mean ambient temperatures in the pens for the four experiments were 11, 11, 14, and 4 °C, respectively. No apparent intra-experimental effects of temperature were found, presumably due to the experimental lay-out which often involved the start of different groups of animals being lagged in time resulting in overlaps between replicates and treatments. Effects of the lower temperature in the last experiment (Chapter 5) cannot be separated from potential effects of the shorter duration of the group housing in that experiment compared to the other three experiments (Table 6.1).

Physical form of the feed, palatability, and nutrient density

Feeding rate is most heavily influenced by the physical form of the feed. When calculated in grams, but not necessarily joules per minute, the feeding rate will be substantially higher on liquid diets than either a powdered or pelleted food,

which in turn can be eaten faster than, say, a food block, which will require much more physical manipulation prior to ingestion. Provision of water in the feed trough, as with the dry-wet feeders used in the work by Morrow and Walker (1994a,b), will alter the rate of ingestion as well as eliminate the need to interrupt a meal in order to drink.

When the food is diluted with fibre, and hence of lower nutrient density, rats maintain a constant daily energy intake by eating larger meals more frequently, and the feeding rate is lowest for the low-energy foods (Johnson *et al.*, 1986). Following any imposed reduction in food availability, through fasting, lower palatability, or restricted water access, food intake is adjusted almost entirely by an increase in meal size (Gentile, 1970; Levitsky, 1970). This is a similar effect to that discussed earlier, when the accessibility of the food is reduced through a consumption cost. However, Levitsky (1970) found that addition of quinine sulphate to the food resulted in smaller, but more frequent meals.

When pigs are fed an amino acid deficient diet, a reduction is seen in feeding rate, and daily food intake decreases through smaller meal sizes (Montgomery *et al.*, 1978). Given a choice of two feeds which differ in their protein content, growing pigs are able to choose a diet which meets their estimated nutrient requirements (Kyriazakis *et al.*, 1990). However, the feeding pattern of growing pigs offered a choice of foods has not been investigated.

In the work presented here, the same type of pelleted, grower diet was used throughout the four experiments, and hence no difference in results was due to the influence of nutrient density, food palatability, or physical form of the feed.

6.3. Consequences for the breeding industry

Many of the findings reported here are of interest to the pig breeding companies and their use of computerized single-space feeders. Three results are of considerable and direct importance to the pig industry. Firstly, that no relationship was found between level of aggression and any of the production variables currently used in the selection indices. This would indicate, that no indirect selection for more aggressive pigs will occur using selection indices which exclude this behavioural measure. Secondly, that a similar level of performance of group housed growing pigs can be achieved with computerized

single-space feeders and multi-space feeding troughs, and that the higher frequency of visits observed with the four-space feeders appears to be clustered into feeding bouts equivalent to a feeder visit as measured by the single-space feeders. And finally, that the measure of daily food intake, currently the only parameter systematically used from the computerized single-space feeders, contains a multitude of different feeding strategies. This may be important to future selection programmes, through the possibility of selecting animals which are specifically suited to a given environment or which are more flexible in their feeding pattern, and therefore adapt more efficiently to changes in the environment.

6.4. Conclusions

From the four experiments presented in this thesis, together with findings from the literature covering the vast area of feeding behaviour, the following conclusions can be drawn:

Decreasing the accessibility of the food, either indirectly by increasing pig:trough ratio or directly by fitting an enclosed race in front of the trough, modifies the feeding behaviour of the animals in the direction of fewer, but longer visits to the trough.

Increasing the social constraint, either directly by increasing the group size or indirectly by offering low levels of protection from other pigs whilst feeding, increases the rate of eating. It is suggested, that feeding rate may be used as an indicative measure of a stressful environment.

Growing pigs are highly successful in adapting to constraints placed on their feeding behaviour, as no significant effects of social and physical environment were found on production performance.

The effects of environmental factors on feeding behaviour were found to be non-linear, and a set of thresholds appears to operate where a change from 'one trough' to 'more than one trough' and from 'one pig' to 'more than one pig' have major influences on the feeding behaviour observed. Another threshold is apparently reached when the size of the group given access to a single-space

feeder is increased from fifteen to twenty pigs which has highly significant consequences for the feeding behaviour of the animals.

No correlations were found between social behaviour (aggression level and rank) and any of the feeding behaviour and production variables. This finding differs from the general consensus that growth and rank are correlated variables when access to food is limited.

