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Title	Effects of social organisation on feeding behaviour in growing pigs
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Qualification	PhD
Year	2000

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The effects of social organisation on feeding behaviour in growing pigs

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A thesis submitted towards the degree of
Doctor of Philosophy
at the University of Edinburgh
2000

Abstract

Group housed pigs make less frequent feeder visits of a longer duration, and eat at a faster rate than pigs housed individually. They also have lower growth rates which may be due to elevated stress associated with aggression and social stress. The aim of this thesis is to investigate the stability of feeding patterns in individual pigs, the effect of grouping and group composition on feeding patterns and to assess the consequences of this shift in feeding behaviour for the welfare and performance of grouped pigs.

The flexibility of feeding behaviour was assessed by restricting the time of access to food of previously *ad libitum* fed pigs to 2 hours per day and then returning them to 24 hr access. When pigs had restricted access to food they made fewer daily feeder visits, of a longer duration, with a higher food intake per visit than the control pigs that had 24 hour access to food throughout. Flexibility was assessed by comparing feeding behaviour before and after restriction. The pigs that experienced a period of restricted feeding either resumed their previous behaviour or showed the same trend as the controls. It was concluded that feeding behaviour was flexible.

A second experiment investigated the effect of grouping on feeding behaviour. Pigs were housed individually for 3 weeks after which they were combined into groups of 4 for 3 weeks, before being returned to individual housing for a further 3 weeks. When grouped, pigs made fewer visits to the feeder of a longer duration than when they were housed individually. Possible explanations for the changes in feeding behaviour are competition, group cohesion, or that the high frequency of feeder visits when the pigs are housed individually is a consequence of a lack of social stimulation. The results suggest that group cohesion is most likely to have been causal in the observed changes in feeding behaviour.

A final experiment investigated the effect of group composition in terms of latent aggressiveness on feeding behaviour. Pigs were kept in litter-groups for 3 weeks from weaning and categorised as 'High' (H) or 'Low' (L) aggressive using an attack latency test. They were then transferred to individual housing for 2 weeks and their feeding behaviour was recorded. In a final 3 week period the pigs were combined into groups of 8 pigs of either all H or all L aggressiveness. Pigs in H groups had higher aggression levels on the day of mixing than pigs in L groups and salivary cortisol concentrations suggest that stress levels may have been elevated when the pigs were grouped. Feeding behaviour changed between individual and group housing in accordance with Experiment 2. There were no differences in feeding behaviour, defined in terms of visits, between pigs in H groups and pigs in L groups. However, when visits were organised into meals it was found that H pigs had more meals per day with longer within meal intervals both when individually and group housed. This suggests that there may be a link between aggressiveness of individuals and meal patterns.

In conclusion, pigs have flexible feeding patterns in terms of a change in time of access to food. Pigs alter their feeding behaviour when group housed in the direction of fewer feeder visits of a longer duration, probably due to the effects of group cohesion. The aggressiveness of individuals within a group had no effect on feeding behaviour. There is potential to categorise the aggressiveness of pigs using feeding behaviour such that aggressiveness could be manipulated in breeding programmes.

I hereby declare that this thesis is of my own composition, and that all assistance has been duly acknowledged. The results presented here have not previously been submitted for any other degree or qualification.

Hannah Bornett

Acknowledgements

There are numerous people who have given me help and advice throughout my project. Firstly, I would like to thank my supervisor Colin Morgan. Colin's door has always been open whenever I've needed help or advice. He has given me immense support with all aspects of the project including the practical work and has always provided useful criticism on my work in record time. Thanks also go to Alistair Lawrence for all his helpful discussions and constructive comments on my thesis chapters. He could always see a way through a problem so quickly! I am also grateful to John Oldham for giving me guidance, especially on the final drafts of my thesis chapters.

I would like to acknowledge the input of Mike Mendl who's ideas enabled the project to come about in the first place and for his advice on experimental design. I am very grateful to Dave Allcroft who has been brilliant at giving me good statistical advice in a form that I could nearly always understand! I would also like to acknowledge Hans Erhard and Rick D'Eath for all the useful discussions on pig aggression, and on the attack latency test that helped me to run the tests so smoothly. Fiona Gebbie did a great job of analysing my salivary cortisol samples and I'd like to thank Susan Jarvis for giving me advice on the collection of the samples. I would also like to thank Gerry Emmans for advice on experimental design and Ilias Kyriazakis for valuable comments on drafts of the meal pattern chapter.

Without the help of the Easter Howgate technical team the smooth running of my experiments would have been impossible. I'd particularly like to acknowledge the help of Joan, Sheena, Jacqui, Dave, Peter, Phil, Lesley and Terry.

I'd like to acknowledge the BBSRC for funding the project.

The students room at Bush has been a fun place to work and I'd like to thank all the fellow postgrads I've shared it with over the past three years for making it a pleasant place to be. In particular, I'd like to thank Jennie who was there for a while at the beginning and did a good job of helping me feel settled in and has always been good at giving help and encouragement; Sarah, Spiridoula and Lee who have been there from the start and we've gone through the trials and tribulations together, and Emma for always being around to share and sympathise with many of my 'pig problems' and for being a good friend over the past couple of years.

On a more personal note, I would like to acknowledge the support of all my friends whilst I've been doing my Ph.D. Joanne was my flatmate in the early days and did a good job of introducing me to the benefits of living in Edinburgh! Since then I seem to have had numerous flatmates but would particularly like to thank Vincent for all his support and the lifts to Bush in my final year. I am also grateful to Ruth, Siobhain, Colin and Diane for making the flat in Braid Road a happy place to live. I'd like to thank Nancy, Nuala, Juliette and Charlotte for all their encouragement.

Finally, I'd like to thank my parents and my sister, Emma for providing huge amounts of encouragement and support (emotional and financial!) throughout my time in Edinburgh.

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Chapter 1

Introduction

As part of normal husbandry practices, growing pigs are routinely group housed and mixed into new groups for example, at weaning, the start of finishing, during transport and at lairage. Mixing results in a disruption of social organisation which leads to an increase in aggression levels (Meese and Ewbank, 1973), and social stress (Hessing *et al.*, 1994), which in turn can compromise welfare and production.

Grouped pigs make fewer feeder visits of a longer duration and eat at a faster rate than individually housed pigs (de Haer and Merks, 1992). In terms of production parameters, food intake (Gonyou *et al.*, 1992) and weight gain (Gonyou *et al.*, 1992; de Haer and de Vries, 1993) have been found to be lower in group housed pigs compared to pigs housed individually. de Haer and de Vries (1993) also found group housed pigs to have less back fat than pigs individually housed and higher digestibility coefficients. This suggests that social constraint when pigs are group housed affects their feeding behaviour and food intake and this has implications for production and welfare.

Competition, social stress and social facilitation are all factors that may be responsible for the differences in feeding behaviour and production parameters seen between grouped and individually housed pigs. So, it is important that the interaction between social behaviour and feeding behaviour be understood such that production systems might be improved accordingly.

Investigating the response to group housing and mixing, in terms of aggression levels and feeding behaviour of individual pigs will determine how adaptable pigs are and the degree of variation between individuals. If there are differences between individuals in the way in which they cope with mixing and group housing it would imply that some pigs are better suited to group living than others. Therefore, it is possible that group composition in terms of the characteristics of individuals could be

manipulated to optimise welfare and production. Indeed, Erhard and Mendl (1997) classified pigs as high or low aggressive using an attack latency test. When the pigs were mixed into groups of differing composition in terms of latent aggressiveness they found that groups of all high aggressive pigs showed higher levels of aggression than groups of all low aggressive pigs or groups of half high aggressive and half low aggressive pigs. In addition, the presence of low aggressive pigs hastened group integration. Ultimately pigs could be genetically selected to be less aggressive and less stressed at mixing whilst maintaining production levels.

To enable the assessment of the effects of social organisation on feeding behaviour, reliable measurements of feeding behaviour, social behaviour, production and stress are necessary. In the first half of this review I will discuss the most appropriate methodologies available to measure these variables. Secondly I will review the literature surrounding the subject area of the thesis; aggression, social organisation, feeding behaviour and social stress.

1.1 Methodology

In what follows I will discuss the methodologies available for measuring feeding behaviour, social behaviour and stress and which are most suitable methods for the kinds of experiment to be conducted here.

1.1.1 Measuring feeding behaviour

Traditionally, the food intake of pigs has been obtained by housing pigs individually and weighing the food offered and refused. In addition, feeding behaviour has been monitored by visual observation, noting at regular intervals whether each animal is eating (Forbes, 1995). These are very time consuming methods and they do not provide detailed records of feeder visits.

With the advent of computerised feeders such as the FIRE system (Feed Intake Recording Equipment, Hunday Electronics, Newcastle), measuring feeding behaviour has become relatively easy. The feeder consists of a fibre glass trough suspended on a load cell. Access to the trough is via a hinged door which operates a micro-switch when opened or closed. There is also a receiver on the side of the door that recognises each individual pig from its ear-transponder as the pig pushes its head through the door. In this way, feeding behaviour of individuals within a group can be recorded. Each feeder is linked to a control box that provides records of entry and exit times at each visit and pre- and post-visit trough weights. This enables the frequency of feeder visits, duration of visits and food intake per visit to be calculated and from these measurements daily food intake, feeding rate and feeder occupation can be obtained (Nielsen *et al.*, 1995).

1.1.2 Behaviour sampling methods

There are many different sampling methods to choose from, some being better suited to measure certain types of behaviour than others. It is important that the most appropriate method is chosen to measure the types of behaviour that are to be observed accurately and reliably. The main methods for sampling behaviour are *ad libitum* sampling, focal sampling, scan sampling and one-zero sampling.

Ad libitum sampling

With this method all behaviour is noted by the observer as and when it occurs. It can be particularly useful when recording rare events, during preliminary experiments to aid hypothesis formulation, and to collect large bodies of data for the formulation of ethograms. The main problem is that there is bias towards behaviours and individuals that are most conspicuous, and more subtle behaviour patterns may be neglected. Bernstein (1991) found that when comparing *ad libitum* with other sampling methods, the importance of quiet submissive responses in regulating agonistic encounters were underestimated. It is likely, when using this method, that a

lot of recording will be involved, consequently, another problem is the collection of imprecise data on rates and durations of frequent events (Altmann 1974).

Focal Sampling.

Focal sampling involves the study of one particular individual for a certain period of time noting all incidences of behaviour. One of the strengths of focal animal sampling is that, in order to stay with the focal individual, the observer follows the individual closely and often obtains observations that would not normally be recorded when using other methods of observation (Martin and Bateson 1993). Although the focal individual receives highest priority for recording its behaviour it does not restrict the investigator to only that individual. When looking at social behaviour it is necessary to record acts where the focal animal is the initiator or receiver so inevitably individuals other than the focal animal are included in the record. Altmann (1973) suggested that focal animal sampling is the best way to study animals in groups as it provides relatively unbiased data relevant to a wide variety of questions about spontaneous social behaviour and it is particularly good for investigating behavioural synchrony among neighbours.

Scan Sampling.

This technique involves the rapid scanning of a group at regular intervals and the behaviour of each individual being recorded. The observer needs to be as instantaneous as possible otherwise the sample approximates a series of short focal-animal samples of unknown duration (Lehner 1979). Scan sampling tends to restrict the observer to recording one or a few behavioural categories. As with *ad libitum* sampling there is a danger that some behaviour patterns will be more conspicuous than others. However, scan sampling is particularly good for assessing individual's time budgets giving a broader spread of data than if focal sampling is employed. In addition, scan sampling can be applied together with focal animal sampling to measure the behaviour of groups. At fixed intervals, for example, between focal individuals the whole group is scanned, normally for a single behavioural category (Martin and Bateson 1993).

One-zero sampling.

This method requires the observer to record whether or not a particular behaviour pattern has occurred during a sample interval. If the same state continues into the next period then another entry is made. The pattern can be recorded either at the end of the period or as the behaviour occurs. The measure obtained is usually expressed as a proportion of all sample intervals in which the behaviour pattern occurred.

There has been much debate over the use of one-zero-sampling mainly as neither frequencies nor durations are measured (Altmann, 1974; Rhine and Linville, 1980; Smith, 1980; Martin and Bateson, 1993). However, one-zero-sampling is easy to apply and has good inter- and intra-observer agreement. Furthermore, it can provide data on more categories than when sampling for frequency and duration. A major advantage is that data are yielded in such a form that samples are easy to separate and are therefore statistically independent (Martin and Bateson 1993).

Discussion of behaviour sampling methods

All the sampling methods discussed have their strengths and weaknesses and, if used appropriately, can be successful. The aims of an experiment will determine the type of data collection technique most suitable. I suggest that for live observations, scan sampling using a check sheet is the best method for determining information on time budgets combined with focal sampling to obtain detail of social interactions. In this way a broad spread of data will be obtained to assess timebudgets, but information on social behaviour, that might be missed if scan sampling alone is used, will be identified using focal sampling. Focal sampling can be recorded using a hand-held event recorder (Workabout, Psion PLC, U.K.) and the Observer, computerised event recorder (Noldus Information Technology, Wageningen, The Netherlands). Video recordings are also valuable in order to obtain more detail on social interactions and can be analysed using scan sampling and also continuous sampling (recording interactions as and when they occur). These can be recorded using either pen and paper on check sheets or the Observer.

1.1.3 Measuring aggressiveness.

The aggressiveness of pigs has been measured using social confrontation tests in varying situations in terms of home pen vs. arena, intruder:test pig weight ratio, the length of the test and the behaviour recorded. Hessing *et al.* (1993) used 1 week old piglets and placed 3 piglets from one litter and 3 piglets from a second litter in an arena. The test lasted for 30 min and occurrences of the behaviours sniffing, threatening, head knocks, biting, fighting, fleeing and submission were recorded and pigs were given a score for aggressiveness on the basis of these observations. Other investigators have used latency to attack as a measure of aggressiveness. Forkman *et al.* (1995) tested pigs in their home pen and used opponents of the same weight. The test lasted for 10 min and the latency to first bite was recorded. Fast attackers therefore were classed as being more aggressive than slow attackers. Jensen *et al.* (1995) put test pigs in a novel arena and introduced them to a smaller, unfamiliar piglet for 15 min. Latency to the start of a fight (5 seconds of uninterrupted butting and biting) was recorded, fast attackers being classed as most aggressive as in Forkman *et al.* (1995). Erhard and Mendl (1997), used a resident/intruder situation in a sectioned off area of the home pen. The intruder was 60% of the body weight of test pig and the time taken from first contact to the start of aggression defined as 'at least one quick bite' was recorded. The test lasted until the start of an attack or for 3.5 min after which the intruder was removed from the pen. In the aggression tests described above the pigs were introduced to one another in a relatively false environment. Therefore, it might be expected that how a pig behaves in this kind of test might not reflect how it behaves in a group situation. However, in a second experiment Erhard *et al.* (1997) found that the attack latency test did predict aggressiveness after regrouping, those pigs with shorter attack latencies fought for longer and more vigorously and accepted their position in the newly formed hierarchy less easily than pigs with longer attack latencies.

1.1.4. The determination of dominance order.

Many definitions of dominance have linked it to aggression, and in practice, dominance orders are often ascertained using outcomes of aggressive interactions; non-aggressive patterns of behaviour may be overlooked. Alternative measures of dominance order include: the priority of access to a resource, submissive behaviour, and outcomes of staged paired contests between group members. However, dominance orders based on competitive interactions, such as priority of access to a resource are not necessarily correlated with orders based on aggression (Beilharz and Zeeb 1982, Bradshaw 1992). In what follows, the various methods for measuring and calculating dominance orders are described.

Paired contests

These involve staged competitions between pairs of animals in order to determine which animal is dominant over another. All combinations of pairs in a group will be contested until a dominance hierarchy is determined for the group as a whole (Bradshaw 1992).

Priority of access to a resource.

Another method of calculating dominance hierarchies involves measuring the priority of access to a resource. This assumes that rank orders are positively associated with gains in individual fitness. Brouns and Edwards (1994) successfully used the priority of access to feed as a method for obtaining feed related dominance hierarchies.

Dominance order based on submissive behaviour.

Jensen (1982) reported that in pigs, submissive behaviour is more important in determining a social hierarchy than aggression. He suggested that the behaviours “retreat” and “head tilt” can be used to determine a social order in terms of an avoidance order, and that these avoidance behaviours seem to reduce aggressive outcomes in social interactions between group housed dry sows. All interactions between groups of five sows were recorded during 1 hour after feeding on days 2, 3 and 4 after group formation. If within a pair of animals the performance of the

behaviours indicated absolute uni-direction, and the score was not less than 2-0, the dominant animal was considered to be that which never showed any avoidance and the pair-relation was considered “settled”. Within each group an “avoidance index” was calculated using the following formula

$$\frac{2a}{n(n-1)} = \text{avoidance index}$$

where a = number of settled pair-relations and n = number of animals in the group. The index expresses the amount of settled pair-relations compared with all the possible combinations in the group. An index of 0 would suggest that no pair has a settled avoidance order, whereas an index of 1 would mean that all pairs are settled.

Dominance values

In this method, for each animal the dominance value can be calculated by the number of wins and the number of defeats in relation to all decisive fights during a period of observation. The value varies between +1 (no defeats) and -1 (no wins) (Otten *et al.*, 1970). Beilharz and Cox (1967) recorded the number of displacements and successful defences of a feeding hole to calculate dominance values for pairs of growing pigs. The results indicated that the animal with the highest dominance value is least submissive in comparison with the rest of the group and hence probably suffers least from intra-group competition. Therefore, dominance value represents an individual's reaction to the social environment.

Dominance Matrix.

Martin and Bateson (1993) describe the construction of a dominance matrix to derive a dominance hierarchy from observations of interactions between individuals. The number of supplants between pairs are placed in a matrix. The matrix is then rearranged so that the individual which is never supplanted is on the top and the

individual which is always supplanted is on the bottom. This method however, can only be applied when the hierarchy is linear.

Social rank index

Lee and Craig (1982) used a social rank index (X) to represent the social status of white leghorn pullets:

$$X = 1/2(D-S+N+1)$$

Where D = the number of other individuals dominated, S = the number dominating the individual in question, and N = the number in the group.

Index of success.

Mendl *et al.* (1992) calculated an index of success in agonistic interactions between pregnant pigs. The formula is:

$$\text{Index of success} = \frac{(\text{no. pigs that an individual is able to displace}) / (\text{no. of pigs that an individual is able to displace}) + (\text{no. pigs that are able to displace the individual})}{2} \times 100$$

An animal's index can therefore vary between 0 and 100. An animal with an index of over 50 would be relatively successful in that it would displace at least as many individuals as would displace it. In this experiment, the index gave a reflection of the experiences of individuals in agonistic encounters during the period after mixing.

A comparison of methods

Bradshaw *et al.* (1998) investigated the consistency of measurement of social status in sows housed in two group dry-sow systems; indoors or outdoors. All sows were observed for 4 hours/day for 10 days with winners, losers and type of agonistic interaction being recorded. The index of success, the level of interaction (measured by counting the total frequency of agonistic interactions), success in interactions as

calculated by the percentage of interactions each sow won, and the matrix dominance hierarchy described by Martin and Bateson (1993) were compared as measures of social status. Spearman rank correlations were calculated to determine the degree of correlation between measures for each system. Index of success, success in interaction and matrix dominance were found to be correlated within each group and between systems. The level of interaction only correlated with matrix dominance in the outdoor system. These results suggest that measures of social status do not result in different hierarchies as long as the outcomes of pairwise interactions are taken into account.

I decided that the Social Rank Index devised by Lee and Craig (1982) would be the most useful method for determining social hierarchy in the experiments conducted in this thesis as it uses data on aggressive interactions recorded when the pigs are group housed rather than data from staged encounters, and it takes into account pairwise interactions. In addition it was used successfully by Nielsen *et al.* (1995) to determine dominance rank in pigs in a similar experimental set-up.

1.1.5. Measuring stress

Attempts have been made to index welfare by assessing factors which may represent physiological stress. The most common method used is the analysis of cortisol concentration in the blood plasma. However, this involves animals being surgically prepared with venous catheters the stress of which can also cause a temporary release of cortisol. In addition, the measurement of cortisol in the blood has physiological limitations. 90% of cortisol in circulation is bound to cortisol-binding globulin and albumin. The remaining 10% is available for uptake by the target tissues. Under stress conditions, the binding capacity of the globulin becomes saturated resulting in an increase in free cortisol. Therefore the measurement of total cortisol concentration in the blood does not necessarily reflect the biologically active fraction of the hormone (Cook *et al.*, 1997).

Non-invasive measurements of stress include measuring concentrations of cortisol in the urine and saliva of the animal, heart-rate, behavioural responses and measures of immunological depression. These methods will be discussed below.

Urinary cortisol.

Carlstead *et al.* (1992) measured urinary corticosteroid concentrations in the response to psychological stressors in felids. It was found that cortisol cleared into urine between 2 and 3 hours post-Adrenocorticotrophic hormone (ACTH) stimulation. Not all the cats exposed to presumed psychological stressors exhibited increased cortisol concentrations. However, it was proposed that these cats actually enjoyed being handled and a more consistent response was seen in non-domestic felids.

Creel *et al.* (1992) also successfully used urinary and faecal cortisol as a measure of stress in dwarf mongooses and wild dogs. Cortisol appears in urine in the free form and should therefore be a good indicator of the stress response of the animal. However, samples are difficult to collect, there is little or no control over the timing of the sample, cortisol concentrations are dependent on urine volume (Cook *et al.*, 1997) and there is a delay of entry of cortisol into the urine.

Salivary cortisol

The measurement of cortisol in saliva is a non-invasive alternative to measuring cortisol in blood plasma and, in general good correlations have been found between plasma cortisol and salivary cortisol concentrations. Cooper *et al.* (1989), Parrot *et al.* (1989), and Parrot and Mission (1989) found good agreement, salivary cortisol concentrations being between 5 and 10% of those found in blood plasma. Blackshaw and Blackshaw (1989) however, found that salivary cortisol was poorly correlated with plasma cortisol. Unconjugated cortisol is secreted into the saliva via passive diffusion into the salivary gland and is therefore, essentially an ultrafiltrate of the free cortisol fraction in the blood (Cook *et al.*, 1996). Saliva samples can easily be collected by allowing pigs to chew on cotton wool buds which are centrifuged and the resulting saliva is analysed using a radioimmunoassay (Parrot, 1989).

Concentrations of cortisol in the saliva of pigs exhibit a circadian rhythm described by Ekkel *et al.* (1996). They sampled pigs every 2 hours over a 24 hour period, and the peak cortisol concentration was found to be at 11.22h. They also proposed the existence of circa-septan and circa-annual rhythms. In a second experiment, Ekkel *et al.* (1997) examined the effect of mixing on the circadian rhythm of cortisol. Behaviour and salivary cortisol concentrations were measured at intervals after mixing. Although the occurrence of fights decreased after mixing, the frequency of bites and head knocks was still more than in an un-mixed control group 5-6 weeks after mixing. A blunted amplitude of circadian rhythmicity would indicate increased stress but the average circadian cortisol was not different between the test group and the control group at day 6 or day 41 after mixing. It was concluded that, although levels of mutual aggression are maintained for many weeks after mixing, it is unclear whether this leads to a state of chronic stress as the salivary cortisol levels remained unaffected in comparison with an unmixed group.

The effects of age, gender and stress on the circadian rhythm of salivary cortisol were examined by Marko *et al.* (1997). In a control group, salivary cortisol was sampled at the ages of 12, 16, 20 and 24 weeks and rhythm characteristics described. At 12 weeks, pigs in two other groups were housed individually for 4 hours with no visual or tactile contact with other pigs. Saliva was collected at various times before and during isolation. In contrast to the findings of Ekkel *et al.* (1996), two peaks in salivary cortisol were found during the late morning and early afternoon. Between 12 and 24 weeks basal salivary cortisol decreased. By 20 weeks the circadian rhythm was found to be stable, hence 20 weeks could be a crucial age for reaching adult rhythm profiles of salivary cortisol. Isolation stress caused an elevation of cortisol in castrates only, gilts remaining unaffected. It is possible that castration increased sensitivity of the hypothalamic-pituitary-adrenocortical (HPA) axis. It was also reported that acute cortisol response was affected by the time of day that the stressor was applied. If basal concentrations were high then overall response to isolation stress was higher than if basal concentrations were low. The results of this

experiment emphasise the importance of the consideration of the effects of age and gender of the pig and the time of stressor application when using salivary cortisol as a physiological indicator of stress.

Behavioural measures of stress.

Behavioural responses to stress may depend on the type of stressor involved (Barnett and Hutson 1987). For example, in response to restraint animals may struggle and vocalise, but in response to cold may shiver and huddle. Measurable behavioural responses to stress include vices, stereotypies and apathetic behaviours. Apathetic behaviours include motionless standing and sitting, have been explained in terms of “learned helplessness”. When an animal learns that responses such as escape are futile it simply remains motionless in a response similar to that of clinical depression in humans (Barnett and Hutson 1987). However, the apathetic behaviours could instead be an indicator of the animal’s adaptation to a restrictive environmental situation.

Stress susceptible animals have also been found to drink more often and investigate their pen and peers more often than normal animals (Robert and Dallaire 1986). It has also been suggested that stressed pigs have a faster rate of eating compared with unstressed pigs (Nielsen 1999). Furthermore, Meese and Ewbank (1973) reported that male and female pigs performed mounting behaviour when socially stressed at mixing.

Desautes *et al.* (1997) studied the behavioural reactivity of pigs in response to an environmental challenge. Vocalisation, locomotion and defaecation scores were measured before and after a 10-min novel environment exposure. Plasma cortisol and ACTH were also measured. Correlations were found between the three behavioural measurements and post-stress ACTH levels suggesting that these measures reflect the level of reactivity to an environmental challenge.

Measuring heart-rate.

Stress may either increase or decrease heart-rate. If stress is prolonged the heart-rate may initially decrease returning to basal levels or subsequently increase being maintained by plasma adrenaline secreted by the adrenal glands (Terlouw *et al.*, 1997). Consequently it can be difficult to interpret the results. Furthermore, the process of measuring heart-rate, (although non-invasive using some 'remote' techniques), may itself cause a change in rate and heart-rate may change as a result of feeding and other activities. These problems mean that heart rate monitoring may be a rather unreliable measure of stress level.

Immunological indicators of stress.

Depression of the immune system as a result of prolonged stress is difficult to measure and normally requires invasive procedures. Mendl *et al.* (1992) studied sows' humoral immunocompetence by measuring serum IgG antibody response to the *Bordetella* bacteria component of an atrophic rhinitis vaccine as part of the study looking at physiological and reproductive correlates of behavioural strategies in pigs. The test failed to show a difference between High, Low and No Success pigs and there was large variation within groups.

Ekkel *et al.* (1995) used a phytohaemagglutinin (PHA) skin test to indicate stress-induced changes in immune reactivity in pigs. PHA causes a hypersensitivity reaction when injected which can be evaluated by measuring parameters such as skin-fold-thickness. Stressed animals are characterized by a delayed reaction with a lower peak than non-stressed animals.

In summary, there are a number of reliable if rather subjective methods of assessing levels of stress in pigs. Behavioural observations are useful, and it is important to combine behavioural and physiological measures, however it is sometimes difficult to determine if a certain behaviour is performed due to increased stress or for some other reason. Heart-rate could be a useful measure as long as one could be relatively

certain about what the changes in rate imply. Measurement of the depression of the immune system would seem to be a rather unreliable, difficult and invasive method of assessing stress response. Measuring plasma cortisol is reliable but also very invasive. Therefore, measuring salivary or urinary cortisol are, on the whole, more favourable methods of obtaining an indicator of the changes in pituitary-adrenal activity. As cortisol is present in the free form in urine and saliva, their analysis may provide a more accurate reflection of stress response than assessing blood plasma. Although the concentrations of cortisol found in saliva are comparatively lower than in urine, the slow clearance of cortisol into the urine and the awkwardness of obtaining urine samples favours the salivary method for pigs.

Having discussed the methodology available to assess the effects of social organisation on feeding behaviour, I will now review the literature on the subjects associated with the topic of this thesis.

1.2. Review of Literature

1.2.1. Aggression

Aggression is defined as '*the act or practice of attacking without provocation*' (Concise Oxford Dictionary, 1995). Pain, fear, thwarting and frustration are all situations that can evoke aggression. Environmental and animal factors such as novelty and levels of testosterone and motivation also influence the propensity to attack, (Archer 1976). Aggression is a major component of pigs' social behaviour and functions include; dominance aggression, to establish position in the hierarchy; competitive aggression, to obtain a resource; and defensive aggression to gain comfort (Giersing and Studnitz, 1996).

Aggressive behaviour in the pig consists of threats, chasing, pushing and pressing, thrusts and bites (Giersing and Studnitz, 1996). Bites are aimed at the head and neck and defensive moves normally involve hiding those areas (McGlone, 1985, Rushen

and Pajor, 1987). Fights comprise reciprocated vigorous biting; Rushen and Pajor (1987) described fights in terms of frequency of bites or time spent in each of five spatial configurations of animals ('T' configuration, parallel, head to head, asymmetric parallel and reverse parallel). Winner pigs show higher incidences of ear bites than loser pigs, whereas loser pigs show higher frequencies of head-under-head pushing and body turns than winner pigs (McGlone, 1985). Defence and submission are normally displayed by turning the body away from the attacker (Rushen and Pajor, 1987).

Individual characteristics of animals such as age, weight, and sex may influence the aggressiveness of that individual and might be reflected in the overall level of aggression in a group. Jensen (1994) investigated the effects of age on fighting between unacquainted piglets during staged encounters. He found that there were no effects of age on the probability that piglets would fight during the test. One week old piglets fought as frequently as older animals (5 and 9 weeks), but fights were significantly shorter and fighting positions were different compared to the older piglets. Erhard and Mendl (1997), found that relative aggressiveness remained consistent over time when attack tests were performed on pigs at 7 and 11 weeks of age. Although attack latencies decreased from 7 to 11 weeks there was a correlation between latency at the two time periods.

Size and weight are reported not be influential factors in the aggressiveness of pigs. Rushen (1988) investigated the size of opponents in confrontation tests and found that this did not affect the likelihood of fights taking place between pigs at the age of five and six weeks. In addition, Erhard and Mendl (1997) found no correlation between body weight and aggressiveness. Various studies have indicated that there is no difference in aggressiveness between male and female pre-pubescent pigs (Hessing *et al.*, 1993; Erhard and Mendl, 1997).

From the above studies it appears that the physical attributes of individuals such as age, size and sex have little influence on the aggressiveness of pigs, so it is possible

that individual differences between pigs are due to differences in 'personality', some pigs being pre-disposed to be more aggressive due to their genetic make up or developmental experiences. Indeed, previous experience and familiarity play a large part in how pigs behave when faced with an unfamiliar individual. The ability to recognise individuals aids the prediction of an outcome of an aggressive encounter, allowing the avoidance of injury during a conflict. This avoids the social stress caused by an aggressive incident and is obviously advantageous in terms of survival. It may be possible for animals to use visual, olfactory and auditory cues to assess an opponent without the need for physical contact (Mendl and Erhard, 1997). Indeed, red deer stags use roaring rate to assess fighting ability (Clutton-Brock and Albon, 1979) and domestic fowl make judgements by estimating the size of an opponent's comb (Rushen, 1985a). However, it may be necessary for a fight to occur initially to allow individuals to ascertain their relative fighting abilities (Bernstein, 1981).

Rushen (1988) proposed that assessment of a potential opponent occurs on first meeting but on subsequent meetings recognition is more important. He conducted experiments to test the existence of pre-fight assessment in young pigs. The results were mostly negative. In all paired contests involving pigs of dissimilar weights the heaviest pig won. If prior assessment of relative fighting ability occurs then it would be expected that fights would be less likely to happen when there is a large difference in weight, however as previously mentioned, weight is not always a good indicator of relative aggressiveness or fighting ability. Indeed, Rushen (1988) found that pigs that differed considerably in body weight were just as likely to fight as pigs of similar weight. Moreover, pigs that lost fights were just as likely to initiate fights as those that won. It may be that as the pigs were still young they had not yet developed the skills required to assess their opponents effectively. However, it was found that pigs did judge their relative fighting abilities during a fight. The eventual losers tended to give up earlier if there was a difference in weight between two piglets. In addition, on a second meeting, losers of a previous contest were less likely to initiate a fight than were previous winners. It was deduced that pigs can

update their assessment of relative fighting ability as a result of victories or defeats in previous encounters.

1.2.2. Social Organisation

It is thought that dominance order reduces the necessity for aggression within groups of animals. In some species; social birds and primates, the dominance order may act as a direct aid in the protection of lower ranking individuals. Dominant individuals may act as group leaders in group defence and police strife within the group. In addition, a dominant individual is free from inhibition by other group members and so has more time to look out and respond to external stimuli (Beilharz and Zeeb, 1982). Another view is that dominance ensures that only as many individuals survive as a resource allows. In this way the dominance order may be said to represent a means of population control.

In a pair of animals, the dominant member achieves an advantage over the other member in competitive situations such as feeding and mating. However, competitive conflict is not the only form of competition; fast or sneaky subordinates can snatch an incentive before a dominant can assert itself. In addition, the motivational status of an animal is important in how it perceives a situation. For example, a sexually motivated male may continue to pursue a female regardless of the fact that a dominant male is nearby (Bernstein, 1981).

The social organisation of wild boar gives us useful information about the natural social organisation of the pig. Studies of wild boar suggest that the main core of the social group is made up of two to four females. Associated with this group are unweaned juveniles, immature 'sub-adults' and one or two boars (Mendl 1994). The females distribute themselves around resources and the males distribute themselves around the females. The extent to which the social organisation of wild boar reflects that of domestic species is shown by studies of domestic species placed in natural environments. Stolba and Wood-Gush (1989) released small groups of domestic

sows with some sub-adults and a boar (all were reared under intensive conditions) into a 2.3 hectare outdoor enclosure and observed their behaviour. They found the behaviour of the pigs to be very similar to that of wild boar. Therefore, it is likely that domestic pigs attempt to adhere to this natural social organisation when kept in intensive conditions.

In intensively kept pigs there are fundamentally two types of social organisation; firstly, the teat order in suckling pigs and later the dominance order which is established after weaning (Meese and Ewbank, 1973). When previously unacquainted pigs are mixed into a group vigorous fighting occurs. This decreases within about an hour and by 48 hours after mixing a stable hierarchy is formed (Meese and Ewbank 1973). In pigs, the hierarchy is usually of a simple linear type, especially in small groups at low stocking densities (Ewbank, 1976; Brouns and Edwards, 1994). However, once formed, the hierarchy is not always stable; Meese and Ewbank (1973) found that there are frequent changes in position within middle ranks of established hierarchies which may be in the form of dominance reversals.

The expression of hierarchical relationships is sensitive to environmental conditions such as housing and method of rearing, and individual characteristics such as weight, age and the aggressiveness of individuals within a group. There seems to be some confusion in the literature over the relationship between social rank and weight. Studies on finishing pigs previously kept apart indicate that dominance order is based on weight (Ewbank, 1976). This is in accordance with Beilharz and Cox (1967) and McBride *et al.* (1964) who found strong correlation between weight at all ages, dominance value, initial weight and subsequent rank respectively. However, in these experiments groups of pigs which were previously acquainted and sometimes made up of complete litters were used. These pigs would have had the opportunity to form a dominance order and may already have weights correlated with their rank. It could be that weight has little effect on rank with pigs from separate litters, though in some cases it may play a part, for example, it would be expected that a heavy pig amongst a group of non-aggressive animals would be at an advantage.

In comparison, Meese and Ewbank (1973), in an experiment using 43 groups of pigs found no correlation between rank and initial weight. McBride *et al.* (1964) investigated the social behaviour of growing pigs and deduced that if there was a large variation in initial weight, then this may be decisive in determining social position. Small differences although giving some advantage would be far from decisive, but on the whole there was a positive correlation. They also found that initial weight and social position together influenced growth; 13% of variability accounted for by social rank.

Meese and Ewbank (1973) reported no correlation between sex and rank, although there was an excess of females in the top three ranks. Nevertheless, males were found to be more aggressive in general and hence sex could play a small part as males were frequently aggressive without attaining high ranks. Beilharz and Cox (1967) found that more consistent dominance relationships are formed in groups of males compared with females and males were dominant to females. However, sex differences could in fact have been a reflection of weight differences between sexes.

Erhard *et al.* (1997) tested pigs for individual aggressiveness using attack latency tests (see section 1.1.3.). Pigs were mixed into groups of 8 of different combinations of high and low aggressiveness. Three combinations were used, i) all high aggressive; 4 'high' pigs from one litter and 4 'high' pigs from a second litter, ii) high/low; 4 'high' aggressive pigs from one litter and 4 'low' aggressive pigs from another litter, iii) all low aggressive; 4 'low' pigs from one litter and 4 'low' pigs from a second litter. Groups consisting of all high pigs experienced the highest levels of aggression, but mixing high aggressive pigs with low aggressive pigs reduced the intensity of fighting after mixing. By mixing all low pigs together this effect was sustained and additionally speeded up group integration, as demonstrated by the willingness of unfamiliar individuals to lie adjacent to one another in the pen.

Position in the dominance order can also influence the feeding behaviour of pigs. Under restrictive feeding regimes, dominant pigs are able to eat at preferred places, at preferred times and have a higher weight gain than subordinates (Brouns and Edwards, 1994). In addition, subordinates attempting to feed are continuously displaced from the feeder causing unrest and frustration (Hansen *et al.*, 1982). However, Brouns and Edwards (1994) found that when sows were fed *ad libitum*, the low ranking sows were able to modify their feeding strategy to achieve a comparable intake with higher ranking animals. This suggests that pigs are flexible in their feeding behaviour.

1.2.3. Feeding behaviour of pigs.

Feeding patterns

Feeding behaviour can be defined as the activities involved in obtaining and ingesting food. The natural habitat for pigs is forest and scrub bush areas with easy access to water providing a varied, omnivorous diet (Graves, 1984; Signoret *et al.*, 1975). Pigs kept extensively spend a large proportion of time rooting in order to obtain food (Stolba and Wood-Gush, 1989). This is in contrast with indoor, restrictively fed pigs that may have a feeding time of just 10 min per day (Signoret *et al.*, 1975). If pigs are fed *ad libitum* they develop stable feeding patterns in terms of time of day of each visit to the feeder, the duration of each visit and the amount eaten per visit. Moreover, feeding patterns are highly individualistic in terms of size and frequency varying from frequent, short visits to the feeder to a few long feeder visits per day, and there is some repeatability between days for the same animal (Labroue *et al.*, 1994; Nielsen *et al.*, 1995). However, as pigs grow there is a trend for a gradual decrease in the number of meals per day, an increase in daily feed intake, and an increase in the rate of eating. These changes result in larger meals and longer inter-meal intervals (Bigelow and Houpt, 1988).

A diurnal pattern of eating.

Pigs have a diurnal pattern of eating and most studies have reported a bi-modal distribution for eating with peaks at the beginning and end of the light period (Feddes *et al.*, 1989; Nienebar *et al.*, 1990; de Haer and Merks, 1992; Morrow and Walker, 1994). Conversely, Young and Lawrence (1994) observed one single peak in feeding activity in the middle of the light period. Discrepancies between these studies may be due to differences in the experimental procedures such as the light-dark regime.

Temperature also plays a part in the diurnal eating pattern of pigs; the highest consumption tending to be at the coolest parts of the day (Feddes *et al.*, 1989) corresponding with the beginning and end of the light period. Therefore, it is probable that it is a combination of light and temperature that dictates the exact diurnal pattern of eating in pigs from day to day with an additional effect of variation in husbandry such as time of feeding. Temperature can also affect meal parameters; in extreme conditions, cold stressed pigs have been found to eat at a slower rate, more frequently and more per unit body weight than pigs at thermoneutral temperatures in order to maintain energy levels (Nienebar *et al.*, 1991).

Food intake and feeding pattern in pigs housed individually and in groups.

The feeding patterns of pigs housed in groups differ from those shown by individually housed pigs. de Haer and Merks (1992) and de Haer and de Vries (1993) compared the feeding patterns of individually housed pigs with pigs housed in groups of 8, and collapsed feeder visits into meals; a meal being classified as a succession of visits with a between visit interval of greater than 5 min. In both studies it was found that grouped pigs ate fewer meals per day, of a longer duration, and ate more food per meal at a faster rate than pigs housed individually. Grouped pigs have also been shown to have lower food intake and growth in comparison with individually penned pigs (Gonyou *et al.*, 1992; de Haer and Merks, 1992; Patterson, 1985).

In contrast, Neilsen *et al.* (1996a) investigated the effect of individual housing on pigs that had previously been housed in groups of 10, and found that, contrary to what was expected, when transferred to individual housing, the pigs made only a small increase to their number of daily visits to the feeder resulting in a significant increase in daily feed intake. This suggests that pigs will continue to perform a feeding pattern that they have previously used successfully even when constraints on their feeding behaviour are removed.

It is apparent that there are differences between the findings of studies that have compared the two housing regimes on different pigs and the study of Nielsen *et al.* (1996a) that subjected the same pigs to the different housing systems. Hence pigs' feeding behaviour may be affected by previous experience, suggesting that feeding patterns are not flexible when pigs are placed in a new environment. It is evident that feeding patterns differ to some extent between individually and grouped pigs. The physical and social factors that may be responsible for this difference are discussed below.

The thermal environment.

It would be expected that the requirement for food of group housed and individually housed pigs might differ due to differences in energy demands. Group housed pigs require more energy for higher activity levels than individually housed pigs, but spend less energy keeping warm as they are able to huddle. Hence the requirement from food to keep warm should decrease when pigs are group housed. However, pigs kept in a thermally stable environment still decrease their food intake and consequently, it seems unlikely that it can explain the decrease in intake and growth seen in group housed pigs (Morgan *et al.*, 1999).

Group size

Petherick *et al.* (1989) compared the performance of growing pigs in groups of 6, 18 and 36. They found that group size had no effect on food intake, but food conversion efficiency was poorer in the group of 36 compared with those in the groups of 6 and 18. In addition, the difference between groups was greatest for a period just after

grouping, suggesting that large groups take longer to integrate than smaller groups, but the effect is not long lasting. Therefore, once the social organisation of a group had stabilised, the effects of group housing on production levels were not significant.

This is consistent with work by Nielsen *et al.* (1995) who suggested that group housed pigs with a single space feeder modify their feeding behaviour when group size reaches 20 in response to increased competition. They modify their feeding behaviour by eating less frequently, more at a time and at a faster rate, resulting in a similar daily intake, growth rate and food conversion ratio for all group sizes. Consequently, Nielsen (1999) suggested that changes in feeding behaviour, particularly eating rate, may reflect concomitant changes in the social environment. However, this has not been experimentally tested and assumes that the feeding pattern of individually housed pigs is in fact a 'preferred' pattern and not one that indicates stress due to social isolation.

It seems, therefore, that group size is not important in terms of production in a non-space restricting environment, once the group has established a stable social organisation. However, the social stress levels of pigs in large groups is high, and high stocking densities and insufficient feeding space could exacerbate stress levels leading to reduced welfare and health problems in the long term. It is possible that it is the mixing of pigs *per se* rather than group housing that is responsible for the reduced intake and gain observed in group housed pigs. Indeed, Hessing and Tielen (1994) found that the mixing and relocation of growing pigs had detrimental effects on average daily gain, especially when relocated to a sub-optimal temperature (14°C). The social stress of integration with unfamiliar animals may therefore contribute to the reduced feed intake and average daily gain observed when pigs are group housed.

Stocking density

High levels of aggression can cause an increase in adrenaline levels resulting in a decrease in food intake, and this is apparent when pigs are first mixed into groups

(Forbes, 1995). It would be expected that at high stocking densities this high level of aggression would be maintained due to a high frequency of social interaction. Furthermore, group integration might be slower than in groups where more space is available for dominance relationships to be established. However in severe space restriction (1.2m²/pig, mean pig weight 25 kg) aggression and exploration levels have been found to be lower, and time spent feeding higher than at a lower stocking density (1.52 m²/pig, Meunier-Salaun *et al.*, 1987). It was suggested that this reflects the flexibility of social structures in stressful environmental conditions; the pigs adopt an avoidance strategy in order to prevent the escalation of aggression. These results also imply that there may be a correlation between aggression levels and time spent feeding. However, Hyun *et al.* (1998) in a study on pigs of mean weight 35.8 kg, housed at higher stocking densities than those in Meunier-Salaun and co-workers' study found that crowded pigs (0.25m²/pig) made fewer visits to the feeder of a longer duration with a higher food intake per visit compared to uncrowded pigs (0.56m²/pigs). In addition, although daily feed intake was not affected by crowding, the weight gain:food intake ratio was reduced in the crowded pigs. This suggests that the feeding pattern is affected by high stocking densities. However, the stocking densities in the experiments described here differed greatly and other factors such as number of feeders would also contribute to feeding pattern and food intake.

Feeder spacing, situation and design.