A change in the social environment from group to individual housing resulted in only a small increase in feeder visits, regardless of the feeding pattern displayed by the pig whilst group housed. This had significant effects on the daily food intake of those animals with few, long visits, and suggests that these pigs were disadvantaged in terms of daily food intake as a result of their feeding pattern whilst group housed. However, no such relationship was found in the other experiments carried out. It is argued that a high feeding frequency is a more flexible feeding pattern.

The various criteria and methods used in the literature to define 'a meal' should be applied with caution to the feeding behaviour data of group housed growing pigs given access to single-space feeders. An appropriate unit of measure to describe this behaviour was found to be a visit to the feeding trough.

6.5. References

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APPENDIX A

Example of raw data accumulated by a FIRE feeder

The values in column order are as follows: Pen number, Pig identity, Date (DD/MM/YY), Time of entry into the feeder (HH:MM:SS), Time of exit (HH:MM:SS), and Food eaten (kg). When pig identity is zero, the feeder has failed to pick up the identity of the pig entering. This may happen if a pig loses its ear transponder, or if two feeder visits happen in rapid succession (see lines 13 and 14 of the sample below). Please note that the events are stored in reverse order of occurrence.

```
4,83,17/09/93,15:08:26,15:10:21,0.040
4,79,17/09/93,15:00:18,15:07:59,0.135
4,73,17/09/93,14:57:58,14:58:32,0.003
4,0,17/09/93,14:57:10,14:57:15,-0.034
4,79,17/09/93,14:49:03,14:54:36,0.188
4,73,17/09/93,14:33:29,14:44:47,0.179
4,56,17/09/93,14:23:21,14:33:13,0.303
4,76,17/09/93,14:20:56,14:23:02,0.028
4,55,17/09/93,14:19:46,14:20:46,0.028
4,0,17/09/93,13:30:12,13:33:15,0.002
4,87,17/09/93,13:22:03,13:30:11,0.135
4,62,17/09/93,13:09:23,13:14:29,0.182
4,0,17/09/93,13:08:04,13:08:22,0.028
4,73,17/09/93,13:00:27,13:08:03,0.181
4,76,17/09/93,12:53:54,13:00:18,0.125
4,55,17/09/93,12:51:11,12:53:45,0.132
4,83,17/09/93,11:54:01,12:07:08,0.274
4,75,17/09/93,11:46:14,11:53:48,0.157
4,0,17/09/93,11:45:39,11:45:42,-0.020
4,62,17/09/93,11:40:19,11:45:32,0.231
4,76,17/09/93,11:37:53,11:40:02,0.059
4,79,17/09/93,09:46:09,09:48:58,0.083
4,55,17/09/93,09:41:01,09:44:48,0.130
4,79,17/09/93,09:33:32,09:39:08,0.054
4,87,17/09/93,09:27:12,09:32:59,0.092
4,55,17/09/93,09:23:29,09:26:38,0.044
4,62,17/09/93,09:18:55,09:19:15,0.013
4,55,17/09/93,09:17:36,09:17:48,0.003
4,0,17/09/93,09:15:19,09:15:23,0.004
4,82,17/09/93,09:14:45,09:15:02,0.059
4,0,17/09/93,09:10:21,09:10:25,0.028
4,0,17/09/93,09:09:19,09:09:22,0.000
4,55,17/09/93,09:08:59,09:09:14,0.011
4,55,17/09/93,09:02:20,09:05:20,0.045
4,73,17/09/93,08:32:11,08:40:17,0.107
4,75,17/09/93,08:21:00,08:21:54,0.020
4,73,17/09/93,08:09:30,08:20:56,0.151
4,79,17/09/93,05:23:19,05:31:39,0.049
4,87,17/09/93,05:19:09,05:23:17,0.076
4,76,17/09/93,05:14:05,05:19:08,0.150
```

APPENDIX B

Method used for spray-marking individuals prior to video recording

In order to identify individual pigs on the video recordings, each pig was spray-marked with a unique integer number ranging between 1 and 20, dependent of group size. The spray-marking of moving objects is rather difficult, and each number was therefore expressed as stripes across the back of the pig, as stripes are both quicker and easier to apply accurately than actual figures. The system was developed from the ear notching system, and consisted of stripes on the rear, middle, and/or shoulder of the pig. Each stripe on the rear represented the value 1 (one), each stripe on the middle represented the value 9 (nine), and each stripe on the shoulder represented the value 3 (three). A pig allocated the number seven would therefore have two spray lines across the shoulder and one across the rear. Figure B.1 shows three pigs marked according to this spraying system.