Nielsen *et al.* (1996b) compared the feeding patterns of growing pigs housed in groups of ten with access to either a single space or four space feeding trough. Pigs given a four space feeder made more frequent visits to the feeder of a shorter duration, and consumed less food per visit than pigs provided with a single space feeder. This implies that by lowering competition levels by decreasing the pig:trough ratio, pigs were able to feed in a less constrained way as demonstrated by feeding patterns similar to that of individually housed pigs. In addition, high levels of allelomimetic feeding were observed in groups with four feeder spaces, and this may be due to social facilitation.

Social facilitation results in a synchronisation of feeding, and complete isolation is thought to depress food intake due to a lack of social facilitation (Hsia and Wood-Gush, 1983). There is some disagreement in the literature on the prevalence of social facilitation in pigs; some of the inconsistencies in results probably being due to differences in experimental designs and procedures. Feddes *et al.* (1989) found that only 30-40% of feeder use was concurrent during times of peak feeder use indicating that social facilitation is not apparent in group housed pigs. Conversely, Hansen *et al.* (1982) in a study of the behaviour and performance of pigs fed from one or several feeders found social facilitation to be particularly apparent during the morning and afternoon coinciding with the diurnal peaks of feeding behaviour previously discussed. Social facilitation at peak times led to strong competition and an increase in aggressive behaviour, but this was less pronounced in groups provided with several feeders. Therefore, it seems to be important for a balance to be struck between the amount of social facilitation and the level of competition that occurs in a group situation if the maximum food intake is to be achieved.

Hsia and Wood-Gush (1983) subjected growing pigs to four different treatments with varying opportunities for the occurrence of social facilitation and competition. It would be expected that conditions that allowed social facilitation without competition would enhance food intake. However, the results indicated that mild competition in groups with a stable linear hierarchy leads to a greater intake of food in a shorter time. Hence, mild competition might be advantageous in terms of food intake, but in cases where competition is fierce, synchronisation of feeding might result in a certain individual not being able to feed at its preferred time due to insufficient trough space. Moreover, this individual may not take the opportunity to feed at less busy times due to the motivation to remain with the rest of the group. The extent to which the thwarting of a preferred feeding pattern affects the well-being of individual pigs depends on the flexibility of their feeding behaviour.

Morrow and Walker (1994) investigated how the number and position of single-spaced feeders affects performance and feeding behaviour of growing pigs housed in groups of 20. The provision of two feeders increased feed intake but had no significant effects on growth or feed conversion ratio. In addition, total feeder occupation time and the number of visits to the feeder were increased with two feeders, while the number of displacements and the amount of queuing were less than with a single feeder. Placing two feeders 2m apart rather than side by side had no significant effects on feed intake or growth but feed conversion ratio was improved by 4%. This improvement was associated with fewer and longer visits to the feeder. Feeder design can also affect feeding patterns of pigs. If feeders are modified so that the race is enclosed by a head guard, the length of each visit and the amount of food consumed per visit increases compared with open races, (Nielsen, 1995). This is consistent with work on rats by Levitsky (1974) who demonstrated that if the accessibility of food supply is hindered by imposing a barrier, then the feeding frequency decreases and the size of the meal increases proportionally.

It is a recurring theme in this review that if social constraint is increased by increasing group size, increasing stocking density, or decreasing the amount of protection from other pigs, feeding variables are altered in the direction of fewer feeder visits to the feeder of a longer duration and an increase in eating rate. Therefore, as previously mentioned, a change in feeding pattern may be indicative of a stressful environment.

1.2.4. Social Stress

In addition to the thwarting of feeding behaviour, high levels of aggression and the disruption of the social organisation of a group can result in social stress. Social stress can occur in group housed pigs and may develop when social interactions are uncontrollable or unpredictable resulting in an altered function of the hypothalamic-pituitary-adrenal system and reduced metabolic efficiency (Wiepkema and Schouten, 1990). Social stress is worsened in situations such as crowding or if there is a lack of

resources, it can also occur when the social skills of penmates are poorly developed (de Jong *et al.*, 1996). Social isolation can also cause stress; Barnett *et al.* (1981) found that pigs penned individually showed an increase in adrenocortical activity.

Decreased growth rate is a common indicator of social stress (Tan and Shackleton, 1990; Hessing and Tielen, 1994). In addition, measures such as onset of puberty, expression of oestrous behaviour and basal levels of cortisol (De Jonge *et al.*, 1996), and changes in feeding behaviour (Nielsen, 1999) can be measured to estimate social stress levels.

Long lasting social stress is not seen often except in conditions of extreme crowding and in dynamic grouping systems. Composition of the social group in rats (Taylor *et al.*, 1987) can affect stress levels of individuals within the group. Groups of all male animals have been found to have increased adrenocortical axis function, but the presence of females obscured the adrenocortical axis stimulation. The social status of an individual within a group is an important determinant of its response to social stress. In general, subordinate males show an increased activity of the adrenocortical axis demonstrated by increased corticosteroid levels and enlarged adrenals, whereas dominant males have a hyperactive sympathetic nervous system.

It has been found that individual animals react differently to social stress situations using different physiological and behavioural patterns which depend on the predictability of the situation and the animal's ability to control it (Henry and Stephens, 1977). It has been reported that top-ranking animals elicit more aggression in social confrontation tests and show higher plasma catecholamine concentrations accompanied by a delayed increase in plasma cortisol compared with bottom ranking pigs (Otten *et al.*, 1997). This suggests that it is the level of aggression elicited that determines the amount of social stress suffered.

Therefore, lower ranking individuals are not always worse off than those dominating them. Indeed, Mendl and Deag (1995) proposed that individuals of different ranks

may be following an alternative strategy. Some individuals in groups of pigs display very low levels of aggression in comparison with group members. These individuals experience low priority of access to resources, but suffer less adverse physiological and reproductive consequences (Mendl *et al.*, 1992). It is suggested that middle ranking individuals, who continue to behave in an aggressive, competitive manner, despite their inability to win over higher ranking individuals, suffer more in terms of increased indicators of physiological stress and related reproductive and health problems than subordinates who adopt alternative strategies. Hence, there are two ways of responding to subordination; accept a low ranking position or continue to resist subordination.

1.3. Conclusions

From the above review it can be concluded that aggression is important in determining social organisation when unfamiliar pigs are mixed into groups. However, excessive levels of aggression results in physical damage, stress and a decrease in production and welfare levels. The level of aggression within a group at mixing and beyond can be affected by factors such as stocking density, group size, and the characteristics of individuals within the group. Feeding behaviour is also affected by these factors and there are large differences in feeding behaviour between group housed and individually housed pigs. This suggests that when group housed, the feeding behaviour of pigs is constrained by other group members. By investigating the relationship between feeding behaviour, aggression and social organisation, social factors responsible for the difference in feeding behaviour between pigs housed as individuals and in groups might be identified. Furthermore, it may be possible to manipulate the group environment such that production and welfare levels are maximised.

1.4 General aim of thesis:

To determine how group housing and social organisation affect the feeding behaviour of growing pigs and the consequences for welfare and production.

This aim is addressed by considering the following questions:

1. Are feeding patterns flexible?

- If grouping puts constraints on feeding behaviour in terms of time of access to the feeder, how well do pigs adapt to a change in time of access food?
- Are there individual differences in behavioural reaction to restricted feeding between pigs that might indicate differences in adaptability and that have implications for welfare?

2. How does grouping unfamiliar pigs affect feeding behaviour?

- How are feeding behaviour, time budget, development of social behaviour and production levels of previously individually housed pigs affected by group housing?
- What are the causal factors for any differences in feeding behaviour between individually and group housed pigs?

3. How does group composition affect feeding behaviour?

- Does the aggressiveness of individuals within a group affect feeding behaviour, social behaviour, production and stress levels?

4. Does grouping and group composition affect meal patterns?

- Meal patterns describe how visits to the feeder are arranged into meals. Are there any differences in meal pattern between pigs in individual and group housing?

Are there any effects of group composition on meal patterns?

The flexibility of feeding patterns in individually housed pigs.

2.1. Introduction

Individual pigs develop stable feeding patterns in terms of time of day of each visit to the trough, the time spent per visit and food intake per visit. These feeding patterns are highly individualistic in terms of frequency and size varying from a few long meals per day to many short meals per day (Labroue *et al.*, 1994; Nielsen *et al.*, 1995).

When pigs are group housed, individuals may be denied access to the feeder at preferred times due to the presence of other group members. Indeed, when compared to individually housed pigs, group housed pigs eat less frequent, but larger meals (de Haer and de Vries, 1993). This suggests that individuals have to alter their feeding behaviour due to constraints imposed by group living. Therefore, it would be advantageous for pigs to have flexible feeding patterns in order to decrease any adverse effects of group feeding. Nielsen *et al.* (1996a), in a study to investigate individual variation in feeding patterns in group housed pigs, found that feeding frequency showed only a small increase when group housed pigs were transferred to individual housing. It was suggested that feeding patterns were not flexible and that pigs will adhere to a pattern that has been successful in the past, even if an environmental change requires greater alteration to be made.

It is expected that restrictively fed pigs would be more subject to stress in response to thwarting of their desired pattern than pigs fed *ad libitum* and express more abnormal behaviours as caused by frustration. In work to investigate the effects of frustration of feeding behaviour in growing pigs, Lewis (1998) found that thwarting of feeding behaviour by providing empty feeders, increased levels of activity, sitting, playing, and nosing of other pigs. In addition, when feeder lids were bolted down, an increase in plasma cortisol concentration was recorded.

Appleby and Lawrence (1987) reported food restriction to be a cause of stereotypies in tethered sows; these may reflect thwarting of feeding behaviour. Moreover, observations of broilers by Kostal *et al.* (1992) showed variation between restrictively fed birds in terms of varying amounts and types of stereotypies and in the amount of time spent resting. Therefore, individual differences between pigs might indicate that some pigs can cope better with a change in time of access to food than others.

The aim of the present experiment was to assess the flexibility of feeding patterns of pigs by restricting their time of access to the feeder. If feeding patterns are flexible then it would be expected that pigs would be able to re-adjust their feeding patterns to that seen under *ad libitum* conditions after a period of restricted feeding i.e. there would be no difference in feeding patterns before and after a period of restriction. In addition, by recording the behaviour of individuals I hoped to determine if there are individual differences in behavioural reaction to restricted feeding between pigs which might indicate differences in adaptability and have implications for welfare.

2.2. Materials and methods

2.2.1. Pigs and treatments

Thirty two pigs (Large White X Landrace; start weight 24 ± 0.3 kg) were used in an experiment of two blocks (16 pigs per block) each block comprising three, two week periods. During the first period all pigs were allowed 24 hr access to food. In the second period eight of the pigs were randomly allocated to a restricted feeding regime whilst the remaining eight pigs continued on 24 hr access to food and acted as controls. In the third period all pigs were again allowed 24 hr access to food. Hence, a total of 16 pigs experienced restriction on their feeding pattern and 16 pigs acted as controls.

2.2.2. Housing

The pigs were housed individually in two rows of eight pens. Each pen had an insulated concrete floor and straw was provided. The pens were 2 x 1m and the sides were constructed of galvanised sheeting, the front consisting of a gate through which the pig could see its opposite neighbour. Each pen was equipped with a metal bowl drinker and a computerised feeder with a plastic trough suspended from a load cell. Access to the feeder was via a door which operated a switch when opened and closed. Each feeder was linked to a control box which contained a Feed Intake Recording Equipment (FIRE) system provided by Hunday Electronics Ltd. (Newcastle). This provided records of entry and exit times at each visit, thus the number and duration of visits could be calculated (the minimum timing interval was 1s). Each morning at 09.00 h records of the trough weight were taken to calculate daily food intake. The trough was then topped up with a weighed quantity of fresh food (BOCM Pauls Ltd., Renfrew: Growercare Sovereign Pellets (for pigs between 20-50kg live weight); 195g protein, 50g oil, 37.5g fibre and 50g ash per kg and Growlean Pellets (for pigs over 50kg live weight); 190g protein, 40g oil, 37.5g fibre and 50g ash per kg). During the restricted feeding period a shutter was fixed to the front of the feeder to prevent access to the door. Artificial lighting was supplied between 06.00h and 20.00h and heating and ventilation were controlled automatically.

2.2.3. Experimental procedure

The pigs were introduced to the experimental pens a few days before the start of the experiment to allow them to acclimatise to their new environment. During this time a little feed was placed on the lip of each trough to encourage the pigs to use the feeder. The experiment began when all the pigs had learnt to use the feeders and from then onwards feeding pattern and feed intake was recorded. Table 2.1 provides details of the time of access to food and the measurements taken in each period. Access to food between 11.00 and 13.00 was chosen for the restricted pigs as this is a time when there is normally a decrease in the number of visits to the feeder (Feddes

et al., 1989; Nienabar *et al.*, 1990; Morgan *et al.*, 1998) and so represents as great an alteration to feeding patterns as can be achieved during the light period. The pens were cleaned and fresh straw provided every other day between 09.00 and 10.00 h.

2.2.4. Behavioural observations

Behaviour sampling took place in the form of scan samples at five minute intervals over four, one hour sessions on each observation day. The sessions were at 09.30-10.30, 11.30-12.30, 13.30-14.30 and 15.30-16.30. At each 5 min interval, the posture (lying, sitting or kneeling and standing) and the behaviour (categories in Table 2.2) of each pig were recorded by the observer walking quietly between the two rows of pens.

Table 2.1 Summary of protocol

	Period 1	Period 2	Period 3
Feeding	All pigs <i>ad-libitum</i> access to food.	8 pigs randomly allocated to restricted access to feeder between 11:00 and 13:00. Remaining 8 pigs continue on <i>ad-libitum</i> access and act as controls.	All pigs returned to <i>ad-libitum</i> access to food.
Observation days	days 4 and 11.	days 1, 2, 4, 8 and 11.	Days 1, 2, 4, 8 and 11.
Weigh	Mondays and Fridays.	Mondays and Fridays.	Mondays and Fridays.

As Table 2.1 indicates, additional observation days were scheduled at the transition between periods to ensure more information on the behaviour of the pigs when times of access to the feeders were altered.

Table 2.2 Behavioural categories used for scan sampling

Behaviour	Description
alert	lying, sitting, kneeling or standing with eyes open, watchful but inactive.
asleep	lying with eyes closed.
rooting	manipulating the floor, straw or wall while lying, sitting, kneeling or standing.
feeding	standing, sitting or kneeling with head in feeder.
nosing	nosing neighbouring pig through gap at front or back of pens or over bars.
drinking	drinking at drinker or manipulating drinker/water.
scampering	rushes round pen, often grunting and carrying straw.
rubbing	rubbs body or head on walls etc.
feeding attempt	noses, pushes or bangs feeder shutter during times of food deprivation.
urinating, defaecating.	

2.2.5. Statistical methods

Data on feeding behaviour for each period of each block were processed using Minitab for Windows (release 11.1) to produce for each animal: the mean number of visits to the feeder, the mean duration of visits and the mean daily feeder occupation (calculated as mean number of visits x mean duration). Daily food intake was recorded as described above and food intake per visit was calculated as daily food intake/mean number of visits. Feeding rate was calculated as daily food intake/feeder occupation. Growth rate was estimated from the slope of the regression of live weight against time.

The proportion of time spent in each behaviour over each observation session was calculated using Minitab for Windows (release 11.1) and means were calculated per period across pigs. The behaviours nosing, scampering, rubbing, urinating and defaecating occurred rarely and so were excluded from further analysis. When the behaviour of pigs in Period 1 was compared with their behaviour in Periods 2 and 3, only data from Observation Days 4 and 11 were used in the analysis. The pig means for the feeding data and the scan samples were then subjected to analysis of variance using GENSTAT for Windows (release 3.2 Lawes Agricultural Trust, 1990) treating the three periods as repeated measures and then analysing the data as if the

experiment were a split plot design (Horgan and Sword, 1995). For the second part of the analysis of the scan samples, Observation Sessions 1 and 3 in each observation day were compared within and between periods also using analyses of variance.

2.3. Results

One pig in each block became ill and results from these pigs (both on the control treatment) were omitted from the statistical analysis. All significance values reported refer to overall treatment, period or interaction effects; standard errors of difference were used to locate the effects more specifically.

2.3.1. Feeding behaviour and performance

The feeding behaviour and performance of the pigs are shown in Table 2.3. The effect of treatment alone was not significant ($P > 0.05$) for any of the variables except for feeder occupancy where the pigs on the control treatment spent more time overall at the feeder than the pigs that had restricted access in period 2 ($P < 0.05$). There were highly significant effects of period and treatment by period interactions in most of the variables studied. In Period 2 the restricted pigs had fewer feeder visits per day ($P < 0.001$) of a longer duration ($P < 0.01$) with a higher food intake per visit ($P < 0.001$) than the control pigs. Feeder occupancy was shorter for the restricted pigs in Period 2 than for the control pigs ($P < 0.001$). Although an increase in visit duration ($P < 0.01$), and a decrease in food intake ($P < 0.001$) was observed for the restricted pigs from Period 1 to Period 2, on both treatments visit duration and feeder occupancy decreased ($P < 0.001$) and food intake per visit and feeding rate increased ($P < 0.001$) over time from Period 1 to Period 3.

As would be expected, as the pigs grew from Period 1 to Period 3 daily food intake increased ($P < 0.001$) and the food conversion ratio became poorer ($P < 0.001$). In Period 2 the daily food intake and live weight gain of the restricted pigs were lower than for the control pigs ($P < 0.001$). However, in Period 3, the daily food intake and live weight gain of the restricted pigs were higher than for the control pigs ($P < 0.001$).

Table 2.3 Feeding behaviour and performance of control (C) and restricted pigs (R). Control pigs had 24h access to food throughout and Restricted pigs had 24h access in periods 1 and 3 and 2h access in Period 2.

	Period (P)	Treatment (T)		sed	T Sig.	sed	P Sig.	sed	TXP Sig.
		C	R						
Visits/day	1	66.2	65.6						
	2	70.1	31.0						
	3	68.1	67.1						
	mean	68.1	55.5	9.81	n.s.	4.29	***	6.07	***
Visit duration (sec)	1	79.3	74.4						
	2	64.5	98.3						
	3	47.5	61.7						
	mean	63.8	78.1	15.06	n.s.	5.66	***	8.00	**
Food (g/visit)	1	27.6	28.1						
	2	33.3	64.9						
	3	36.8	43.9						
	mean	32.6	45.6	7.81	n.s.	3.60	***	5.10	***
Feed rate (g/min)	1	21.9	24.7						
	2	32.8	39.3						
	3	47.7	50.9						
	mean	34.1	38.3	2.64	n.s.	2.12	***	3.00	n.s.
Feeder occupancy (min/day)	1	66.7	62.1						
	2	57.8	35.9						
	3	45.1	51.3						
	mean	56.5	49.7	3.05	*	2.39	***	3.38	***
Food intake (g/day)	1	1419	1477						
	2	1827	1364						
	3	2053	2407						
	mean	1767	1749	67.5	n.s.	40.2	***	56.8	***
Weight gain (g/day)	1	947	964						
	2	997	828						
	3	927	1053						
	mean	957	948	33.8	n.s.	32.1	n.s.	45.3	***
Food conversion ratio (kg food/kg gain)	1	1.50	1.54						
	2	1.85	1.66						
	3	2.23	2.32						
	mean	1.86	1.84	10.049	n.s.	0.047	***	0.066	**

2.3.2. Flexibility of feeding behaviour

An indication of the flexibility in the feeding behaviour of the pigs can be gained by comparisons between Period 1 and Period 3 which were respectively before and after the imposition of the restricted time of access. Although there was a marked reduction in the number of daily feeder visits in Period 2, in Period 3 the pigs recovered to the values seen in Period 1 (Table 2.3). The duration of feeder visits was slightly lower in Period 3 than Period 1 but this was also seen in the control pigs. There was a large increase in the food intake per visit during Period 2 but this

reduced in Period 3 to be somewhat higher than in Period 1 but the control pigs also showed a steady increase throughout the course of the experiment. Feeder occupation showed a similar pattern of change to that seen in the control pigs. The pattern of timing of the feeder visits in Period 1 was similar to that seen in Period 3 for both the treatment and control pigs (Figs 2.1A-D). The only slight difference, seen in both groups of pigs, was a small increase in the peak at 09.00h and decrease around 15.00 to 19.00h in Period 3 compared to Period 1. This may have been due to the pigs becoming accustomed to receiving fresh food at 09.00h. Taking these observations together, it is apparent that the feeding behaviour of the pigs was flexible in that the pigs that experienced a period of restricted access resumed their previous behaviour or showed the same trend as seen in the control pigs.

There was a marked reduction in feeder visits seen on the day of imposition of the restriction, irrespective of the mean number of daily visits in the previous 14 days, as can be seen from the range of pigs in Fig. 2.2. During the period of restricted access some pigs showed a slow increase in the number of visits as the period progressed but the effect was not generally large. On the day of the removal of restriction the original number of visits was resumed (and sometimes exceeded) and then remained fairly steady for the remainder of the period.

The daily food intakes over the first Period were similar for the control and restricted groups of pigs (Fig. 2.3) but the restricted pigs consumed significantly less in Period 2 (Table 2.3) and the effect was immediate on imposition of the restriction. Food intake was severely reduced initially and then began to recover during the course of Period 2 but, even after 14 days, the pigs were still not consuming as much as the controls. Immediately the restriction to access was removed, on the first day of Period 3, the food intake of the previously restricted pigs recovered to be at a level above that of the control pigs and remained at a higher level for the remaining 14 days of the experiment.

Fig. 2.1 Number of feeder visits according to time of day made in Periods 1 (—) and 3 (-----) by (A) Block 1 pigs that had restricted access in Period 2; (B) Block 2 pigs that had restricted access in Period 2; (C) Block 1 control pigs; (D) Block 2 control pigs.

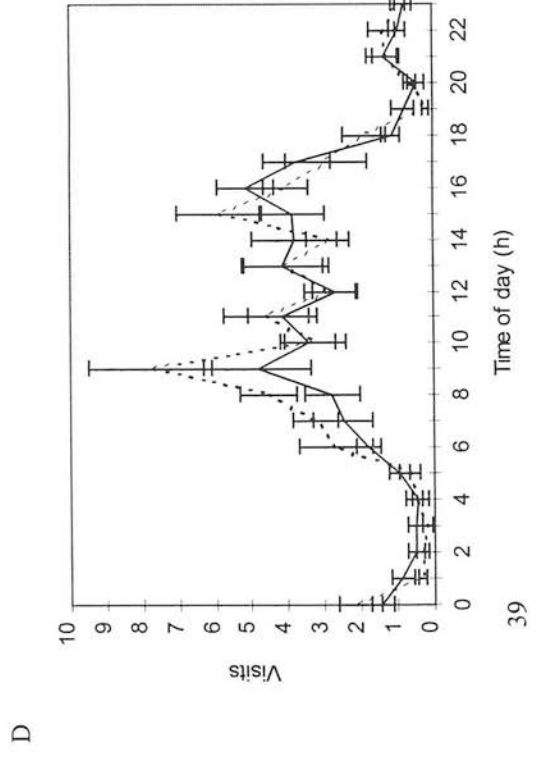
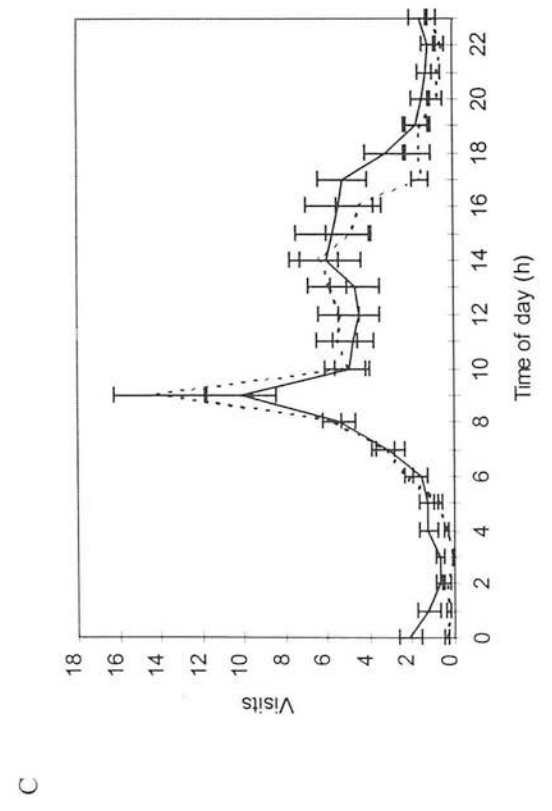
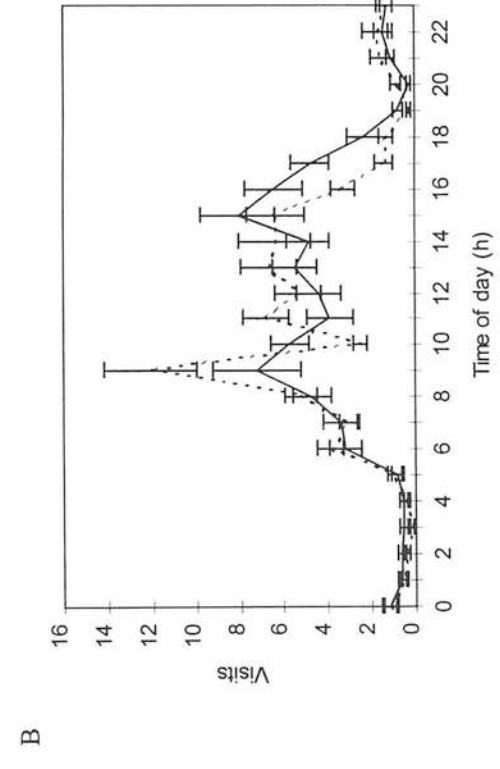
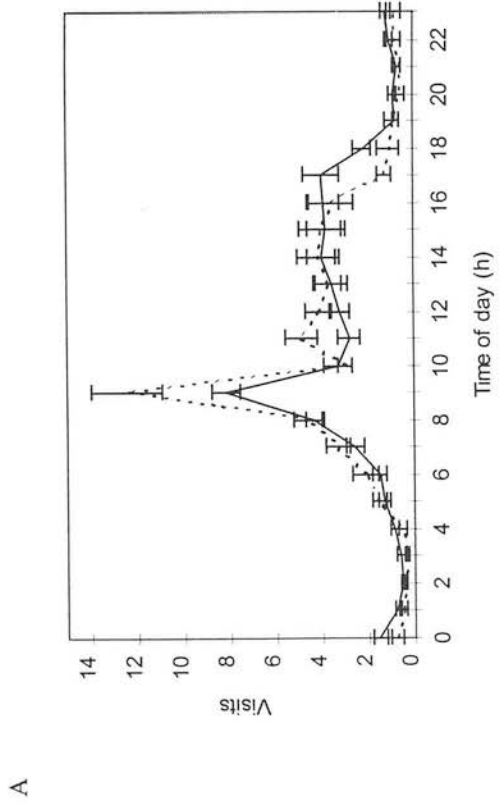


Fig. 2.2. Number of feeder visits per day according to day of experiment by four pigs that had restricted access in Period 2 (Days 15 to 28).

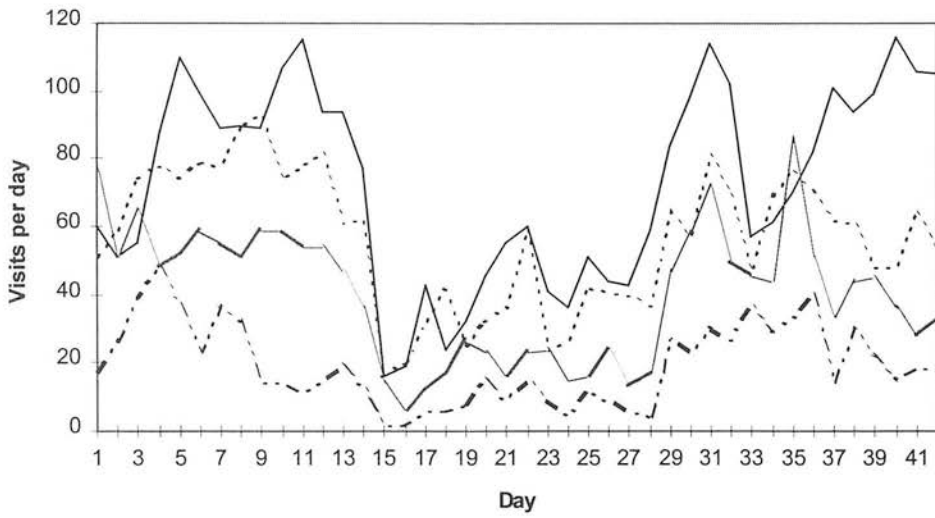
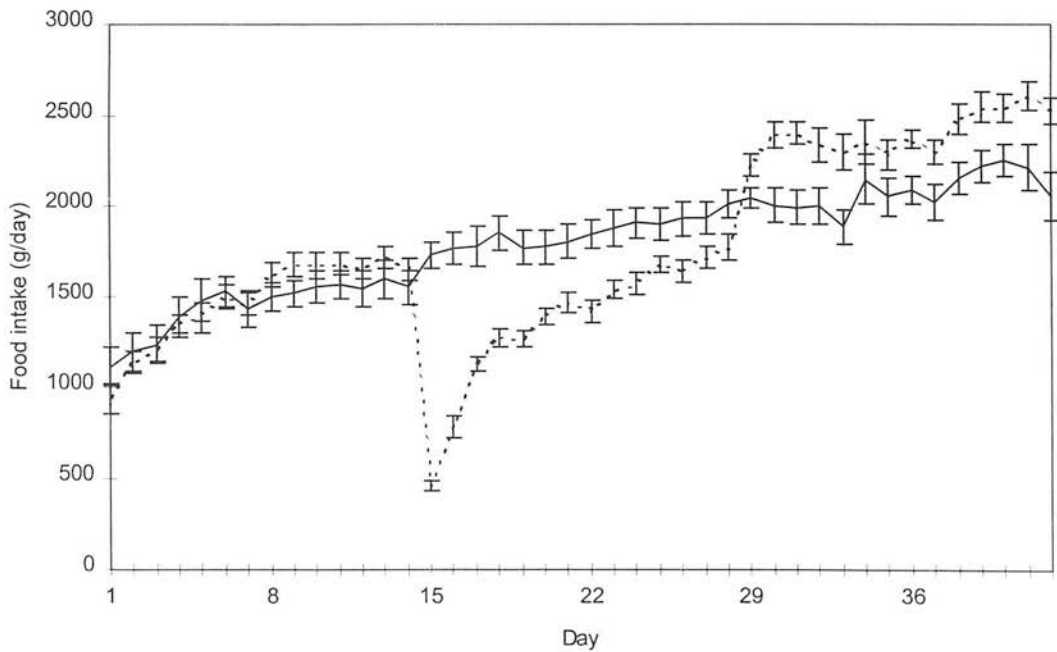


Figure 2.3. Food intake (g/d) according to day of experiment for control pigs (—) and pigs that had restricted access (-----) in Period 2 (days 15-28).



2.3.3. Time budgets

The mean proportion of total observed time spent in each behaviour per period across pigs was calculated for restricted and control pigs and is shown in Table 2.4. Pigs spent the majority of time sleeping and rooting and there were large variations between pigs for all the behaviours recorded. The effect of treatment alone was not significant for any of the behaviours recorded, however, there were significant effects of period for most behaviours recorded and some small treatment by period interactions. The proportion of the total observed time spent alert decreased over periods for control and restricted pigs ($P < 0.05$). The proportion of total observed time spent sleeping increased, and proportion of time spent rooting decreased for all pigs during Period 2, ($p < 0.001$). However, restricted pigs spent less time sleeping, and more time rooting than the control pigs in Period 2 ($P < 0.05$). The proportion of observed time spent feeding decreased for all pigs in Period 2 ($p < 0.001$), and the restricted pigs spent more time feeding in Period 3 than the control pigs ($P < 0.05$). There were no significant differences between treatments, periods or treatment by period interaction for the proportion of total observed time spent drinking.

Table 2.4 Mean proportion (%) of total observed time control and restricted pigs spent in each behaviour across each period.

Behaviour	Period	Control	Restrict	T sed	T sig	P sed	P sig	T X P sed	T X P sig
alert	1	3.91	3.37						
	2	3.15	3.44						
	3	2.79	2.13						
	mean	3.28	2.98	0.583		0.414	*	0.586	
asleep	1	28.86	31.79						
	2	44.56	37.25						
	3	38.40	33.82						
	mean	37.27	34.29	3.308		1.778	***	2.515	*
rooting	1	55.43	53.54						
	2	42.70	50.30						
	3	47.82	50.73						
	mean	48.65	51.52	3.416		1.790	***	2.532	*
feeding	1	8.36	8.41						
	2	6.47	5.02						
	3	7.98	10.17						
	mean	7.60	7.87	0.693		0.721	***	1.020	*
drinking	1	1.81	1.74						
	2	2.33	1.43						
	3	2.36	2.30						
	mean	2.17	1.83	0.345		0.298		0.422	

Comparisons of observation sessions 1 (9.30-10.30) and 3 (13.30-14.30) between periods 1, 2 and 3.

It was likely that some of the effects of restricted feeding were being masked by considering the behaviour data of each day as a whole. Therefore, Observation Sessions 1 and 3 were analysed in more detail as they gave information about the behaviour of the pigs before and after the restricted pigs were allowed access to food. Table 2.5a shows the results when behaviour in Observation Session 1 was compared between periods. In Session 1, Period 2, the restricted pigs spent more time rooting ($P<0.05$) and less time sleeping ($P<0.05$) than the control pigs. In addition there was a trend for the restricted pigs to spend more time alert in Session 1, Period 2 ($P=0.067$). In contrast, when behaviour in Observation Session 3 was compared between periods (see Table 2.5b) there were no effects of period, but restricted pigs slept more in Session 3, Period 2, than the control pigs ($P<0.05$). Therefore, the main effects of Period were in Observation Session 1, prior to access to food for the restricted pigs rather than in Observation Session 3, after pigs had fed. The results from these comparisons and other comparisons between sessions and periods are summarised in Table 2.6a and 2.6b. In some cases there were also effects of day, session, treatment interactions, however these seemed to reflect the variability between days within periods rather than comparisons between periods and sessions which were of interest here. Furthermore, the biological significance of these interactions was difficult to discern. As can be seen from Tables 2.5-2.6, when timebudgets were compared between Periods 1 and 3, pigs either resumed their previous behaviour when returned to 24 hour access to food in Period 3, or showed a trend similar to the control pigs.

Table 2.5a Mean proportion (%) of observed time spent in each behaviour by the control and restricted pigs in Observation Session 1 Periods 1, 2 and 3.

Behaviour	Period	Control	Restricted	T sed	T sig	P sed	P sig	T X P sed	T X P sig
alert	1	6.01	2.40						
	2	3.36	5.77						
	3	3.36	2.40						
	mean	4.25	3.52	1.111		1.267		1.791	
asleep	1	34.1	40.6						
	2	63.7	51.4						
	3	59.1	65.4						
	mean	52.3	52.5	4.630		3.510	***	4.960	*
rooting	1	51.4	48.1						
	2	26.0	38.9						
	3	28.8	23.1						
	mean	35.4	36.7	4.250		3.520	***	4.980	*
drinking	1	1.20	0.72						
	2	1.44	0.24						
	3	1.44	1.68						
	mean	1.36	0.88	0.444		0.509		0.719	

Table 2.5b. Mean proportion (%) of observed time spent in each behaviour by the control and restricted pigs in Observation Session 3 Periods 1, 2 and 3.

Behaviour	Period	Control	Restricted	T sed	T sig	P sed	P sig	T X P sed	T X P sig
alert	1	5.77	3.60						
	2	3.60	3.60						
	3	3.12	1.68						
	mean	4.17	2.96	1.191		1.001		1.416	
asleep	1	22.4	23.3						
	2	20.2	30.0						
	3	26.4	18.5						
	mean	23.0	24.0	4.340		3.170		4.490	*
rooting	1	59.9	59.1						
	2	64.7	62.5						
	3	57.9	63.2						
	mean	60.8	61.6	4.460		3.360		4.760	
drinking	1	2.40	1.68						
	2	3.12	1.44						
	3	3.12	3.84						
	mean	2.88	2.32	0.178		0.777		1.098	

Table 2.6a Behaviour of restricted (R) pigs and control (C) pigs in Observation Sessions 1 (09.30-10.30h) and 3 (13.30-14.30h), within Periods 1, 2 and 3.

Within Period 1	Within Period 2	Within Period 3
<p>Effect of treatment</p> <ul style="list-style-type: none"> □ No effects <p>Effect of session</p> <ul style="list-style-type: none"> □ Pigs slept more in Session 1 than in Session 3 P<0.001. □ Pigs rooted more in Session 3 than in Session 1 P<0.01. □ Pigs spent more time feeding in Session 3 than in Session 1 P<0.05. 	<p>Effect of treatment</p> <ul style="list-style-type: none"> □ R pigs slept less than C pigs in Session 1. P<0.05 □ C pigs spent more time drinking than R pigs P<0.05. <p>Effect of session</p> <ul style="list-style-type: none"> □ Pigs slept more in Session 1 than in Session 3 p<0.001. □ Pigs rooted more in Session 3 than in Session 1 P<0.001. □ Pigs spent more time drinking in Session 3 than in Session 1 P<0.001. <p>Restricted pigs made more feeding attempts in Session 1 than in Session 3. P<0.01.</p>	<p>Effect of treatment</p> <ul style="list-style-type: none"> □ R pigs rooted less than C pigs in Session 1. P<0.05. □ R pigs spent more time feeding than C pigs P<0.05. <p>Effect of session</p> <ul style="list-style-type: none"> □ Pigs slept more in Session 1 than in Session 3 P<0.001. □ Pigs rooted more in Session 3 than in Session 1 P<0.001. □ Pigs spent more time drinking in Session 3 than in Session 1 P<0.001.

Table 2.6b Behaviour of restricted (R) pigs and control (C) pigs in Observation Sessions 1 (09.30-10.30h) and 3 (13.30-14.30h), between Periods 1 and 2; 2 and 3; and 1 and 3.

Between Periods 1 and 2	Between Periods 2 and 3	Between Periods 1 and 3
<p>Session 1</p> <p>Effects of period</p> <ul style="list-style-type: none"> □ All pigs slept more in Period 2 than in Period 1 P<0.001. □ All pigs rooted less in Period 2 than in Period 1 P<0.001. <p>Effects of treatment × period</p> <ul style="list-style-type: none"> □ In Period 1, R pigs spent less time alert than C pigs P<0.05. □ In Period 2, R pigs spent less time sleeping than C pigs P<0.01. □ In Period 2, R pigs spent more time rooting than C pigs P<0.05. □ 	<p>Session 1</p> <p>Effects of period</p> <ul style="list-style-type: none"> □ R pigs rooted more in Period 2 than in Period 3. <p>Effects of treatment × period</p> <ul style="list-style-type: none"> □ In Period 2, R pigs slept less than C pigs P<0.05. □ In Period 2, R pigs spent less time drinking than C pigs P<0.01 □ In Period 3, R pigs spent more time drinking than C pigs P<0.01. 	<p>Session 1</p> <p>Effects of period</p> <ul style="list-style-type: none"> □ All pigs slept more in Period 3 than in Period 1 P<0.001 □ All pigs rooted less in Period 3 than in Period 1 P<0.001. <p>Effects of treatment × period</p> <ul style="list-style-type: none"> □ No effects
<p>Session 3</p> <p>Effects of period</p> <ul style="list-style-type: none"> □ No effects <p>Effects of treatment × period</p> <ul style="list-style-type: none"> □ No effects 	<p>Session 3</p> <p>Effects of period</p> <ul style="list-style-type: none"> □ All pigs rooted less in Period 3 than in Period 2 P<0.05 <p>Effects of treatment × period</p> <ul style="list-style-type: none"> □ In Period 3, R pigs spent more time drinking than C pigs P<0.05. 	<p>Session 3</p> <p>Effects of period</p> <ul style="list-style-type: none"> □ No effects <p>Effects of treatment × period</p> <ul style="list-style-type: none"> □ No effects

2.3.4. Feeding attempts in restrictively fed pigs.

Fig. 2.4 shows the mean proportion of feeding attempts across pigs per day of observation in Period 2. The proportion of observed time making feeding attempts was highest on the second day of restriction and then declined. In addition pigs spent a larger proportion of time making feeding attempts in Observation Session 1 than in Observation Session 3 (see Table 2.6). However, there was a large variation between pigs. Some pigs started off on the first day of restriction making a large number of attempts but this number usually decreased over time in Period 2. Other pigs continued to make a large number of attempts through till the end of Period 2 whereas a few pigs made hardly any feeding attempts during the observed time. For examples refer to Fig 2.5.

Figure 2.4. Mean proportion of scans per observation day that restricted pigs made feeding attempts in Period 2.

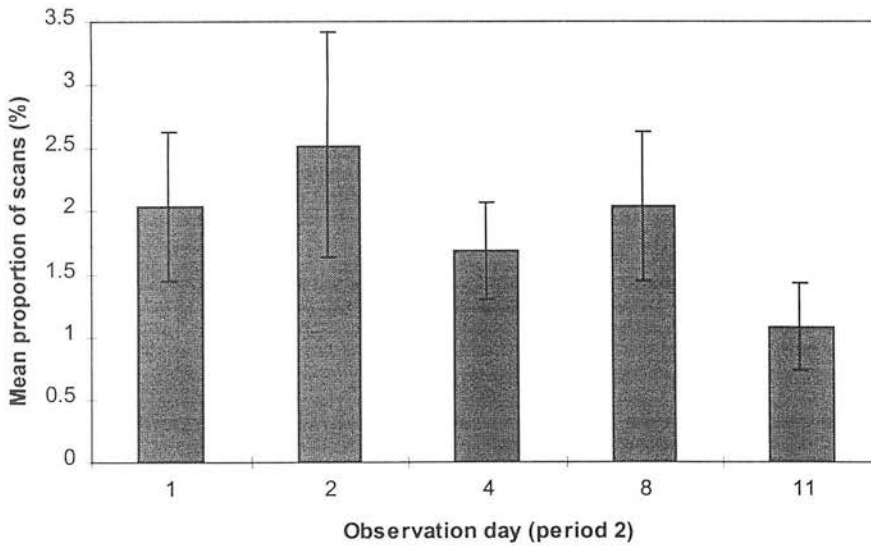
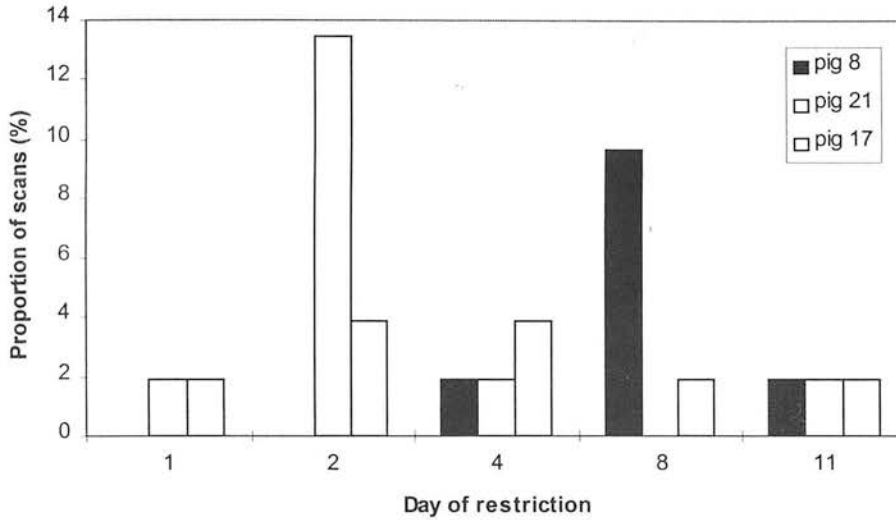


Figure 2.5. Proportion of scans that pigs 8, 21, and 17 made feeding attempts on each of the 5 observation days in Period 2.



2.4. Discussion

2.4.1. Feeding behaviour

When the pigs had free access to food they visited the feeder between 65 and 70 times a day, as has been reported by de Haer and de Vries (1993). The timing of visits was similar to that seen in group housed pigs with a peak in the morning, followed by a trough around mid day and a broader peak of activity in the afternoon (Nielsen *et al.*, 1996a; Morgan *et al.*, 1998). As would be expected, the restricted time of access to the feeder from 24h to 2h in Period 2 resulted in a substantial reduction in the number of daily visits to the feeder. However, on removal of the restriction in Period 3 the number of visits returned to the level in Period 1 over a short period of time and were the same as for the control pigs which had not experienced the restriction. Thus the pigs' feeding behaviour appears to be more flexible than suggested by Nielsen *et al.* (1996a) who found that group housed pigs, when subsequently housed individually showed only a small increase in the number of visits. They concluded on the basis of this result that feeding patterns in the pig, once established are resistant to change. However, it is possible that grouping pigs puts constraints on their feeding patterns that are different from those imposed by a restricted feeding regime. A further indication of the flexibility in the pigs' feeding

behaviour is shown by their ability to adapt over a short time after the restriction was removed.