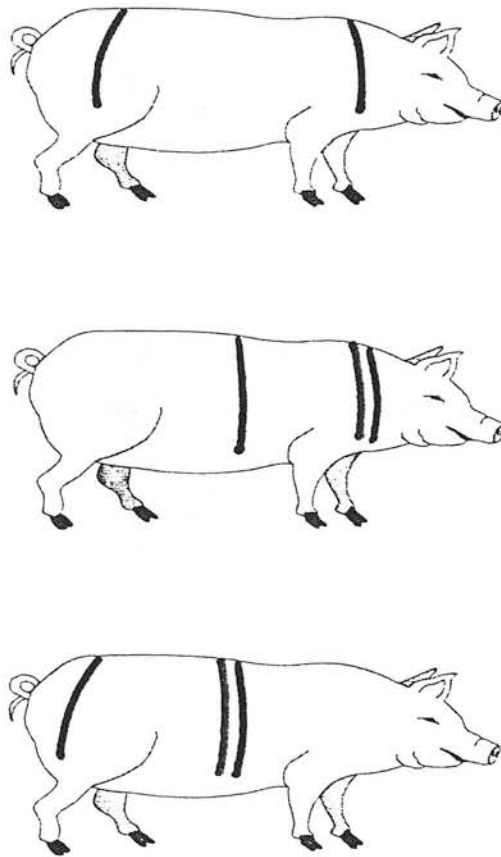


Figure B.1. Pigs marked as numbers 4, 15, and 19, respectively.

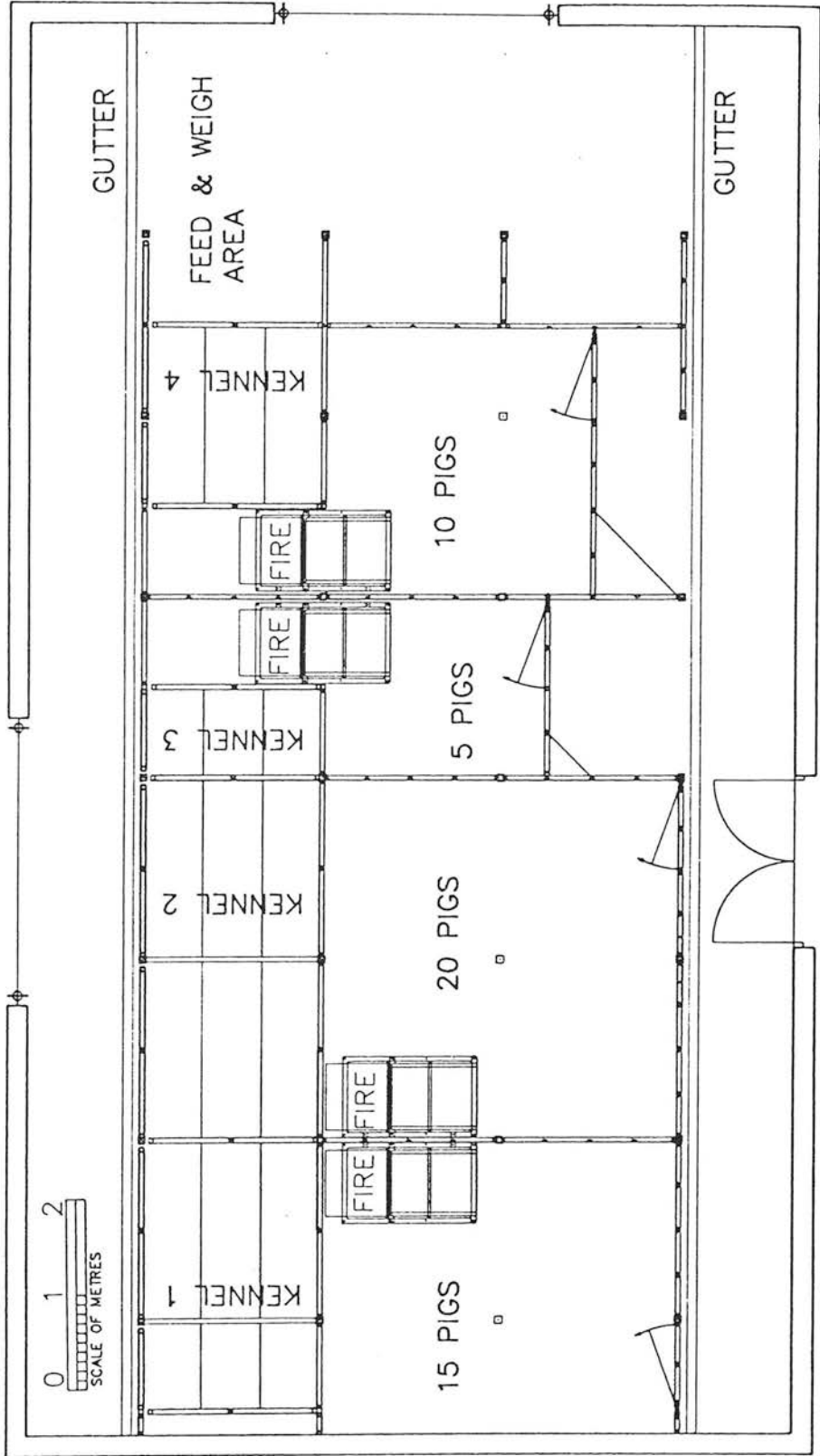


Figure C.1. Pens used in the experiment presented in Chapter 2.

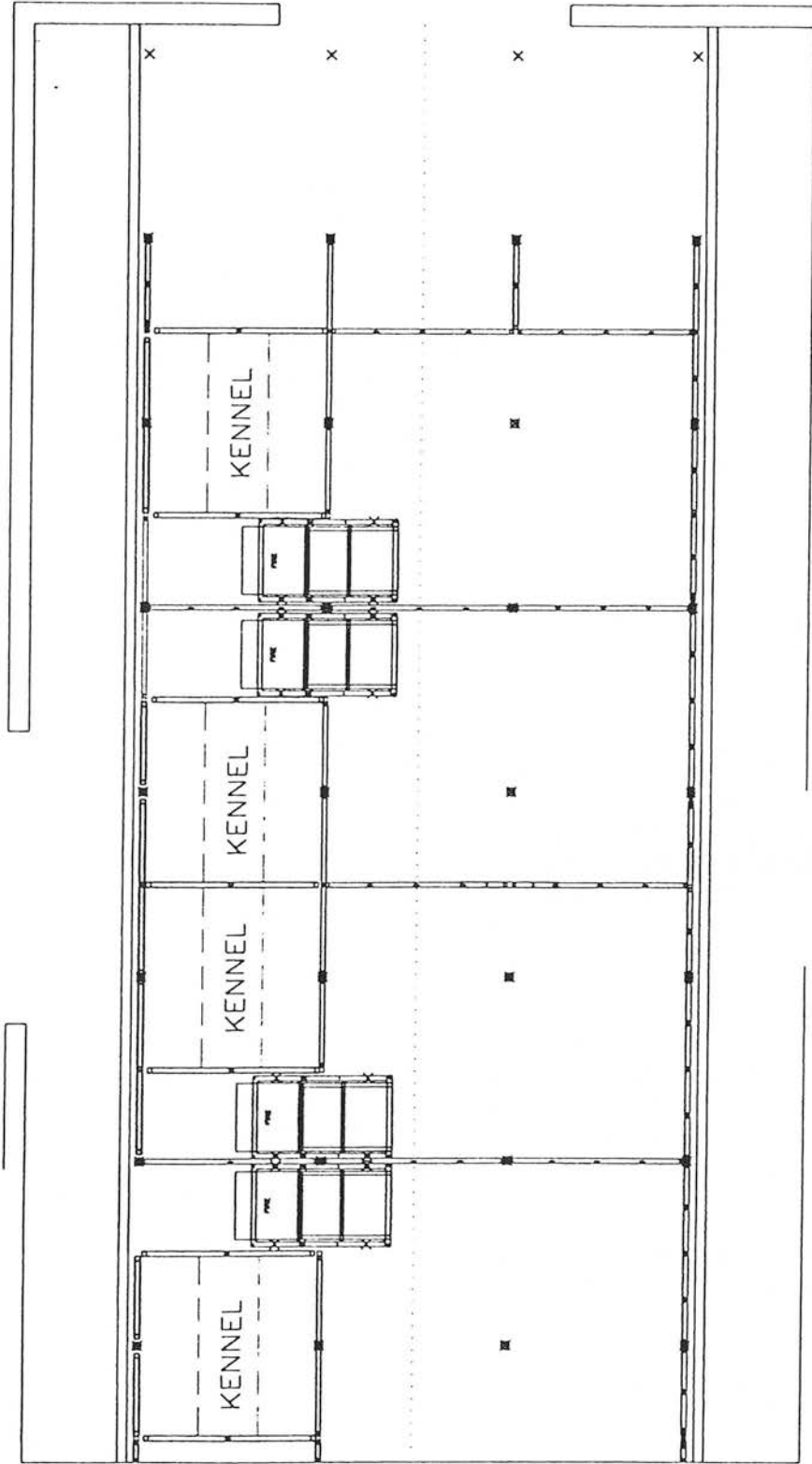


Figure C.2. Pens used in the experiments presented in Chapters 3-5.