When the period of restriction was imposed the pigs showed only a slow adaptation to the new conditions in terms of daily food intake, which did not attain the levels seen in the controls, even after 14 days. In Period 1 the pigs occupied the feeders for about 60 min out of the 24h available but in period 2, even though they had a full 120 min available for feeding, they did not use this amount of time for this purpose. The mean feeder occupation time was only 35.9 min. Thus it is apparent that, although the pigs were hungry, they could not spend the full time available in feeding activity. In the first couple of days this may have been due to the pigs not expecting the restriction but they would have learnt this quickly and would be expected to maximise the time available to eat. That they did not do this is likely to be a consequence of the limitation of stomach capacity to process large quantities of food in a short time. Food intake is controlled in part by the rate of gastric emptying (Rayner and Gregory, 1989). Kyriazakis and Emmans (1995) found that food intake was immediately depressed in pigs that were switched from a standard cereal-based food to a bulky food. However there was an adaptation over time as food intake recovered and this response was also seen here as food intake approached that of the controls after 14 days.

2.4.2. Time budgets

Analysis of the mean proportion of observed time spent in each behaviour indicated that when all the observation sessions were taken in to account there was little difference between the restricted and control pigs or between periods. However, when individual observation times were analysed in detail more disruption was revealed as described below.

Over all three periods, pigs slept more, and rooted less between 09.30h and 10.30h (Session 1), than between 13.30h and 14.30h (Session 3) indicating that all pigs were

more active in Observation Session 3 compared with Observation Session 1. However, when Observation Session 1 was compared between Periods 1 and 2, restricted pigs spent less time sleeping and more time rooting than the control pigs. Furthermore, the restricted pigs spent a larger proportion of time making feeding attempts in Session 1 compared with Session 3. These results are consistent with work by Savory and Maros (1993) who found that restrictively fed broiler breeder chickens were more active than *ad libitum* fed birds and activities that seemed to reflect feeding motivational state were walking before feeding time, and drinking and pecking the floor litter and sitting after feeding time. In addition, work by Terlouw *et al.* (1993a) on meal-fed pigs found that the pigs demonstrated an anticipatory response in the form of a decrease in blood glucose level up to 1 hour prior to the delivery of food. Therefore, in the present experiment, the pigs may have been anticipating food expressed by an increase in time spent active and alert, and showing frustration by attempting to gain access to the feeder in Observation Session 1 in Period 2.

2.4.3. Comparisons between periods.

Between Periods 1 and 2, in Session 1, the proportion of time spent sleeping decreased and rooting increased more for the restricted pigs than for the control pigs. Stress susceptible pigs have been found to spend more time manipulating their environment than normal animals (Robert and Dallaire 1986). Hence, the increase in proportion of time spent rooting in this session by the restricted pigs could be an indication of elevated stress levels. Furthermore, proportion of time spent alert increased for the restricted pigs and decreased for the control pigs in this session. These results further support the hypothesis that restricted pigs were anticipating access to food in Session 1, Period 2.

As expected, the proportion of observed time spent feeding decreased for the restricted pigs in Period 2. However, there was a similar but smaller decrease for the control pigs. It is possible that the control pigs (particularly those with restrictively

fed neighbours) were affected by the behaviour of the restricted pigs due to a lack of synchronisation of feeding as a result of decreased social facilitation compared with Periods 1 and 3. Hsia and Wood-Gush (1983) reported that increasing the opportunity for social facilitation increased food intake and decreased total feeding time; food intake being greatest when housing allowed mild competition if the hierarchy was stable. However, in the present experiment there was no evidence in the feeding data that the control pigs increased their number of visits when the restricted pigs were given access to the feeder between 11.00 and 13.00h.

In Session 1, between Periods 2 and 3, restricted pigs increased the proportion of time spent sleeping more than the control pigs, and decreased the proportion of time spent rooting less than the control pigs. It is feasible that compared with Period 2, in Period 3 restricted pigs were less agitated and stressed due to the reinstatement of 24 hour access to food. Alternatively, restricted pigs could have spent less time rooting in compensation for the observed increase in time they spent feeding in Session 1, Period 3. This is verified by an increase in food intake made by the restricted pigs in Period 3.

Control pigs spent more time drinking than restricted pigs in Session 1 of Period 2. This can be accounted for by them having a higher food intake than the restricted pigs and therefore having a larger requirement for water. The amount of water drunk is normally correlated with the amount of food ingested (Agricultural Research Council 1981). It would be expected that as the pigs increased in size, their drinking rate would increase and they would therefore spend a smaller proportion of time spent drinking. However, the restricted pigs increased the proportion of observed time spent drinking between Periods 2 and 3 in both observation sessions. It is conceivable that this was due to the increase in food intake from Period 2 to 3. There was no evidence of excessive drinking which may have indicated increased stress levels (Robert and Dallaire 1986), or unsatisfied feeding motivation. Lawrence and Terlouw (1993) suggested that in food restricted sows, sustained drinking, beyond that of metabolic requirements is probably controlled by the feeding motivational

system which may result in the redirection of feeding motivation to drinkers or chains.

Contrary to what might be expected, some pigs continued to make feeding attempts in Session 3 after they had had access to food. However, Lawrence and Illius (1989) found that the commercial level of food restriction for sows resulted in high levels of operant response suggesting that feed restriction gives rise to high and sustained levels of feeding motivation throughout the day. Hence, it could be that by being allowed access to food for only a relatively short period of time these pigs were still hungry, and eating a small amount of food increased their feeding motivation. Indeed, Rushen (1985b) reported that sows demonstrated increased stereotypic rooting and drinking in the post-feeding period and Terlouw *et al.* (1993b) found frequency of stereotypic behaviour increased after a small ration of food was provided. This may have been due to an increase in feeding motivation caused by positive feedback in the early stages of a meal. If an animal is not allowed to eat until satiation then this positive feedback overrules the negative feedback effects of the food ingested (Wiepkema, 1971). Therefore if the pigs did not take full advantage of the two hour feeding slot, as discussed previously, then they would still be left with a strong motivation to feed and hence continue to make feeding attempts even after access to food. Alternatively, pigs could have been attempting to adhere to the feeding pattern they used successfully in Period 1 when they had 24 hour access to food.

The number of feeding attempts made by the restricted pigs in period 2 was very variable between pigs. However, in general, the proportion of observed time spent making feeding attempts was greatest on the second day of restriction. On Day 1, the pigs had no previous experience of the restricted feeding regime and so could not anticipate when the feeder shutters would be removed. In addition, once the shutters had been removed, they had no concept that the shutters might be replaced in 2 hours time. Therefore any feeding attempts made would more likely be due to feeding motivation and frustration and not to anticipation. By Day 2 of restriction pigs

would have been increasingly more hungry and might also have started anticipating and learning when food would be available so the proportion of observed time spent making feeding attempts was at its highest. On subsequent days, feeding attempts decreased slightly but the extent of this varied between pigs. Anticipation rather than hunger or frustration may have been more causal in the performance of feeding attempts later in Period 2.

The variability of timing and number of feeding attempts made by individual pigs could be indicative of individual differences between pigs and different abilities to cope with the change in time of access to food. This is consistent with work by Kostal *et al.* (1992) who investigated individual variation in behaviour of restricted-fed broiler breeders and found that greatest variation between birds was shown in stereotyped pecking at the drinker, empty feeder and walls and in resting. In addition different birds specialised in stereotyped pecking at drinker or feeder. Birds which showed the most stereotyped behaviour also had lower plasma corticosterone concentrations and this points to a decrease in stress levels in these birds. Moreover, Terlouw *et al.* (1991) suggested that group feeding competition tests and long term restrictive feeding and housing regimes induced variable behavioural responses indicating individual differences between pigs.

It is difficult to gauge the level of stress and frustration of the pigs during the period of restriction. Stress susceptible pigs have been found to spend more time manipulating their environment than normal animals (Robert and Dallaire, 1986). Hence, the increase in proportion of time spent rooting in Session 1, Period 2 by the restricted pigs could be an indication of elevated stress levels. Although feeding attempts were observed, no other abnormal behaviours such as persistent rooting at the same spot, or excessive drinking which may have indicated increased stress levels (Robert and Dallaire, 1986), or unsatisfied feeding motivation (Lawrence and Terlouw, 1993) were detected. It could be that the restricted feeding regime imposed was not severe enough to induce such behaviours, alternatively, the provision of straw may have provided alternative stimulation. Indeed, work by Whittaker *et al.*

(1998) showed that the provision of straw reduced levels of stereotypies in food restricted pregnant sows. Finally, it is possible that the period of restriction was not long enough for stereotypic behaviours to develop. Vocalisations were not recorded, however, some restricted pigs did appear to vocalise more than others, particularly in the observation session before access to food in Period 2 and this could have been an indication of anticipation, frustration or stress.

By comparing Periods 1 and 3 it was possible to determine the effects of the period of food restriction on the behaviour of the pigs. There were no treatment effects or treatment by period interactions, even though there had been differences between treatments in Period 2. It can be assumed therefore, that the change in time of access to food in Period 2 did not affect how pigs behaved in Period 3 and hence their time budgets were flexible. There were some differences between periods but these occurred for all pigs and were probably a consequence of increasing age and size. This is consistent with the conclusions from the feeding data.

2.4.4. Conclusions

The results from this experiment suggest that feeding patterns are flexible in the pig in response to a period of restricted feeding. Their patterns were similar before and after restriction. The pigs with restricted access to feed did not achieve the same food intake as the controls, probably due to physical constraints in dealing with the food in a short time. However, it is unlikely that pigs would suffer from stress if they are prevented from displaying their desired pattern provided feeding is not restricted to a period that is insufficient for them to feed to their requirements. Furthermore, the time budgets also appear to have been resilient across periods, suggesting that behaviours other than feeding pattern are also flexible in the face of an enforced period of restricted feeding. Individual differences between pigs were observed in terms of changes in feeding patterns, time budgets and performance of feeding attempts. This suggests that pigs have differing abilities to cope with a change in time of access to food and could indicate that some pigs are better at adapting to new

situations than others. This might have implications when pigs are mixed into groups in that those which are more flexible should adapt more quickly and be less stressed if they can not adhere to their preferred feeding pattern. However, as previously discussed, it is possible that the effect of a physical restriction in the form of a reduction in time of access to the feeder may have different effects on the feeding behaviour of pigs than a restriction imposed by group mates in a social situation.

Chapter 3.

The effect of group housing on feeding patterns and social behaviour of previously individually housed growing pigs.**3.1. Introduction**

Normal farming practices require that growing pigs are frequently grouped and mixed, for example, at weaning, at the start of finishing, during transport and at lairage. This results in a disruption of social organisation which can lead to an increase in aggression (Meese and Ewbank, 1973), and social stress (Hessing *et al.*, 1994), which in turn can compromise welfare and growth. Moreover, differences between pigs kept as individuals and as groups have been reported in terms of feeding behaviour. It has been found that group housed pigs modify their feeding behaviour by eating less frequently, consuming more food at a time and at a faster rate compared to pigs housed individually (de Haer and Merks, 1992). In addition, pigs in individual housing have higher digestibility coefficients related to smaller, more frequent meals as described by de Haer and de Vries (1993). In terms of production variables, the latter authors found that group housed pigs had significantly lower growth rates, and less back fat than pigs housed individually. Furthermore, Gonyou *et al.* (1992) found that pigs housed individually gained more weight and had a higher food intake than pigs housed in groups of five.

Competition at the feeder, social facilitation, and social stress are all factors that may be responsible for the differences in feeding behaviour and production variables between group housed and individually housed pigs. Social facilitation in group housed pigs results in synchronised feeding, but can lead to increased competition for feeder space in pigs kept in groups, caused by the motivation to feed simultaneously. Therefore a balance between the amount of competition and the amount of social facilitation that occurs in a group situation must be found if the maximum food intake is to be achieved (Hsia and Wood-Gush, 1983). In addition, neophobic responses to unfamiliar pigs and environment when mixed may also play a part.

Indeed, Tan *et al.* (1991) found that merely moving pens of pigs, without mixing, also resulted in a decline in productivity.

Although there have been studies on the differences in feeding behaviour between group housed and individually housed pigs, there are few reports in the literature of experiments where the two housing regimes have been imposed on the same pigs. Nielsen *et al.* (1996a) found that group housed pigs did not greatly alter their feeding behaviour when they were subsequently individually housed, suggesting that feeding behaviour in pigs was not as flexible as previously postulated. However, the pigs were housed individually after a period of grouping, and it would be useful to ascertain the effects of grouping after an initial period of individual housing which would allow individual pigs' feeding patterns to develop in an unconstrained way.

The aim of this experiment was to investigate the effects of grouping on feeding pattern, time budgeting and the social development of pigs kept as individuals from weaning before grouping. This was achieved by housing pigs individually from weaning with *ad libitum* access to food to allow them to develop their preferred feeding patterns. Following this, individuals were mixed into groups of four pigs. Finally, the pigs were returned to their individual pens. By comparing feeding patterns between periods of the experiment, and investigating the development of social behaviour within the groups, I hoped to determine the effects of grouping on individual pigs. In addition, possible causal factors for differences in feeding patterns between individually and group housed pigs might be found.

3.2. Methods

3.2.1. Animals and treatments

The experiment consisted of three blocks each comprising 3, three week periods. Blocks were run consecutively as only four pens with recording equipment were available. For each block, 4 Large White × Landrace, unrelated, male pigs were

used. In the first and third blocks, the pigs were kept in individual pens for the first period, after which they were combined into a group for the second period. Finally they were returned to their individual pens for the third period. To assess any effects of moving pigs, in the second block 4 pigs were housed individually over the 3 periods but were randomly allocated to different pens at the end of each period. The mean (\pm s.e.) weight of the pigs at the start of the experiment was 22.5 ± 0.7 kg.

3.2.2. Housing

The pigs were kept in a naturally ventilated room divided into four pens (3.8×2.9 m) into which some natural light could enter. To ensure that an equal amount of light was maintained throughout the experiment and that there was sufficient light for video recordings, artificial lighting was switched on at 06:00 h and turned off at 20:00 h. The front of the pens consisted of bars whereas the sides were solid sheets to eliminate physical contact between pigs in adjacent pens. Each pen contained an insulated kennel (1.9×1.9 m), a dunging area, a single-space computerised feeder (FIRE, Feed Intake Recording Equipment, Hunday Electronics Ltd., UK) and a metal bowl drinker. The pens were cleaned and fresh straw provided between 08:30 and 09:00 daily. To increase the insulation of the kennels, five straw bales were arranged around the walls of each kennel when the pigs were small, in the first period of each block, and straw was always provided on the floor of the kennel.

Each feeder consisted of a race, the width of which could be altered so that only one pig could enter the feeder at a time (during the periods of grouping), and a fibre glass trough suspended on a load cell which could be accessed by pushing a door hinged to the feeder frame. Each pig was fitted with an ear transponder so that the electronic system could identify which pig was entering the feeder as it pushed its head through the door. In addition, the trough weight immediately prior to entry, together with the time and duration of each visit and the post-visit trough weight were recorded by the computer control system.

3.2.3. Experimental procedure

Pigs were weaned at 4 weeks of age and moved to individual housing. At approximately 20 kg the pigs were transferred to the experimental building where they were allowed a few days to adjust to their new environment and to learn how to use the feeders. During this time a small amount of food was sprinkled on the lip of the feeder in each pen to encourage the pigs to feed. If after two days any pig had not eaten, it was held in the race for a few minutes until it started to feed.

The protocol for Blocks 1 and 3 is summarised in Table 3.1. Throughout the control block (Block 2), all periods were conducted as Period 1 in Blocks 1 and 3.

Table 3.1 Summary of protocol for Blocks 1 and 3.

	Period 1	Period 2	Period 3
Individual/ group	individual	group	individual
Behavioural observations	one day per week	one day per week	one day per week
Video recordings	one day in week 2	days 1, 2, 4, 5, 9, 11 and 17	one day in week 2
Weigh	Mon., Wed. and Fri.	Mon., Wed. and Fri.	Mon., Wed. and Fri.

3.2.4. Behavioural observations.

Live behavioural observations were in the form of a combination of focal and scan samples (Martin and Bateson, 1993) at 5 min intervals over four, one hour sessions on each observation day. The behaviour of the first focal pig was recorded continuously for five minutes followed by an instantaneous scan of all the animals' positions in the pen, postures and behaviours using the categories in Table 3.2. The procedure was repeated for the second pig and so on, so that each animal was observed for a total of fifteen minutes using focal sampling and on thirteen occasions using time sampling in each hour of observation. The one hour sessions were at 09.00-10.00, 11.00-12.00, 13.00-14.00 and 15.00-16.00. To record the live behavioural observations a hand held event recorder (Workabout, Psion PLC, U.K.)

and the Observer Package (Noldus Information Technology, Wageningen, The Netherlands) were used.

To ensure that individual pigs could be easily identified on the video recordings, each pig was numbered using a durable marker spray before recording commenced. Video recordings were analysed by time sampling the behaviour of each pig at 10 minute intervals using the categories in Table 3.2. In addition, during the period of grouping, aggressive interactions were recorded as and when they occurred, the initiator, the receiver, the type of aggression (refer to Table 3.3), and the outcome being noted. A bout of aggression was considered finished if there was a break in that behaviour of greater than 5 seconds. Finally, lying partners were recorded at each scan sample when the pigs were lying together in the pen.

Table 3.2 Behavioural categories used for time sampling and focal sampling.

Position	Posture	Behaviour
kennel	assumed lying	assumed sleeping
pen	lying	alert asleep rooting floor, straw or wall nosing pig
	sit/kneel	alert rooting floor, straw or wall nosing pig
	standing	alert rooting floor, straw, wall nosing pig moving aggressive mounting drinking urinating defaecating
feeder	standing	feeding displacing other pig

Lesion scores were recorded to give a measure of damage to the pigs to give an indication of welfare. The total number of lesions on each pig were counted on the front, middle and rear of the pig and a severity grade of mild (scratches and minor

redness), medium (scratches and small wounds), or severe (severe wounds) was given to the pig as a whole.

Table 3.3 Aggression recorded from video recordings.

Type of aggression	Description
Threat	pig directs aggression at another pig but makes no physical contact.
Knock	pig knocks another pig with the head or snout with a rapid upwards or sideways movement
Chase	pig runs after another pig in a threatening manner
Fight	vigorous reciprocated aggression (repeated biting and pushing).
Displacement	pig displaces another pig from the feeder, drinker or lying area by mounting, nosing, pushing or biting, the result is successful or non-successful.
Submission	pig turns head and body away from the aggressor, often sits down or stands with tail and ears drooped, may retreat and hide head and ears.

3.2.5. Statistical methods

The data for the control pigs and the grouped pigs were treated separately. Data on feeding behaviour were processed using Minitab for Windows (release 11.1) to produce for each animal: a mean number of visits to the feeder, the mean duration of visits, the mean food intake per visit, feeding rate and food intake per day. Growth rate was estimated from the slope of the regression of live weight against time. Behaviour data from the time samples were processed in Minitab for Windows (release 11.1) and the proportion of total observed time spent in each behaviour was calculated for each pig on each observation day. Means per period were calculated and these together with the pig means from the feeding data were then subjected to analysis of variance using Genstat for Windows (release 3.2, Lawes Agricultural Trust, 1990) treating the three periods as repeated measures.

The data from the live focal samples were processed and total duration spent in each behaviour per observation day were calculated using the Observer (Noldus, Information Technology, Wageningen, The Netherlands). The total duration of time

spent in each behaviour was then compared between periods and between blocks using analysis of variance as above.

The frequency and type of aggression that occurred on each observation day after grouping were analysed using repeated measures treating each observation day as a repeated measure. The scores for the behaviours chasing, displacing at the lying area and threatening were log 10 transformed to normalise the data. Dominance matrices for each group were constructed and the Social Rank Index (Lee and Craig 1982) was used to determine dominance orders.

$$\text{Social Rank Index} = 1/2(D-S+N+1)$$

Where D = the number of other individuals dominated, S = the number dominating the individual in question, and N = the number in the group.

3.3. Results

3.3.1. Feeding behaviour

Control pigs: As a result of equipment malfunction records of food intake were lost for one pig in Period 3. There was no effect of period on the number of visits to the feeder (Table 3.4a) but the mean duration of visits was higher in Period 2 than in the other two periods ($P<0.05$). Food intake per visit was lower in Period 1 than in Periods 2 and 3 ($P<0.05$) and feeding rate was greater in Period 3 than Periods 1 and 2 and greater in Period 2 than Period 1 ($P<0.05$). Food intake increased across the periods being greater in Period 3 than 2 ($P<0.05$) and greater in Period 2 than 1 ($P<0.05$). Period effects on weight gain and food conversion ratio were not significant.

Grouped pigs : The number of daily feeder visits was significantly lower in Period 2 when the pigs were grouped than when they were housed individually in Periods 1 ($P<0.001$) and 3 ($P<0.01$) (Table 3.4b). The number of visits was also less in Period 3 than Period 1 ($P<0.05$). Visit duration was longer in Period 2 than Period 1 ($P<0.01$) and 3 ($P<0.05$) and food intake per visit was lower in Period 1 than Periods 2 and 3 ($P<0.001$). Feeding rate increased over time being greater in Period 2 than Period 1 ($P<0.01$) and greater in Period 3 than Period 2 ($P<0.001$). Food intake and weight gain were greater in Period 3 than Periods 1 and 2 ($P<0.001$ and $P<0.01$, respectively). Food conversion ratio was poorer in Period 3 than in Periods 1 and 2 ($P<0.001$).

Table 3.4a Effect of moving pigs between pens on feeding pattern, food intake and production level (pigs were individually housed in Periods 1, 2 and 3, but moved to different pens at the end of each period).

	1	Period 2	3	Period s.e.d.	Period sig.
Visits/day	56.7	42.8	38.8	5.17	NS
Visit duration	65.6	82.1	72.0	3.44	*
Food intake/visit	27.8	54.4	66.2 ⁺	6.43	*
Feeding rate (g/min)	26.2	38.9	51.8 ⁺	2.86	*
Food intake (g/day)	1480	2084	2788 ⁺	143.6	*
Weight gain (g/day)	962	1136	1106	76.2	NS
Food conversion ratio (kg food/kg gain)	1.54	1.86	2.49 ⁺	0.243	NS

Each value is a mean of 4 (3)⁺ pigs.

Table 3.4b *Effect of grouping pigs on feeding pattern, food intake and production levels (pigs were individually housed in Periods 1 and 3, and housed as a group of 4 pigs in Period 2).*

	1	Period 2	3	Period s.e.d.	Period sig.
Visits/day	60.7	22.9	43.8	6.80	***
Visit duration	62.2	144.6	98.5	18.43	**
Food intake/visit	26.3	82.2	79.0	13.35	***
Feeding rate (g/min)	25.8	33.6	50.7	2.62	***
Food intake (g/day)	1507	1683	2816	109.9	***
Weight gain (g/day)	942	963	1129	52.5	**
Food conversion ratio (kg food/kg gain)	1.60	1.78	2.53	0.125	***

Each value is a mean of 8 pigs.

A graph of the mean number of feeder visits across time of day was plotted for the pigs that were grouped in Period 2 (Fig. 3.1). The graph shows that there were two peaks in feeding activity at 09.00 and 16.00h and these peaks did not differ between periods of the experiment.

3.3.2. Time budgets

Results from the analysis of the video time samples, indicate that there were no significant effects of period on the time-budgets of the control pigs (Table 3.5a). The grouped pigs (Table 3.5b) slept more in Periods 2 and 3 than in Periods 1, and slept more in Period 3 than in Period 1 ($P < 0.01$). Time spent rooting and feeding decreased in Period 2 ($P < 0.01$). The mean proportion of time spent moving decreased across Periods ($P < 0.001$).

Fig3.1. Time of day of visits to the feeder in Period 1, pigs individually housed (—); Period 2, pigs group housed (----) and Period 3, pigs returned to individual housing (.....).

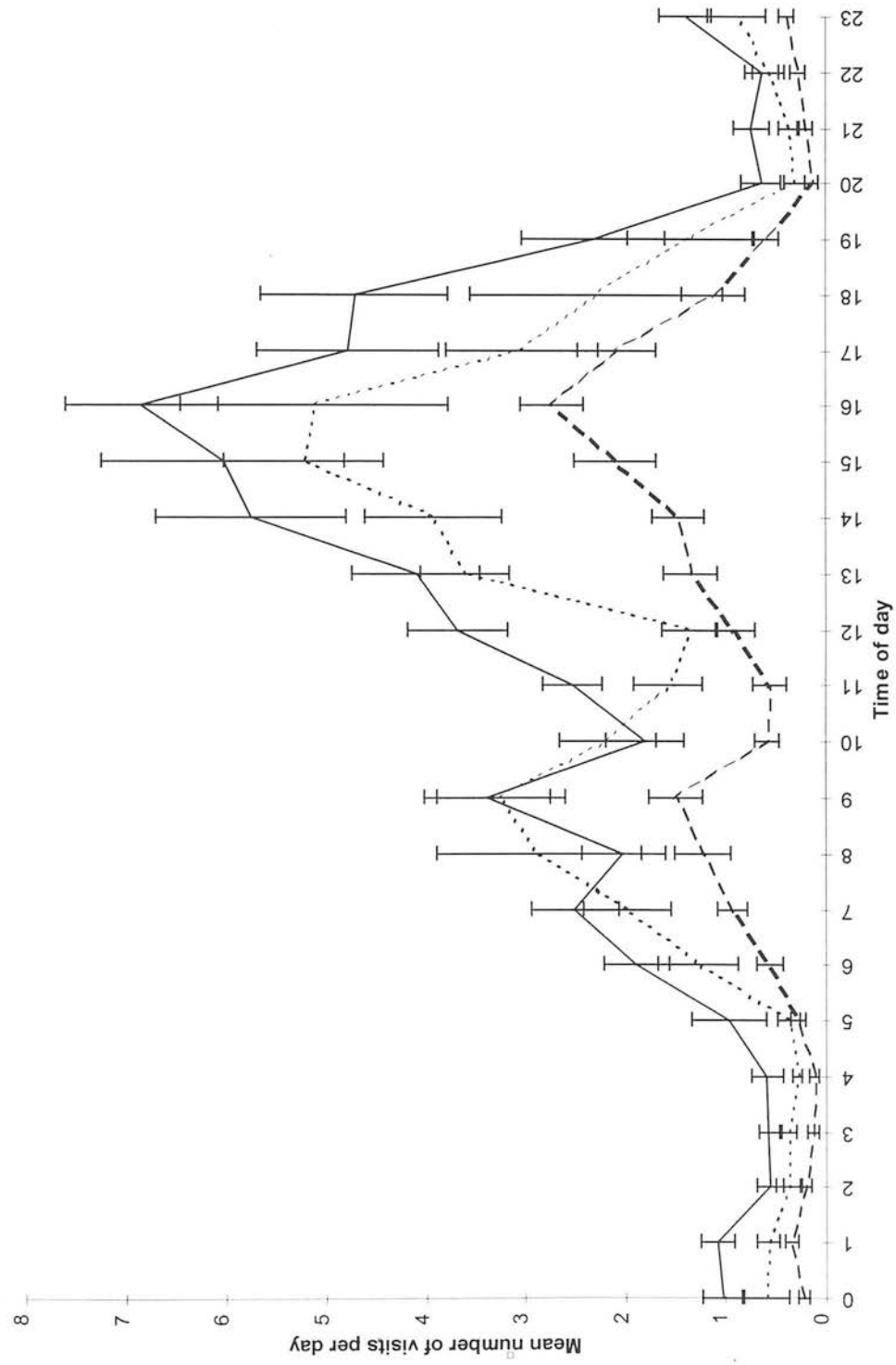


Table 3.5a Mean percentage of observations spent in each behaviour, Block 2 (pigs were housed individually throughout experiment, but moved to a new pen at the end of each period).

Behaviour	Period	Mean/period	Period s.e.d.	Period sig.
Alert	1	0.73		
	2	1.35		
	3	1.01		
	mean	1.03	0.930	NS
Asleep	1	51.2		
	2	63.3		
	3	69.3		
	mean	61.4	6.42	NS
Rooting	1	35.7		
	2	27.0		
	3	20.6		
	mean	27.8	5.26	NS
Feeding	1	9.10		
	2	6.63		
	3	7.43		
	mean	7.72	1.485	NS
Moving	1	2.86		
	2	1.69		
	3	1.35		
	mean	1.97	1.147	NS

Table 3.5b Mean percentage of observations spent in each behaviour Blocks 1 and 3 (pigs were individually housed in Periods 1 and 3, and housed as a group of 4 pigs in Period 2).

Behaviour	Period	Mean / period	Period sed	Period sig
Alert	1	1.01		
	2	0.95		
	3	0.59		
	mean	0.85	0.439	NS
Asleep	1	59.6		
	2	70.1		
	3	66.7		
	mean	65.5	2.97	**
Rooting	1	28.9		
	2	14.6		
	3	26.5		
	mean	23.3	3.22	**
Feeding	1	8.11		
	2	4.45		
	3	6.21		
	mean	6.26	0.761	**
Moving	1	2.19		
	2	1.38		
	3	0.00		
	mean	1.19	0.416	***

Table 3.7 Dominance orders of pigs in Blocks 1 and 3 calculated using Social Rank Index.

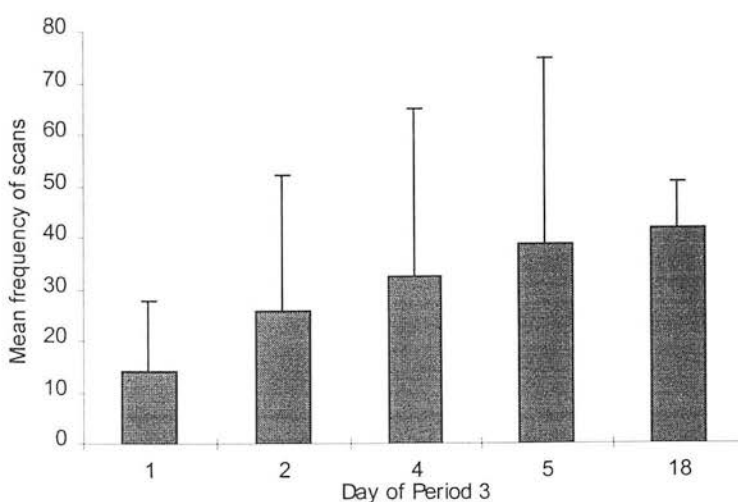
Day after grouping	Dominance order	
	Block 1	Block 3
1	2>1>3>4	11>9>12>10
2	1>2>3>4	11>9>12>10
4	2>1>3=4	11>12>10>9
5	1>2=3=4	11>9>12>10
18	3>2>4>1	9=11=12>10

3.3.5. Initiators, receivers and winners.

The proportion of interactions in which each pig was an initiator, receiver and winner were calculated as a mean per video day. Pearson correlations were calculated in Minitab, the results of which are shown in Table 3.8. The correlations suggest that initiators were winners and receivers normally did not win. In addition, there was a negative correlation between initiator and receiver, hence those pigs that initiated a lot of aggression generally did not receive much aggression.

Table 3.8 Pearson's correlations (r) between initiators, receivers and winners for pigs in Blocks 1 and 3, $n = 40$.

	r	Significance
Initiator and receiver	-0.445	$P < 0.01$
Initiator and winner	0.685	$P < 0.001$
Receiver and winner	-0.383	$P < 0.01$

Fig. 3.2 Mean number of scans in which pigs were lying adjacent to each other in the pen in Period 2 of Blocks 1 and 3.

3.3.6 Lesion Scores

The total number of lesions decreased with time after grouping ($P < 0.05$) (refer to Figs. 3.3a and 3.3b) as did the severity and there were differences between pigs. The pig that was originally resident in the pen suffered the least lesions in both groups (pig 2 in Block 1, and Pig 11 in Block 3).

Fig. 3.3a Total number of lesions per pig Period 2, Block 1

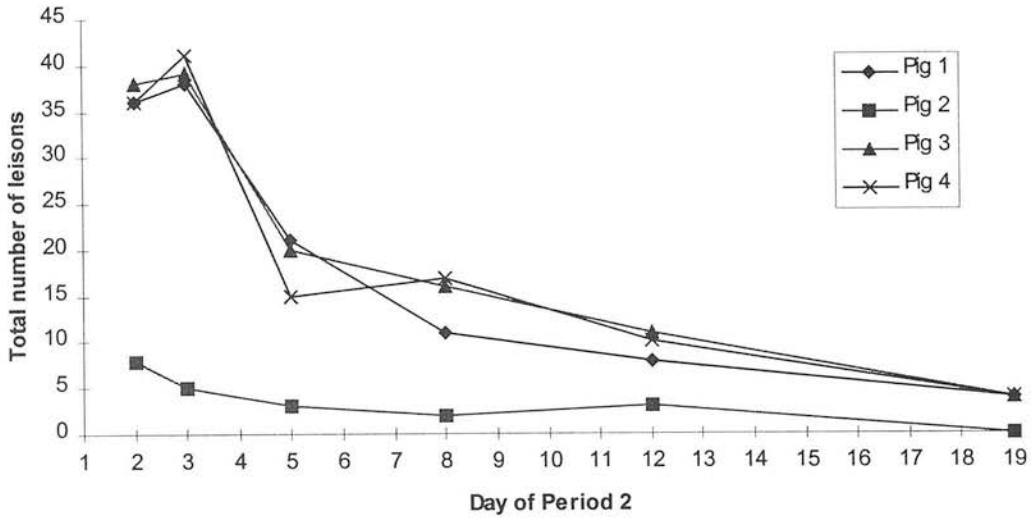
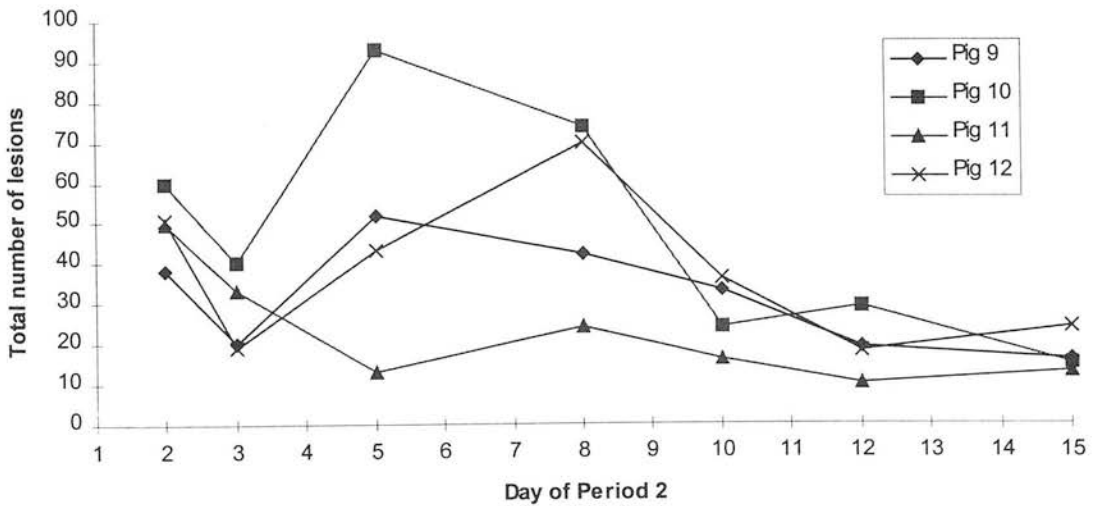


Fig. 3.3b Total number of lesions per pig, Period 2, Block 3.



The control pigs made a small, unexplainable increase in visit duration in Period 2. Apart from this there were no significant differences in the feeding behaviour, time budgets, or production variables of the control pigs between periods that could not be explained by the increasing size of the pigs. This suggests that the changes in feeding patterns observed in the group housed pigs were due to the social factors imposed by group housing rather than effects of moving the pigs to a new pen. This is in contrast with findings of Tan *et al.* (1991). They used groups of 6 pigs and mixed them into new groups of varying ratios of familiar:unfamiliar animals and found that moving pens of pigs without mixing resulted in a decrease in productivity.

There were differences between the pigs that were grouped in Period 2 in the extent to which they altered their feeding patterns between periods. Reasons for this variability between pigs is not clear.

3.4.2. Social Behaviour

The frequency of aggression decreased over time from mixing and this is consistent with reports in the literature that fighting decreases after the formation of a stable social hierarchy (Ewbank, 1976; Meese and Ewbank, 1973).

Dominance orders were calculated for each group. However, their reliability is doubtful as the number of aggressive interactions, particularly towards the end of the period of grouping were too low to confidently determine the hierarchy. In addition, the pigs were growing, and developing socially, so factors that might have affected dominance status may have been changing across time.

The percentage of aggressive interactions that each pig initiated, received and won were calculated. There was a correlation suggesting that pigs that initiated fights also won them. This is consistent with the theory that pigs can assess the fighting ability of others (Mendl and Erhard, 1997). Thus, there is no benefit of initiating a fight if the outcome is already certain. However, there was variability between pigs, some

3.4. Discussion

Groups of 4 pigs were used in the present experiment, and it is conceivable that pigs in larger groups may behave differently. Nielsen *et al.* (1995) compared the feeding behaviour of pigs housed in groups of 5, 10, 15 or 20. They found a threshold effect for feeding behaviour; the pigs housed in groups of 20 differing significantly from pigs housed in groups of 15 or less, the latter being similar. Therefore, the results discussed here are likely to apply to groups of pigs up to 15 in size, but not to larger groups.

3.4.1. Feeding behaviour

As expected, pigs altered their feeding patterns when grouped in the direction of less frequent visits to the feeder, of longer duration and more food eaten per visit and this is consistent with previous findings when individually housed pigs were compared with similar, but different, pigs in groups (de Haer and Merks, 1992, Gonyou *et al.*, 1992). The experiment reported here studied the same pigs as individuals and in groups. The pigs that were group housed in Period 2 showed a similar trend in feeding behaviour when housed as individuals in Periods 1 and 3 as the control pigs that were housed individually throughout the experiment. Thus the period of grouping had no lasting effect on feeding behaviour. This flexibility in feeding behaviour is consistent with results from Chapter 2 in which individually housed, *ad libitum* fed pigs were subjected to a period of restricted access to food, after which they either resumed their pre-restriction behaviour or showed the same trend as seen in non-restricted control pigs. This contrasts with the results of Nielsen *et al.* (1996a) who reported that previously group housed pigs made only small modifications to their feeding behaviour when they were transferred to individual housing, indicating that their feeding patterns were relatively inflexible. However, the pigs in that experiment were not allowed a period of individual housing prior to grouping, so their 'preferred' feeding pattern might have been less well defined.

The control pigs made a small, unexplainable increase in visit duration in Period 2. Apart from this there were no significant differences in the feeding behaviour, time budgets, or production variables of the control pigs between periods that could not be explained by the increasing size of the pigs. This suggests that the changes in feeding patterns observed in the group housed pigs were due to the social factors imposed by group housing rather than effects of moving the pigs to a new pen. This is in contrast with findings of Tan *et al.* (1991). They used groups of 6 pigs and mixed them into new groups of varying ratios of familiar:unfamiliar animals and found that moving pens of pigs without mixing resulted in a decrease in productivity.

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initiated more than they won and vice-versa suggesting that some pigs are more adept at assessing relative fighting abilities than others. Alternatively, they have a higher level of aggressiveness and will attack even though there is little chance of them winning. There was also some inconsistency within pigs which could be a consequence of them becoming more experienced at assessing relative fighting abilities over time, or perhaps differences in motivation to initiate aggression.

As would be expected the number of lesions decreased with time from mixing. As lesions were not counted on days consistent with the video recordings it was difficult to relate lesion scores to aggression levels. However, previous studies have shown that it is the frequency of aggressive interactions (Barnett *et al.* 1992) rather than the duration of interactions (Moore *et al.*, 1994) that correlate with lesion scores. Although the resident pig in each group did not receive less aggression than the other group members they did receive fewer lesions. This could be due to them having a greater resource holding potential. However, resident pigs did not consistently appear high in the dominance orders.

It is possible that aggression and competition between pigs were responsible for the change in feeding pattern when pigs were grouped. Alternatively, there may have been an effect of group cohesion such that individuals were reluctant to leave the group to feed. Finally, when individually housed, pigs might have displayed different feeding patterns to those of group housed pigs as a consequence of lack of social stimulation. Each of these hypotheses will be considered below.

3.4.3. Competition.

The pigs showed 2 peaks in feeder visits across the day in all three periods (see Fig. 3.1), and this was consistent between pigs, indicating that they ate at similar times of day. Therefore, when the pigs were group housed it was likely that there would be preferred times of the day when all pigs would be motivated to feed resulting in competition for feeder access. This might lead to fewer feeder visits of a longer duration as, once the pigs had gained access to the feeder, they remained there

longer. Reasons for this might be either that the pigs were aware that they would not be able to gain access again for a 'longer than desired' between meal interval, or because they had had to wait for a 'longer than desired' meal interval since the previous meal and were therefore hungry resulting in a longer time to reach satiation.

If competition for access to the feeder was fierce it would be expected that the number of observed displacements from the feeder would be high. However, displacements from the feeder were relatively rare, suggesting that competition was not a constraining factor. Furthermore, it might be expected that dominant pigs would not have to alter their feeding patterns to the same extent as lower ranking pigs. Indeed, Pluske and Williams (1996) suggested that dominant pigs may suffer less from stress-induced suppression of feeding than subordinate pigs. However, in the present experiment dominance status could not be clearly determined, and all pigs changed their feeding behaviour in a similar way between Periods 1 and 2.

It has been found that pigs housed in groups of greater than 15 (Nielsen *et al.*, 1995), or in groups of 10 pigs with a one-space feeder (Nielsen *et al.*, 1996b) have to modify their feeding behaviour to a greater extent than pigs housed in groups of less than 15, or in groups of 10 pigs with a four-space feeder respectively. In the present experiment, the conditions were also below the thresholds, in terms of group size and pig:trough ratio that Nielsen *et al.* (1995 and 1996b) found resulted in changed feeding patterns, yet in this work feeding pattern still changed across periods. It seems unlikely therefore, that competition between pigs was a major factor in the alteration of feeding patterns.

3.4.4. Group Cohesion

A second explanation is that group cohesion results in pigs being reluctant to leave the group to feed. Houston and Sumida (1985) proposed that each behaviour has an associated tendency which increases when the behaviour is not performed and decreases when the behaviour is performed. The behaviour that is expressed at any

one time is the behaviour with the highest tendency at that time. In this case, we could postulate a rather constant motivation to stay with the group, but variable feeding motivation dependent on time since the last meal. As motivation to feed becomes stronger it will out compete the motivation to stay with the group. Once feeding commences, positive feedback (Wiepkema, 1971) from the food ingested maintains feeding motivation so that meal duration becomes extended. As the pigs become satiated, feeding motivation will decline allowing expression of the social tendency resulting in a return to the group. The problem can also be considered in terms of costs and benefits. These pigs' motivational decisions presumably relate to the evolutionary costs of leaving the group and the benefits of feeding and *vice versa*. When the benefits of one motivation outweighs the benefits of the other then the pig switches behaviour (McFarland, 1989).

It could be argued that the pigs were synchronising their behaviour rather than there being an effect of group cohesion. Indeed it can be difficult to distinguish between the two. Moreover, some degree of behavioural synchronisation might in fact be a consequence of social facilitation. For example; when housed in a group, a satiated individual might have increased motivation to feed due to the presence of a group mate in the feeder (Hsia and Wood-Gush, 1983). However, synchronisation has a time component in that behaviours are performed in unison, whereas cohesion could be defined as a 'force' that keeps the pigs together in a group. Thus there is a difference in that the pigs are motivated for the company of other group members rather than purely synchronising their behaviour. Therefore, the group of pigs could be cohesive without all performing the same behaviours at the same time; some may be lying rooting whereas others are lying sleeping in the same area.

The motivation for company was demonstrated in an experiment by Jones *et al.* (1999) who demonstrated that pairs of pigs given a choice of access to either a heated, ammonia polluted compartment or an unheated, unpolluted compartment spent most time in the polluted-heated compartment. Even as air temperature increased, instead of increasing time spent in the unpolluted compartment the pigs

remained in the polluted-heated compartment. It was suggested that pigs were more motivated to remain in heated-polluted compartment for companionship rather than thermal comfort.

3.4.5. High frequency of feeder visits as a consequence of lack of social stimulation.

When the pigs were individually housed their behavioural repertoire was considerably less diverse and they spent more time rooting and less time sleeping than when group housed. Nielsen *et al.* (1996a) also reported increases in time spent rooting substrate when pigs were individually housed after a period of group housing. It could be that pigs were more active when individually housed in order to keep warm whereas when group housed, pigs were able to huddle for warmth. Furthermore, there may have been a greater requirement for rest when the pigs were grouped due to energy expenditure caused by frequent social interaction. Alternatively, the increase in time spent sleeping when group housed might suggest that pigs were more content whereas when individually housed they were agitated and so were more active and spent more time rooting and feeding. This theory suggests that the high frequency of feeder visits when pigs were individually housed might be due to lack of social stimulation resulting in a change in the behavioural priorities of the pigs; rooting and feeding becoming important as the only sources of positive stimulation in the pen. However, Chapter 2 pigs housed in individual pens that had visual, and some physical contact with neighbouring pigs and had straw provided made a similar number of visits to the feeder to pigs in the present experiment. This would suggest that lack of social stimulation is unlikely to be a major factor responsible for the differences in feeding behaviour between individually and group housed pigs.