APPENDIX D

Abstracts of thesis in Danish, French, and German

Ædeadfærd hos slagtesvin: Det sociale og fysiske miljøes indflydelse

De fleste Britiske avlsstationer for svin anvender i dag computerstyrede foderautomater til enkelt dyr i forbindelse med selektionsprogrammerne. Udvikling af disse foderautomater har muliggjort automatisk måling af ædeadfærden hos individuelle slagtesvin, samtidig med at dyrene er opstaldet i grupper. Denne afhandling beskriver ædeadfærden hos voksende svin og undersøger, hvorledes forskellige aspekter af det sociale og fysiske miljø påvirker dyrenes ædeadfærd og produktionsniveau. Fire forsøg blev udført med henblik på at undersøge effekten af de følgende faktorer: Gruppestørrelse, design af foderautomat, antal ædepladser og individuel opstaldning.

Når adgangen til foderet indskrænkes, enten indirekte som følge af en stigning i dyr:trug forholdet, eller direkte ved hjælp af en aflukket indgang, som anbringes foran fodertruget, sker der ændringer i dyrenes ædeadfærd i retning af færre, men længerevarende besøg til fodertruget.

En øget social konkurrence, enten direkte som følge af en stigning i gruppestørrelsen, eller indirekte som følge af nedsat beskyttelse ved fodertruget fra andre dyr i gruppen, medfører en stigning i ædehastigheden. Samtlige slagtesvin formåede at kompensere for hindringer, der var pålagt deres ædeadfærd, idet der ikke fandtes signifikante forskelle i produktionsniveauet som følge af ændringer i det sociale og fysiske miljø. Der blev ikke fundet korrelationer mellem socialadfærd (aggressionsniveau og rang), og de målte ædeadfærds- og produktionsparametre.

En ændring i det sociale miljø fra gruppeopstaldning til individuel opstaldning resulterede i en kun mindre stigning i antallet af trugbesøg, og var uafhængig af det ædemønster, dyret havde udvist mens det var gruppeopstaldet. Denne ændring i ædemønstret havde imidlertid en signifikant virkning på den daglige foderoptagelse hos grise med få, korte trugbesøg, hvilket antyder, at disse dyr var forfordelte medens gruppeopstaldet med hensyn til daglig foderoptagelse, og ikke, som først antaget, antallet af trugbesøg.

I diskussionsafsnittet overvejes forskellige kriterier, der i litteraturen er brugt til at definere 'et måltid', og gyldigheden af sådanne klassificeringer af besøg til fodertruget diskuteres kortfattet. Forholdet mellem ædemønster og tilgængeligheden til fodertruget undersøges nærmere, og ændringer i ædehastigheden placeres i sammenhæng med social konkurrence og foretrukne ædehastighed. Desuden gennemgås en række andre miljømæssige faktorer og deres indvirkning på ædeadfærden.

Comportement alimentaire des porcs en croissance: Effets de l'environnement physique et social.

Le développement de systèmes d'alimentation à auge monoplace informatisées, utilisés couramment par la plupart des éleveurs pour la reproduction dans leur programme de sélection, a permis de suivre automatiquement le comportement alimentaire individuel de porcs tout en les gardant dans un environnement social. Cette thèse examine en détail le comportement alimentaire des porcs en croissance et étudie comment différents éléments de l'environnement physique et social modifient le comportement alimentaire et la performance de production des animaux. Quatre expériences ont été montées, étudiant les effets des facteurs suivants: taille du groupe, l'agencement de systèmes d'alimentation, espace à l'auge et logement individuel.

Diminuer l'accessibilité à la nourriture, soit indirectement en augmentant le rapport porc/auge, soit directement en plaçant devant l'auge un couloir dont la porte d'accès se bloque dès que l'animal l'a franchie, modifie le comportement alimentaire des animaux dans le sens de visites moins fréquentes mais plus longues à l'auge.