3.4.6. Conclusions

In conclusion, grouping effects on feeding behaviour were in the form of a change in feeding pattern in the direction of fewer feeder visits of a longer duration. Feeding patterns were shown to be flexible as the period of grouping had no lasting effects on feeding behaviour. Frequency of aggression decreased across time from mixing as the groups became more stable. The evidence reported here suggests that competition did not constrain feeding behaviour when the pigs were group housed. Moreover, it is unlikely that a lack of social stimulation was responsible for the comparatively high frequency of feeder visits when the pigs were housed individually. Therefore, the most probable mechanism for the change in feeding behaviour when the pigs were group housed is that of group cohesion.

Chapter 4.

The effect of group composition, in terms of latent aggressiveness, on feeding and social behaviour of growing pigs.**4.1. Introduction**

Individual pigs have stable feeding patterns in terms of frequency of feeder visits, visit duration and food intake per visit. These feeding patterns are highly individualistic ranging from a few, large meals to many small meals per day (Nielsen *et al.*, 1995). The feeding behaviour of group-housed pigs has been found to differ from that of pigs housed individually in that they make fewer visits to the feeder of a longer duration (Chapter 3; Nielsen *et al.*, 1996a). In Chapter 3 it was suggested that there are three mechanisms to explain these changes. Firstly, competition at the feeder results from the pigs all being motivated to feed at similar times of day. Secondly, group cohesion results in pigs being reluctant to leave the group to feed. Thirdly, that a lack of social stimulation when pigs are individually housed is responsible for the change in feeding behaviour as feeding is more important as a positive source of stimulation. It was concluded that group cohesion was the most likely mechanism responsible for the changes in feeding behaviour between individual and group housing.

It might be expected that for a group to be cohesive it would need to be fully integrated. However, when pigs are mixed into new group it takes time (48 hours, Meese and Ewbank, 1973) for a social organisation to be established. Moreover, Erhard *et al.* (1997) classified pigs as high or low aggressive using an attack latency test and found that high aggressive pigs take longer to integrate into a group at mixing than low aggressive pigs. In addition, levels of aggression were higher in groups composed entirely of high aggressive pigs than in a group with a mixture of high and low aggressive animals. The lowest aggression levels were observed in groups of entirely low aggressive pigs suggesting that welfare of pigs in “low” groups is perhaps superior to that of pigs in “high” groups. Thus, it is possible that

group composition in terms of latent aggressiveness will affect the feeding behaviour of individuals within the group. This might have implications for production and welfare levels.

Pigs may suffer stress when they are mixed into new groups as they are unable to adhere to a feeding pattern that they have used successfully in the past. However, in Chapter 2, it was found that pigs had flexible feeding patterns and suggested that as long as pigs have sufficient time to eat enough food to fulfil their requirement it is unlikely that they would suffer from stress. In addition, it may be difficult to disentangle stress caused by the thwarting of feeding behaviour from stress caused by increased aggression levels around the time of mixing. Ekkel *et al.* (1997) found no differences in the circadian rhythm of cortisol between mixed and un-mixed groups of pigs. However, they found that pigs that were mixed had problems adapting to the procedure of mixing. Five to six weeks, after mixing although fighting had subsided, there were more bites and knocks than in the unmixed controls. They concluded that mixing affects the social stability of groups in the long term but it was uncertain whether the pigs suffered chronic stress.

This experiment investigated the effect of group composition in terms of latent aggressiveness on feeding behaviour, social behaviour and stress levels. By recording changes in feeding pattern at grouping together with behavioural and stress measurements, it was possible to determine the extent to which group composition affects feeding behaviour, performance and welfare of individuals within a group.

4.2. Methods.

The experiment consisted of 3 replicates each comprising 3 periods. In Period 1 pigs were housed with their littermates after weaning for 3 weeks. Each pig's aggressiveness was assessed and they were classified as being either high or low aggressive. In Period 2, 8 high aggressive and 8 low aggressive pigs were transferred to individual housing where their feeding patterns and food intake were recorded for 2 weeks. In Period 3, the 16 pigs were combined into 2 groups, one group consisting

of 8 high aggressive pigs and the other of 8 low aggressive pigs. Food intake, feeding patterns and social behaviour were recorded across the 3 week period. In total there were 3 replicates of each group composition.

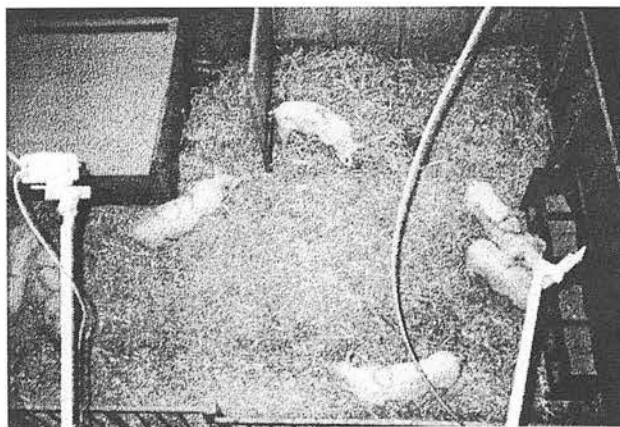
The methods for each period are described in detail in the following.

4.2.1. Period 1

Pigs and housing

In each replicate 3-4 litters totalling 25-27 Large White X Landrace male and female pigs (test pigs) were weaned at a mean (\pm s.e.) of 34.7 ± 1.9 days at a mean (\pm s.e.) weaning weight of 9.9 ± 0.3 kg. Around 1 week later a similar number of litters/pigs were weaned to act as 'intruder pigs' in the attack latency tests (see below). All the pigs were housed in litter groups in pens 2.70 x 3.75m (see Fig. 4.1). The fronts of the pens consisted of bars whereas the side and back walls were made of galvanised sheeting to ensure there was no visual or physical contact between litters. Each pen was provided with a kennel 1.15 x 3.75m a metal bowl drinker and two 3-space feeders. Pens were cleaned, fresh straw provided and feeders topped up daily between 08.00 and 09.00h. Artificial lighting was supplied between 06.00 and 20.00h and heating and ventilation were controlled automatically.

Fig. 4.1. Pen layout Period 1, pigs housed in littergroups



Attack latency tests.

Attack latency tests were performed on days 19 and 20 after weaning in accordance with the method of Erhard and Mendl (1997a). Pigs within each test litter were ranked for weight and were paired with a similarly ranked pig in an intruder litter i.e. the heaviest pig in the test litter was matched with the heaviest pig in the intruder litter. At the time of the test the mean weight of the test and intruder pigs were 18.8 ± 0.596 and 11.17 ± 0.340 kg respectively. Where possible the intruder pig was around 60% of the body weight of the test pig as suggested by Erhard and Mendl (1997) however this was not always possible and the percentage difference in body weight ranged from 46.46-81.82%, mean 62.85 (s.e. 0.686)%. The pigs were tested in a random order.

Procedure:

The tests were performed in a sectioned off area of the test pig's home pen measuring 1.9 x 2.7m, this gave the test pig the advantage of being the 'resident' animal. The test pig was firstly placed into the area and the intruder pig was introduced to it. The time between the test pig being placed in the area and the intruder being introduced was kept to a minimum and was never more than 5 minutes. The latency to attack; the time taken from the first nose contact made by the test pig to the onset of aggression (at least one quick bite) was recorded. The intruder pig was removed immediately after the first aggressive act or after 3.5 minutes if the test pig did not attack. The behaviour (nosing, pushing, head knocks and attempts to escape) of the test pig prior to attack, or until the end of the test if there was no attack, was also recorded. If at any time either pig became unduly distressed the test was terminated. The test was repeated the following day with different intruder pigs (pigs from another intruder litter). Thus each test pig was tested on 2 occasions and each intruder pig was used twice. If the intruder pig attacked the test pig the result was classified as 'no attack'.

Categorisation:

For the rest of this chapter I will refer to fast attackers as ‘High’ aggressive (H) pigs and slow attackers as ‘Low’ aggressive (L) pigs as in Erhard *et al.* (1997). From all the test pigs 8 fast attackers (‘High’ aggressive ‘H’ pigs) and 8 non attackers or slow attackers (‘Low’ aggressive ‘L’ pigs) were selected to progress into Period 2. From each test litter at least 2 and no more than 3 pigs were selected for each aggressiveness category. Where possible the selection was also balanced for weight and sex.

Measurements

Pigs were weighed twice a week on a Monday and Friday. Litters were video recorded on one day during Period 1 for 12 hours using time-lapse video recording equipment. Each pig was marked with a letter using a permanent marker pen so that it could be easily identified on the video recording. Salivary cortisol was sampled during Week 2 of Period 1 using the method described below.

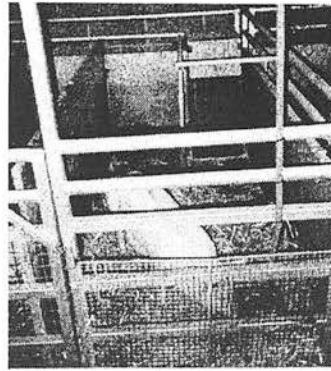
4.2.2. Period 2

Pigs, housing and experimental procedure

The 16 pigs that were selected in Period 1 were transported in a trailer to a different building where they were housed individually in two rows of 8 pens for 2 weeks. The pens measured 2 x 1m and the sides were made of galvanised sheeting the front consisting of a gate through which the pig could see its opposite neighbour. The floor was made of insulated concrete and straw was provided. Each pen was equipped with a metal bowl drinker and a computerised feeder with a trough suspended by a load cell (see Fig. 4.2). Access to the feeder was via a door which operated a switch when opened and closed, providing records of entry and exit times at each visit, thus the number and duration of visits could be calculated. Each morning at 09.00h records of the trough weight were taken so that daily food intake could be calculated. The trough was then topped up with a weighed quantity of fresh food. Pens were cleaned and fresh straw provided every other day between 08.30

and 09.30. Artificial lighting was supplied between 06.00h and 20.00h and heating and ventilation were controlled automatically.

Fig. 4.2 Pen layout in Period 2 pigs housed individually.



Measurements

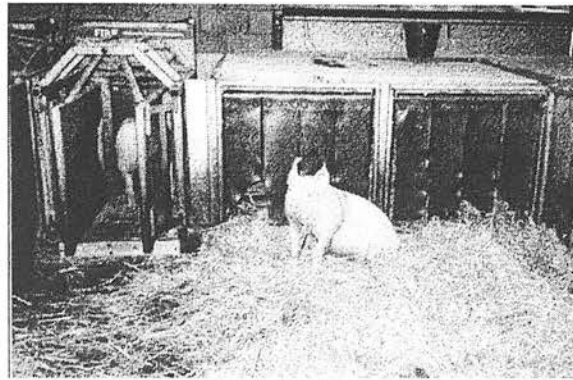
Pigs were weighed twice a week on a Monday and Friday. On Day 4, live behaviour observations in the form of scan samples at 5-min intervals over four, 1-h sessions were made. The sessions were at 09.30-10.30h, 11.30-12.30h, 13.30-14.30h and 15.30-16.30h. At each 5-min interval, the observer walked quietly between the two rows of pens and recorded the posture (lying, sitting/kneeling or standing) and behaviour (categories in Table 4.1) of each pig. Saliva was collected on Days 2 and 3 and Days 9 and 10 of Period 2 using the method described below.

4.2.3. Period 3

The pigs were transported to another building in a trailer and put in a holding pen. Each pig was then weighed, ear-tagged with a transponder, marked with a durable marker spray (so easily identifiable on video recordings) and allocated to the correct pen (either the 'High' aggressive pen or the 'Low' aggressive pen). The pens (3.8 x 2.9m) were adjacent to each other within a naturally ventilated room into which some natural light could enter. To ensure that an equal amount of light was maintained throughout the experiment and that there was sufficient light for the video recordings, artificial lighting was supplied between 06.00 and 20.00h. The front of the pens consisted of bars whereas the sides were solid sheets, thus physical contact between the pens was eliminated. Each pen contained an insulated kennel (1.9 x 1.9m), a dunging area, a single-space computerised feeder (FIRE, Feed Intake Recording

Equipment, Hunday Electronics Ltd., UK) and a metal bowl drinker. The feeders were topped up and the pens were cleaned and fresh straw provided daily between 08.30 and 09.00h daily.

Fig. 3.3 Pen Layout in Period 3, pigs housed in groups of 8.



Each feeder consisted of a race which only one pig could enter at a time and a fibre glass trough suspended on a load cell which was accessed by pushing a door hinged to the feeder frame. The electronic system could recognise each pig's identity from the ear transponder as the pig pushed its head through the feeder door. In addition, trough weight immediately prior to entry, together with time of day and the duration of each visit and the post-visit trough weight were recorded by the computer-controlled system.

Measurements

Daily feed intake and feeding patterns were recorded throughout Period 3 using the FIRE feeders. Video recordings were made on day 1 (day of mixing), days 2, 4, 5, 9, 11, 16 and 19. On the morning of each video day the pigs were re-marked with a marker spray. Pigs were weighed twice a week on a Monday and Friday. Salivary cortisol was sampled on days 2 and 3, and days 17 and 18 according to the methods described below.

Room temperature was recorded twice a day at 08.00 and 16.00h throughout.

4.2.4. Food

In Period 1 pigs were given *ad libitum* access to a food (BOCM Pauls Startercare Easiwean Pellets) containing 215g protein, 85g oil, 18g fibre, and 60g ash per kg for the first 10-14 days after which they were transferred onto a second food (BOCM Pauls Ltd, Renfrew: Growercare Sovereign Pellets; for pigs between 20 and 50kg live weight); which contained 195g protein, 50g oil, 37.5g fibre and 50g ash per kg. They remained on this feed until the end of the experiment.

4.2.5. Salivary cortisol sampling

To provide a physiological measure of the stress levels of individuals throughout the experiment, changes in salivary cortisol concentrations were measured. Saliva was collected over 2 consecutive days at the time points detailed in the above sections. On each day saliva was collected at 10.00h and 14.00h \pm 60 min. These times were chosen as pigs have a circadian rhythm of cortisol concentration described by Ekkel *et al* (1996). They reported a peak around mid-morning and a decrease in concentrations through the afternoon and evening. Therefore a higher concentration of cortisol would be expected in the morning (10.00h) than in the afternoon (14.00h). In addition, a blunted amplitude of circadian rhythm has been reported when pigs are exposed to stress (Pedersen *et al.*, 1993). Therefore, by sampling at 10.00h and 14.00h any major changes in rhythm should be detected. Pigs were allowed to chew on two large veterinary cotton buds (Millpledge, Retford, Notts.), which were immediately placed in a tube. As soon as samples from all the pigs had been collected the buds were spun in a centrifuge cooled to below 5°C for 2 min at 3000rpm. If after this time the buds were still moist they were spun for a further 2 min. The resulting 0.5-1ml of saliva was then kept frozen at -20°C until analysis.

Analytical technique

The saliva was analysed using a solid phase radioimmunoassay (Coat-A-Count, Diagnostic Products Corporation, 5700 West 96th Street, Los Angeles, CA). in duplicate (where there was enough saliva) samples. On the day of analysis the

samples were thawed and centrifuged at 5000rpm in a micro-centrifuge for 5 minutes and the supernatant transferred into a clean container ready for analysis. Where there was sufficient saliva, samples were analysed in duplicate using 200T1 per sample. The minimum detection limit of the assay was 0.35ng/ml. For further details of the standards and assay statistics see Appendix 1.

4.2.6. Analysis of video recordings.

To record the time budgets of the pigs, video tapes were scan sampled; the posture and behaviour of each pig being recorded every 10-min according to Table 4.1. To obtain records of social behaviour the Observer Event Recorder (Noldus Information Technology, Wageningen, The Netherlands) was used. The initiator, type of behaviour (see Table 4.2) and the receiver of the behaviour were recorded as and when the behaviour occurred. The resulting event log was subjected to statistical analysis using the Observer to obtain frequency and duration of each initiator-behaviour-receiver sequence.

4.2.7. Statistical Methods

For comparisons of pigs in Periods 2 and 3 it was necessary to address the problem of having different basic experimental units in these two periods. For Period 2, pigs were individually housed and therefore each pig was an independent experimental unit, whereas for Period 3, pigs were group-housed and so individual pigs were no longer independent and therefore the groups now strictly formed the independent units. In order to perform an analysis which included data from both periods we had to have the same experimental unit. With the relatively small number of groups, the use of group as an experimental unit would have resulted in an unreliable analysis, as there would have been very few degrees of freedom for estimating the between-group variation. Therefore, I chose to use individual pigs as the units, although I recognise that due to their not being independent throughout the experiment, variation between pigs within groups will have been underestimated and that between pigs in different

groups overestimated to some extent. Ideally there should have been more groups on each treatment but this was not possible on the resources available.

Feeding behaviour data

Data on feeding behaviour were processed using Minitab for Windows (release 11.1) to produce for each animal: a mean number of feeder visits, the mean duration of visits, the mean food intake per visit, feeding rate and food intake per day. Weight gain was estimated from the slope of regression of live weight against time. The means for each pig for Periods 2 and 3 were then subjected to analysis of variance using Genstat for Windows (release 3.2, Lawes Agricultural Trust, 1990).

Behaviour data from scan samples (video scans Periods 1 and 3, live scans Period 2).

Behaviour data from the scan samples were processed in Minitab for Windows (release 11.1) and the percentage of total observed time spent in each behaviour calculated for each pig on each observation day. Means per pig (Period 1) means per pig per observation session (Period 2) and means per pig per day (Period 3) were then subjected to analysis of variance using Genstat for Windows (release 3.2, Lawes Agricultural Trust, 1990).

Social behaviour data

The Observer (Noldus Information Technology, Wageningen, The Netherlands) was used to calculate for each pig, the frequency of each behaviour, the total duration of fighting and nosing and mean bout lengths of fighting and nosing for each video recording. Frequencies, durations and bout lengths were then subjected to analysis of variance treating each day as a repeated measure.

Salivary cortisol

Some values for the concentration of cortisol were below the lowest concentration that could be detected by the assay (0.035 ng/ml). Therefore, those samples containing <0.035 ng/ml were all given the value 0.034 ng/ml. The data for the

concentration of cortisol were skewed and so were log 10 transformed to normalise. Genstat for Windows (release 3.2, Lawes Agricultural Trust, 1990) was used to analyse the data using repeated measures ANOVA to investigate the effect of time of day of sampling, sampling day, period, aggressiveness and any interactions between factors.

Table 4.1 *Ethogram for scan sampling Period 2 live scans, Period 3 video scans.*

Behaviour	Description
alert	head up, eyes open, watchful but inactive
asleep	lying eyes closed (pigs in kennel assumed asleep)
rooting	manipulating straw, floor, walls or fixtures
feeding	standing, head in feeder
nosing	nosing pen-mate
drinking	drinking or manipulating drinker
scampering	running in circles, head shaking, play-fighting, carrying straw.
aggression	knocking, fighting, chasing pen-mate
displacing	displacing other pig from feeder, by pushing, biting or mounting
moving	walking, trotting or running
mounting	pig places front legs on back of pen-mate
eliminating	urinating, defaecating

Table 4.2 *Ethogram for continuous recording of social behaviour Period 3.*

Behaviour	Description
threat	directs aggression at pen-mate but makes no physical contact
head knock	knock/snap at pen-mate with head or snout with rapid upward or sideways movement
fight	vigorous, repeated pushing and biting
chase	pig runs after another threatening or biting
displacement	displacing pen-mate from feeder
win	pig wins fight
interrupt	pig interrupts fight
nosing	pig noses pen-mate

4.3. Results

All significance values reported refer to overall treatment, period, day or interaction effects; standard errors of difference were used to locate the effects more specifically.

4.3.1. Attack latency

The results of the attack latency tests are shown in Table 3. One test could not be conducted, as the intruder pig was ill. Intruder pigs attacked the test pig on 5 occasions, all in Block 3. Test pigs tried to escape on 10 occasions, twice in Blocks 1 and 2 and 6 times in Block 3.

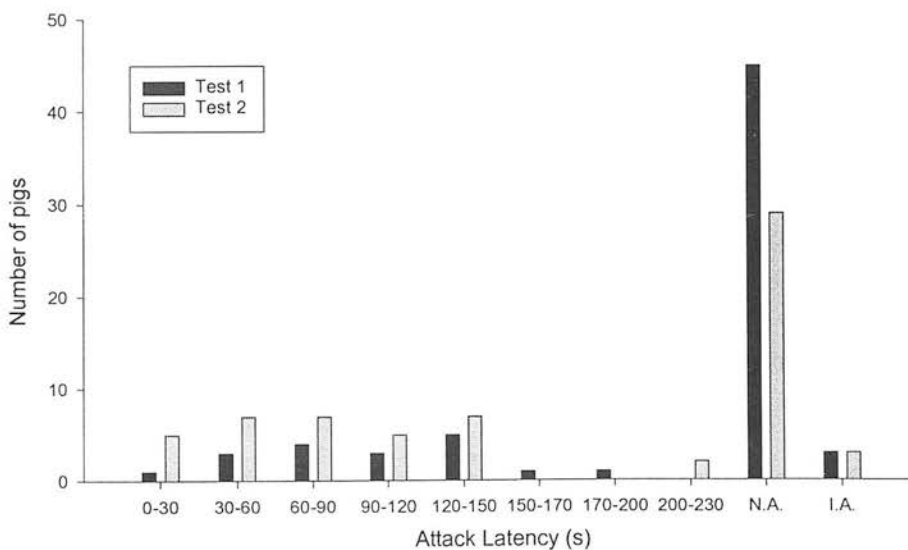
Table 4.3 Attack latencies (s) of pigs in Period 1. X = no attack, I.A. = intruder attacked. Pigs that were selected as High Aggressive (H pigs) are in blue, and Low Aggressive (L pigs) are in red.

Block 1				Block 2				Block 3				
Litter	Pig	Test 1	Test 2	Litter	Pig	Test 1	Test 2	Litter	Pig	Test 1	Test 2	
787	283	X	106	498	333	53	Intruder ill	230	365	I.A.	49	
	284	X	129		335	171	29		366	140	82	
	287	X	96		337	81	138		367	X	X	
	285	X	X		338	150	X		368	I. A.	125	
	286	X	X		331	X	X		369	104	X	
			332		X	X	370		X	I.A.		
969	279	118	66	334	X	X	371		X	135		
	281	X	127	506	314	127	206		372	X	55	
	282	X	55		315	124	X		373	I.A.	70	
	248	X	X		318	X	76		793	383	98	55
	249	X	X		322	X	132			384	28	7
	280	X	X		313	X	X			385	X	X
250	X	X	317		X	X	387			X	67	
			320	X	X	388	85			95		
						389	67	40				
964	234	74	37	7876	330	152	53	1798	374	X	24	
	235	150	73		327	X	71		375	51	11	
	236	112	53		323	X	130		376	X	X	
	233	X	X		324	X	X		377	X	I.A.	
	238	X	X		326	X	X		378	X	41	
	240	X	X		328	X	X		380	X	106	
	241	X	X		329	X	X		381	X	20	
976	242	X	96						382	131	10	
	244	X	209									
	246	54	X									
	243	X	X									
	247	X	X									

The distribution of attack latency is shown in Fig. 4.4. Most attacks occurred between 0 and 150s. There was a correlation between test 1 and test 2 (Spearman Rank correlation, $r = 0.5907$, $n = 48$, $P < 0.001$). The tendency to attack increased from test 1 to test 2, the number of non-attackers decreasing from test 1 to test 2.

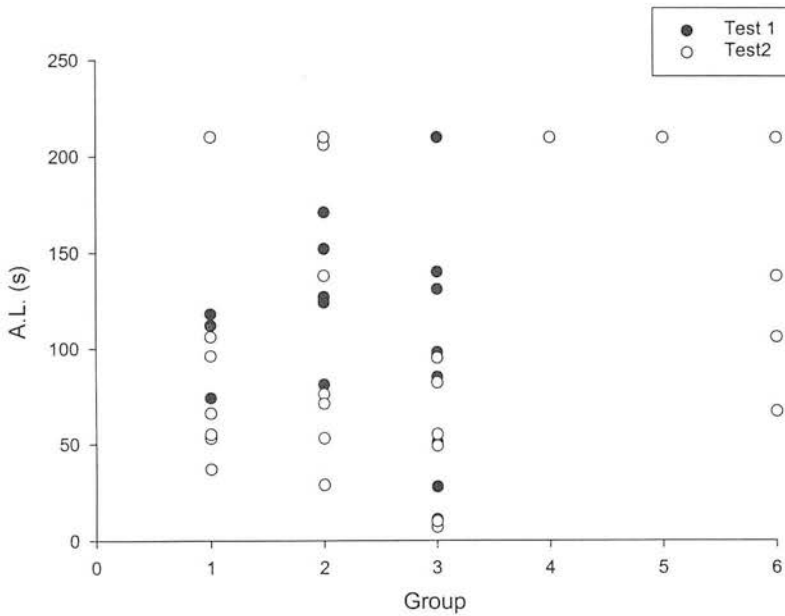
L pigs were selected on the basis that they did not attack in both tests. However, in Blocks 1 and 2, there were more than 8 pigs that did not attack. Pickup and D'Eath (2000) found that pigs that attacked also had a short time from the first snout contact to the first incidence of head knocks, pushes and shoves, and a high level of persistence of interest in the intruder. Therefore, the amount of non-fighting aggression that takes place pre-attack is related to the likelihood of an attack occurring. Thus, pigs that were involved in no, or little of this type of behaviour were selected as 'low' aggressive pigs. In Block 3, there were very few pigs that did not attack on both occasions and there were constraints in that no less than 2 pigs and no more than 3 pigs could be selected from each litter for each category. Therefore, 3 pigs had to be categorised as 'Low' aggressive even though they attacked in the second test.

Fig. 4.4 Distribution of attack latency on test 1 and test 2. (N.A. = not attack, I.A. = intruder attack).



The distribution of attack latencies for selected pigs grouped in Period 3 are shown in Fig. 4.5. A Mann-Whitney test indicated that there was a significant difference between the attack latencies of the pigs in H and L groups; the medians were 96 and 210 s respectively ($P < 0.001$).

Fig. 4.5 Attack latencies in Test 1 (filled circle) and Test 2 (empty circle) of pigs in each group in Period 3 (groups 1, 2 and 3 'High' aggressive, groups 4, 5 and 6 'Low' aggressive). Points overlap where more than one pig has the same attack latency (e.g. all pigs in group 4 did not attack on either test and so have a single point at 210s on the graph).

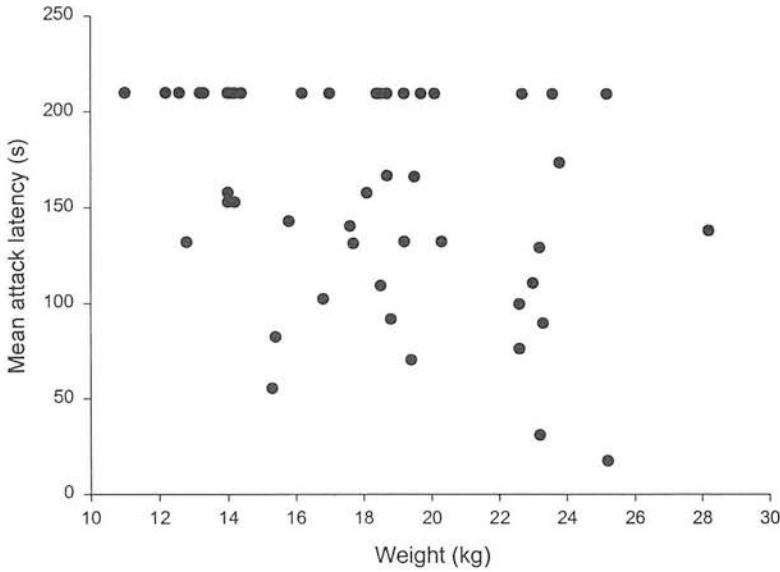


Effects of Sex and Weight.

So that the effects of sex and weight, and comparisons between attack latency and other variables could be investigated a mean attack latency score was calculated (Non-attackers being given the maximum score of 210s). A Mann-Whitney test indicated that there was no significant effect of sex on attack latency. The median attack latency for males was 192 s, the median for females was 155.5 s. In addition, there was no difference in weight between pigs in the H category and pigs in the L category. The mean (\pm s.e.) weight for pigs subsequently selected as H pigs 18.70 ± 0.7279 kg, and for the L pigs 17.57 ± 0.9431 kg. However, there was an effect of

weight on attack latency (refer to Fig. 4.6). A negative Spearman Rank correlation suggested that heavier pigs may have shorter latencies to attack than lighter pigs ($r = -0.2918$ $n = 48$, $P < 0.05$).

Fig 4.6 Scatterplot of weight vs. mean attack latency.



4.3.2. Time budgets

Period 1

Any differences between the time budgets of pigs that were subsequently categorised as H or L pigs were assessed using analysis of variance. The results are shown in Table 4.4. The behaviours displacing and eliminating occurred rarely and were therefore discarded from the analysis. Aggression was also excluded as this was analysed separately (see section 4.3.3.). Data for the percentage of observed time spent sitting or kneeling, alert, drinking and moving were log₁₀ transformed to normalise the data.

There were no significant differences between H and L pigs in the percentage of time spent in any of the postures or behaviours.

Table 4.4 Percentage of observed time spent in each posture and behaviour in Period 1 (pigs in litter-groups).

Posture/ Behaviour	High	Low	s.e.d.	sig.
Lying	67.85	69.26	1.614	n.s.
Sitting/kneeling (log10)	0.125	0.125	0.060	n.s.
Standing	31.64	30.24	1.587	n.s.
Alert (log10)	0.152	0.086	0.086	n.s.
Asleep	61.71	64.47	1.947	n.s.
Rooting	24.0	23.4	2.05	n.s.
Feeding	6.48	6.59	0.761	n.s.
Moving (log10)	0.091	0.046	0.0455	n.s.
Scampering	1.18	1.24	0.306	n.s.

Period 2

The percentage of observed time spent in each posture and behaviour in each observation session (09.30-10.30, 11.30-12.30, 13.30-14.30, 15.30-16.30) was analysed using repeated measure ANOVA treating each hour as a repeated measure. Data for sitting/kneeling, alert, drinking and scampering were normalised by Log10 transformation. Results are shown in Table 4.5.

There was an effect of time of observation session on most of the behaviours recorded. Pigs spent more time lying and less time standing in Session 1 than in Sessions 2, 3 and 4 ($P < 0.001$), more time rooting in Sessions 3 and 4 than in Sessions 1 and 2 ($P < 0.05$), and more time feeding in Sessions 2 and 3 than in Sessions 1 and 4 ($P < 0.001$). There were no significant effects of session or aggressiveness on time spent sitting or kneeling and drinking. There were some effects of aggressiveness and aggressiveness x session interactions, however they show no discernible pattern.

Period 3

The results of the time budget analysis for Period 3 are shown in Table 4.6.

There were no effects of day of Period 3 or aggressiveness on the time spent alert or moving. There were effects of day on time spent rooting (more on Days 16 and 19 than days 1-11 ($P < 0.001$)) and scampering ($P < 0.01$). Aggressiveness effects were found only on time spent sleeping (L pigs more than H pigs ($P < 0.05$)) and time spent

in the feeder (H pigs more than L pigs ($P < 0.001$)). There were also day x aggressiveness interactions for time spent sleeping (L pigs more than H pigs on days 1, 2, and 6 ($P < 0.01$), see Fig. 4.7) and rooting (H pigs more on days 1, 2, and 16 than L pigs ($P < 0.05$), see Fig. 4.8).

Table 4.5 Percentage of observed time pigs spent in each posture and behaviour over each observation session in Period 2, pigs housed individually.

Posture/ Behaviour	Session (S)	High	Low	S s.e.d.	S sig.	Aggress. s.e.d.	Aggress. sig.	SXA s.e.d.	SXA sig.
Lying	1	80.8	71.2						
	2	58.7	70.5						
	3	59	54.6						
	4	66	58.7						
	mean	66.1	63.7	4.21	***	6.05	n.s.	5.96	*
Sit/kneel log10	1	0.207	0.297						
	2	0.297	0.090						
	3	0.438	0.426						
	4	0.346	0.357						
	mean	0.322	0.293	0.0926	n.s.	0.0879	n.s.	0.1310	n.s.
Standing	1	17.3	25.6						
	2	38.5	28.5						
	3	36.2	41.3						
	4	29.2	35.9						
	mean	30.3	32.9	3.82	***	3.43	n.s.	5.40	n.s.
Alert log10	1	0.168	0.285						
	2	0.175	0.157						
	3	0.352	0.258						
	4	0.168	0.297						
	mean	0.216	0.249	0.0870	n.s.	0.0679	n.s.	0.0123	n.s.
Asleep	1	61.9	45.5						
	2	33.0	49.7						
	3	29.2	23.4						
	4	33.7	31.7						
	mean	39.4	37.6	5.14	***	3.93	n.s.	7.27	*
Rooting	1	31.1	43.9						
	2	50.3	38.5						
	3	53.5	62.5						
	4	58.1	56.4						
	mean	48.3	50.3	4.68	***	3.56	n.s.	6.62	*
Feeding	1	4.17	7.69						
	2	12.82	10.25						
	3	10.58	8.97						
	4	5.45	7.37						
	mean	8.25	8.57	1.502	***	1.068	n.s.	2.124	n.s.
Drinking log10	1	0.117	0.039						
	2	0.078	0.039						
	3	0.168	0.129						
	4	0.039	0.157						
	mean	0.101	0.091	0.0604	n.s.	0.0409	n.s.	0.0854	n.s.

Table 4.6 Percentage of observed time spent in each posture and behaviour on days 1, 2, 4, 5, 9, 11, 16 and 19 of Period 3 (pigs housed in groups of 8 high or low aggressive pigs).

	Day	Highs	Low	D s.e.d.	D sig.	A s.e.d.	A sig.	DxA s.e.d.	DxA sig
Alert log 10	1	0.236	0.121						
	2	0.157	0.113						
	4	0.198	0.116						
	5	0.076	0.101						
	9	0.207	.0140						
	11	0.260	0.086						
	16	0.132	0.086						
	19	0.084	0.139						
	mean	0.169	0.115	0.0383	n.s.	0.0325	n.s.	0.0541	n.s.
Asleep	1	73.91	79.48						
	2	75.69	80.97						
	4	76.52	77.54						
	5	76.99	78.49						
	9	76.18	79.23						
	11	76.80	78.35						
	16	71.85	79.11						
	19	77.76	75.55						
	mean	75.71	78.59	1.246	n.s.	1.179	*	1.762	**
Rooting	1	15.48	12.46						
	2	14.70	12.42						
	4	14.43	14.00						
	5	13.67	13.57						
	9	15.03	13.35						
	11	13.23	13.83						
	16	19.03	15.32						
	19	15.01	17.85						
	mean	15.07	14.10	1.009	***	0.987	n.s.	1.426	*
Feeding log10	1	0.662	0.514						
	2	0.745	0.548						
	4	0.732	0.619						
	5	0.721	0.524						
	9	0.756	0.566						
	11	0.791	0.664						
	16	0.786	0.545						
	19	0.716	0.592						
	mean	0.739	0.572	0.0459	n.s.	0.0309	***	0.0649	n.s.
Moving log10	1	0.398	0.915						
	2	0.106	0.080						
	4	0.120	0.118						
	5	0.139	0.147						
	9	0.109	0.031						
	11	0.063	0.080						
	16	0.063	0.047						
	19	0.077	0.031						
	mean	0.095	0.075	0.0352	n.s.	0.0187	n.s.	0.0498	n.s.
Scampering log10	1	0.000	0.031						
	2	0.125	0.119						
	4	0.049	0.101						
	5	0.096	0.140						
	9	0.077	0.062						
	11	0.062	0.118						
	16	0.124	0.055						
	19	0.016	0.046						
	mean			0.0308	**	0.0161	n.s.	0.0436	n.s.

Fig.4.7 Percentage of observed time spent sleeping by groups of 'High' and groups of 'Low' aggressive pigs in Period 3.

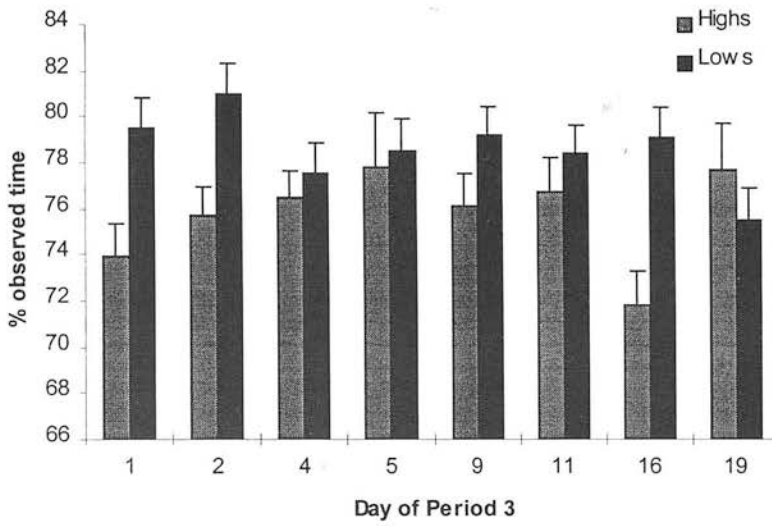
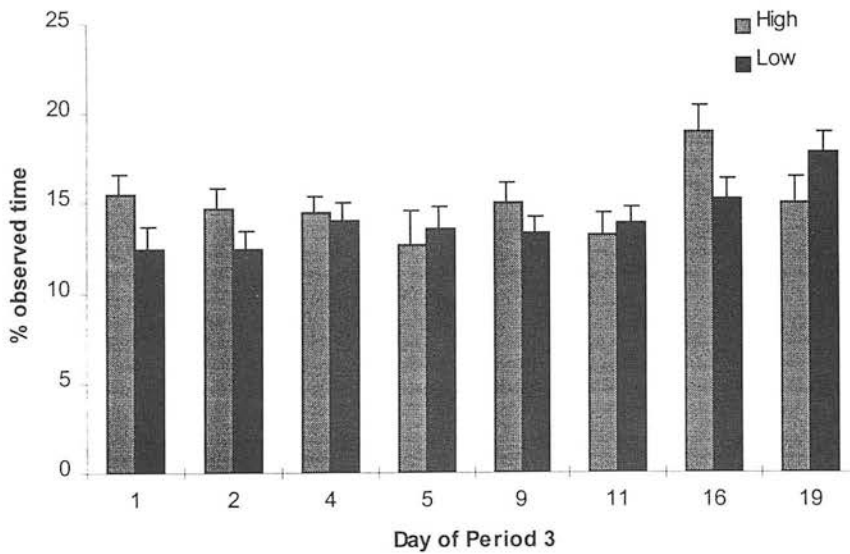


Fig. 4.8 Percentage of observed time spent rooting by groups of 'High' and groups of 'Low' pigs in Period 3.



4.3.3. Social Behaviour

Period 1

Differences in social behaviour between High (H) and Low (L) pigs in Period 1 were assessed using analysis of variance. Data for the frequency of threats, knocks, fights, chases, and displacements were normalised by log₁₀ transformation. Clear winners were rarely observed so the 'win' data were excluded from the analysis. Table 4.7 shows that there were no significant differences in social behaviour between H and L pigs except a higher frequency of displacements from the feeder made by H pigs. However, there were trends for H pigs to have a higher frequency of chases ($P=0.091$) and threats ($P=0.08$) than the L pigs.

Table 4.7 Frequency and duration of social behaviour of pigs in Period 1 (litter-groups).

Behaviour	High	Low	Mean	s.e.d.	sig
frequency of threats log 10	0.217	0.092	0.155	0.070	n.s.
frequency of knocks log 10	0.595	0.512	0.553	0.100	n.s.
frequency of fights log 10	0.241	0.288	0.265	0.086	n.s.
frequency of chases log 10	0.063	0.013	0.038	0.029	n.s.
frequency of feeder displacements log 10	0.140	0.025	0.083	0.038	**
frequency of nosing	1.46	1.75	1.60	0.438	n.s.
duration of fighting log 10	0.97	0.82	0.90	0.278	n.s.
duration of nosing log 10	1.04	1.25	1.14	0.205	n.s.

Period 3

The data were such that a large part of it was made up of zero entries due to the decrease in aggressive behaviour over time and certain pigs not being involved in many interactions. Therefore, the data were split into that which contained more than 50% zeros and that containing less than 50% zeros. Data for the frequency of knocks, and frequency and duration of fights and nosing contained less than 50% zeros. Therefore, these data could be analysed by day of Period 3 using repeated measures ANOVA treating each day as a repeated measure. The data for the frequency of threats, chases and displacements from the feeder contained more than 50% zeros and so days were combined to give total values for the entire period. Results for the frequency (refer to Fig. 4.9 for frequency of fights), duration (refer to

Fig. 4.10 for duration of fights) and bout lengths of social behaviour are shown in Tables 4.8 and 4.9 and summarised in Table 4.10.

Table 4.8 Frequency, total duration and bout length of aggressive interactions on days (D) of Period 3 (pigs housed in groups of 8 high aggressive or 8 low aggressive pigs (A)).

Behaviour	Day (D)	Highs	Lows	D s.e.d.	D sig.	A. s.e.d.	A sig.	DxA s.e.d.	DxA sig.
Knock log10	1	0.310	0.467						
	2	0.432	0.518						
	4	0.495	0.435						
	5	0.526	0.557						
	9	0.463	0.501						
	11	0.428	0.531						
	16	0.403	0.473						
	19	0.332	0.354						
	mean	0.424	0.479	0.0516	**	0.0616	n.s.	0.0730	n.s.
Frequency of fighting log 10	1	0.731	0.467						
	2	0.419	0.412						
	4	0.237	0.324						
	5	0.298	0.335						
	9	0.290	0.252						
	11	0.232	0.259						
	16	0.207	0.366						
	19	0.085	0.277						
	mean	0.312	0.336	0.0492	***	0.0449	n.s.	0.0696	***
Duration of fighting log 10	1	2.33	1.587						
	2	1.227	1.316						
	4	0.720	0.957						
	5	0.902	1.040						
	9	0.872	0.841						
	11	0.667	0.927						
	16	0.775	1.243						
	19	0.273	0.966						
	mean	0.971	1.109	0.1505	***	0.1329	n.s.	0.2128	***
Bout length of fighting log 10	1	1.709	1.176						
	2	0.975	1.005						
	4	0.646	0.735						
	5	0.762	0.821						
	9	0.667	0.686						
	11	0.531	0.661						
	16	0.663	1.011						
	19	0.237	0.811						
	mean	0.774	0.863	0.1247	***	0.1042	n.s.	0.1764	**
Frequency of Nosing log10	1	0.242	0.339						
	2	0.338	0.326						
	4	0.375	0.408						
	5	0.474	0.373						
	9	0.330	0.315						
	11	0.326	0.294						
	16	0.337	0.167						
	19	0.309	0.178						
	mean	0.341	0.300	0.0494	**	0.417	n.s.	0.689	n.s.

Table 4.8 continued.

Duration of	1	0.764	0.955						
Nosing log10	2	1.033	0.907						
	4	1.059	1.274						
	5	0.407	1.107						
	9	0.980	0.940						
	11	1.091	0.902						
	16	1.095	0.610						
	19	1.040	0.785						
	mean	1.059	0.935	0.1549	n.s.	0.1241	n.s.	0.2191	n.s.
Bout length	1	0.580	0.756						
of nosing	2	0.821	0.731						
log 10	4	0.812	1.005						
	5	1.082	0.860						
	9	0.813	0.730						
	11	0.901	0.741						
	16	0.890	0.542						
	19	0.826	0.592						
	mean	0.840	0.745	0.1301	n.s.	0.0904	n.s.	0.1840	n.s.

Table 4.9 Frequency of aggressive interactions, where the data consisted of greater than 50% zero entries in Period 3 (pigs housed in groups of 8 high aggressive or 8 low aggressive pigs).

Behaviour	Highs	Lows	Aggress. s.e.d.	Aggress. sig.
Threat log10	0.806	0.678	0.0722	n.s. (P=0.083)
Chase log10	0.434	0.391	0.1339	n.s.
Displace from feeder log 10	0.321	0.155	0.0723	*

Fig 4.9 Mean frequency of fights in Period 3

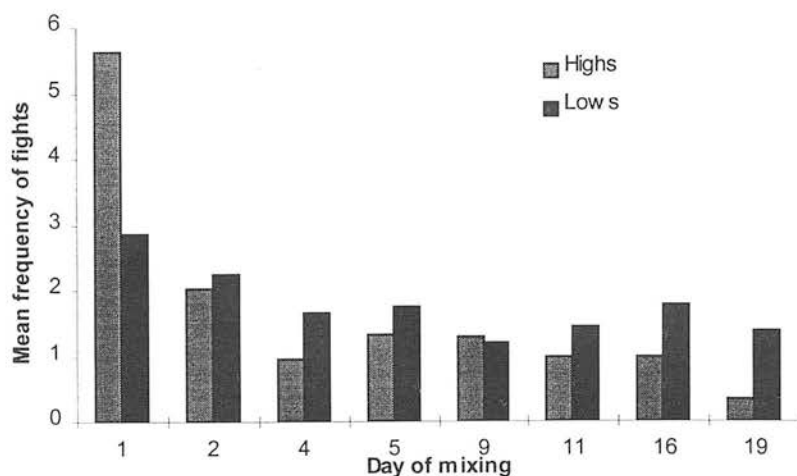
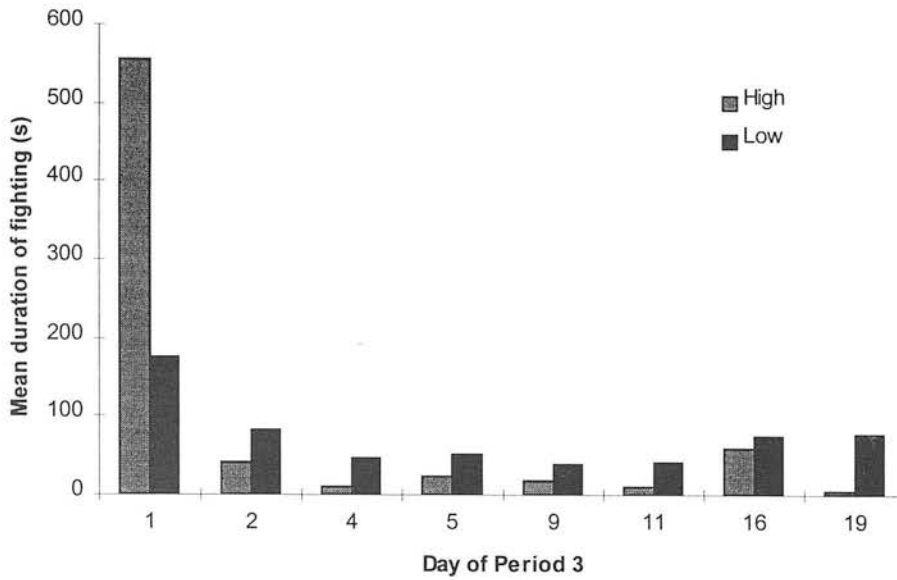


Fig. 4.10 The mean duration of fighting per day of Period 3.**Table 4.10** Summary of social behaviour Period 3, pigs housed in groups of 8 High aggressive (H) or 8 Low aggressive (L) pigs.

Behaviour	High/Low	Day	High/Low x Day
Frequency of threats	P=0.08 Trend for H to make more threats than L.	Not analysed	Not analysed
Frequency of knocks	No effect	P<0.01 More knocks day 5 than days 1 and 19. More on days 2, 4, 5, 9 and 11 than on day 19	No effect
Frequency of fights	No effect	P<0.001 Most fights day 1. More fights day 2 than days 4-19. No difference between frequency of fights days 4-19.	P<0.001 Day 1, H more fights than L. Days 2-11 no differences. Days 16 and 19, L more fights than H.
Duration of fights	No effect	P<0.001 Longest day 1. Longer day 2 than days 4, 9, 11 and 19. Longer day 16 than day 19.	P<0.001 H longer day 1. L longer days 16 and 19.
Mean fight bout length	No effect	P<0.001 Longest bouts day 1. Longer day 2 than day 4, 9, 11 and 19. Longer day 16 than day 19.	P<0.001 L longer than H day 19.
Frequency of chasing	No effect	Not analysed	Not analysed
Frequency of feeder displacements	P<0.05 H greater than L	Not analysed	Not analysed
Frequency of nosing	No effect	P<0.01 Nose more on day 5 than on days 1, 9, 11, 16 and 19.	No effect
Duration of nosing	No effect	No effect	No effect
Mean nosing bout length	No effect	No effect	No effect

4.3.4. Feeding Behaviour

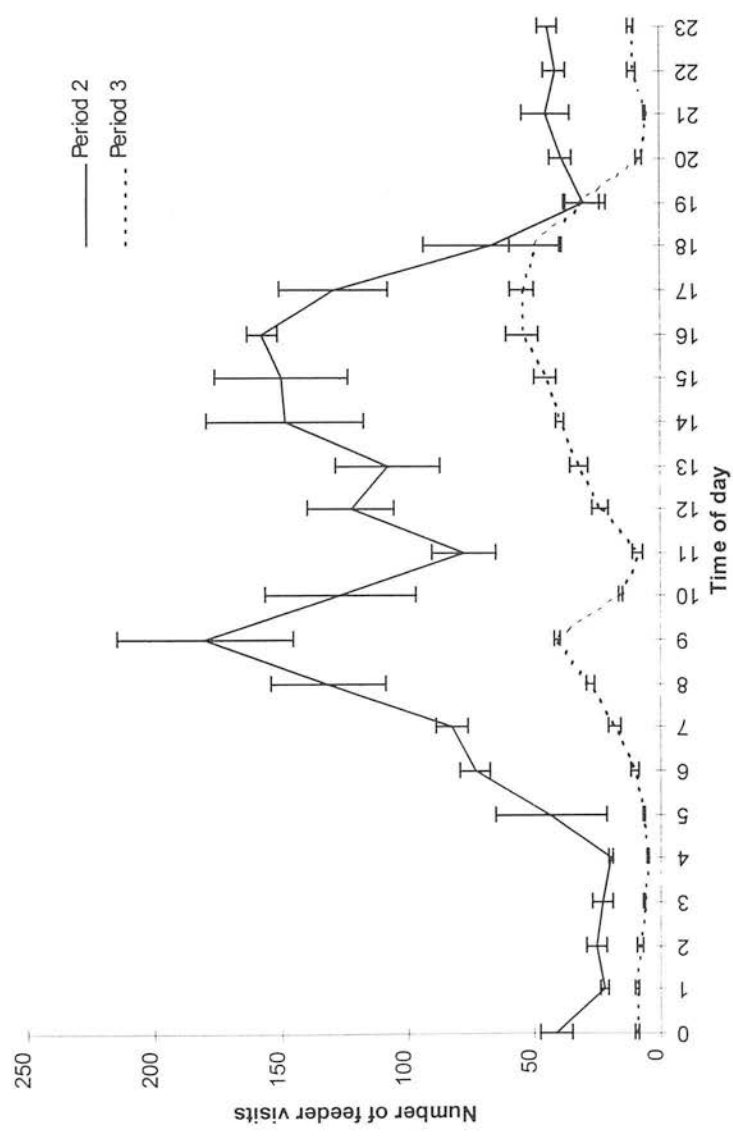
When individually housed in Period 2, and when group housed in Period 3, pigs showed a bi-modal pattern of eating with peaks around 09.00h and 16.00 hours (refer to Fig. 4.11). The feeding behaviour of all pigs changed between individual and group housing (see Table 4.11). The frequency of feeder visits decreased from Period 2 to Period 3 ($P<0.001$), visit duration increased ($P<0.001$) and food intake per visit increased ($P<0.001$). Pigs ate at a faster rate in Period 3 than in Period 2 ($P<0.001$). Food intake and feeder occupation also increased from Period 2 to Period 3 ($P<0.001$). However, weight gain decreased ($P<0.05$) and food conversion ratio became poorer ($P<0.001$).

There were no effects of aggressiveness and no period x aggressiveness interactions.

Table 4.11 Feeding behaviour and performance of pigs in Period 2 (housed individually) and Period 3 (housed in groups of 8 High aggressive or 8 Low aggressive pigs).

	Period	High	Low	Period s.e.d.	Period Sig	Aggress. s.e.d.	Aggress. sig.	P X A s.e.d.	P X A sig.
Visits/day	2	126.6	114.5						
	3	31.7	27.6						
	mean	79.2	71.1	5.82	***	6.75	n.s.	8.23	n.s.
Visit duration	2	30.23	43.0						
	3	114.7	111.1						
	mean	72.5	77.0	7.15	***	8.33	n.s.	10.98	n.s.
Food intake/visit	2	11	15						
	3	107	156						
	mean	59	86	28.4	***	25.8	n.s.	40.1	n.s.
Feeding rate (g/min)	2	27.37	26.60						
	3	35.25	35.33						
	mean	31.31	30.96	0.876	***	1.997	n.s.	1.239	n.s.
Food intake (g/day)	2	1533	1471						
	3	1757	1697						
	mean	1645	1584	41.9	***	73.3	n.s.	59.2	n.s.
Feeder occupation	2	59.3	60.9						
	3	48.9	47.4						
	mean	54.1	54.2	2.13	***	3.39	n.s.	3.01	n.s.
Weight gain (kg/day)	2	0.936	0.907						
	3	0.863	0.859						
	mean	0.899	0.883	0.0301	*	0.0372	n.s.	0.0426	n.s.
Food conversion ratio (kg food/kg gain)	2	1.664	1.626						
	3	2.068	1.992						
	mean	1.866	1.809	0.0466	***	0.0476	n.s.	0.0659	n.s.

Fig. 4.11 Time of day of visits to the feeder in Period 2 (pigs housed individually) and in Period 3 (pigs housed in groups of 8).

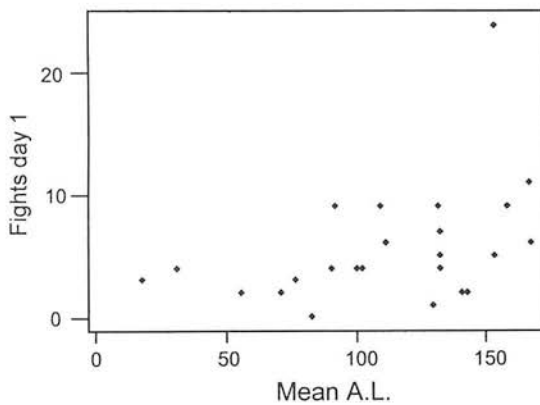


4.3.5. Relationship between attack latency and aggression levels in Period 3

Comparisons were made between attack latency and frequency and duration of fights on day 1 of Period 3 plotting scatterplots and calculating correlation coefficients.

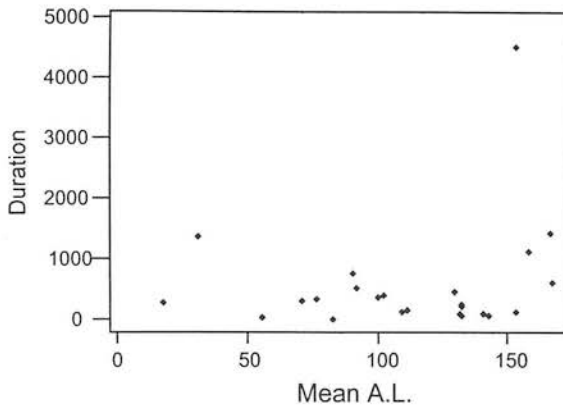
There was no correlation between mean attack latency and the frequency of fights on day 1 when data from all pigs were considered. However, converse to what might be expected, when only data from H pigs were used, there was a positive correlation between mean attack latency and frequency of fights on day 1 ($r = 0.420$, $n = 24$, $P = <0.05$). Therefore, as mean attack latency increased, pigs had a higher frequency of fights on day 1 of Period 3 (refer to Fig 4.12).

Fig. 4.12 Scatterplot of Mean attack latency and the frequency of fights on day 1 of Period 3 of High Aggressive pigs.



There was no relationship between mean attack latency and the total duration of fighting or mean bout length on day 1 of Period 3 both when data from H and L pigs, and data from only H pigs were considered (refer to Fig. 4.13).

Fig. 4.13 Scatterplot of mean attack latency (s) and total duration of fighting (s) on day 1 of Period 3.



4.3.6. Salivary cortisol

There was an effect of Period of the experiment on salivary cortisol concentrations (see Table 4.12). Concentrations were higher in Period 1 when the pigs had just been weaned and were housed with their littermates than in Periods 2 and 3 ($P < 0.001$). However, there were no differences in the mean salivary cortisol concentrations between Period 2 and Period 3. There were no effects of aggressiveness alone on cortisol concentration, however there was an aggressiveness by period interaction; L pigs having a higher mean salivary cortisol concentration than H pigs in Period 2 ($P < 0.01$). There was also an effect of period x time of day of sampling. The mean concentration of cortisol at 10.00h decreased from Period 1 to Period 2 whilst at 14.00h it decreased from Period 1 to Period 2, and increased from Period 2 to Period 3 ($P < 0.01$).

Table 4.12 The effect of Period (Period 1 littermates, Period 2 individual housing and Period 3 groups of 8) and Aggressiveness (High or Low aggressiveness) on salivary cortisol concentrations in pigs

	Period (P)	Aggressiveness (A)		P sed	P sig	A sed	A sig	P x A sed	P x A sig
		High	Low						
cortisol ng/ml (log10)	1 (n=192)	0.2418	0.2168	max-min 0.00998				max-min 0.01411	
	2 (n=384)	0.1817	0.2085						
	3 (n=384)	0.2009	0.1874	max.rep				max.rep	
	mean	0.2014	0.2017	0.00815	***	0.01282	n.s.	0.01152	*

The effect of day within period and time of day of sampling were also investigated (refer to Table 4.13 and Fig. 4.14 for results). There was a significant effect of day on cortisol concentration ($P < 0.001$); the highest concentration being on Day 1 (the beginning of Period 1), the lowest on Day 6 (the end of Period 2). There was some consistency in cortisol concentrations between consecutive sampling days except that there were significant differences between cortisol concentrations between days 1 and 2 and days 5 and 6. In addition there was a day \times aggressiveness interaction; H pigs had lower salivary cortisol concentrations than L pigs on Day 3 (first sample day of Period 2), and on Day 5 (third sample day of Period 2). However, on day 10 (the final sample day of Period 3) H pigs had higher concentrations of cortisol than L pigs ($p < 0.05$)

There was no effect of time of day of sample on cortisol concentration. There were however day \times time interactions ($P < 0.05$) and day \times time \times aggressiveness interactions ($P < 0.05$). However, the biological significance of these interactions is difficult to discern.

Fig. 4.14 Salivary cortisol concentration ng/ml on saliva sampling days in Periods 1 (Days 1 and 2), 2 (Days 3-6), and 3 (days 7-10) for pigs of High and Low aggressiveness.

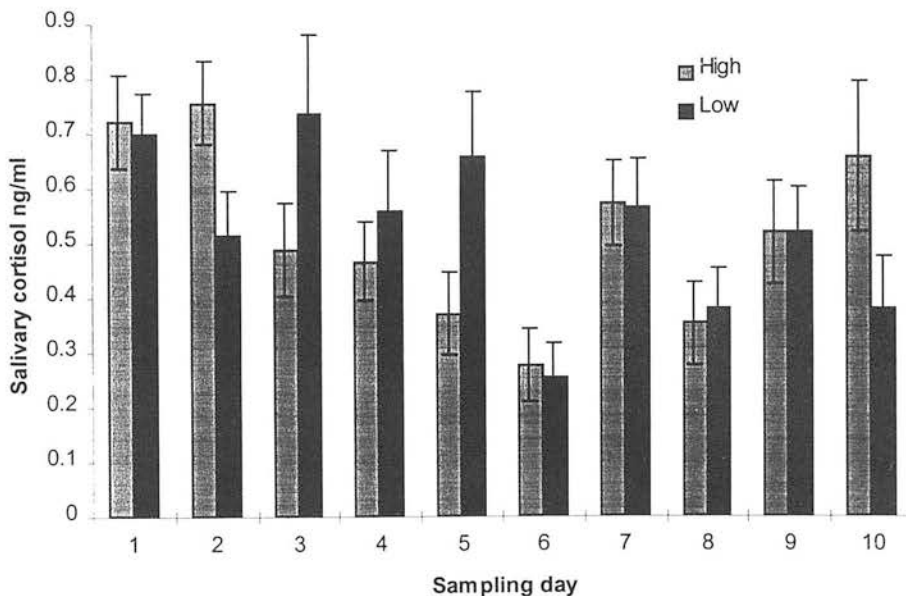


Table 4.13 The effect of sampling day, time of day (10.00h or 14.00h), and Aggressiveness (High or Low) on salivary cortisol concentrations.

Cortisol ng/ml (log 10) Day (D)	Time (T)				D s.e.d.	T s.e.d.	T sig.	A s.e.d.	A sig.	DXT s.e.d.	DXT sig.	DXA s.e.d.	DXA sig.	TXA s.e.d.	TXA sig.	DXAXT s.e.d.	DXAXT sig.
	10.00h High	10.00h Low	14.00h High	14.00h Low													
1	0.250	0.231	0.266	0.229													
2	0.222	0.201	0.224	0.198													
3	0.214	0.250	0.189	0.237													
4	0.195	0.214	0.183	0.201													
5	0.162	0.248	0.180	0.197													
6	0.171	0.164	0.165	0.151													
7	0.217	0.197	0.180	0.197													
8	0.157	0.152	0.197	0.188													
9	0.171	0.193	0.228	0.205													
10	0.243	0.155	0.212	0.214													
mean	0.200	0.200	0.202	0.202	0.014	0.004	n.s.	0.013	n.s.	0.017	*	0.017	*	0.014	n.s.	0.027	*

4.4. Discussion

The attack latency test did predict the aggressiveness of groups on the day of mixing. Pigs in H groups had a higher frequency and duration of fighting on Day 1 of Period 3 than pigs in L groups. However, an individual's attack latency did not predict how aggressive that individual would be within the group. In addition, differences in aggression levels between pigs in H and pigs in L groups were not consistent across Period 3; pigs in L groups increased their aggression levels towards the end of the period relative to pigs in H groups. Thus, the attack latency test did not predict aggression levels in groups towards the end of Period 3. As expected feeding behaviour changed between individual and group housing, but there were no effects of group composition on feeding behaviour. Attack latency, and the effect of group composition on feeding behaviour, performance and welfare are discussed below.

Groups of 8 pigs, made up of 2 or 3 pigs from each of 3 or 4 litters, were used in the present experiment. It is possible that pigs in larger groups, or with a different composition in terms of pigs from each litter may behave differently. Nielsen *et al.* (1995) compared the feeding behaviour of pigs housed in groups of 5, 10, 15 or 20. A threshold effect for feeding behaviour was found; the pigs housed in groups of 20 differing significantly from pigs housed in groups of 15 or less, the latter being similar. Therefore, the results discussed here are likely to apply groups of pigs up to 15 in size, but not to larger groups. Erhard *et al.* (1997) mixed pigs into groups of 8 consisting of 4 pigs from one litter and 4 pigs from another litter. Therefore, in the following discussion, where the results from their experiment are compared with the results from the present experiment contrasts may partly be due to these differences in the compilation of groups.

4.4.1. Attack latency

There was a correlation between latency to attack in test 1 and test 2 with a decrease in time to attack and more pigs attacking in test 2 than in test 1. This is in accordance with Erhard and Mendl (1997) who described the change as a short term

priming effect of repeating the test on consecutive days. It is likely that habituation to the test resulted in increased confidence and likelihood to attack in test 2. Erhard and Mendl (1997) used results from 3 datasets. In datasets 1 and 2 pigs were tested at 11 weeks of age on 2 consecutive days. In dataset 3, pigs were tested at 7 and 11 weeks of age. The distribution of attack latency in the present experiment was different to that found by Erhard and Mendl (1997) in data sets 1 and 2. In these datasets they found that a large number of pigs attacked in the first 40 seconds of the test. In the present experiment attacks tended to take place later; between 30 and 150 seconds. A possible reason for this inconsistency is that the pigs used here were younger than those used by Erhard and Mendl (1997) in data sets 1 and 2, and it may be that aggressiveness develops with age. Indeed, Erhard and Mendl (1997) investigated the effect of age on attack latency using results from dataset 3 and found that pigs had slower attack times at 7 weeks compared to 11 weeks of age but there was consistency between tests.

In agreement with Erhard and Mendl (1997) there were no differences in A.L. between males and females. This is as would be expected as the pigs had not yet reached sexual maturity. Hessing *et al.* (1993) classified aggressiveness using a social confrontation test between 3 piglets from one litter and 3 piglets from another litter rather than an attack latency type test but they also found no effect of gender on aggressiveness. Due to restrictions of availability of piglets, some litters were older than others when the tests were performed, but no effects of age on A.L. were found. However, there was an effect of weight on A.L.; heavy pigs tending to attack faster than lighter pigs. This is contrary to findings by Rushen (1988) and Erhard and Mendl (1997) who reported age and weight not to be influential in aggressiveness of pigs. However, when the data from the two categories H and L were compared there were no differences between pigs selected for each category. Thus, there was an absolute effect of weight on A.L. but no categorical effect.

4.4.2. Timebudgets

As expected, in Period 1, there were no differences in the time budgeting between the pigs subsequently categorised as High or Low aggressive. There were also no differences, of biological significance, in timebudgets, between H and L pigs in Period 2. In Period 3, H pigs were generally more active than L pigs. Throughout Period 3, L pigs spent more time sleeping than H pigs. In addition, H pigs spent more time rooting than L pigs on the first 2 days of Period 3 and had more aggressive interactions on day 1 of Period 3. This suggests that pigs in L groups had more social stability than pigs in H groups, particularly on the first 2 days of Period 2. Although analysis of the feeding data showed no differences between H and L pigs, H pigs did spend more of the observed time in the feeder in Period 3. It is possible that these pigs spent more time in the feeder not actually feeding but blocking access to the feeder for group mates. Alternatively, pigs may have been using the race of the feeder to retreat from an aggressor. Indeed pigs were sometimes observed rushing into the race to terminate an aggressive interaction.

4.4.3. Social behaviour

In Period 1, when the pigs were housed in their litter-groups, the occurrence of overt aggression such as fights and knocks was low. However, H pigs made more displacements from the feeder, and there was a trend for them to have a higher frequency of chases and threats than L pigs. This suggests that H pigs tend to be more aggressive than L pigs when in their litter-groups, but they express this in the form of subtle, non damaging aggression. These results are consistent with the attack latency results and confirm that the A.L. test does give us useful information about the aggressiveness of individual pigs at the time of the test.

When the pigs were mixed at the beginning of Period 3 groups of both H and L pigs had a greater frequency and duration of fights on day 1 and this generally declined over days from mixing. There were differences between groups of all H pigs and all L pigs. Although the pigs in H groups had a higher frequency and duration of fights

than pigs in L groups on day 1, they decreased the frequency of fighting across the 3 week Period. The pigs in L groups on the other hand, had a lower frequency and duration of fighting on day 1 than pigs in H groups but maintained slightly higher levels of aggression and had higher frequencies and durations of fighting than pigs in H groups on days 16 and 19 after mixing. It would have been useful to have a measure of intensity of fighting such as lesion scores as it could be that the pigs in L groups did little damage when fighting compared to the pigs in H groups. However, this was not feasible as the pigs had to be transported together in a trailer to a different building between Periods 2 and 3 and it would not be possible to distinguish between lesions sustained from transport and those received from fighting at mixing. It is possible that the high levels of aggression on Day 1 of Period 3 facilitated the establishment of a social order for the pigs in H groups. The pigs in L groups on the other hand did not do this and consequently may not have established a social order and levels of aggression were maintained at a higher level relative to the pigs in H groups. This is in contrast with the results of Erhard *et al.* (1997), who suggested that groups of all low aggressive pigs integrated into the group faster and had lower levels of aggression at mixing. However, they did not record aggression levels in the groups past day 7 from mixing.

Why do groups of low aggressive animals show this pattern of aggression? It could be that low aggressive animals tend to avoid aggression wherever possible or do not allow fights to escalate. If fights are avoided, and not allowed to escalate, important information about the relative fighting ability of an opponent might not be determined. This could lead to a delay in the development of stable social organisation. Indeed, Rushen (1988) suggested that young pigs are unable to assess their chances of winning an aggressive interaction without fighting. On a second meeting previous losers were less likely to initiate fights, and fights were of a shorter duration. This suggests that initially, when pigs are mixed, determinative fights are essential in the establishment of a social hierarchy.

4.4.4. Did attack latency reflect aggression levels when the pigs were mixed into groups?

Although there was a relationship between the categories H and L and aggression levels when the pigs were grouped, there were no correlations between mean attack latency and the frequency or duration of fights on day 1 of Period 3. Therefore, attack latency seems to be reflected in the overall aggression levels of the group rather than the amount of aggression initiated by the individual pigs within a group.

It is conceivable that housing the pigs individually in Period 2 had some effect on their aggressiveness. Erhard and Mendl (1997) found attack latency to be repeatable across a 4 week interval. Thus in terms of the time delay from testing to mixing it is unlikely there would have been an effect on individual pig's aggressiveness. However, housing the pigs individually in Period 2 may have had an effect on their aggressiveness due to a lack of social stimulation for the 2 week period. Byrd and Briner (1999) found rats reared in isolation (isolated from days 14-30) to show significantly more fighting and non-aggressive social behaviour than non-isolated rats and more fighting than briefly isolated rats (isolated from day 14 to 21) when they were mixed into groups at 30 days of age. Furthermore, in an investigation of aggression and play fighting in golden hamsters, Onyekwere and Ramirez (1994) found isolation to increase aggression levels. The results from these studies would suggest that any changes in aggressiveness of the pigs during Period 2 would most likely be in the direction of an increase in aggressiveness.

4.4.5. Feeding behaviour

As expected the pigs decreased their frequency of visits to the feeder, increased their visit duration and increased their food intake per visit from Period 2 to Period 3. This confirms previous findings (Chapter 3). In addition, pigs ate at a faster rate in Period 3 than in Period 2. This could be due to the increasing size of the pigs or to social stress. Indeed, Nielsen (1999) suggested that changes in feeding rate can

reflect changes in the social environment and so can be used as an indicator of social stress.

Although H pigs made more displacements from the feeder than L pigs, there were no effects of aggressiveness on feeding behaviour. This suggests that group composition in terms of latent aggressiveness, and subsequently social organisation does not affect either feeding pattern or food intake. In Chapter 3, I proposed the theory that group cohesion is likely to be responsible for the changes in pigs' feeding behaviour between individual and group housing. Moreover, group integration and a stable social organisation may be important in the development of group cohesion. If feeding behaviour is unaffected by group composition, then what are the implications for the group cohesion theory? It is possible that aggressiveness and aggression levels do not affect group cohesion. Indeed some pigs would lie together in the pen soon after an aggressive encounter. Silk *et al.* 1996 reported monkeys to approach and interact non-aggressively with their former opponents at much higher rates immediately after an aggressive interaction. They suggested that this reconciliation behaviour may have implications for group cohesion. This may also be true in pigs; at mixing, fighting is essential to determine a social order, whilst the evolutionary benefits of being together in a group are also important. Therefore, it is possible that the development of a cohesive group occurs alongside the development of a stable social organisation. In addition, there will always be a certain amount of reassessment of the hierarchy. Thus, the group may be cohesive even when there are relatively high levels of aggression. Therefore, the group cohesion that provides the motivation for the company of other pigs may still act even if a stable social organisation has not been formed and this would explain why there were no differences in feeding behaviour between pigs in H groups and pigs in L groups.

4.4.6. Consequences for production and welfare

There were no effects of group composition on food intake, weight gain and food conversion ratio; thus production levels were unaffected. However, there was a decrease in weight gain and food conversion ratios became poorer in Period 3

compared to Period 2. This change could be due to the increasing size of the pigs. However, in Chapter 3, it was found that there were no significant changes in weight gain and food conversion ratio over a 9 week period in pigs housed individually. Thus, there, must be some consequence of mixing and group housing that results in a decrease in production variables. One explanation could be that pigs experience social stress when group housed which results in a reduction in production levels.

Without the presence of stressors, salivary cortisol concentrations decrease with age in growing pigs and this may be due to a shift in plasma cortisol from a relatively unbound form to a bound form from birth to 6 weeks of age (Kattesh *et al.*, 1990). Ruis *et al.* (1997) found that basal cortisol decreased between the ages of 12 and 24 weeks and suggested that this was due to an extension of the increased binding to corticosteroid-binding-globulin. A stable adult rhythm was reached at around 20 weeks, or near puberty (Evans *et al.* 1988). The pigs in the present experiment were between 4 and 12 weeks of age when their saliva was sampled, so it would be expected that their levels of salivary cortisol would be decreasing over the course of the experiment. When differences in salivary cortisol concentrations between periods were considered it was discovered that the pigs had higher concentrations of cortisol when they were housed in litter-groups in Period 1. However, contrary to what would be expected, there were no differences in cortisol concentrations between Periods 2 and 3. The pigs had not yet reached maturity and so the levels of cortisol should have decreased from Period 2 to Period 3. This may suggest that stress levels were elevated when the pigs were group housed in Period 3. Conversely, Barnett *et al.* (1981) investigated the effects of individual and group penning of 2 year old pigs on plasma corticosteroids. Their results inferred that there was an acute stress response to grouping that had decreased to normal levels after 24 hours, whilst individual penning resulted in a chronic stress response as shown by elevated mean corticosteroid concentrations.

Ekkel *et al.* (1996) described the circadian rhythm of cortisol in the saliva of young pigs and found a peak in saliva around mid-morning. A blunted circadian rhythm of

cortisol may be used as an indicator of increased stress and decreased welfare. de Jong *et al.* (2000) reported barren housed pigs to have blunted circadian rhythms of salivary cortisol compared to enriched housed pigs at 22 weeks at age. Therefore, in the present experiment, any small differences in cortisol concentrations at 10.00h and 14.00h between periods may be indicative of a blunted amplitude. It was expected that cortisol concentrations would be higher at 10.00h than at 14.00h. Overall, there were no differences in cortisol concentrations between samples taken at 10.00h and 14.00h. However, there was an interaction between sampling time and period of the experiment. In Periods 1 and 2 there were no differences in salivary cortisol between samples taken at 10.00h and 14.00h. In Period 3, however, when the pigs were group housed, cortisol concentrations were higher at 14.00h than at 10.00h. This might indicate a blunted circadian rhythm (concentration at 10.00h having decreased relative to the concentration at 14.00h), and therefore may be indicative of increased stress levels when the pigs were group housed. At 10.00h the mean salivary cortisol concentration decreased across Periods. This could be explained by the increasing age of the pigs. On the other hand, at 14.00h, cortisol concentrations decreased from Period 1 to Period 2 but increased from Period 2 to Period 3. Hence, when the pigs were individually housed in Period 2, concentrations of cortisol were decreased at 14.00h compared to concentrations in Periods 1 and 3. This effect is difficult to explain but could be an effect of stress due to a lack of social stimulation.

These findings are contrary to the those of Ekkel *et al.* (1997). They investigated the effects of mixing on behaviour and circadian salivary cortisol concentration. They compared groups of un-mixed pigs with groups of pigs (9 weeks of age) that had been transported and then mixed with unfamiliar animals. Saliva was sampled at 2 hour periods over 24 hours on day 6 and day 41 after mixing and agonistic interactions were recorded immediately after mixing and 5 to 6 weeks afterwards. As in the present experiment they also found that mixing lead to vigorous fighting for some days to establish a social rank, but this rank was not very stable, and chronically increased levels of mutual aggression were found many weeks after mixing when the real fighting had subsided. The average cortisol level was not

different between mixed and un-mixed groups at day 6 or day 41. In addition, salivary cortisol was higher at day 41 than at day 6 for mixed groups and un-mixed control groups. They suggested that the increase in cortisol was probably age related. However, this is in contrast to other authors (Ruis *et al.*, 1997; Kattesh *et al.*, 1990 and Evans *et al.*, 1988) who reported decreases in cortisol concentration with age. In the present experiment saliva sampling could not always be taken on the same days as social behaviour was video recorded due to the logistics of the experiment. Therefore, it was not possible to directly compare relative stress and aggression levels. Ekkel *et al.* (1997) concluded that they could not determine if the persistence of aggression after mixing reflects a state of chronic stress because there were no differences in the circadian rhythm of salivary cortisol between mixed and un-mixed groups. In contrast, other authors (Parrot and Mission, 1989; Bradshaw *et al.* 1996) have reported that pigs do show an elevated salivary cortisol response to mixing. However, in these studies salivary cortisol was measured at intervals within 24 hours of mixing, hence the acute response to mixing were measured rather than chronic effects over the long term.

Although there were no effects of aggressiveness alone on salivary cortisol concentrations, there were period x aggressiveness interactions. In Period 2, L pigs had higher salivary cortisol than H pigs. This suggests that L pigs had higher stress levels and were perhaps less able to cope with the lack of social stimulation than H pigs. This in turn might suggest that aggressiveness and motivation for company might come hand in hand; less aggressive animals being more sociable. However, as no direct measure of sociability was made, and there were no differences in the amount of non-aggressive social interactions made by H and L pigs I can only speculate.

When pigs were mixed into new groups at the start of Period 3, it was anticipated that H pigs would have higher levels of cortisol than L pigs due to the elevated levels of aggression at that time. However, there were no differences between H and L pigs on the first 3 sampling days in Period 3. Saliva was not collected on the day of

mixing in Period 3 as it would have interfered with the video recordings of the aggressive behaviour on that day. Therefore, saliva was collected for the first time in Period 3 on the day after mixing. By that time aggression levels had subsided and there were no differences in aggression levels between H and L pigs and thus a difference in cortisol concentrations would not be expected. Towards the end of Period 3 (on sampling day 10) H pigs had higher cortisol concentrations than L pigs. This would suggest that aggression levels do not affect cortisol concentrations as L pigs had higher aggression levels in the last few days of Period 3 than H pigs.

It would have been useful to have a control block where pigs were kept as litter-groups throughout the 8 week experiment so that differences in cortisol concentration could be attributed to either age or treatment. Unfortunately, within the constraints of this experiment it was not possible. Thus from the results obtained here, it seems that mixing and group housing may have some effect on stress levels, but further studies would be required with a control to draw clear conclusions. There were no effects of aggressiveness on cortisol concentrations which would suggest that stress levels, at least in the long term, were not affected by aggressiveness and thus welfare measured in these terms is not compromised by mixing high aggressive pigs together. However, it would have been useful to have measures of cortisol immediately after mixing which, combined with lesion scores, would perhaps have provided more information on acute levels of stress at mixing. This may have given information on what is 'better' welfare for the pigs; to fight vigorously when mixed to establish a social order (as showed by the pigs in H groups) or to have lower levels of aggression at mixing have elevated aggression levels for extended periods after mixing (as shown by the pigs in L groups).

4.4.7. Conclusion

In conclusion, attack latency successfully predicted aggressiveness on Day 1 of grouping; groups of H pigs had a higher frequency of fighting and spent longer fighting on Day 1 than groups of L pigs. However, groups of all H and all L pigs did not remain consistent in their behaviour. Although pigs in H and L groups decreased aggression levels after the day of mixing, pigs in L groups increased their aggression levels relative to pigs in H groups towards the end of Period 3. This suggests that groups of H pigs fight more at mixing but this fighting enables social status to be determined more easily than pigs in the L groups. In Period 3, pigs altered their feeding behaviour in the direction of fewer visits to the feeder of a longer duration and ate more food per visit. They also ate at a faster rate than in Period 2 which may be indicative of social stress. There were no effects of group composition on feeding behaviour. In terms of stress and welfare, it was difficult to determine the exact effects of mixing and group housing on salivary cortisol levels. However, the results suggest that stress levels may have been elevated in Period 3. There were no differences between pigs in H and pigs in L groups on salivary cortisol concentrations, which suggests that in the long term mixing H pigs together does not compromise their welfare. Therefore, group composition, in term of latent aggressiveness does not affect feeding behaviour or production levels. However, there are some effects on aggression levels, pigs in H groups having higher levels of aggression at mixing, which may cause short term welfare problems.

The effect of grouping and group composition on meal patterns of growing pigs.

5.1. Introduction

Satiety centres in the hypothalamus play an important part in the control of short-term food intake. The release of nutrients from foods in the digestive tract results in an increase in concentrations of nutrients in the blood. This increase in nutrient concentration is detected by the satiety centre and the animal stops eating (McDonald *et al.*, 1996). When an animal ends a meal due to satiation, the probability of it starting another meal is low. However, the probability of starting a meal increases with time, as satiation decreases, with a concomitant increase in feeding motivation (Tolkamp and Kyriazakis, 1999). Thus, it is important to consider the fundamental principles of satiety when interpreting feeding behaviour.

Feeding behaviour can be described using variables such as the time of day of visits to the feeder, number of visits per day, visit duration and food consumed per visit (Nielsen *et al.*, 1995; Chapters 2 and 3). Feeder visits are separated by very short to very long intervals and are generally clustered into bouts or meals (Tolkamp and Kyriazakis, 1999). Therefore, the analysis of feeding behaviour in terms of meals may be biologically, more significant than an analysis based purely on feeder visits. Methods have been developed that separate intervals between visits into within and between meal intervals. To distinguish between the short pauses that occur within a meal and the longer lengths of time between meals a meal criterion needs to be determined. A meal criterion indicates the shortest interval between visits that can be considered an interval between meals (Tolkamp *et al.*, 1998)

A common method uses log-survivorship curves (Slater and Lester, 1982) which plot the frequency of intervals with a length $>t$ (on Y axis) against interval length t (on X axis). These cumulative frequencies are normally log-transformed and give a useful

initial impression of the frequency distribution of between feeding intervals by visual inspection without too many assumptions (Tolkamp *et al.*, 1998). Visual assessment can be used to estimate meal criteria from these curves but this method can be rather subjective. Quantitative methods such as log-frequency analysis (Langton *et al.*, 1995) estimate the values of parameters of the processes that lead to a log-survivorship curve. This method relies on the assumption that the pattern of eating follows a random model such that the probability of a visit to the feeder in a given time interval is constant resulting in the slope of the log-survivorship curve being constant (Bigelow and Houpt, 1988).

Tolkamp *et al.* (1998) challenged the method of log-frequency analysis as the assumption of a random model of eating is in conflict with the idea of satiety. This model has the underlying assumption that the probability of an animal initiating a meal is independent of the duration of the non-feeding interval. However, the satiety concept dictates that meals are not randomly distributed in time. Therefore, the negative exponential model for between-meal intervals is incompatible with the satiety concept and there was a need for a more appropriate model.

Using feeding data from dairy cows, Tolkamp *et al.* (1998) confirmed that the method assuming randomness did not describe their data correctly. As an alternative they found that 2-log normal distributions best described the interval between visits to the feeder. Tolkamp and Kyriazakis (1999) further investigated the use of the 2-log normal model. They found that the addition of a third log-normal improved the fit of the model and suggested that this third distribution represents intervals associated with the cows drinking during a meal.

The log-normal distribution model was therefore established for ruminant feeding behaviour. Growing pigs are simple stomached animals, very different from mature ruminants. Bigelow and Houpt (1988), in a paper describing the feeding and drinking behaviour of young pigs, used the log survivorship function to determine a meal criterion of 10 min for the shortest inter-meal interval. However, pigs, like all

animals, do not eat in a random fashion. To take this into account Morgan *et al.* (2000a) tested the applicability of the method developed by Tolkamp *et al.* (1998) to feeding data from growing pigs. In contrast to Tolkamp *et al.* (1998), they found that the model with 2-log normal distributions did not fit the data much better than a model that assumed a random process. However, Morgan *et al.* (2000a) concluded that the log-normal model is more consistent with physiological principles. Later Morgan *et al.* (2000b), confirmed that the random process model was not appropriate for the analysis of intervals between feeder visits. They showed that the success of the model in the past was a result of the way in which the data were combined. When the data were separated into day and night intervals the random process model did not describe the data well and it was confirmed that the starting probability increased with time since the last visit. Morgan *et al.* (2000a) also found that, like Tolkamp and Kyriazakis (1999), a model with three Gaussian distributions resulted in a better fit than the two process model indicating the presence of a third distribution.

In summary, the biological significance of these three distributions is as follows. Pigs eat in meals separated by long intervals, a meal is made up of clusters of eating bouts separated by shorter intervals which may, in some cases, be associated with drinking, within each bout of eating, short intervals occur as pigs continuously move in and out of the feeder (Morgan *et al.*, 2000a).

In Chapter 4, feeding behaviour was measured in terms of time of day of visits to the feeder, number and duration of visits and food intake per visit. Pigs were housed individually for 2 weeks before being combined into groups of 8 pigs of either all High or all Low aggressiveness. When group housed, pigs made fewer visits to the feeder, of a longer duration and ate more food per visit, at a faster rate than when individually housed. However, there were no effects of group composition in terms of latent aggressiveness on feeding patterns described in terms of feeder visits. Tolkamp *et al.* (2000) found that the analysis of feeding behaviour of cows based on visits to be very different and more biologically significant to those done on a meal

basis. Daily visits and intake per visit were very variable and the probability of cows ending a visit did not change greatly with visit length. However, when log normal models were employed to estimate individual meal criteria, meal size decreased during the day and the probability of cows ending and starting a meal increased with meal length and interval between meals. Therefore, it would be interesting to determine if there are differences in the way visits are organised into meals between individual and group housed pigs and between groups of differing composition. This may provide more information on how pigs change their feeding behaviour when group housed and the effects of social constraint on feeding patterns. Thus the aims of this chapter are to investigate the effects of grouping and group composition on meal patterns.

5.2. Methods

5.2.1. Datasets

Data on the feeding behaviour of 48 pigs were collected using feed intake recording equipment (FIRE, Hunday Electronics Ltd. Newcastle). The time of day of visits to the feeder, duration of visits, and food intake per visit were recorded. Details of the pigs, housing and experimental procedure are given in Chapter 4. Briefly, pigs were housed in litter groups for three weeks post-weaning and their aggressiveness was determined using attack latency tests and they were categorised as being either 'High' or 'Low' aggressive (Period 1). The pigs were then transferred to individual housing for 2 weeks where recording of their feeding patterns commenced (Period 2). Finally, they were combined into groups of 8 pigs (3 groups of all High aggressive pigs, 3 groups of all Low aggressive pigs) for a further 3 weeks (Period 3).

5.2.2. Data handling and statistical analysis

Data on feeding behaviour were processed using Minitab for Windows (release 11.1) to produce for each animal: a mean number of feeder visits, and the interval between visits for Period 2 and Period 3. These data were transferred to GENSTAT for

Windows (release 3.2. Lawes Agricultural Trust, 1990) for analysis. The intervals between visits for individual pigs were log-transformed and the model of two Gaussian density functions was fitted to the distribution of the log transformed data as described by Tolkamp *et al.* (1998).

$$y = p * (1 / (\sigma_1 \sqrt{2\pi})) * \exp(-(t - \mu_1)^2 / 2\sigma_1^2) + (1 - p) * (1 / (\sigma_2 \sqrt{2\pi})) * \exp(-(t - \mu_2)^2 / 2\sigma_2^2)$$

Where y is the probability density, p is the proportion of intervals belonging to the first distribution, σ_1 and σ_2 are the standard deviations of the first and second distribution, μ_1 and μ_2 are the mean log(interval length) of the first and second distribution, and t is the log(interval length) in seconds. These parameters were used to estimate the meal criterion where the two log normals crossed. The data from all pigs in Period 2 were combined and the data from all pigs in Period 3 were also combined and the 2-log normal model applied to the two datasets so that meal pattern parameters for all pigs combined in each period could be calculated as follows. Proportion of intervals within meals = p , proportion of intervals between meals = $1 - p$, meals/day = visits $\times (1 - p)$. The mean within meal interval was calculated as the back transformed mean $\exp(\mu_1 + 0.5 \sigma_1^2)$ and the mean between meal interval was calculated as $\exp(\mu_2 + 0.5 \sigma_2^2)$.

The means of the meal parameters determined for each pig were subjected to analysis of variance to assess the effects of individual or group housing, and aggressiveness. Data for meal criteria, meals/day and within meal intervals were normalised by log10 transformation. Two pigs were excluded from the analysis, one in Period 2 and one in Period 3 as the model was not resolvable.

On further examination of the data, it was found that, for some individual pigs in either or both periods, a third minor peak was present between the distributions

representing within and between meal intervals. For those individual pigs, a model with three Gaussian density functions was fitted to the distribution of the log-transformed intervals, as described by Tolkamp and Kyriazakis (1991).

$$\begin{aligned}
 y = & p * (1 / (\sigma_1 \sqrt{2\pi})) * \exp(-(t - \mu_1)^2 / 2\sigma_1^2) \\
 & + (1 - p - q) * (1 / (\sigma_2 \sqrt{2\pi})) \\
 & * \exp(-(t - \mu_2)^2 / 2\sigma_2^2) + q * (1 / (\sigma_3 \sqrt{2\pi})) \\
 & * \exp(-(t - \mu_3)^2 / 2\sigma_3^2)
 \end{aligned}$$

where q is the proportion of intervals in the third distribution, σ_3 and μ_3 are the standard deviation and the mean log(interval length) of the third distribution. Because the distribution of pigs for which the 3-log normal fitted better than the 2-log normal was small no further analysis was performed.