Augmenter la compétition sociale soit directement en augmentant la taille du groupe soit indirectement en offrant de bas niveaux de protection contre les autres porcs à l'auge augmente la vitesse d'ingestion. Tous les porcs ont réussi à s'adapter à la contrainte placée sur leur comportement alimentaire et se sont accommodés au manque d'espace à l'auge puisque la performance de production n'était pas influencée de façon significative par l'environnement physique et social. Nulle corrélation n'est apparue entre le comportement social (niveau d'agressivité et rang) et aucune des variances de comportement alimentaire et de croissance.

Un changement dans l'environnement social, de loge collective à loge individuelle n'a résulté qu'en une légère augmentation de visites à l'auge quel qu'ait été le comportement alimentaire manifesté par le porc en loge collective. Cependant, ceci avait des effets marquants sur la consommation alimentaire journalière de ces animaux avec des visites longues et peu nombreuses et suggère que ces porcs étaient désavantagés dans leur consommation alimentaire journalière plutôt que dans le nombre de visite à l'auge, quand ils étaient en loges collectives.

La discussion générale considère les critères variés utilisés dans la recherche pour définir "un repas", discute, brièvement, de la validité de telles classifications de visites à l'auges et étudie le rapport entre l'accessibilité à la nourriture et le comportement alimentaire. Les effets sur la vitesse d'ingestion sont placés dans le contexte de la compétition et de la vitesse préférée de consommation. Un grand nombre de facteurs environnementaux additionnels et leur influence sur le comportement alimentaire est aussi examiné.

Das Freßverhalten von Mastschweinen: Einflüsse der sozialen und physischen Umwelt

Die Entwicklung von computergesteuerten Einzeltier-Fütterungssystemen, die zur Zeit von den meisten Zuchtorganisationen in ihren Selektionsprogrammen verwendet werden, hat es ermöglicht, das Freßmuster von Einzeltieren in Gruppenhaltung zu erfassen. Die vorliegende Arbeit beschäftigt sich detailliert mit dem Freßmuster von Mastschweinen und untersucht, wie verschiedene Bestandteile der sozialen und physischen Umwelt das Freßverhalten und die Mastleistung der Tiere beeinflussen. Vier Versuche wurden durchgeführt, die die folgenden Faktoren untersuchten: Gruppengröße, Trogdesign, Freßplatzbreite und Einzel- oder Gruppenhaltung.

Ein Herabsetzen der Erreichbarkeit des Futters, entweder indirekt durch Erhöhung des Tier/Trog-Verhältnisses oder direkt durch Anbringen eines geschlossenen Laufgangs vor dem Trog verändert das Freßverhalten der Tiere hin zu weniger, dafür aber längeren Besuchen am Trog. Eine Erhöhung des sozialen Wettbewerbs, entweder direkt durch Erhöhung der Gruppengröße oder indirekt durch Anbieten von weniger Schutz vor anderen Schweinen während der Futteraufnahme erhöht die Freßrate. Allen Schweinen gelang es, sich der Einschränkung ihres Futteraufnahmeverhaltens und der Verringerung des Freßplatzangebotes anzupassen, was daran zu erkennen ist, daß sich keine signifikanten Auswirkungen der sozialen und physischen Umwelt auf die Mastleistung zeigten. Es wurden keine Korrelationen zwischen Sozialverhalten (Aggressionsgrad und Rang) und den einzelnen Variablen des Freßverhaltens und der Mastleistung gefunden.

Ein Wechsel der sozialen Umwelt von Gruppen- zu Einzelhaltung führte nur zu einer kleinen Erhöhung der Anzahl der Trogbesuche, unabhängig vom Freßmuster, das die Tiere während der Gruppenhaltung zeigten. Er hatte jedoch signifikante Auswirkungen auf die tägliche Futteraufnahme der Tiere mit wenigen, langen Trogbesuchen. Dies legt den Schluß nahe, daß diese Tiere in der Gruppenhaltung in Bezug auf ihre tägliche Futteraufnahme benachteiligt waren und nicht was die Anzahl der Trogbesuche betrifft.

Die allgemeine Diskussion erwähnt verschiedene Kriterien, die in der Literatur beschrieben werden um eine "Mahlzeit" zu beschreiben, diskutiert kurz die Gültigkeit solcher Klassifizierungen der Trogbesuche, und geht auf das Verhältnis zwischen Erreichbarkeit des Futters und Freßmuster ein. Die Auswirkungen auf die Freßrate werden in den Zusammenhang zu Konkurrenz und bevorzugter Freßrate gestellt. Eine große Anzahl zusätzlicher Umweltfaktoren und ihr Einfluß auf das Freßverhalten wird besprochen.