5.3. Results

5.3.1. 2-log normal model

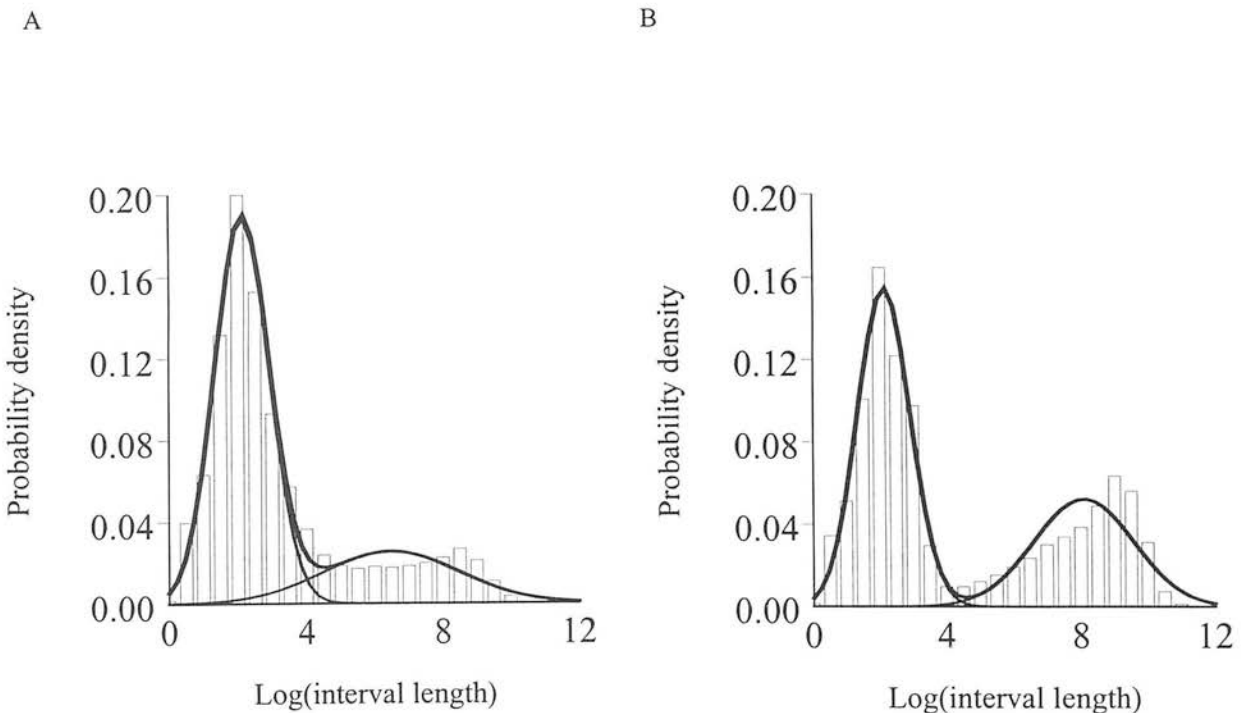
The distribution of the log-transformed intervals for the combined data from all pigs when individually housed in Period 2 is shown in Fig 5.1A, and when group housed in Period 3 in Fig. 5.1B with the fitted two Gaussian probability density functions. The parameters of the model for each period are shown in Table 5.1.

Table 5.1 Parameters of the 2-log normal model for combined data from all pigs in Period 2 (individually housed) and Period 3 (group housed).

Period	p	μ_1	μ_2	σ_1	σ_2	Meal criterion (s)
2	0.74661	2.12282	6.4772	0.79194	1.9868	54.12
3	0.61330	2.13219	8.0886	0.79144	1.4774	82.95

The 2-log normal fitted better for all pigs combined in Period 3 than in Period 2. Although the first distribution fitted well for pigs in both periods, in Period 2 the second distribution did not fit the data (see Fig. 5.1A). However, for some individual pigs in Period 2 the 2-log normal model did fit well (see Fig. 5.2).

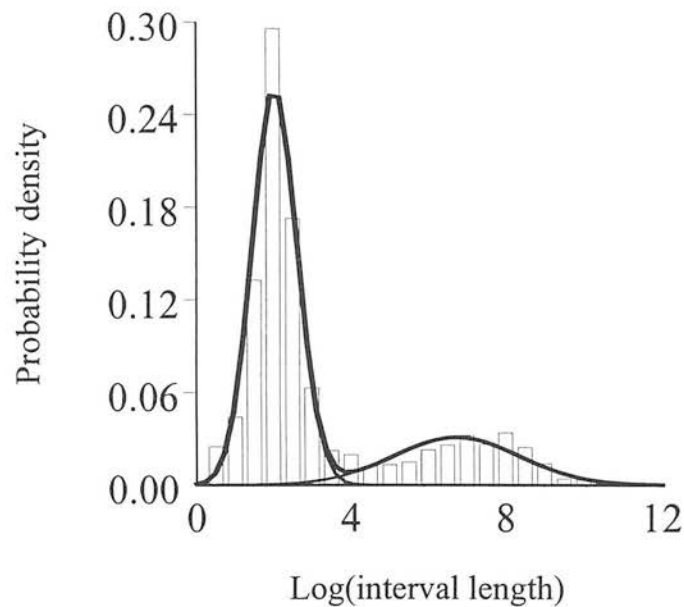
Fig. 5.1 Probability density function of log transformed interval length (seconds) with 2-log normal model. A. combined data from all pigs in Period 2 (pigs housed individually). B. for combined data from all pigs in Period 3 (pigs housed in groups of 8).



The effects of Period and aggressiveness on meal pattern parameters are shown in Table 5.2. For most of the parameters there was an effect of period. Pigs made fewer visits to the feeder in Period 3 than in Period 2 ($P < 0.001$). Meal criteria were longer in Period 3 than in Period 2 ($P < 0.001$) and the mean number of meals per day

decreased from Period 2 to Period 3 ($P < 0.001$). However, there was no difference in the mean within meal interval length between the two periods. The mean interval between meals increased in Period 3 ($P < 0.001$). Thus pigs ate fewer meals with longer intervals between meals when group housed in Period 3 than when individually housed in Period 2.

Fig. 5 2 Probability function of log-transformed interval length (seconds) with a 2-log normal model for Pig 280, Replicate 1, Period 2.

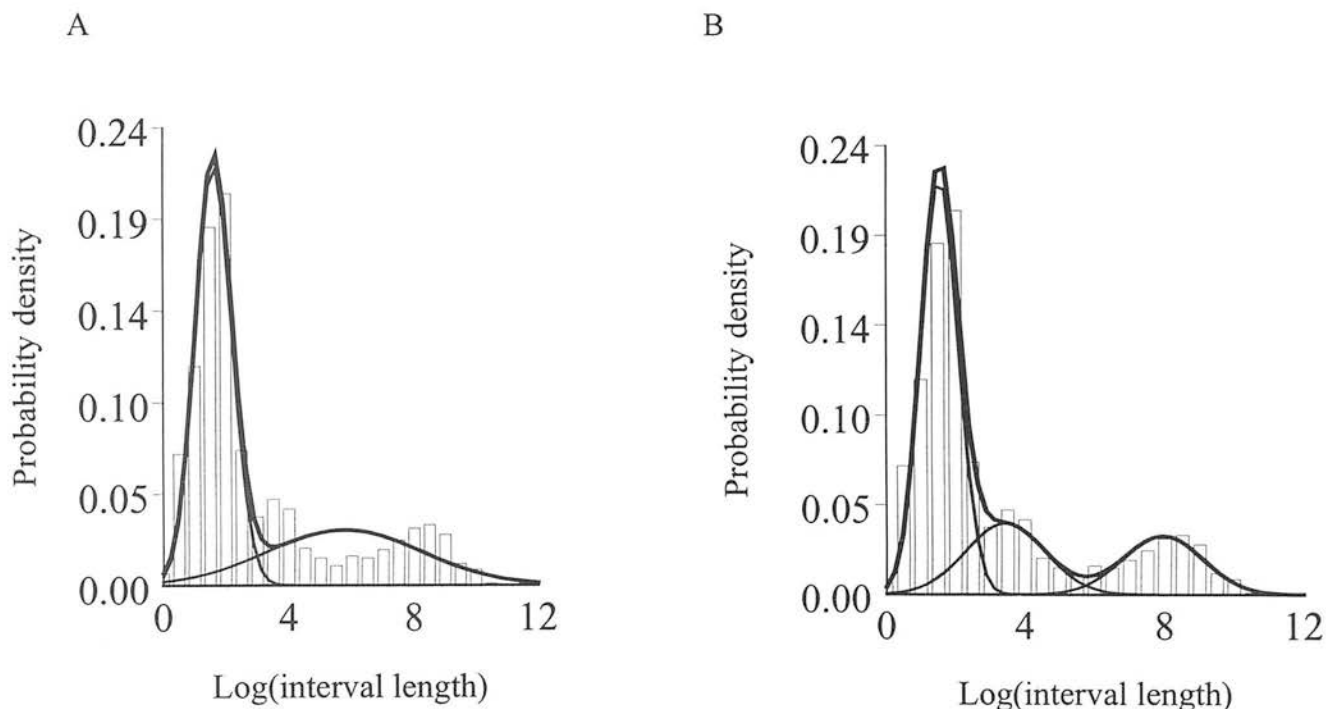


There were no effects of aggressiveness on feeder visits, meal criterion, or between meal interval length. However, High aggressive pigs had more meals per day ($P < 0.05$) and longer within meal intervals ($P < 0.05$) than Low aggressive pigs in both periods. There were no period \times aggressiveness interactions.

5.3.2. 3-log normal

For some pigs in either period, the 2-log normal model did not fit well and a third distribution appeared to be present (see Fig 5.3A). Indeed, for some of those pigs when the 3-log normal distribution was applied it provided a better fit (see Fig 5.3B).

Fig. 5.3 Probability functions of log-transformed interval length (seconds) with a log normal models for Pig 335, Block 2 Period 2. A. fitted with the 2-log normal model. B. fitted with the 3-log normal model.



However, for many of the pigs the 3-log normal model did not prove to be a better fit than the 2-log normal model (e.g. Fig 5.4A and 5.4B). Predicted values of the meal criterion tended to increase when the 3-log normal model was employed (see Table 5.3). These values are unrealistic and position the meal criterion in the middle of the second major distribution rather than between the minor and second peaks.

Fig 5.4. Probability function of log-transformed interval length (seconds) fitted with log normal models for Pig 315 Replicate 2, Period 3. A. fitted with the 2-log normal model, B. fitted with the 3-log normal model.

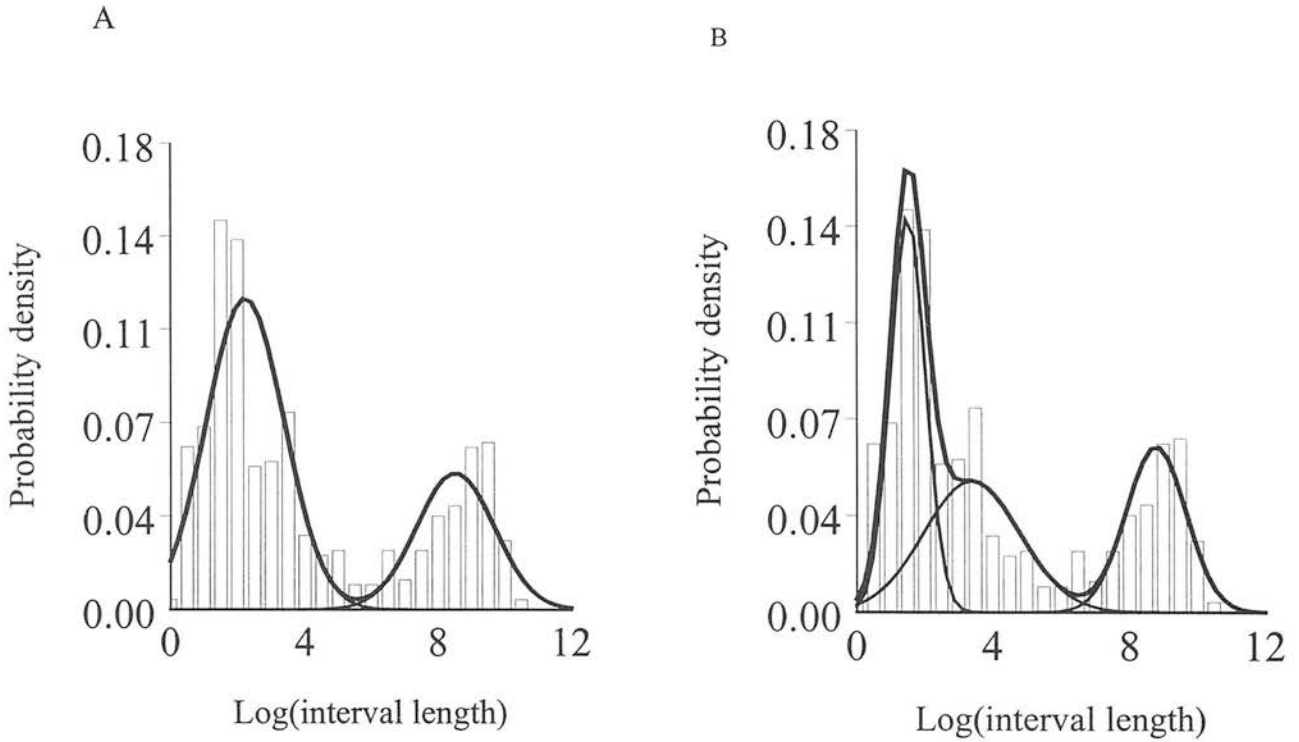


Table 5.3. A comparison of mean number of meals per day and meal criterion for Pig 335 in Period 2 and Pig 315 in Period 3 as predicted by the 2-log normal and 3-log normal models.

Pig/ Period	2-log normal model		3-log normal model	
	Meals/day	Meal criterion (s)	Meals per day	Meal criterion (s)
Pig 335 Period 2	31.97	19.2	35.42	313.8
Pig 315 Period 3	10.05	81.0	20.35	772.8

5.4. Discussion

The 2-log normal model successfully described the meal patterns of the pigs both when individually and group housed. When group housed, the pigs altered their meal patterns in the direction of fewer meals and longer intervals between meals. In addition, meal criteria were longer when the pigs were group housed. Thus pigs ate less frequent meals when group housed in Period 3 than when individually housed in

Period 2. Although group composition did not affect meal patterns, H pigs had more meals per day and longer within meal intervals than L pigs across Periods 2 and 3.

5.4.1. The model

The 2-log normal distribution was more successful at describing feeding behaviour of the pigs than the 3-log normal distribution. Although the 3-log normal fitted the data better than the 2-log normal for some pigs, it was difficult to determine the biological significance of the third minor (middle) distribution as it did not occur consistently in the same place between the first and second major distributions. Tolkamp and Kyriazakis (1999) suggested that in dairy cows, the third distribution could be explained by drinking behaviour; cows leaving the feeder for a short duration to visit the drinker. Morgan *et al.* (2000a) found that, for some pigs, drinking could account for the middle distribution, but for others longer interval lengths were present in the middle distribution that were too long to be associated with drinking as the distance from the feeder to the drinker was only 2m.

In the present experiment the middle distribution is also unlikely to be associated with drinking as it was often associated with the second major peak rather than the first major peak. For those pigs where the middle distribution was associated with the second, it is possible that the middle distribution is explained by differences in interval length between meals during the day and at night (Morgan *et al.* 2000b). Thus, the shorter between meal intervals of the middle distribution may occur during the day whereas the longer between meal intervals associated with the second distribution occur at night. If this was the case, it would be expected that there would a higher proportion of shorter between meal intervals during the day resulting in the middle distribution being larger than the second distribution, there being more visits during the day than during the night. However, on examination of the data it was clear that, although day time visits accounted for some of the middle distribution, there were too many day time visits associated with the second major distribution for

the effect of day and night to be responsible for the occurrence of the middle distribution.

Therefore, it was difficult to determine a biological relevance for the presence of the middle minor distribution. In addition, the meal criteria predicted from the 3-log normal model were increased to an unrealistic level; far greater than that reported by Morgan *et al.* (2000a) who reported a meal criterion of 321 (s) when data from 16 pigs were combined. Furthermore, unlike Morgan *et al.* (2000a), where including the 3rd distribution reduced the error (σ_2) on T_2 , and therefore reduced the backtransformed mean, in the present dataset, the intermeal interval multiplied by the number of meals came to more than 24 hours. Thus, it can be concluded that the 2-log normal model is the most appropriate model to use to describe the data presented here.

5.4.2. The effect of grouping on meal patterns

The results showed a clear difference in meal pattern between individually and group housed pigs. When the pigs were group housed, they had a larger proportion of intervals in the second distribution rather than the first distribution than when individually housed. This indicates that interval length between visits increased when the pigs were group housed. The mean number of meals per day decreased from individual to group housing and consequently the mean between meal interval also increased. Thus pigs decreased their number of daily visits when group housed and this resulted in fewer meals but the mean within meal interval did not change. Therefore, meal length must have increased due to an increase in visit duration rather than an increase in within meal intervals. This is consistent with the results in Chapter 5.

5.4.3. Effect of group composition on meal patterns.

In contrast to the analysis of feeding behaviour in terms of visits (Chapter 4) meal pattern analysis did reveal some effects of aggressiveness. H pigs had more meals per day and longer within meal interval both when individually and group housed. This result is difficult to interpret, but it could be that there is a subtle link between feeding behaviour and aggressiveness, for example, they could be traits that make up part of a 'personality'. Forkman *et al.* (1995) suggested that there are three personality traits in domestic pigs: aggression, sociability and exploration. Part of the trait exploration could be associated with feeding behaviour. Perhaps H pigs are generally more dominant at the feeder, whereas L pigs are more agitated and do not pause as much between visits within a meal in order to avoid displacement from the feeder. This would explain the longer within meal intervals in H pigs which are more confident in maintaining their occupancy of the feeder. However, Erhard (1998) found no evidence that there were distinct personality types in populations of pigs. Forming groups composed of a mixture of high and low aggressive pigs might have given more information on the differences between high and low aggressive pigs.

Alternatively, the differences in meal patterns between H and L pigs could be a consequence of genetic selection; pigs that have high production levels tending to have a certain feeding pattern type which is different from those pigs with lower production levels. Indeed, various genetic correlations between feeding pattern parameters and production levels have been reported in the literature. In a phenotypic study, Quiniou *et al.* (1999) found that lean Pietrain pigs were characterised by a high number of small meals (meal criterion of 10 min) whilst fat Meishan pigs had a small number of large meals per day. As would be expected, food intake per day is closely correlated with weight gain (Labroue *et al.* 1997; Hall *et al.*, 1999a). Feed intake per meal (successive visits performed by the same animal within 2 min) and feeding rate also show close genetic associations with production traits, having a positive correlation with gain but a negative correlation with carcass lean content (Labroue *et al.*, 1997). Hall *et al.* (1999a) did not define a meal criterion

but reported that pigs that have a few large meals per day have higher daily gain and lower food conversion ratio but have more backfat than pigs that have many, small meals per day. They also suggested that food intake per visit and the number of visits may be useful selection criteria in pig breeding programmes. In a second paper Hall *et al.* (1999b), verified this by incorporating daily food intake and feeding pattern traits into a breeding programme. They found that including food intake improved food efficiency, but it was not necessary to include all feeding pattern parameters; the number of visits per day was the most useful parameter to include. However, in the present study, there were no differences between H and L pigs in terms of visits to the feeder, thus it is feasible that feeding patterns based how feeder visits are combined into meals are more important than visits alone.

The results from these studies described above suggest that there is there is a link between feeding pattern and production and the results presented here give evidence of a link between aggressiveness and meal pattern. It is possible that by selecting for increased gain and efficiency, selection programmes in the past have also selected for certain feeding patterns and perhaps aggressiveness. If this was the case it would be predicted from the above that as H pigs eat more meals than L pigs they should therefore have lower production levels, but should be leaner than L pigs. However, as reported in Chapter 4 (Table 4.11), there were no differences in gain or food conversion ratio between H and L pigs and backfat depth was not determined. Therefore, it is difficult to determine if pigs have inadvertently been selected to be more aggressive through breeding programmes to improve production levels.

5.4.4. Conclusions

The 2-log normal model was the most appropriate model to describe the meal patterns of the pigs both when individually and group housed. Grouping altered feeding patterns in the direction of fewer, longer meals with longer between meal intervals. There were no effects of group composition on meal patterns but individual H pigs had more meals per day and longer within meal intervals than low aggressive pigs both when individually and group housed. An explanation for this difference in meal patterns is difficult to determine. There are genetic correlations between feeding and production parameters and it is possible that pigs have been unknowingly selected to be more aggressive during breeding programmes intended to increase production levels. However, as there were no effects of group composition on meal patterns or production levels, the relevance of this difference between H and L pigs is unlikely to have important implications for welfare or production. There were differences in feeding behaviour between environments (individual and group housing) which may pose problems if feeding behaviour were to be used in genetic selection programmes. Nevertheless, the difference in meal patterns between high and low aggressive individuals was consistent across environments and so it is possible that feeding behaviour could be used as a tool for identifying high aggressive pigs within the population.

General Discussion

6.1. Introduction

The main objectives of this thesis were to determine the effect of group housing on the feeding behaviour of growing pigs and the consequences for welfare and production. The literature suggests that group housed pigs have different feeding patterns (de Haer and Merks, 1992; Gonyou *et al.* 1992), and have lower production levels (de Haer and de Vries, 1993) than pigs housed individually. Thus the social environment, in some way, constrains feeding behaviour and production levels and it is important that this interaction is understood. In addition, physical factors such as stocking density (Meunier-Salaun *et al.*, 1987), and feeder spacing, situation and design (Nielsen *et al.*, 1996b) can also influence feeding behaviour. An increase in stocking density, and a decrease in feeding space, along with an increase in vulnerability at the feeder can increase the social constraint imposed on pigs in a group. The increase in social constraint is reflected in the feeding behaviour of pigs by a decrease in the number of feeder visits, an increase in visit duration and an increase in eating rate. Therefore, feeding behaviour may be indicative of a stressful environment (Nielsen, 1999). Social stress can also be induced by increased aggression levels and the disruption of the social organisation of a group, as happens at mixing. The level of aggression at mixing has been found to be influenced by the characteristics of individuals within the group. Erhard *et al.* (1997) found that groups of high aggressive pigs had higher aggression levels at mixing, and were slower to integrate into a group than low aggressive pigs. Therefore, it is important to investigate the relationship between social organisation and feeding behaviour as it might have important implications for welfare and production levels.

When pigs are group housed they may be denied access to the feeder at a preferred time due to the presence of other group members. Consequently, pigs may be

restricted in their time of access to the feeder. In chapter 2, the flexibility of feeding behaviour was investigated by assessing how a change in the time of access to food affects feeding patterns, food intake and behaviour. By comparing feeding behaviour before and after a period of restriction it was found that there were no differences in feeding patterns pre- and post-restriction that did not also occur in the control pigs. It was concluded therefore that pigs have flexible feeding behaviour and that consequently pigs should be adaptable enough to continue to make a desired number of visits even if they are restricted in the time of access to the feeder by pen-mates.

If feeding behaviour is flexible, and not constrained in response to an altered time of feeder access, then social aspects of being in a group must be responsible for the reported differences in feeding patterns between individually and group housed pigs. Chapter 3 investigated the effects of grouping on feeding behaviour of previously individually housed pigs in an attempt to confirm the differences in feeding behaviour between similar, but different pigs housed individually and in groups that have been reported in previous studies (de Haer and Merks, 1992; Gonyou *et al.*, 1992). Potential mechanisms responsible for any change were also considered. The results confirmed that pigs do alter their feeding behaviour in the direction of fewer visits to the feeder of a longer duration when group housed. Possible mechanisms responsible for this change include competition, group cohesion or that the high frequency of feeder visits when pigs are individually housed is a consequence of a lack of social stimulation. Of these different possibilities, the results suggested that group cohesion is most likely to have been causal in the observed changes in feeding behaviour.

Erhard *et al.* (1997) found that group integration was faster and aggression levels were lower in groups comprised entirely of low aggressive pigs than in groups comprised entirely of high aggressive pigs. This may affect group cohesion and consequently feeding behaviour. In addition, it would be expected that there would be higher levels of competition in groups consisting entirely of high aggressive pigs,

and that in such groups competition may play a greater part in the alteration of feeding patterns between individual and group housing than group cohesion. Therefore, a final experiment (Chapter 4) considered the effects of group composition, in terms of latent aggressiveness on feeding behaviour and social behaviour, and the consequences for welfare and production levels. Pigs were classified and being High or Low aggressive using an attack latency test. The test successfully predicted level of aggression on the day of mixing but not later in the period. Pigs altered their feeding patterns between individual and group housing as in Chapter 3. The feeding data was also subjected to meal pattern analysis (Chapter 5). The analysis, using the 2-log normal model, revealed that meal patterns also differ between individual and group housing. The number of meals decreased, meal length increased and between meal interval increased on going from individual to group housing. Aggressiveness did not affect feeding behaviour in terms of visits, but H pigs did have more meals and longer between meal intervals than L pigs throughout Periods 2 and 3.

In what follows I will discuss the findings described above and the implications of these findings for production and welfare levels and the consequences for production systems.

6.2. How flexible was feeding behaviour?

In Chapter 2, it was found that pigs do have flexible feeding behaviour in response to a change in time of access to the feeder. Thus pigs are adaptable in terms their feeding behaviour and they should be able to alter their feeding pattern, if necessary, when mixed into a group. However, in the 2 hours access to food provided, the pigs were not able to eat as much as the control pigs that had 24 hour access to the feeders. In Period 1 when all pigs had 24 hour access to food they occupied the feeders for only 60 min and therefore should have been able to fit their feeding into a 2 hour slot. That they did not was probably due to difficulties in processing large volumes of food in a relatively short space of time. In addition, the total feeding time required may be longer as 'feeder occupation' does not take into account the

time that pigs withdraw from the feeder to chew their food and so does not equate with total eating time. This should not be as much of a problem when pigs are group housed. In this situation, one would expect that, although pigs may not be able to eat at preferred times of the day, they should still be able to spread their feeding across the day and it would not be confined to a 2 hour slot. Nevertheless, evidence from Chapter 2 suggests that pigs can cope with a severe restriction on their time of feeder access.

6.3. How did grouping affect feeding behaviour?

As predicted, grouping affected feeding patterns in the direction of a decrease in the number of feeder visits, an increase in visit duration and an increase in food intake per visit (Chapters 3 and 4). This is consistent with previous findings when the feeding behaviour of individually housed pigs were compared with similar, but different pigs housed in groups (de Haer and Merks, 1992; Gonyou *et al.*, 1992). In addition, in Chapter 4, there was an increase in eating rate between individual and group housing. That eating rate was only affected in Chapter 4, is probably a consequence of group size. Group size and consequently social constraint was larger in Chapter 4, (8 pigs) than in Chapter 3 (4 pigs). This is compatible with the theory of Nielsen (1999) who suggested that feeding parameters change in the direction described above with increasing social constraint.

In terms of meal patterns it was found that group housing decreased the number of meals taken, increased meal length, and increased the intervals between meals. These results complement the findings that feeder visits per day decrease and visit duration increases when pigs are group housed. It might be expected that within meal intervals would decrease when the pigs were grouped, as pausing from eating to chew whilst at the feeder might increase the risk of displacement from the feeder. However, the mean interval between visits within meals did not change when the pigs were group housed. An increase in visit duration was responsible for the increase in meal length when the pigs were grouped rather than pigs taking longer pauses from the feeder within a meal. Perhaps the threat of displacement was not

great enough for a change in within meal interval length but was sufficient to keep pigs in the feeder for a longer duration. Indeed, displacements from the feeder in both Chapters 3 and 4 were rare. Alternatively, pigs may need to withdraw from the feeder briefly to chew, or attend the drinker, and this is more important than retaining a position at the feeding space.

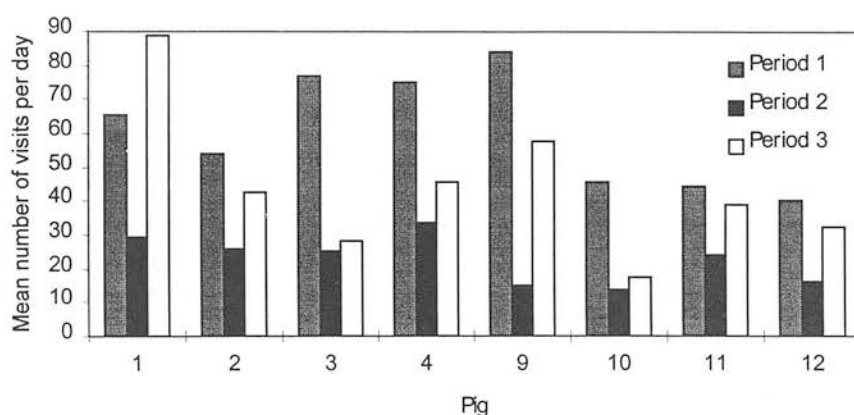
6.4. Adaptability

In chapter 2, pigs were shown to be flexible in their feeding behaviour, but most pigs made feeding attempts when they had restricted feeder access. There was variability between pigs in the timing and frequency of feeding attempts, some pigs made many attempts to gain feeder access at the start of the period of restriction and then decreased feeding attempts towards the end of this period, presumably because they were learning when food was available. Other pigs had no pattern in the performance of feeding attempts. Perhaps these pigs were less adaptable than those that seemed to learn the time of access. In addition there was variation between pigs in how they changed their feeding behaviour between periods of the experiment; some pigs altered their feeding behaviour to a greater extent than others. This could also be a reflection of adaptability; those pigs being more rigid in their feeding behaviour perhaps being less adaptable.

Similar variability between pigs was seen in Chapter 3; when transferred from individual to group housing, some pigs altered their feeding behaviour to a greater extent than others (see Fig 6.1). The extent to which they returned to their original feeding pattern after the period of grouping also varied between pigs and this too may be an indicator of differing levels of adaptability between individuals. For example, pigs 3 and 10 did not increase their number of visits to as great an extent as the other pigs on return to individual housing. However, in general, pigs were flexible in their feeding behaviour after the period of group housing and returned to a feeding pattern comprising a high frequency of short feeder visits. This is in contrast with the results of Nielsen *et al.* (1996a) who found previously group housed pigs only made small modifications in their feeding behaviour when transferred to individual housing. This suggests that the period of individual

housing prior to grouping may affect how pigs behave when they are returned to individual housing after being grouped. The pigs may have learnt a feeding strategy that was successful when they were initially individually housed and returned to it when they were again individually housed after a period of grouping. The findings in Chapters 2 and 3 suggest that pigs are adaptable in their feeding behaviour to a change in time of feeder access and to the social environment but that adaptability may vary between pigs and might depend on previous experience.

Fig 6.1. The mean number of visits for pigs in Chapter 3, Block 1 (pigs 1-4) and in Block 3 (pigs 9-12) in Period 1 (pigs housed individually), Period 2 (pigs group housed) and Period 3 (pigs housed individually).



6.5. Social behaviour

In accordance with other studies (Ewbank, 1976; Meese and Ewbank, 1973), total aggression decreased over time from mixing in both Chapters 3 and 4. The type of aggression as a proportion of the total aggression remained relatively constant over time, fights being the most common form of aggression, followed by knocks, and then threats and chases. It might be expected that across time from mixing this ratio of types of aggression employed to maintain the social hierarchy might change in the direction of fewer fights and an increase in non-damaging aggression such as threats. That this did not occur is perhaps a reflection of the instability of the social order. Indeed it was impossible to determine a stable social order in either of the groups in Chapter 3. The main problem with determining a hierarchy was that towards the end of the period of grouping, when one would expect the social order to be stable, the

occurrence of aggressive interactions was insufficient to ascertain which group member was dominant over the other. In addition, as the pigs were growing they were developing physically and socially over time and this may also have affected the stability of the dominance order. Perhaps an alternative method, not based on aggressive interactions, such as food competition tests (Brouns and Edwards, 1994), or paired arena tests (Bradshaw, 1992), would have been better employed to assess dominance in the groups. However, these kind of tests might not always reflect dominance in an 'everyday' situation and can depend on the motivation of the individuals at the time of the test. Perhaps a better indication of the establishment of a stable social organisation is that the number of scan samples in which pigs were lying together in the pen in the period of grouping (Chapter 3) increased over time from mixing. This measure of how willing an individual is to lie next to an unfamiliar individual can be used as an indicator of stable hierarchy formation (Erhard *et al.*, 1997). Therefore, it could be argued that social organisation did become more stable over time from mixing. A measure of group integration and the formation of a stable hierarchy may in fact be more useful and more important here, than determining the dominance order of individuals within a group.

6.6. Group composition

Erhard *et al.* (1997), suggested that aggression levels and the speed of group integration varies depending on the characteristics of the individuals within a group. They found that groups of high aggressive pigs showed more aggression at mixing and integrated into a group slower than low aggressive pigs. In Chapter 4, group composition was manipulated by categorising pigs as high (H) or low (L) aggressive using an attack latency test. Groups were then formed consisting of either all H pigs or all L pigs. Groups of all H pigs had higher levels of aggression on the day of mixing compared to groups of all L pigs. However, although levels of aggression generally decreased from mixing, they remained elevated in L pigs towards the end of the grouping period. Reasons for this surprising difference between groups of H and L pigs are unclear. In contrast to Erhard *et al.* (1997) it was suggested that because L pigs do not fight as much as H pigs on the day of mixing (fewer fights of

a shorter duration), 'assessment' fights were not performed thus hindering the formation of a social organisation. Therefore, fighting to determine relative social status when pigs are mixed may be essential in the formation of a hierarchy. In that case, breeding pigs that have a low latent aggressiveness, may be disadvantageous in terms of decreasing aggression in groups of pigs in the long term. However, the elevated levels of aggression shown by the L pigs towards the end of the grouping period still occurred at a low level relative to the level on the day of mixing. Therefore, there may still be some advantage in breeding pigs to have a lower latent aggressiveness.

It was predicted that differences between H and L groups in terms of aggression level, competition, and speed of group integration may have affected feeding behaviour. However, there was no effect of group composition on feeding behaviour either in terms of visits or meal patterns. Surprisingly, H pigs had more meals per day and longer within meal intervals than L pigs both when housed individually and in groups. There is a genetic link between some feeding and production parameters and a few breeding programmes incorporate feeding variables (Labroue *et al.*, 1997; Hall *et al.*, 1999). It has been suggested that aggressiveness may have been inadvertently selected for alongside production parameters. However, as no effects of aggressiveness on production parameters were found and, in the scope of the experiments conducted here (few pigs compared to a breeding experiment), it is impossible to say if aggressiveness could have been selected for in this way.

6.7. Why are feeding patterns different between pigs housed individually and in groups?

It would seem that aggressiveness and aggression levels have very little influence on feeding behaviour (at least in the group sizes used here) so there must be other mechanisms responsible for the observed change in feeding behaviour from individual to group housing. I will now discuss the possible mechanisms responsible for this change.

6.7.1. Competition

If it is assumed that the feeding behaviour of pigs when individually housed is their 'preferred pattern', when group housed, they may be unable to perform that pattern due to the presence of other group members. As resources are decreased, competition is perhaps the most rational mechanism to consider. The pig:trough ratio increased from 1:1 to 4:1 in Chapter 3 and from 1:1 to 8:1 in Chapter 4. If competition was a governing factor, once pigs gained access to the feeder they would be expected to stay there longer due to an increased feeding motivation as a result of a longer than desired inter-meal interval. However, as discussed in Chapter 3, competition did not appear to be a particularly strong effect in Chapters 3 or 4, there being very few displacements from the feeder, and little obvious queuing at the feeder. In addition, according to the results of Nielsen *et al.* (1995 and 1996a), the group sizes and pig:trough ratios used in this work were not high enough to cause large modifications in feeding behaviour. That the pigs in both Chapters 3 and 4 all made large modifications to their feeding behaviour whilst being housed in relatively small groups, and with a low pig:trough ratio makes it seem very unlikely that competition is a major factor in the alteration of feeding patterns between individual and group housing. More evidence to dismiss competition as a potential mechanism comes from Chapter 4. It was predicted that competition would be greater in groups of H pigs, but neither aggressiveness of individuals within a group, or levels of aggression in Period 3 had an effect on feeding behaviour.

However, that eating rate increased when the pigs were group housed in Chapter 4 and not in Chapter 3 is likely to be a result of there being a larger group size and a higher pig:trough ratio leading to increased competition in Chapter 4. Therefore, competition is unlikely to be responsible for the basic change in feeding behaviour (i.e. decreased feeder visits and increased visit duration and food intake per visit) when previously individually housed pigs are group housed. However, when group

size is larger, as in Chapter 4, competition may be responsible for the additional affect of an increase in eating rate.

6.7.2. A high frequency of feeder visits when pigs are individually housed is a consequence of a lack of social stimulation.

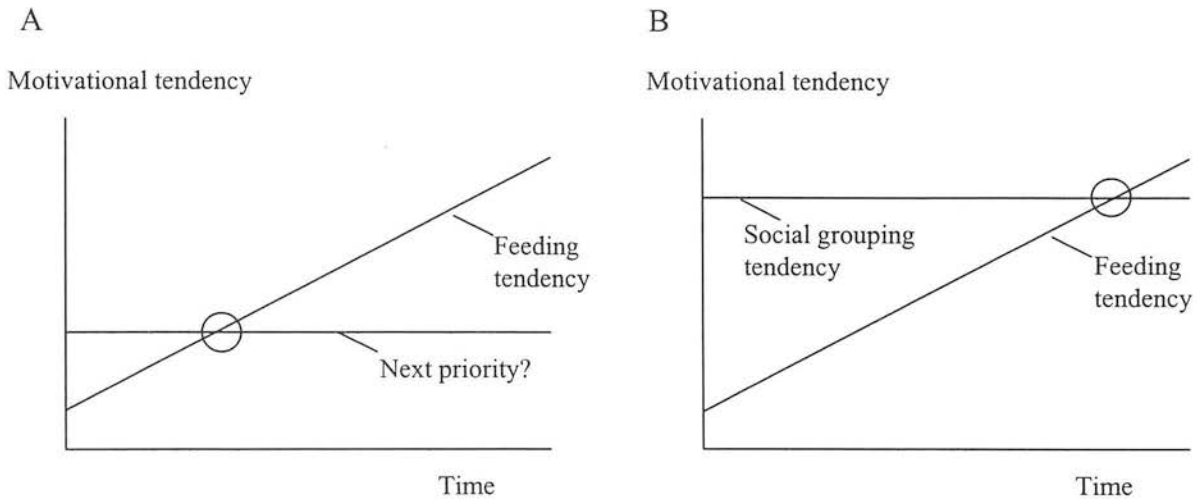
It is rather assumed that the feeding pattern of pigs when they are individually housed is their preferred feeding pattern. However, it is possible that this pattern is in fact an indication of a poor environment which lacks stimulation. Thus the second mechanism to explain the change in feeding behaviour when pigs are group housed is that when individually housed, pigs visit the feeder frequently due to a lack of social stimulation. The behavioural repertoire of the pigs when they were individually housed was less diverse than when group housed, and pigs spent more time rooting and feeding as the only positive sources of stimulation in the pen. However, this mechanism was also rejected. In Chapters 2 and 4, pigs were housed individually but had visual, and some physical contact with neighbouring pigs and made similarly high levels of feeder visits as those individually housed in Chapter 3, where the pigs had no visual or physical contact with neighbours. So a lack of social stimulation when individually housed is unlikely to be responsible for the difference in feeding behaviour between individually and group housed pigs.

6.7.3. Group cohesion

The most likely mechanism responsible for the alteration in feeding behaviour when pigs are moved from individual to group housing is group cohesion; pigs being reluctant to leave the group to feed. This results in pigs making fewer visits to the feeder of a longer duration. Therefore, when group housed the pigs require a higher level of motivation to feed than when individually housed due to the competing motivation to stay with the group. Thus when they visit the feeder they are hungry and remain there for longer, until satiation or until the motivation to be with the group outweighs that to continue feeding. Fig. 6.2 shows the motivational priorities of pigs when individually and group housed. If it is assumed that when group housed

social group tendency has a higher priority than the 2nd highest priority when individually housed, feeding motivation will have to be higher to be expressed. A strong motivation to remain with other pigs was reported by Jones *et al.* (1999). They found that in a choice test, pigs were motivated to stay in ammonia polluted conditions in order to have company of another pig rather than choosing an unpolluted compartment.

Fig. 6.2 Motivational priorities when pigs are A. individually housed and B. group housed.



It was anticipated that group composition might have some effect on group cohesion which would influence feeding behaviour. However, no effect of group composition on feeding behaviour was found. In Chapter 4, I discussed the possibility that group aggression levels and the formation of the social hierarchy might not affect group cohesion. The concept proposed was that fighting is important in establishing a stable social organisation, whilst the evolutionary benefits of being in a group are also important. Thus the group may be cohesive even though there are high levels of aggression; the two actions being independent of one another and having different functions.

In summary, evidence from all the experiments reported here suggest that the most probable mechanism resulting in a decrease in feeder visits and an increase in visit duration and food intake per visit when previously individually housed pigs are

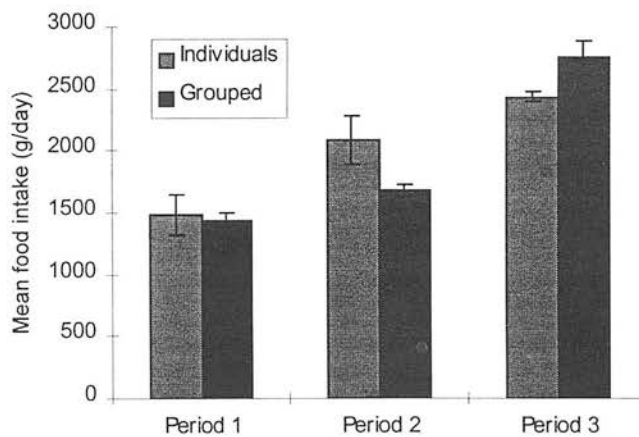
grouped, is that of group cohesion. The increase in eating rate when pigs were housed in larger groups in Chapter 4 was probably an additional effect caused by increased social constraint and competition for food.

6.8. Consequences for production

Restriction on the time of access to the feeder (Chapter 2) decreased the daily food intake of the pigs. However, over the course of the period of restriction food intake began to recover but pigs could not achieve an intake comparable to the control pigs. As previously discussed, this was probably due to difficulties in processing large volumes of food in a relatively short space of time. Therefore, when pigs are group housed, and might not be able to gain access to food at preferred times, food intake might be expected to decrease. In Chapter 3, it was not statistically appropriate to directly compare the feeding and production parameters of the pigs that were grouped in Period 2 with those that remained individually housed throughout. However, for the pigs that were housed individually throughout the experiment there was a significant increase in feed intake from Period 1 to Period 2, and from Period 2 to Period 3. On the other hand, for pigs that were grouped in Period 2, there was no difference in food intake between Period 1 and Period 2, but a significant difference between Periods 2 and Period 3 when the pigs were returned to individual pens (see Fig. 6.3). This suggests that the period of group housing suppressed the rate of increase of food intake that would be expected as the pigs increased in size. A similar pattern was seen with live weight gain, pigs gaining less weight when group housed than comparable, individually housed pigs. There were no significant effects of Period on food conversion ratio for the pigs housed individually throughout in Chapter 3. However, food conversion ratio increased in pigs that were grouped in Period 2 when they were subsequently returned to individual housing. There was no difference in food conversion ratio between Period 1 and Period 2 which suggests that group housing did not affect the efficiency of production. In Chapter 4, group composition had no effect on food intake, weight gain or food conversion ratio.

Therefore, consistent with the findings of Gonyou *et al.* (1992) and de Haer and de Vries (1993), group housing reduces food intake and weight gain of pigs when compared to individually housed pigs. However, grouping does not seem to affect food conversion ratio. Thus pigs do not fulfil their potential for intake and gain when group housed but maintain their efficiency. This is in accordance with previous studies (Patterson, 1985; Spicer and Aherne, 1987) that reported no significant effect of group housing on food conversion ratio. These findings are in contrast to Hall *et al.* (1999a) who investigated the relationship between feeding pattern parameters and production. They reported that pigs that have a few large meals per day have higher daily gain and lower food conversion ratios than pigs that have many, small meals per day. However, these results were regarding variation between individuals within a group situation rather than the larger differences between individually and group housed animals.

Fig. 6.3. Mean food intake per day of pigs in Chapter 3, Period 1, all pigs housed individually; Period 2, Grouped pigs housed in groups of 4, Individual pigs housed individually; Period 3, all pigs housed individually.



As pigs are flexible in their feeding behaviour, they should have been able to fit in enough feeding time to eat as much food as when they were individually housed. Indeed in Chapter 2 the total time spent feeding was in the region of 1 hour per day. Therefore, in a group of 8 pigs, as in Chapter 4, the feeder would be occupied for only 8 out of the 24 hours available. Again, this implies that social factors associated with group housing are likely to be responsible for the decrease in food intake and

live weight gain. Group cohesion may act to prevent pigs from eating as much as they did when they were individually housed. Social interaction takes up time when pigs are group housed leaving them less time to feed. Furthermore, social stress may decrease food intake via physiological changes associated with the release of stress hormones (Forbes, 1995).

6.9. Consequences for welfare

Welfare concerns when pigs are group housed are normally related to aggression. However, it is possible that the thwarting of a pig's desired feeding pattern might also be a welfare concern. When group housed, pigs may not be able to eat at preferred times of the day and this may cause stress. In Chapter 2, pigs were denied access to the feeder at times of the day when there are normally peaks in feeder visits, thus a severe restriction was imposed on their feeding patterns. In general pigs were adaptable to this restriction and it was suggested in Chapter 2 that so long as pigs had sufficient time across the day to eat their requirement of food, it is unlikely that they would suffer from stress. However, pigs did make attempts to gain access to the feeder when they had restricted feeder access. Feeding attempts are likely to be a result of motivation to feed and how much stress the thwarting of feeding behaviour caused is difficult to determine. It would have been useful to have had a physiological measure of stress such as salivary cortisol concentration to make comparisons between restricted and control pigs, and pigs that made a high number of feeding attempts and those that made few feeding attempts. There were no signs of abnormal behaviours such as persistent rooting or excessive drinking that might have been an indicator of increased stress levels. Thus it can be concluded that in small groups, with a low pig:trough ratio, the thwarting of feeding behaviour itself is unlikely to be a welfare concern. However, in larger groups with fewer feeder spaces the restriction on feeding behaviour may be more severe and cause greater stress to individual pigs.

When pigs are mixed into groups, increased aggression levels are probably the greatest welfare concern. Fighting can cause physical injury in the form of lesions,

increased susceptibility to disease and social stress. In Chapters 3 and 4, fighting was greatest on the day of mixing and decreased over time from mixing. Lesion scores are probably the most reliable indicator of welfare when pigs are first mixed and these were recorded in Chapter 3. Lesion scores were greatest soon after mixing and decreased with time from mixing. There were differences in lesion scores between pigs, indicating that some pigs received more aggression than others, thus the welfare of some individuals within a group may be more affected than others at mixing. There were some indications from the salivary cortisol measurements (Chapter 4) that stress levels might be elevated when the pigs were group housed but the results were not conclusive.

Aggression levels were also affected by the aggressiveness of individuals within the group (Chapter 4). On the day of mixing, groups comprised of all high aggressive pigs had a higher frequency of fights and spent more time fighting than groups comprised of all low aggressive pigs. Low aggressive pigs however, had elevated levels of aggression towards the end of the period of grouping compared to high aggressive groups. Interestingly, there were no differences in salivary cortisol concentrations between high and low aggressive groups. It is difficult to determine if the pigs suffered acute stress at mixing as saliva samples had to be taken the day after mixing when the highest levels of aggression had subsided. Saliva was not collected on the day of mixing because of the disruption it would have caused to the video recordings of aggressive behaviour. In the longer term there were no indications that any of the groups were suffering from elevated cortisol levels. Thus the results of this work indicate that mixing might not cause chronic stress in groups of pigs. However, further studies need to be done to confirm this in larger groups of pigs which reflect commercial systems.

Therefore, although aggression at mixing can be a welfare concern if aggression levels are high, in the group sizes used here it seems that pigs are not unduly stressed by group housing and mixing.

6.10. Implications for production systems

The results from this thesis suggest that so long as production systems include adequate provision of feeding space such that pigs are able to eat sufficient food for their requirement across the day then it is unlikely that they will suffer from chronic stress as a result of the thwarting of feeding behaviour. There is evidence in the results that mixing increases levels of aggression in pigs. Furthermore, aggression levels are higher at mixing in groups comprised of entirely high aggressive pigs than in groups comprised of entirely low aggressive pigs. However, in this study, groups of low aggressive pigs seemed unable to establish a stable social organisation and aggression levels remained elevated for up to 3 weeks after mixing. This poses a dilemma for the production system as to what is better for the pigs' welfare. More research in this area is required to determine this. However, it remains that increased aggression levels at mixing are a problem for welfare and thus the production of pigs in stable groups should be recommended.

It is possible that feeding behaviour may be used as a determinate for pigs that have a higher predisposition for aggressiveness. Indeed, as previously discussed, with validation, meal patterns could potentially be used to determine aggressiveness. Furthermore, the meal patterns of H and L pigs differed both when the pigs were individually housed and when group housed. This suggests that the difference in meal patterns is stable across environments and this would facilitate identification of different pig types in breeding programmes. Although, the results presented here do not clearly show whether it is better to have groups of high aggressive or groups of low aggressive animals, it would still be useful to have such a predictor. However, further research is required in order to validate the differences in meal patterns between high and low aggressive animals. Feeding behaviour variables could also be used as an indicator of social stress; a decrease in daily feeder visits, and increases in visit duration and eating rate being indicators of an increase in social constraint. Therefore, measuring feeding patterns in commercial systems may be of use as a potential welfare indicator.

6.11. General conclusions

In summary, feeding behaviour was flexible in response to a change in time of feeder access. This suggests that pigs are adaptable to new environmental conditions. Group housing altered the feeding behaviour of previously individually housed pigs in terms of number of daily visits, and number of meals per day. The number of daily visits decreased, visit duration and food intake per visit increased when pigs were group housed. Similarly the number of meals per day decreased when pigs were group housed and meal length and the intervals between meals increased.

The attack latency test successfully predicted aggression levels on the first day of mixing; groups of high aggressive pigs having a higher frequency and duration of fights than groups of low aggressive pigs. However, later in the period of grouping groups of low aggressive pigs had elevated levels of aggression relative to the high aggressive groups. Group composition in terms of latent aggressiveness did not affect feeding behaviour, but high aggressive individuals have more meals per day than low aggressive individuals across environments.

Group cohesion is the most likely mechanism responsible for the change in feeding behaviour between individual and group housing. Social constraint in terms of increasing group size may have the additional affect of increasing eating rate. In terms of welfare and production, the results of this work indicate that pigs are not unduly stressed as a result of the change in feeding behaviour at mixing and there were no differences in salivary cortisol concentrations between individual and group housed pigs. This suggests that group housing did not cause chronic stress in pigs. Group housing reduced weight gain and food intake but did not affect FCR, but group composition in terms of aggressiveness did not affect production parameters.

Production systems should ensure that there are sufficient feeding spaces for pigs to eat their requirement for food. Although the results did not indicate acute or chronic stress when pigs were mixed, aggression levels were high on the day of mixing and this resulted in lesions. Keeping pigs in stable groups would avoid these welfare

problems at mixing. With further validation, it may be possible to use meal patterns as a determinant of aggressiveness. The categorisation of the aggressiveness of pigs using feeding behaviour would allow a large number of pigs to be tested automatically (compared to an attack latency test) and, therefore, aggressiveness of pigs could be manipulated in breeding programmes. In addition, feeding behaviour could be used to determine poor welfare as a result of social constraint.

6.12 Further research

In terms of feeding behaviour, further evidence is required to support the theory that group cohesion is responsible for the change in feeding patterns between individual and group housing. Measures such as lying preferences, proximity measures and an index of association would be useful to determine the extent of cohesion within a group. The possibility that aggressiveness is linked to meal pattern also needs to be assessed further by conducting large scale trials where the feeding behaviour and aggressiveness of individuals can be assessed. Firstly however, further research is required to validate the attack latency test. Although the attack latency test gave an indication of the aggressiveness of groups on the day of mixing, it did not relate to aggression levels later. Therefore, research is required on a large scale in order to fully understand how the test predicts the behaviour of pigs when they are mixed into new groups and after the initial fighting has subsided.

It is evident from the previous discussion that it is important that more research is conducted to determine the exact effects of group composition on welfare. This research would include salivary cortisol sampling on a greater scale than in Chapter 4 such that differences in circadian rhythm between groups of differing composition could be determined. It would also be essential to include a control where pigs are kept as litter groups throughout such that changes in cortisol due to age could be identified. In addition, it would be useful to include groups comprised a mixture of high and low aggressive pigs or groups that reflect the proportion of high or low aggressiveness in commercial situations. The presence of pigs that are neither high

or low aggressive in the population has been somewhat disregarded in this thesis. The extremes of aggressiveness were used in order to maximise any effect. The presence of these 'middling' pigs within a group may influence group dynamics. Therefore, it would be interesting to also classify these pigs and include them in future experiments.

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Appendix I Derivation of feeding behaviour data.

1. Raw data

The event recorder from the FIRE feeder was read and an ASCII data file was created each day. Data files gave details of feeder visits as shown in Table 1.

Table 1. Section of data output from a FIRE feeder.

Pen	Pig	Day	Month	Year	Time of entry			Time of exit			Food intake (g)
					Hour	Min	Sec	Hour	Min	Sec	
2	51	27	10	99	8	21	05	8	22	05	0.040
2	86	27	10	99	8	18	54	8	19	27	0.016
2	81	27	10	99	8	18	23	8	18	31	0.004
2	85	27	10	99	8	17	23	8	17	43	0.022
2	89	27	10	99	8	11	49	8	16	52	0.114

2. Consolidation of data files

The ASCII data files from each day in each period of the experiment were combined in order resulting in 1 file for each experimental period. This was then read into Minitab Release 9.1 and a worksheet was created to run from 00.01h of the first complete day to 23.59h of the final day of the period by removal of any data falling outside of these times.

3. Calculation of visit variables.

From the worksheet the standard Minitab commands were used to calculate means of the number of visits to the feeder per day, visit duration, food intake per visit, feeder occupation, feeding rate and food intake per day. Duration of each visit was calculated by converting the hours, minutes and seconds of entry and exit into seconds and then subtracting the exit time from the entry time, correcting where necessary for visits that spanned midnight. In calculating feeding behaviour variables, visits with negative food intakes were removed and visit duration was plotted against food intake so that outliers representing impossibly large food intakes combined with short visits durations were also removed. In addition, long visits (probably a result of the feeder door becoming lodged open) were removed. Mean food intake per visit was calculated by dividing the daily food intake by the number

of daily visits. The mean feeder occupation per day was calculated by multiplying the mean number of visits per day by the mean visit duration. Feeding rate was then the result of the daily food intake divided by feeder occupation and this was confirmed by linear regression of food intake and visit duration.

Appendix II Statistical analysis.

Below are examples of the structure of the statistical analysis conducted on the various sources of data obtained from the experiments in this thesis. GENSTAT for Windows (release 11.1) was used to carry out the analyses.

1. Feeding data (Chapter 2).

Variate: visits

2 Blocks, 3 Periods, 30 pigs (2 ill removed from analysis), 2 treatments (control, restricted).

Analysis of variance treating each period as a repeated measure.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	1	551.0	551.0	0.24	
Block x Pig stratum					
Treatment	1	3791.0	3791.0	1.64	0.210
Residual	29	66955.3	2308.8	7.83	
BlockxPigxPeriod stratum					
Period	2	4646.6	2323.3	7.88	<0.001
Period x treat.	2	6682.2	3341.1	11.33	<0.001
Residual	58(2)	17098.5	294.8		
Total	93(2)		99453.5		

Table of means

Grand mean 61.8

Period	1	2	3
	65.9	52.0	67.6

Treatment	1	2
	68.1	55.5

Period x Treatment	1	2
1	66.2	65.6
2	70.1	34.0
3	68.1	67.1

Standard errors of differences of means

	Period	Treatment	Period x Treatment
Rep.	32	48	16
s.e.d.	4.29	9.81	10.99
Except when comparing meas with the same level (s) of treatment			6.07

2. Timebudgets (Chapter 3) pigs that were grouped in Period 2.

Analysis of variance

2 Blocks, 8 pigs, 3 Periods.

Variate: rooting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Block stratum	1	394.73	394.73	16.92	
Blockx Pig stratum	6	139.97	23.33	0.56	
Block x Pigx Period stratum					
Period	2	931.41	465.70	11.24	0.001
Residual	14	580.26	41.45		
Total	23	2046.37			

Table of means

Grand mean 23.3

Period	1	2	3
	28.9	14.6	26.5

Standard errors of difference of means

	Period
Rep.	8
d.f.	14
s.e.d.	3.22

3. Social Behaviour (Chapter 4).

Analysis of variance

3 Blocks, 48 pigs, 8 days 2 treatments (High or Low aggressive).

Variate: fight (log 10 transformed)

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Block stratum	2	1.07812	0.53906	2.78	
Block x Pig stratum					
Treatment	1	0.05579	0.05579	0.29	0.594
Residual	44	8.53027	0.19387	3.34	
Blockxpigxday stratum					
Day	7	5.60584	0.80083	13.78	<0.001
Dayx treatment	7	1.65552	0.23650	4.07	<0.001
Residual	314	18.24440	0.05810		
Total	375	35.08716			

Tables of means

Grand mean 0.324

Day	1	2	4	5	9	11	16	19
	0.599	0.415	0.281	0.316	0.271	0.245	0.286	0.181

Treatment	High	Low
	0.312	0.336

Day x Treatment	High	Low
1	0.731	0.467
2	0.419	0.412
4	0.237	0.324
5	0.298	0.335
9	0.290	0.252
11	0.232	0.259
16	0.207	0.366
19	0.085	0.277

Standard errors of differences of means

	Day	Treatment	Day x Treatment
Rep	48	192	24
s.e.d.	0.0492	0.0449	0.0791
d.f.	314	44	261.19
Exept when comparing means with the same level (s) of treatment			0.0696
d.f.			314

Appendix III Saliva Cortisol Radioimmunoassay

(Coat-A-Count[®] Cortisol Kit provided by Diagnostic Products Corporation UK,
Euro/DPC Limited., Glyn Rhonway, Llanberis, Gwynedd, LL55 4EL)

The Coat-A-Count Cortisol procedure is a solid phase radioimmunoassay in which ¹²⁵I-labelled cortisol competes for a fixed time with cortisol in the pig sample for antibody sites. Because the antibody is immobilised to the wall of a polypropylene tube, by decanting the supernatant the competition is terminated and the antibody-bound fraction of the radiolabelled cortisol is isolated. Counting the tube in a gamma counter then yields a number, which converts by way of a calibration curve to a measure of the cortisol present in the sample.

What follows are the 'in-house' methods for the Scottish Agricultural College, Aberdeen where the samples were analysed.

Preparation of saliva samples

After collection of the samples, freeze at -20C to precipitate the mucins. On the day of assay, thaw the samples, centrifuge at 5000rpm in a micro-centrifuge for 5 minutes, and transfer the supernatant to a clean container.

Standards

Six vials of standard in human serum are supplied in the kit (see table below). The zero standard (A) contains 2.0ml and standards B-F contain 1.0ml.

Standard	Reagents for 1 Std. Curve		Reagents for 2 Std. Curves		200µl sample ∴ x 5 multiplication factor	
	Working Solution	0.9% Saline	Working Solution	0.9% Saline	Defined Dose ng/tube	Dose ng/ml
A	100µl A	900µl	200µl	1800µl	0	0
B3	500µl B2	500µl	1000µl	1000µl	0.25	0.125
B2	500µl B1	500µl	1000µl	1000µl	0.05	0.25
B1	500µl B	500µl	1000µl	1000µl	0.1	0.5
B	100µl B	900µl	200µl	1800µl	0.2	1.0
C	50µl C	450µl	100µl	900µl	1.0	5.0

Standard	Reagents for 1 Std. Curve		Reagents for 2 Std. Curves		200µl sample ∴ x 5 multiplication factor	
	Working Solution	0.9% Saline	Working Solution	0.9% Saline	Defined Dose ng/tube	Dose ng/ml
D	50µl D	450µl	100µl	900µl	2.0	10
E	50µl E	450µl	100µl	900µl	4.0	20
F	50µl F	450µl	100µl	900µl	10.0	50

Quality Controls and First Antibody

These were stored at -20C in 500µl aliquots of low, medium and high quality controls.

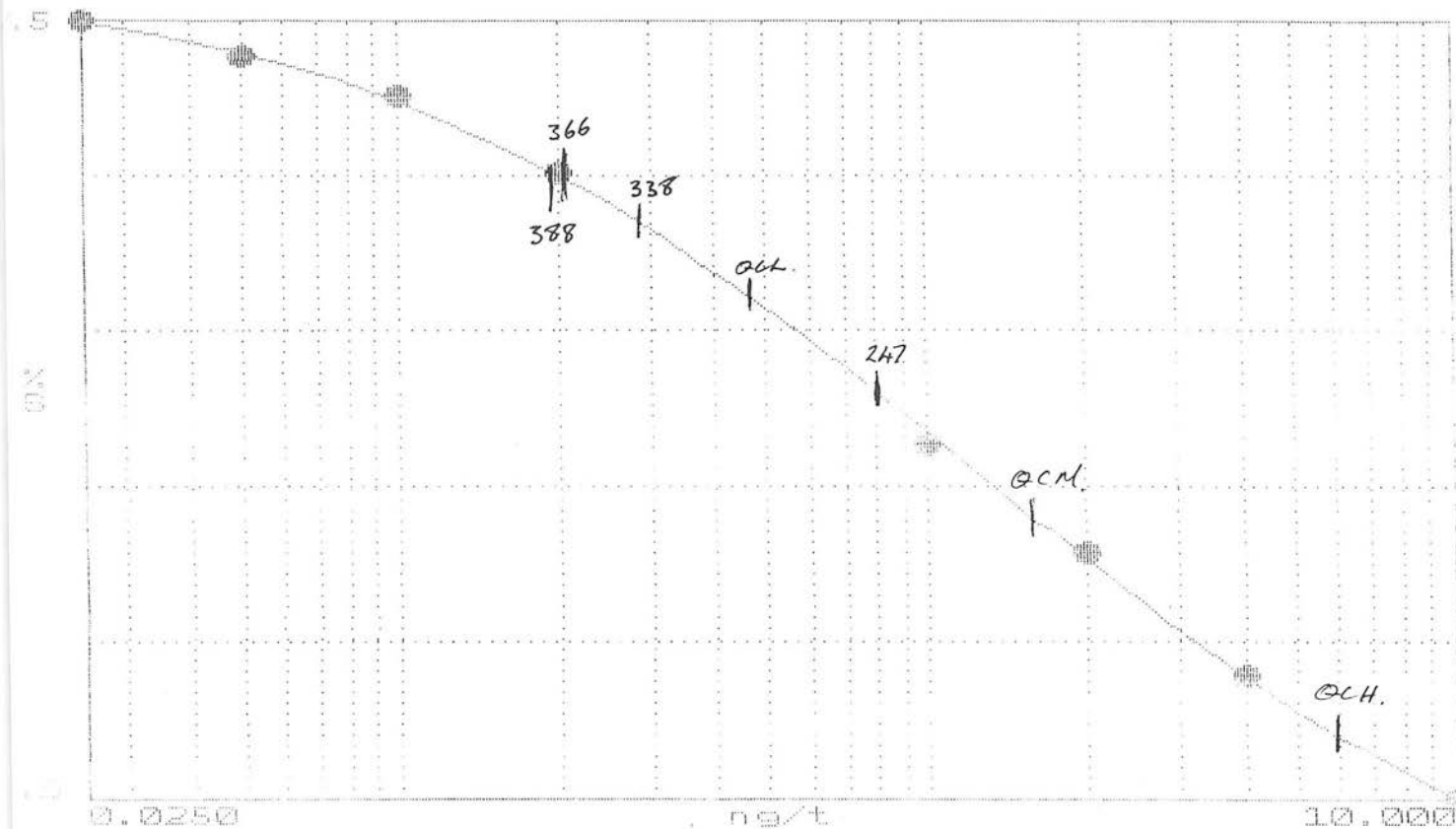
The first antibody was supplied in the kit, coated on the polypropylene tubes.

Assay Method

- Remove the samples and quality controls from the freezer and remove the standards, 0.9% physiological saline, tracer and antibody coated tubes from the fridge. Allow all components to come to room temperature.
- Label plain (uncoated) polypropylene tubes in duplicate for the total count (TC) and non-specific binding (NSB) tubes. Label antibody coated polypropylene tubes (supplied in the kit) in duplicate for the zero standard (Bo), standards (B3-F), low, medium and high quality controls and the samples.
- Centrifuge and prepare the saliva samples as outlined above.
- Pipette 200µl of zero standard A in duplicate into the Bo and NSB tubes. Pipette 200µl of standards B3-F, quality controls or samples in duplicate into appropriate tubes.
- Add 1000µl of tracer to all the tubes. Cap the total count tubes and place to one side.
- Vortex all the tubes and incubate for three hours at room temperature.
- Tip the tubes upside down (except the total count tubes) to remove the supernatant and allow to drain for 30 minutes. Before up righting the tubes, strike them sharply on absorbent paper to remove any droplets. Count all the tubes for 1 minute on the gamma counter.

Fig. 1. Standard curve and statistics for salivary cortisol assay showing where 3 examples (pigs 366, 388 and 338) fall on the standard curve. QCM, QCH and QCL being standards.

Assay Type: RIA %REF. BOUND



STD #	CPM	DEFINED DOSE	%B/F	CALC. DOSE	% DIFF
1	44220	0.02500	97.55	0.02449	-2.06
2	42497	0.05000	93.69	0.05280	5.61
3	40562	0.10000	89.38	0.09373	-6.27
4	36350	0.20000	81.39	0.19775	-1.13
5	24741	1.00000	53.19	1.06873	6.87
6	19188	2.00000	41.69	1.94109	-2.95
7	13583	4.00000	29.16	3.93486	-1.63
8	7819	10.00000	16.32	10.01003	0.10

Curve Fit : LOG16710 Transform X : LOG Transform Y : NONE
 Corr. Coef. : 0.9999 Slope : -0.7376
 Det. Limit : 0.0250 Para. Coef. : .9996
 %NSB/Total : 0.8220 %Ref/Total : 73.131
 ED20 : 7.3808 ED50 : 1.2597 ED80 : 0.2201
 %Sigma Std. : 3.7697
 A : 46706.2 B : 0.738 D : 1.030 D : -461.08
 RME : 0.55496

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Endocrinology Section

SALIVA CORTISOL RADIOIMMUNOASSAY VALIDATION: PhD

Minimum detection limit: 0.350ng/ml

Summary Sheet						
	Mean ng/ml	n	S.E.M.	n	Coefficient of Variation	n
Inter-Assay Variation:						
Low Quality Control	2.64	103	0.03	103	11.0	103
Medium Quality Control	8.36	104	0.06	104	7.4	104
High Quality Control	28.57	96	0.19	96	6.6	96
Intra-Assay Variation:						
Low Quality Control	2.63	14	0.08	14	8.2	14
Medium Quality Control	8.37	14	0.19	14	6.2	14
High Quality Control	28.60	14	0.64	14	5.8	14
Effective Dose:						
ED 80	1.11	14	0.03	14	11.1	14
ED 50	6.31	14	0.09	14	5.0	14
ED 20	36.42	14	0.37	14	3.8	14
% Binding	70	14	0.57	14	3.0	14



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Applied Animal Behaviour Science 70 (2000) 127–141

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The effect of group housing on feeding patterns and social behaviour of previously individually housed growing pigs

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Accepted 15 April 2000

Abstract

Group housed pigs make less frequent feeder visits of longer duration, and eat at a faster rate than pigs housed individually. They also have lower growth rates which may be due to elevated stress levels resulting from changes in the concentrations of hormones, such as cortisol and adrenaline associated with aggression and social stress. The aim of this experiment was to investigate the effects of grouping on feeding pattern, time budgeting and the social behaviour of pigs kept as individuals from weaning until grouping. In total, 12 Large White × Landrace male pigs (four pigs per block) mean (\pm S.E.) start weight 22.5 ± 0.7 kg were housed individually for 3 weeks (Period 1) after which in two replicates (Blocks 1 and 3), pigs were combined into a group of four (Period 2) before being returned to individual housing for a further 3 weeks (Period 3). In Block 2, the four pigs remained as individuals across periods but were moved between pens at the end of Periods 1 and 2 to account for any pen effects. Feeding pattern and food intake were recorded throughout and pigs were weighed three times a week. Video recordings and live behavioural observations were made to record time budgets and social behaviour. Grouped pigs made less visits to the feeder in Period 2 than when they were housed individually in Periods 1 ($P < 0.001$) and 3 ($P < 0.01$). Visit duration was longer in Period 2 than in Periods 1 ($P < 0.01$) and 3 ($P < 0.05$). Food intake and weight gain were greater in Period 3 than in Periods 1 and 2 ($P < 0.001$ and $P < 0.01$, respectively). There were no significant effects of moving pigs between pens in Block 2 on feeding behaviour and time budgets. In Period 2, grouped pigs slept more ($P < 0.01$) and spent less time feeding ($P < 0.01$) and rooting ($P < 0.01$) than in Periods 1 and 3. The frequency of aggression decreased over time from

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mixing ($P < 0.001$). Possible explanations for the changes in feeding behaviour when pigs are moved from individual to group housing are competition, group cohesion, or that the high frequency of feeder visits when the pigs are housed individually is a consequence of a lack of social stimulation. Of these different possibilities, the results suggest that group cohesion is most likely to have been causal in the observed changes in feeding behaviour. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Pig-feeding and nutrition; Feeding behaviour; Mixing; Aggression; Social organisation

1. Introduction

Normal farming practices require that growing pigs are frequently grouped and mixed, for example, at weaning, at the start of finishing, during transport and at lairage. This results in a disruption of social organisation which can lead to an increase in aggression (Meese and Ewbank, 1973), and social stress (Hessing et al., 1994), which in turn can compromise welfare and growth. Moreover, differences between pigs kept as individuals and as groups have been reported in terms of feeding behaviour. It has been found that group housed pigs modify their feeding behaviour by eating less frequently, consuming more food at a time and at a faster rate compared to pigs housed individually (de Haer and Merks, 1992). In addition, pigs in individual housing have higher digestibility coefficients related to smaller, more frequent meals as described by de Haer and de Vries (1993). In terms of production parameters, the latter authors found that group housed pigs had significantly lower growth rates, and less back fat than pigs housed individually. Furthermore, Gonyou et al. (1992) found that pigs housed individually gained more weight and had a higher food intake than pigs housed in groups of five.

Competition at the feeder, social facilitation, and social stress are all factors that may be responsible for the differences in feeding behaviour and production parameters between group housed and individually housed pigs. Social facilitation in group housed pigs results in synchronised feeding, but can lead to increased competition for feeder space in pigs kept in groups, caused by the motivation to feed simultaneously. Therefore, a balance between the amount of competition and the amount of social facilitation that occurs in a group situation must be found if the maximum food intake is to be achieved (Hisa and Wood-Gush, 1983). In addition, neophobic responses to unfamiliar pigs and environment when mixed may also play a part. Indeed, Tan et al. (1991) found that merely moving pens of pigs, without mixing, also resulted in a decline in productivity.

Although, there have been studies on the differences in feeding behaviour between group housed and individually housed pigs, there are few reports in the literature of experiments where the two housing regimes have been imposed on the same pigs. Nielsen et al. (1996a) found that group housed pigs did not greatly alter their feeding behaviour when they were subsequently individually housed, suggesting that feeding behaviour in pigs was not as flexible as previously postulated. However, the pigs were housed individually after a period of grouping, and it would be useful to ascertain the effects of grouping after an initial period of individual housing which would allow individual pigs' feeding patterns to develop in an unconstrained way.

The aim of the present experiment was to investigate the effects of grouping on feeding pattern, time budgeting and the social development of pigs kept as individuals from weaning before grouping. This was achieved by housing pigs individually from weaning with *ad libitum* access to food to allow them to develop their preferred feeding patterns. Following this, individuals were mixed into groups of four pigs. Finally, the pigs were returned to their individual pens. By comparing feeding patterns between periods of the experiment, and studying the development of social behaviour within the groups, we investigated the effects of grouping on individual pigs. In addition, possible causal factors for differences in feeding patterns between individually and group housed pigs might be found.

2. Methods

2.1. *Animals and treatments*

The experiment consisted of three blocks each comprising three, 3-week periods. Blocks were run consecutively as only four pens with recording equipment were available. For each block, four Large White \times Landrace, unrelated, male pigs were used. In the first and third blocks, the pigs were kept in individual pens for the first period, after which they were combined into a group for the second period. Finally they were returned to their individual pens for the third period. To assess any effects of moving pigs, in the second block four pigs were housed individually over the three periods, but were randomly allocated to different pens at the end of each period. The mean (\pm S.E.) weight of the pigs at the start of the experiment was 22.5 ± 0.7 kg.

2.2. *Housing*

The pigs were kept in a naturally ventilated room divided into four pens (3.8 m \times 2.9 m) into which some natural light could enter. To ensure that an equal amount of light was maintained throughout the experiment and that there was sufficient light for video recordings, artificial lighting was switched on at 06.00 h and turned off at 20.00 h. The front of the pens consisted of bars whereas the sides were solid sheets to eliminate physical contact between pigs in adjacent pens. Each pen contained an insulated kennel (1.9 m \times 1.9 m), a dunging area, a single-space computerised feeder (FIRE, Feed Intake Recording Equipment, Hunday Electronics Ltd., UK) and a metal bowl drinker. The pens were cleaned and fresh straw provided between 08.30 and 09.00 h daily. To increase the insulation of the kennels, five straw bales were arranged around the walls of each kennel when the pigs were small, in the first period of each block, and straw was always provided on the floor of the kennel.

Each feeder consisted of a race, the width of which could be altered so that only one pig could enter the feeder at a time (during the periods of grouping), and a fibre glass trough suspended on a load cell which could be accessed by pushing a door hinged to the feeder frame. Each pig was fitted with an ear transponder so that the electronic system could identify which pig was entering the feeder as it pushed its head through the door. In

Table 1
Summary of protocol for Blocks 1 and 3

	Period 1	Period 2	Period 3
Individual/group	Individual	Group	Individual
Behavioural observations	1 day per week	1 day per week	1 day per week
Video recordings	1 day in week 2	Days 1, 2, 4, 5, 9, 11 and 17	1 day in week 2
Weigh	Monday, Wednesday and Friday	Monday, Wednesday and Friday	Monday, Wednesday and Friday

addition, the trough weight immediately prior to entry, together with the time and duration of each visit and the post-visit trough weight were recorded by the computer control system.

2.3. Experimental procedure

Pigs were weaned at 4 weeks of age and moved to individual housing. At approximately 20 kg pigs were transferred to the experimental building where they were allowed a few days to adjust to their new environment and to learn how to use the feeders. During this time a small amount of food was sprinkled on the lip of the feeder in each pen to encourage the pigs to feed. If after 2 days any pig had not eaten, it was held in the race for a few minutes until it started to feed.

The protocol for Blocks 1 and 3 is summarised in Table 1. Throughout the control block (Block 2), all periods were conducted as Period 1 in Blocks 1 and 3.

2.4. Behavioural observations

Live behavioural observations were in the form of a combination of focal and scan samples (Martin and Bateson, 1993) at 5 min intervals over four, 1 h sessions on each observation day. The behaviour of the first focal pig was recorded continuously for 5 min followed by an instantaneous scan of all the animals' positions in the pen, postures and behaviours using the categories in Table 2. The procedure was repeated for the second pig and so on, so that each animal was observed for a total of 15 min using focal sampling and on 13 occasions using time sampling in each hour of observation. The 1 h sessions were at 09.00–10.00, 11.00–12.00, 13.00–14.00 and 15.00–16.00 h. To record the live behavioural observations a hand held event recorder (Workabout, Psion PLC, UK) and the Observer Package (Noldus Information Technology, Wageningen, The Netherlands) were used.

To ensure that individual pigs could be easily identified on the video recordings, each pig was numbered using a durable marker spray before recording commenced. Video recordings were analysed by time sampling the behaviour of each pig at 10 min intervals using the categories in Table 2. In addition, during the period of grouping, aggressive interactions were recorded as and when they occurred, the initiator, the receiver, the type of aggression (refer to Table 3), and the outcome being noted. About of aggression was considered finished if there was a break in that behaviour of >5 s. Finally, lying partners were recorded at each scan sample when the pigs were lying together in the pen.

Table 2
Behavioural categories used for time sampling and focal sampling

Position	Posture	Behaviour
Kennel	Assumed lying	Assumed sleeping
Pen	Lying	Alert
		Asleep rooting floor, straw or wall
		Nosing pig
	Sit/kneel	Alert
		Rooting floor, straw or wall
		Nosing pig
	Standing	Alert
		Rooting floor, straw, Wall
		Nosing pig
		Moving
Aggressive		
Mounting		
Drinking		
Urinating		
Feeder	Standing	Defecating
		Feeding
		Displacing other pig

2.5. Statistical methods

The data for the control pigs and the grouped pigs were treated separately. Data on feeding behaviour were processed using Minitab for Windows (release 11.1) to produce for each animal: a mean number of visits to the feeder, the mean duration of visits, the mean food intake per visit, feeding rate and food intake per day. Growth rate was estimated from the slope of the regression of live weight against time. Behaviour data from the time samples were processed in Minitab for Windows (release 11.1) and the proportion of total observed time spent in each behaviour was calculated for each pig on each observation day. Means per period were calculated and these together with the pig means from the feeding

Table 3
Aggression recorded from video recordings

Type of aggression	Description
Threat	Pig directs aggression at another pig but makes no physical contact
Knock	Pig knocks another pig with the head or snout with a rapid upwards or sideways movement
Chase	Pig runs after another pig in a threatening manner
Fight	Vigorous reciprocated aggression (repeated biting and pushing)
Displacement	Pig displaces another pig from the feeder, drinker or lying area by mounting, nosing, pushing or biting, the result is successful or non-successful
Submission	Pig turns head and body away from the aggressor, often sits down or stands with tail and ears drooped, may retreat and hide head and ears

data were then subjected to analysis of variance using Genstat for Windows (release 3.2, Lawes Agricultural Trust, 1990) treating the three periods as repeated measures.

The data from the live focal samples were processed and total duration spent in each behaviour per observation day were calculated using the Observer (Noldus, Information Technology, Wageningen, The Netherlands). The total duration of time spent in each behaviour was then compared between periods and between blocks using analysis of variance as above.

The frequency and type of aggression that occurred on each observation day after grouping were analysed using repeated measures treating each observation day as a repeated measure. The scores for the behaviours chasing, displacing at the lying area and threatening were log 10 transformed to normalise the data. Dominance matrices for each group were constructed and the social rank index (Lee and Craig, 1982) was used to determine dominance orders:

$$\text{social rank index} = \frac{1}{2}(D - S + N + 1)$$

where D is the number of other individuals dominated, S the number dominating the individual in question, and N the number in the group.

3. Results

3.1. Feeding behaviour

3.1.1. Control pigs

As a result of equipment malfunction records of food intake were lost for one pig in Period 3. There was no effect of period on the number of visits to the feeder (Table 4) but the mean duration of visits was higher in Period 2 than in the other two periods ($P < 0.05$). Food intake per visit was lower in Period 1 than in Periods 2 and 3 ($P < 0.05$) and feeding rate was greater in Period 3 than Periods 1 and 2 and greater in Period 2 than Period 1 ($P < 0.05$). Food intake increased across the periods being greater in Period 3 than 2

Table 4
Effect of moving pigs between pens on feeding pattern, food intake and production level^a

	Period			Period S.E.D.	Period significance
	1	2	3		
Visits/day	56.7	42.8	38.8	5.17	NS
Visit duration	65.6	82.1	72.0	3.44	*
Food intake/visit	27.8	54.4	66.2 ⁺	6.43	*
Feeding rate (g/min)	26.2	38.9	51.8 ⁺	2.86	*
Food intake (g/day)	1480	2084	2788 ⁺	143.6	*
Weight gain (g/day)	962	1136	1106	76.2	NS
Food conversion ratio (kg food/kg gain)	1.54	1.86	2.49 ⁺	0.243	NS

^a Pigs were individually housed in Periods 1, 2 and 3, but moved to different pens at the end of each period. Each value is a mean of four (3)⁺ pigs.

Table 5
Effect of grouping pigs on feeding pattern, food intake and production levels^a

	Period			Period S.E.D.	Period significance
	1	2	3		
Visits/day	60.7	22.9	43.8	6.80	***
Visit duration	62.2	144.6	98.5	18.43	**
Food intake/visit	26.3	82.2	79.0	13.35	***
Feeding rate (g/min)	25.8	33.6	50.7	2.62	***
Food intake (g/day)	1507	1683	2816	109.9	***
Weight gain (g/day)	942	963	1129	52.5	**
Food conversion ratio (kg food/kg gain)	1.60	1.78	2.53	0.125	***

^a Pigs were individually housed in Periods 1 and 3, and housed as a group of four pigs in Period 2. Each value is a mean of eight pigs.

($P < 0.05$) and greater in Period 2 than 1 ($P < 0.05$). Period effects on weight gain and food conversion ratio were not significant.

3.1.2. Grouped pigs

The number of daily feeder visits was significantly lower in Period 2 when the pigs were grouped than when they were housed individually in Periods 1 ($P < 0.001$) and 3 ($P < 0.01$) (Table 5). The number of visits was also less in Period 3 than Period 1 ($P < 0.05$). Visit duration was longer in Period 2 than Periods 1 ($P < 0.01$) and 3 ($P < 0.05$) and food intake per visit was lower in Period 1 than Periods 2 and 3 ($P < 0.001$). Feeding rate increased over time being greater in Period 2 than Period 1 ($P < 0.01$) and greater in Period 3 than Period 2 ($P < 0.001$). Food intake and weight gain were greater in Period 3 than Periods 1 and 2 ($P < 0.001$ and $P < 0.01$, respectively). Food conversion ratio was poorer in Period 3 than in Periods 1 and 2 ($P < 0.001$).

A graph of the mean number of feeder visits across time of day was plotted for the pigs that were grouped in Period 2 (Fig. 1). The graph shows that there were two peaks in feeding activity at 09.00 and 16.00 h and these peaks did not differ between periods of the experiment.

3.2. Time budgets

Results from the analysis of the video time samples, indicate that there were no significant effects of period on the time-budgets of the control pigs (Table 6). The grouped pigs (Table 7) slept more in Periods 2 and 3 than in Period 1 ($P < 0.01$). Time spent rooting and feeding decreased in Period 2 ($P < 0.01$). The mean proportion of time spent moving decreased across periods ($P < 0.001$).

3.3. Aggression and dominance orders

The frequency of aggression decreased ($P < 0.001$), and there were changes in the type of aggression over time from mixing (Table 8). There was an effect of day after mixing on the

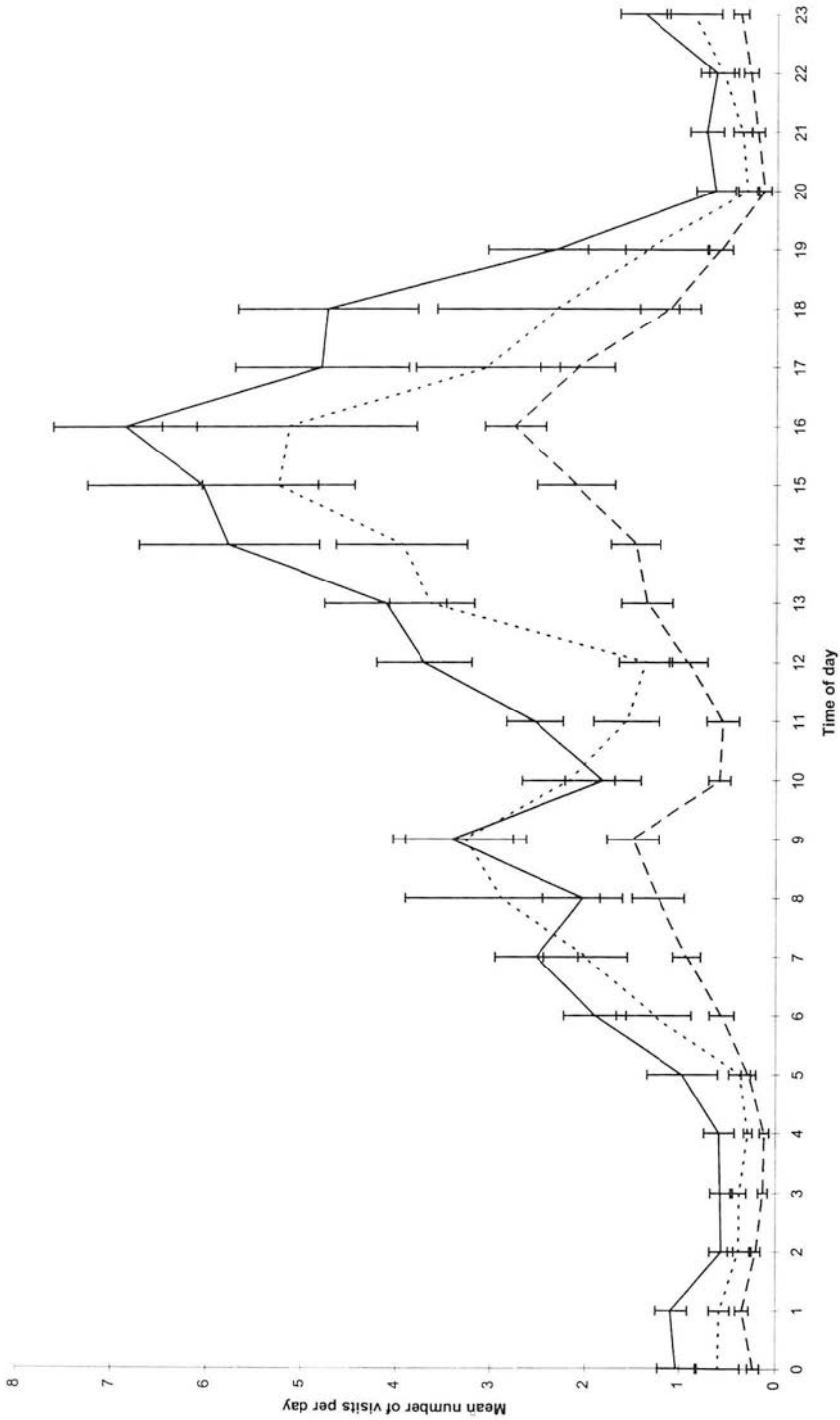


Fig. 1. Time of day of visits to the feeder in Period 1, pigs individually housed (—); Period 2, pigs group housed (---) and Period 3, pigs returned to individual housing (.....).

Table 6

Mean percentage of observations spent in each behaviour, Block 2^a

Behaviour	Period	Mean/period	Period S.E.D.	Period significance
Alert	1	0.73		
	2	1.35		
	3	1.01		
	Mean	1.03	0.930	NS
Asleep	1	51.2		
	2	63.3		
	3	69.3		
	Mean	61.4	6.42	NS
Rooting	1	35.7		
	2	27.0		
	3	20.6		
	Mean	27.8	5.26	NS
Feeding	1	9.10		
	2	6.63		
	3	7.43		
	Mean	7.72	1.485	NS
Moving	1	2.86		
	2	1.69		
	3	1.35		
	Mean	1.97	1.147	NS

^a Pigs were housed individually throughout experiment, but moved to a new pen at the end of each period.

number of threats ($P<0.01$), knocks ($P<0.001$), fights ($P<0.001$), chases ($P<0.001$) displacements from the feeder ($P<0.05$) and displacements from the lying area ($P<0.001$). These effects were, in general in the direction of a decrease across days from mixing.

Dominance orders were very unstable, probably because the frequency of aggressive interactions, particularly towards the end of Period 2, was relatively low so that accurate measures of dominance could not be obtained. Indeed, some pairs of pigs did not interact aggressively at all during some of the video recordings. It was expected that dominance orders would be more stable once the groups were settled and an indication of this would be when the pigs were observed lying together in the pen (Ewbank and Meese, 1971). Indeed, the incidence of pigs lying together in the pen increased over time from mixing.

4. Discussion

Groups of four pigs were used in the present experiment, and it is conceivable that pigs in larger groups may behave differently. Nielsen et al. (1995) compared the feeding behaviour of pigs housed in groups of 5, 10, 15 or 20. They found a threshold effect for feeding behaviour; the pigs housed in groups of 20 differing significantly from pigs housed in groups of 15 or less, the latter being similar. Therefore, the results discussed here are likely to apply to groups of pigs up to 15 in size, but not to larger groups.

Table 7
Mean percentage of observations spent in each behaviour Blocks 1 and 3^a

Behaviour	Period	Mean/period	Period S.E.D.	Period significance
Alert	1	1.01		
	2	0.95		
	3	0.59		
	Mean	0.85	0.439	NS
Asleep	1	59.6		
	2	70.1		
	3	66.7		
	Mean	65.5	2.97	**
Rooting	1	28.9		
	2	14.6		
	3	26.5		
	Mean	23.3	3.22	**
Feeding	1	8.11		
	2	4.45		
	3	6.21		
	Mean	6.26	0.761	**
Moving	1	2.19		
	2	1.38		
	3	0.00		
	Mean	1.19	0.416	***

^a Pigs were individually housed in Periods 1 and 3, and housed as a group of four pigs in Period 2.

4.1. Feeding behaviour

As expected, pigs altered their feeding patterns when grouped in the direction of less frequent visits to the feeder, of longer duration and more food eaten per visit and this is consistent with previous findings when individually housed pigs were compared with

Table 8
Changes in total aggressive interactions and type of aggression across days in Period 2^a

Behaviour	Day (D)					Day S.E.D.	Day significance
	1	2	4	5	18		
Total aggressive interactions	61.2	28.7	25.5	24.7	21.9	3.50	***
Threat (log 10)	0.21	0.17	0.26	0.08	0.00	0.07	**
Knock	10.25	7.25	2.75	6.75	5.25	1.02	***
Fight	48.75	17.50	19.50	18.75	15.00	3.06	***
Chase (log 10)	0.33	0.27	0.29	0.20	0.08	0.057	***
Displace at feeder	2.25	3.25	1.50	0.50	1.37	0.82	*
Displace at lying area (log 10)	0.00	0.00	0.08	0.08	0.15	0.03	***

^a Values in table are the mean number of occasions pigs were involved in each type of aggression.

similar, but different, pigs in groups (de Haer and Merks, 1992; Gonyou et al., 1992). The experiment reported here studied the same pigs as individuals and in groups. The pigs that were group housed in Period 2 showed a similar trend in feeding behaviour when housed as individuals in Periods 1 and 3 as the control pigs that were housed individually throughout the experiment. Thus, the period of grouping had no lasting effect on feeding behaviour. This flexibility in feeding behaviour is consistent with results from a previous experiment (Bornett et al., 2000) in which individually housed, *ad libitum* fed pigs were subjected to a period of restricted access to food, after which they either resumed their pre-restriction behaviour or showed the same trend as seen in non-restricted control pigs. This contrasts with the results of Nielsen et al. (1996a) who reported that previously group housed pigs made only small modifications to their feeding behaviour when they were transferred to individual housing, indicating that their feeding patterns were relatively inflexible. However, the pigs in that experiment were not allowed a period of individual housing prior to grouping, so their 'preferred' feeding pattern might have been less well defined.

The control pigs made a small, unexplainable increase in visit duration in Period 2. Apart from this there were no significant differences in the feeding behaviour, time budgets, or production parameters of the control pigs between periods that could not be explained by the increasing size of the pigs. This suggests that the changes in feeding patterns observed in the group housed pigs were due to the social factors imposed by group housing rather than effects of moving the pigs to a new pen. This is in contrast with findings of Tan et al. (1991). They used groups of six pigs and mixed them into new groups of varying ratios of familiar:unfamiliar animals and found that moving pens of pigs without mixing resulted in a decrease in productivity.

There were differences between the pigs that were grouped in Period 2 in the extent to which they altered their feeding patterns between periods. Reasons for this variability between pigs is not clear.

4.2. *Social behaviour*

The frequency of aggression decreased over time from mixing and this is consistent with reports in the literature that fighting decreases after the formation of a stable social hierarchy (Meese and Ewbank, 1973; Ewbank, 1976).

It is possible that aggression and competition between pigs were responsible for the change in feeding pattern when pigs were grouped. Alternatively, there may have been an effect of group cohesion such that individuals were reluctant to leave the group to feed. Finally, when individually housed, pigs might have displayed different feeding patterns to those of group housed pigs as a consequence of lack of social stimulation. Each of these hypotheses will be considered below.

4.3. *Competition*

The pigs showed two peaks in feeder visits across the day in all three periods (see Fig. 1), and this was consistent between pigs, indicating that they ate at similar times of day. Therefore, when the pigs were group housed it was likely that there would be preferred

times of the day when all pigs would be motivated to feed resulting in competition for feeder access. This might lead to fewer feeder visits of a longer duration as, once the pigs had gained access to the feeder, they remained there longer. Reasons for this might be either that the pigs were aware that they would not be able to gain access again for a 'longer than desired' between meal interval, or because they had had to wait for a 'longer than desired' meal interval since the previous meal and were, therefore, hungry resulting in a longer time to reach satiation.

If competition for access to the feeder was fierce it would be expected that the number of observed displacements from the feeder would be high. However, displacements from the feeder were relatively rare, suggesting that competition was not a constraining factor. Furthermore, it might be expected that dominant pigs would not have to alter their feeding patterns to the same extent as lower ranking pigs. Indeed, Pluske and Williams (1996) suggested that dominant pigs may suffer less from stress-induced suppression of feeding than subordinate pigs. However, in the present experiment dominance status could not be clearly determined, and all pigs changed their feeding behaviour in a similar way between Periods 1 and 2.

It has been found that pigs housed in groups of >15 (Nielsen et al., 1995), or in groups of 10 pigs with a one-space feeder (Nielsen et al., 1996b) have to modify their feeding behaviour to a greater extent than pigs housed in groups of <15, or in groups of 10 pigs with a four-space feeder, respectively. In the present experiment, the conditions were also below the thresholds, in terms of group size and pig:trough ratio that Nielsen et al. (1995) found resulted in changed feeding patterns, yet in this work feeding pattern still changed across periods. It seems unlikely, therefore, that competition between pigs was a major factor in the alteration of feeding patterns.

4.4. Group cohesion

A second explanation is that group cohesion results in pigs being reluctant to leave the group to feed. Houston and Sumida (1985) proposed that each behaviour has an associated tendency which increases when the behaviour is not performed and decreases when the behaviour is performed. The behaviour that is expressed at any one time is the behaviour with the highest tendency at that time. In this case, we could postulate a rather constant motivation to stay with the group, but variable feeding motivation dependent on time since the last meal. As motivation to feed becomes stronger it will out compete the motivation to stay with the group. Once feeding commences, positive feedback (Wiepkema, 1971) from the food ingested maintains feeding motivation so that meal duration becomes extended. As the pigs become satiated, feeding motivation will decline allowing expression of the social tendency resulting in a return to the group. The problem can also be considered in terms of costs and benefits. These pigs' motivational decisions presumably relate to the evolutionary costs of leaving the group and the benefits of feeding and vice versa. When the benefits of one motivation outweighs the benefits of the other then the pig switches behaviour (McFarland, 1989).

It could be argued that the pigs were synchronising their behaviour rather than there being an effect of group cohesion. Indeed it can be difficult to distinguish between the two. Moreover, some degree of behavioural synchronisation might in fact be a consequence of

social facilitation. For example, when housed in a group, a satiated individual might have increased motivation to feed due to the presence of a group mate in the feeder (Hisa and Wood-Gush, 1983). However, synchronisation has a time component in that behaviours are performed in unison, whereas cohesion could be defined as a 'force' that keeps the pigs together in a group. Thus, there is a difference in that the pigs are motivated for the company of other group members rather than purely synchronising their behaviour. Therefore, the group of pigs could be cohesive without all performing the same behaviours at the same time; some may be lying rooting whereas others are lying sleeping in the same area.

The motivation for company was demonstrated in an experiment by Jones et al. (1999) who demonstrated that pairs of pigs given a choice of access to either a heated, ammonia polluted compartment or an unheated, unpolluted compartment spent most time in the polluted-heated compartment. Even as air temperature increased, instead of increasing time spent in the unpolluted compartment the pigs remained in the polluted-heated compartment. It was suggested that pigs were more motivated to remain in heated-polluted compartment for companionship rather than thermal comfort.

4.5. High frequency of feeder visits as a consequence of lack of social stimulation

When the pigs were individually housed their behavioural repertoire was considerably less diverse and they spent more time rooting and less time sleeping than when group housed. Nielsen et al. (1996a) also reported increase in time spent rooting substrate when pigs were individually housed after a period of group housing. It could be that pigs were more active when individually housed in order to keep warm whereas when group housed, pigs were able to huddle for warmth. Furthermore, there may have been a greater requirement for rest when the pigs were grouped due to energy expenditure caused by frequent social interaction. Alternatively, the increase in time spent sleeping when group housed might suggest that pigs were more content whereas when individually housed they were agitated and so were more active and spent more time rooting and feeding. This theory suggests that the high frequency of feeder visits when pigs were individually housed might be due to lack of social stimulation resulting in a change in the behavioural priorities of the pigs; rooting and feeding becoming important as the only sources of positive stimulation in the pen. However, Bornett et al. (2000) found that pigs housed in individual pens that had visual, and some physical contact with neighbouring pigs and had straw provided made a similar number of visits to the feeder to pigs in the present experiment. This would suggest that lack of social stimulation is unlikely to be a major factor responsible for the differences in feeding behaviour between individually and group housed pigs.

5. Conclusions

In conclusion, grouping effects on feeding behaviour were in the form of a change in feeding pattern in the direction of fewer feeder visits of a longer duration. Feeding patterns were shown to be flexible as the period of grouping had no lasting effects on feeding behaviour. Frequency of aggression decreased across time from mixing as the groups

became more stable. The evidence reported here suggests that competition did not constrain feeding behaviour when the pigs were group housed. Moreover, it is unlikely that a lack of social stimulation was responsible for the comparatively high frequency of feeder visits when the pigs were housed individually. Therefore, the most probable mechanism for the change in feeding behaviour when the pigs were group housed is that of group cohesion.

Acknowledgements

The authors wish to thank Mr. D. Allcroft (Biomathematics and Statistics Scotland) for his statistical advice and Dr. M.J. Mendl for comments on the experimental design and procedures. H.L.I. Bornett was supported by a BBSRC research studentship. The experiment was funded by the Scottish Office Agriculture, Environment and Fisheries Department.

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The flexibility of feeding patterns in individually housed pigs

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Abstract

Group-housed pigs may be prevented from expressing their desired feeding pattern by more dominant individuals in the group. Indeed, when compared with individually housed pigs, group housed pigs eat less frequent, but larger meals. Therefore, it would be advantageous for pigs to have flexible feeding patterns in order to decrease the impact of group housing. The aim of this study was to assess the flexibility of feeding patterns by restricting the time of access to food of pigs previously given food ad libitum and then returning them to 24-h access. Thirty-two Large White × Landrace pigs were used in an experiment of two blocks (16 pigs per block) each comprising three, 2-week periods. In each block; during period 1, all pigs were allowed 24-h access to food after which, in period 2, eight of the pigs had access to the feeder restricted between 11:00 and 13:00 h of each day. The remaining eight pigs continued on 24-h access to food and acted as controls. In period 3, all pigs were again returned to 24-h access to food. Daily feeding pattern and food intake were recorded throughout. Behavioural observations in the form of scan samples were made and pigs were weighed twice a week. In period 2 the restricted pigs had fewer visits to the feeder per day, 34.0 v. 70.1 ($P < 0.001$); of a longer duration, 98.3 v. 64.5 s ($P < 0.01$); with a higher food intake per visit, 64.9 v. 33.3 g ($P < 0.001$) than the control pigs. Daily food intake and live-weight gain were lower ($P < 0.001$) for the restricted pigs in period 2 than for the control pigs. Restricted pigs spent more time rooting ($P < 0.05$), and less time sleeping ($P < 0.05$) than the control pigs in period 2. In addition, there was a trend for pigs to spend more time alert in the observation session prior to access to food in the second period when they were restricted and they made attempts to gain access to the feeders in this session. An indication of flexibility was gained by comparing feeding behaviour and time budgets between periods 1 and 3. The pigs that experienced a period of restricted feeding either resumed their previous behaviour or showed the same trend as the controls. In periods 1 and 3 daily feeder visits were 66.2 and 68.1 for control pigs, and 65.6 and 67.1 for restricted pigs. Mean durations of visits were 79.3 and 47.5 s, and 74.4 and 61.7 s respectively. It was concluded that feeding behaviour was flexible and time budgets were resilient across periods.

Keywords: feeding behaviour, pigs, time.

Introduction

Individual pigs develop stable feeding patterns in terms of time of day of each visit to the trough, the time spent per visit and food intake per visit. These feeding patterns are highly individualistic in terms of frequency and size varying from a few long meals per day to many short meals per day (Labroue *et al.*, 1994; Nielsen *et al.*, 1995).

When pigs are group housed, individuals may be denied access to the feeder at preferred times due to the presence of other group members. Indeed, when compared with individually housed pigs, group

housed pigs eat less frequent, but larger meals (de Haer and de Vries, 1993). This suggests that individuals have to alter their feeding behaviour due to constraints imposed by group living. Therefore, it would be advantageous for pigs to have flexible feeding patterns in order to decrease any adverse effects of group feeding. Nielsen *et al.* (1996), in a study to investigate individual variation in feeding patterns in group housed pigs found that feeding frequency showed only a small increase when group housed pigs were transferred to individual housing. It was suggested that feeding patterns were not flexible and that pigs will adhere to a pattern that has

been successful in the past even if an environmental change requires greater alteration to be made.

It is expected that pigs given food at a restricted level would be more subject to stress in response to thwarting of their desired pattern than pigs given food *ad libitum* and express more abnormal behaviours as caused by frustration. In work to investigate the effects of frustration of feeding behaviour in growing pigs, Lewis (1998) found that thwarting of feeding behaviour by providing empty feeders, increased levels of activity, sitting, playing and nosing of other pigs. In addition, when feeder lids were bolted down, an increase in plasma cortisol concentration was recorded.

Appleby and Lawrence (1987) reported food restriction to be a cause of stereotypies in tethered sows; these may reflect thwarting of feeding behaviour. Moreover, observations by Kostal *et al.* (1992) of broilers given food at a restricted level showed variation between birds in terms of varying amounts and types of stereotypies and in the amount of time spent resting. Therefore, individual differences between pigs might indicate that some pigs can cope better with a change in time of access to food than others.

The aim of the present experiment was to assess the flexibility of feeding patterns of pigs by restricting their time of access to the feeder. If feeding patterns are flexible then it would be expected that pigs would be able to re-adjust their feeding patterns to that seen under *ad libitum* conditions after a period of restricted feeding i.e. there would be no difference in feeding patterns before and after a period of restriction. In addition, by recording the behaviour of individuals we hoped to determine if there are individual differences in behavioural reaction to restricted feeding between pigs which might indicate differences in adaptability and have implications for welfare.

Material and methods

Pigs and treatments

Thirty-two pigs (Large White \times Landrace; start weight 24 (s.e. 0.3) kg) were used in an experiment of two blocks (16 pigs per block) each block comprising three, 2-week periods. During the first period all pigs were allowed 24-h access to food. In the second period, eight of the pigs were randomly allocated to a restricted feeding regime whilst the remaining eight pigs continued on 24-h access to food and acted as controls. In the third period all pigs were again allowed 24-h access to food. Hence, a total of 16 pigs experienced restriction on their feeding pattern and 16 pigs acted as controls.

Housing

The pigs were housed individually in two rows of eight pens. Each pen had an insulated concrete floor and straw was provided. The pens were 2 \times 1 m and the sides were constructed of galvanized sheeting, the front consisting of a gate through which the pig could see its opposite neighbour. Each pen was equipped with a metal bowl drinker and a computerized feeder with a trough suspended from a load cell. Details of the feeder are given by Morgan *et al.* (2000). Briefly, access to the feeder was via a door which operated a switch when opened and closed, providing records of entry and exit times at each visit, thus the number and duration of visits could be calculated. Each morning at 09:00 h records of the trough weight were taken to calculate daily food intake. The trough was then topped up with a weighed quantity of fresh food (BOCM Pauls Ltd, Renfrew: Growercare Sovereign Pellets (for pigs between 20 and 50 kg live weight); 195 g protein, 50 g oil, 37.5 g fibre and 50 g ash per kg and Growlean Pellets (for pigs over 50 kg live weight); 190 g protein, 40 g oil, 37.5 g fibre and 50 g ash per kg). During the restricted feeding period a shutter was fixed to the front of the feeder to prevent access to the door. Artificial lighting was supplied between 06:00 and 20:00 h and heating and ventilation were controlled automatically.

Experimental procedure

The pigs were introduced to the experimental pens a few days before the start of the experiment to allow them to acclimatize to their new environment. During this time a little food was placed on the lip of each trough to encourage the pigs to use the feeder. The experiment began when all the pigs had learnt to use the feeders and from then onwards feeding pattern and food intake was recorded. Table 1 provides details of the time of access to food and the measurements taken in each period. Access to food between 11:00 and 13:00 was chosen for the restricted pigs as this is a time when there is normally a decrease in the number of visits to the feeder (Feddes *et al.*, 1989; Nienaber *et al.*, 1990; Morgan *et al.*, 1998) and thus represents as great an alteration to feeding patterns as can be achieved during the light period. The pens were cleaned and fresh straw provided every other day between 09:00 and 10:00 h.

Behavioural observations

Behaviour sampling took place in the form of scan samples at 5-min intervals over four, 1-h sessions on each observation day. The sessions were at 09:30 to 10:30, 11:30 to 12:30, 13:30 to 14:30 and 15:30 to 16:30. At each 5-min interval, the posture (lying, sitting or kneeling and standing) and the behaviour (categories in Table 2) of each pig were recorded by the observer

Table 1 Summary of protocol

	Period 1	Period 2	Period 3
Feeding	All pigs <i>ad libitum</i> access to food.	Eight pigs randomly allocated to restricted access to feeder. Given food only between 11:00 and 13:00 h. Remaining eight pigs continue on <i>ad libitum</i> access and act as controls.	All pigs returned to <i>ad libitum</i> access to food.
Observation days	Days 4 and 11.	Days 1, 2, 4, 8 and 11.	Days 1, 2, 4, 8 and 11.
Weigh	Mondays and Fridays.	Mondays and Fridays.	Mondays and Fridays.

walking quietly between the two rows of pens. As Table 1 indicates, additional observation days were scheduled at the transition between periods to ensure more information on the behaviour of the pigs when times of access to the feeders were altered.

Statistical methods

Data on feeding behaviour for each period of each block were processed using Minitab for Windows (release 11.1) to produce for each animal: the mean number of visits to the feeder, the mean duration of visits and the mean daily feeder occupation (calculated as mean number of visits \times mean duration). Daily food intake was recorded as described above and food intake per visit was calculated as daily food intake per mean number of visits. Feeding rate was calculated as daily food intake per min of feeder occupation. Growth rate was estimated from the slope of the regression of live weight against time.

Table 2 Behavioural categories used for scan sampling

Behaviour	Description
Alert	Lying, sitting, kneeling or standing with eyes open, watchful but inactive.
Asleep	Lying with eyes closed.
Rooting	Manipulating the floor, straw or wall while lying, sitting, kneeling or standing.
Feeding	Standing, sitting or kneeling with head in feeder.
Nosing	Nosing neighbouring pig through gap at front or back of pens or over bars.
Drinking	Drinking at drinker or manipulating drinker/water.
Scampering	Rushing around pen, often grunting and carrying straw.
Rubbing	Rubbing body or head on walls etc.
Feeding attempt	Nosing, pushing or banging feeder shutter during times of food deprivation.
Urinating, defaecating.	

The proportion of time spent in each behaviour over each observation session was calculated using Minitab for Windows (release 11.1) and means were calculated per period across pigs. The behaviours nosing, scampering, rubbing, urinating and defaecating occurred rarely and so were excluded from further analysis. When the behaviour of pigs in period 1 was compared with their behaviour in periods 2 and 3, only data from observation days 4 and 11 were used in the analysis.

The pig means for the feeding data and the scan samples were then subjected to analysis of variance using GENSTAT for Windows (Lawes Agricultural Trust, 1990) treating the three periods as repeated measures and then analysing the data as if the experiment were a split plot design (Horgan and Sword, 1995). For the second part of the analysis of the scan samples, observation sessions 1 and 3 in each observation day were compared within and between periods also using analyses of variance.

Results

One pig in each block became ill and results from these pigs (both on the control treatment) were omitted from the statistical analysis. All significance values reported refer to overall treatment, period or interaction effects; standard errors of difference were used to locate the effects more specifically.

The feeding behaviour and performance of the pigs are shown in Table 3. The effect of treatment alone was not significant ($P > 0.05$) for any of the variables except for feeder occupancy where the pigs on the control treatment spent more time overall at the feeder than the pigs that had restricted access in period 2 ($P < 0.05$). There were highly significant effects of period and treatment by period interactions in most of the variables studied. In period 2 the restricted pigs had fewer feeder visits per day ($P < 0.001$) of a longer duration ($P < 0.01$) with a

Table 3 Feeding behaviour and performance of control and restricted pigs. Control (C) pigs had 24-h access to food throughout and restricted (R) pigs had 24-h access in periods 1 and 3 and 2-h access in period 2

	Period (P)	Treatment (T)		s.e.d. and significance		
		C	R	T	P	T × P
Visits per day	1	66.2	65.6			
	2	70.1	34.0			
	3	68.1	67.1			
	mean	68.1	55.5	9.81	4.29***	6.07***
Visit duration (s)	1	79.3	74.4			
	2	64.5	98.3			
	3	47.5	61.7			
	mean	63.8	78.1	15.06	5.66***	8.00**
Food intake (g per visit)	1	27.6	28.1			
	2	33.3	64.9			
	3	36.8	43.9			
	mean	32.6	45.6	7.81	3.60***	5.10***
Feeding rate (g/min)	1	21.9	24.7			
	2	32.8	39.3			
	3	47.7	50.9			
	mean	34.1	38.3	2.64	2.12***	3.00
Feeder occupancy (min/day)	1	66.7	62.1			
	2	57.8	35.9			
	3	45.1	51.3			
	mean	56.5	49.7	3.05*	2.39***	3.38***
Food intake (g/day)	1	1419	1477			
	2	1827	1364			
	3	2053	2407			
	mean	1767	1749	67.5	40.2***	56.8***
Weight gain (g/day)	1	947	964			
	2	997	828			
	3	927	1053			
	mean	957	948	33.8	32.1	45.3***
Food conversion ratio (kg food per kg gain)	1	1.50	1.54			
	2	1.85	1.66			
	3	2.23	2.32			
	mean	1.86	1.84	0.049	0.047***	0.066**

higher food intake per visit ($P < 0.001$) than the control pigs. Feeder occupancy was shorter for the restricted pigs in period 2 than for the control pigs ($P < 0.001$). Although an increase in visit duration ($P < 0.01$) and a decrease in food intake ($P < 0.001$) was observed for the restricted pigs from period 1 to period 2, on both treatments visit duration and feeder occupancy decreased ($P < 0.001$) and food intake per visit and feeding rate increased ($P < 0.001$) over time from period 1 to period 3.

As would be expected, as the pigs grew from period 1 to period 3 daily food intake increased ($P < 0.001$) and the food conversion ratio became poorer ($P < 0.001$). In period 2 the daily food intake and live-weight gain of the restricted pigs were lower than for the control pigs ($P < 0.001$). However, in period 3, the daily food intake and live-weight gain of the

restricted pigs were higher than for the control pigs ($P < 0.001$).

Flexibility of feeding behaviour

An indication of the flexibility in the feeding behaviour of the restricted pigs can be gained by comparisons between period 1 and period 3 which were respectively before and after the imposition of the restricted time of access. Although there was a marked reduction in the number of daily feeder visits in period 2, in period 3 the pigs recovered to the values seen in period 1 (Table 3). The duration of feeder visits was slightly lower in period 3 than period 1 but this was also seen in the control pigs. There was a large increase in the food intake per visit during period 2 but this reduced in period 3 to be somewhat higher than in period 1 but the control pigs also showed a steady increase throughout the

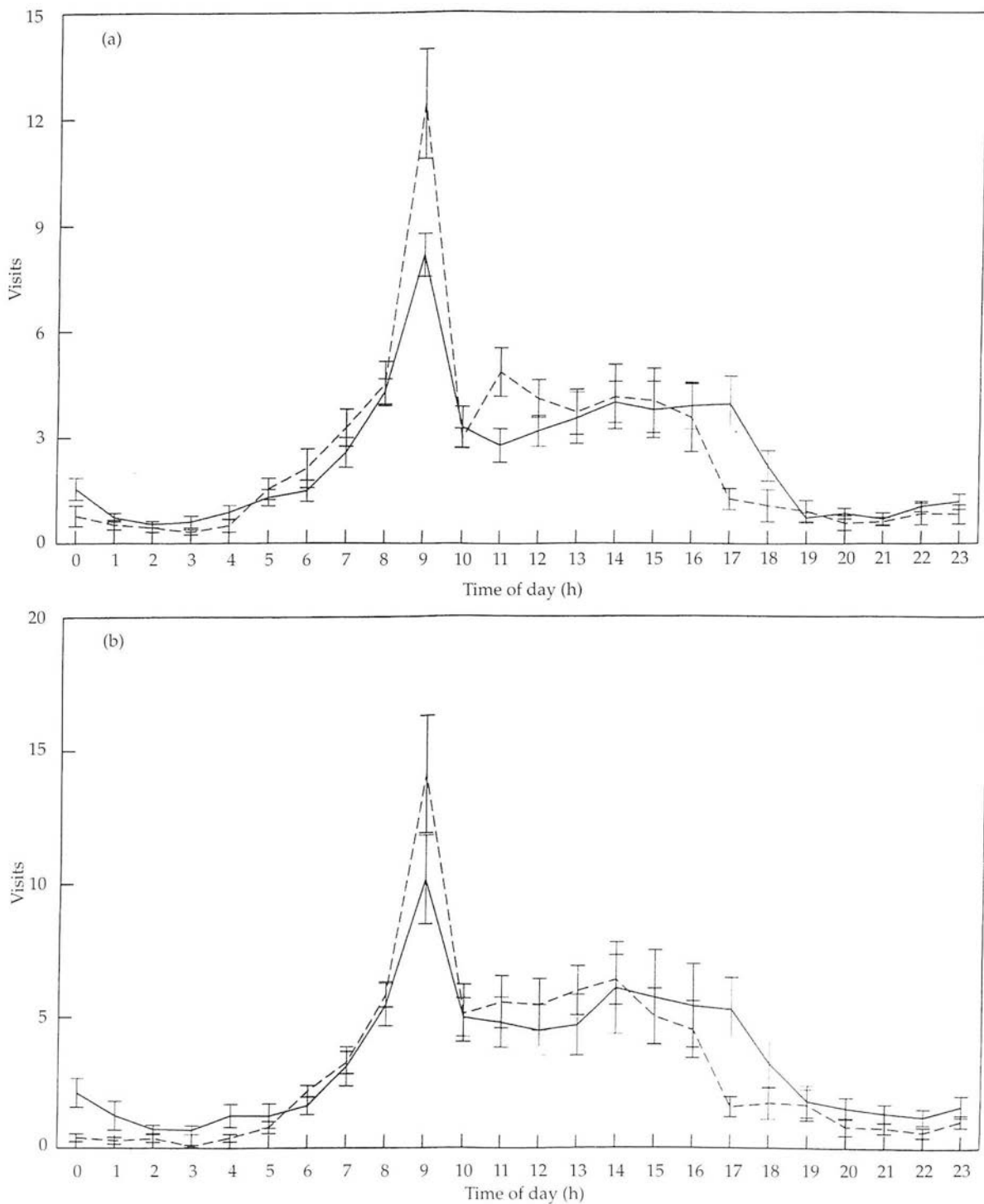


Figure 1 Number of feeder visits according to time of day made in periods 1 (—) and 3 (- - -) by (a) block 1 pigs that had restricted access in period 2; (b) block 1 control pigs.

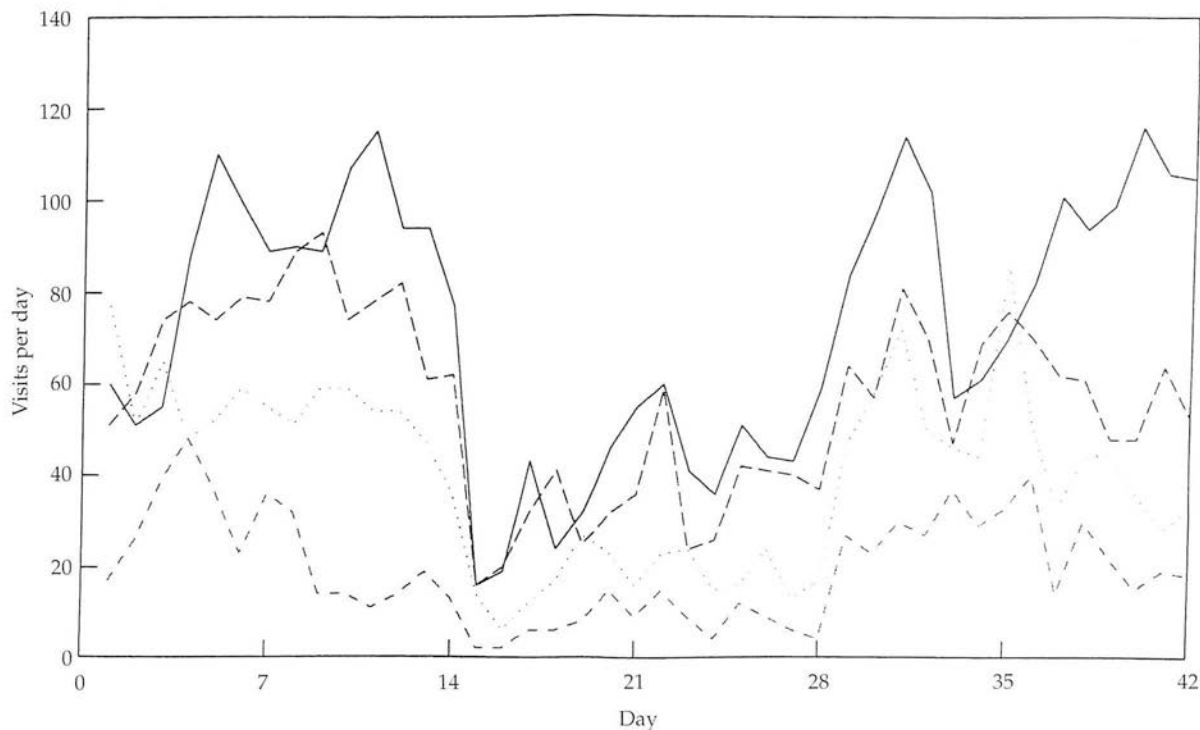


Figure 2 Number of feeder visits per day according to day of experiment by four pigs that had restricted access in period 2 (days 15 to 28).

course of the experiment. Feeder occupation showed a similar pattern of change to that seen in the control pigs. The pattern of timing of the feeder visits in period 1 was similar to that seen in period 3 for both the treatment and control pigs (Figure 1a and b). The only slight difference, seen in both groups of pigs, was a small increase in the peak at 09:00 h and decrease around 15:00 to 19:00 h in period 3 compared with period 1. This may have been due to the pigs becoming accustomed to receiving fresh food at 09:00 h. Taking these observations together, it is apparent that the feeding behaviour of the pigs was flexible in that the pigs that experienced a period of restricted access resumed their previous behaviour or showed the same trend as seen in the control pigs.

There was a marked reduction in feeder visits seen on the day of imposition of the restriction, irrespective of the mean number of daily visits in the previous 14 days, as can be seen from the range of pigs in Figure 2. During the period of restricted access some pigs showed a slow increase in the number of visits as the period progressed but the effect was not generally large. On the day of the removal of restriction the original number of visits

was resumed (and sometimes exceeded) and then remained fairly steady for the remainder of the period.

The daily food intakes over the first period were similar for the control and restricted groups of pigs (Figure 3) but the restricted pigs consumed significantly less in period 2 (Table 3) and the effect was immediate on imposition of the restriction. Food intake was severely reduced initially and then began to recover during the course of period 2 but, even after 14 days, the pigs were still not consuming as much as the controls. Immediately the restriction to access was removed, on the 1st day of period 3, the food intake of the previously restricted pigs recovered to be at a level above that of the control pigs and remained at a higher level for the remaining 14 days of the experiment.

Time budgets

The mean proportion of total observed time spent in each behaviour per period across pigs was calculated for restricted and control pigs and is shown in Table 4. Pigs spent the majority of time sleeping and rooting and there were large variations between pigs

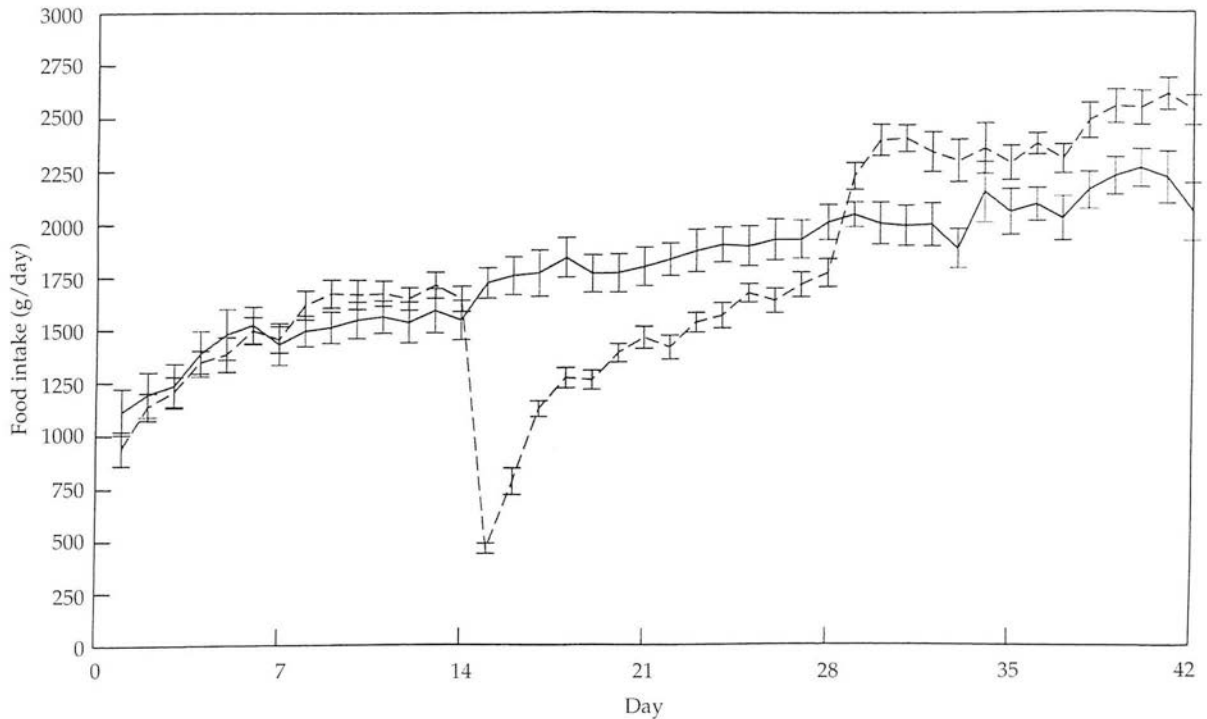


Figure 3 Food intake (g/day) according to day of experiment for control pigs (—) and pigs that had restricted access (---) in period 2 (days 15 to 28).

Table 4 Mean proportion (%) of total observed time control (C) and restricted (R) pigs spent in each behaviour across each period

Behaviour	Period (P)	Treatment (T)		s.e.d. and significance		
		C	R	T	P	T × P
Alert	1	3.91	3.37			
	2	3.15	3.44			
	3	2.79	2.13			
	mean	3.28	2.98	0.583	0.414*	0.586
Asleep	1	28.86	31.79			
	2	44.56	37.25			
	3	38.40	33.82			
	mean	37.27	34.29	3.308	1.778***	2.515*
Rooting	1	55.43	53.54			
	2	42.70	50.30			
	3	47.82	50.73			
	mean	48.65	51.52	3.416	1.790***	2.532*
Feeding	1	8.36	8.41			
	2	6.47	5.02			
	3	7.98	10.17			
	mean	7.60	7.87	0.693	0.721***	1.020*
Drinking	1	1.81	1.74			
	2	2.33	1.43			
	3	2.36	2.30			
	mean	2.17	1.83	0.345	0.298	0.422

for all the behaviours recorded. The effect of treatment alone was not significant for any of the behaviours recorded, however, there were significant effects of period for most behaviours recorded and some small treatment by period interactions. The proportion of the total observed time spent alert decreased over periods for control and restricted pigs ($P < 0.05$). The proportion of total observed time spent sleeping increased, and proportion of time spent rooting decreased for all pigs during period 2,

($P < 0.001$). However, restricted pigs spent less time sleeping and more time rooting than the control pigs in period 2 ($P < 0.05$). The proportion of observed time spent feeding decreased for all pigs in period 2 ($P < 0.001$), and the restricted pig spent more time feeding in period 3 than the control pigs ($P < 0.05$). There were no significant differences between treatments, periods or treatment by period interaction for the proportion of total observed time spent drinking.

Table 5 Mean proportion (%) of observed time spent in each behaviour by the control (C) and restricted (R) pigs (a) in observation session 1 (09:30 to 10:30 h) of periods 1, 2 and 3

Behaviour	Period (P)	Treatment (T)		s.e.d. and significance		
		C	R	T	P	T × P
Alert	1	6.01	2.40			
	2	3.36	5.77			
	3	3.36	2.40			
	mean	4.25	3.52	1.111	1.267	1.791
Asleep	1	34.1	40.6			
	2	63.7	51.4			
	3	59.1	65.4			
	mean	52.3	52.5	4.630	3.510***	4.960*
Rooting	1	51.4	48.1			
	2	26.0	38.9			
	3	28.8	23.1			
	mean	35.4	36.7	4.250	3.520***	4.980*
Drinking	1	1.20	0.72			
	2	1.44	0.24			
	3	1.44	1.68			
	mean	1.36	0.88	0.444	0.509	0.719

(b) in observation session 3 (13:30 to 14:30 h) of periods 1, 2 and 3

Behaviour	Period (P)	Treatment (T)		s.e.d. and significance		
		C	R	T	P	T × P
Alert	1	5.77	3.60			
	2	3.60	3.60			
	3	3.12	1.68			
	mean	4.17	2.96	1.191	1.001	1.416
Asleep	1	22.4	23.3			
	2	20.2	30.0			
	3	26.4	18.5			
	mean	23.0	24.0	4.340	3.170	4.490*
Rooting	1	59.9	59.1			
	2	64.7	62.5			
	3	57.9	63.2			
	mean	60.8	61.6	4.460	3.360	4.760
Drinking	1	2.40	1.68			
	2	3.12	1.44			
	3	3.12	3.84			
	mean	2.88	2.32	0.178	0.777	1.098

Comparisons of observation sessions 1 (09:30 to 10:30 h) and 3 (13:30 to 14:30 h) between periods 1, 2 and 3

It was likely that some of the effects of restricted feeding were being masked by considering the behaviour data of each day as a whole. Therefore, observation sessions 1 and 3 were analysed in more detail as they gave information about the behaviour of the pigs before and after the restricted pigs were allowed access to food. Table 5a shows the results when behaviour in observation session 1 was

compared between periods. In session 1, period 2, the restricted pigs spent more time rooting ($P < 0.05$) and less time sleeping ($P < 0.05$) than the control pigs. In addition there was a trend for the restricted pigs to spend more time alert in session 1, period 2 ($P = 0.067$). In contrast, when behaviour in observation session 3 was compared between periods (see Table 5b) there were no effects of period, but restricted pigs slept more in session 3, period 2, than the control pigs ($P < 0.05$). Therefore, the main

Table 6 Behaviour of restricted (R) pigs and control (C) pigs in observation sessions 1 (09:30 to 10:30 h) and 3 (13:30 to 14:30 h) (a) within periods 1, 2 and 3

Within period 1	Within period 2	Within period 3
Effect of treatment • No effects	Effect of treatment • R pigs slept less than C pigs in session 1 ($P < 0.05$). • C pigs spent more time drinking than R pigs ($P < 0.05$).	Effect of treatment • R pigs rooted less than C pigs in session 1 ($P < 0.05$). • R pigs spent more time feeding than C pigs ($P < 0.05$).
Effect of session • Pigs slept more in session 1 than in session 3 ($P < 0.001$). • Pigs rooted more in session 3 than in session 1 ($P < 0.01$). • Pigs spent more time feeding in session 3 than in session 1 ($P < 0.05$).	Effect of session • Pigs slept more in session 1 than in session 3 ($P < 0.001$). • Pigs rooted more in session 3 than in session 1 ($P < 0.01$). • Pigs spent more time drinking in session 3 than in session 1 ($P < 0.001$). Restricted pigs made more feeding attempts in session 1 than in session 3 ($P < 0.01$).	Effect of session • Pigs slept more in session 1 than in session 3 ($P < 0.001$). • Pigs rooted more in session 3 than in session 1 ($P < 0.01$). • Pigs spent more time drinking in session 3 than in session 1 ($P < 0.001$).
(b) between periods 1 and 2; 2 and 3; and 1 and 3		
Between periods 1 and 2	Between periods 2 and 3	Between periods 1 and 3
Session 1 Effects of period • All pigs slept more in period 2 than in period 1 ($P < 0.001$). • All pigs rooted less in period 2 than in period 1 ($P < 0.001$). Effects of treatment \times period • In period 1, R pigs spent less time alert than C pigs ($P < 0.05$). • In period 2, R pigs spent less time sleeping than C pigs ($P < 0.01$). • In period 2, R pigs spent more time rooting than C pigs ($P < 0.05$).	Session 1 Effects of period • R pigs rooted more in period 2 than in period 3. Effects of treatment \times period • In period 2, R pigs slept less than C pigs ($P < 0.05$). • In period 2, R pigs spent less time drinking than C pigs ($P < 0.01$). • In period 3, R pigs spent more time drinking than C pigs ($P < 0.01$).	Session 1 Effects of period • All pigs slept more in period 3 than in period 1 ($P < 0.001$). • All pigs rooted less in period 3 than in period 1 ($P < 0.001$). Effects of treatment \times period • No effects
Session 3 Effects of period • No effects Effects of treatment \times period • No effects	Session 3 Effects of period • All pigs rooted less in period 3 than in period 2 ($P < 0.05$). Effects of treatment \times period • In period 3, R pigs spent more time drinking than C pigs ($P < 0.05$).	Session 3 Effects of period • No effects Effects of treatment \times period • No effects

effects of period were in observation session 1, prior to access to food for the restricted pigs rather than in observation session 3, after pigs had eaten. The results from these comparisons and other comparisons between sessions and periods are summarized in Table 6a and b. In some cases there were also effects of day, session, treatment interactions, however these seemed to reflect the variability between days within periods rather than comparisons between periods and sessions which were of interest here. Furthermore, the biological significance of these interactions was difficult to discern.

As can be seen from Tables 5 and 6, when time budgets were compared between periods 1 and 3, pigs either resumed their previous behaviour when returned to 24-h access to food in period 3, or showed a trend similar to the control pigs.

Feeding attempts in pigs given food at a restricted level

Figure 4 shows the mean number of feeding attempts across pigs per day of observation in period 2. The proportion of observed time making feeding attempts was highest on the 2nd day of restriction and then declined. In addition pigs spent a larger proportion of time making feeding attempts in observation session 1 than in observation session 3 (see Table 6). However, there was a large variation between pigs. Some pigs started off on the 1st day of restriction making a large number of attempts but this number usually decreased over time in period 2. Other pigs continued to make a large number of attempts through till the end of period 2 whereas a few pigs made hardly any feeding attempts during the observed time. For examples refer to Figure 5.

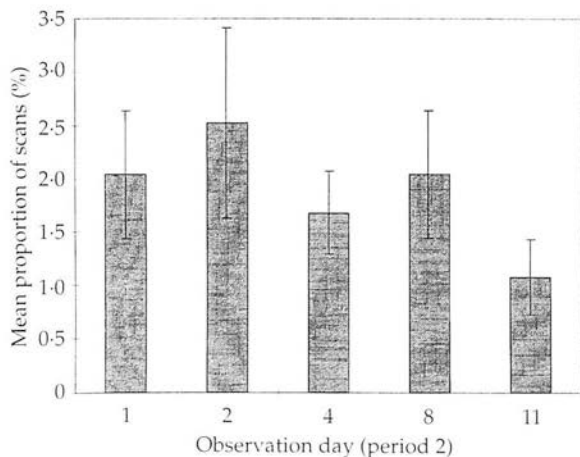


Figure 4 Mean proportion of scans in which restricted pigs made feeding attempts according to observation day in period 2.

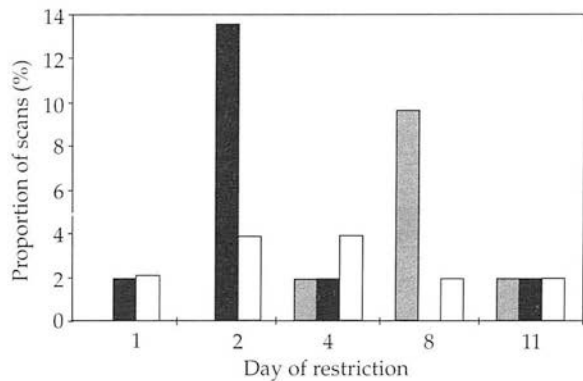


Figure 5 Proportion of scans in which pigs 8, 21, and 17 made feeding attempts on each of the five observation days in period 2.

Discussion

Feeding behaviour

When the pigs had free access to food they visited the feeder between 65 and 70 times a day, as has been reported by de Haer and de Vries (1993). The timing of visits was similar to that seen in group housed pigs with a peak in the morning, followed by a trough around mid day and a broader peak of activity in the afternoon (Nielsen *et al.*, 1996; Morgan *et al.*, 1998). As would be expected, the restricted time of access to the feeder from 24 h to 2 h in period 2 resulted in a substantial reduction in the number of daily visits to the feeder. However, on removal of the restriction in period 3 the number of visits returned to the previous level over a short period of time and were the same as for the control pigs which had not experienced the restriction. Thus the pigs' feeding behaviour appeared to be more flexible than suggested by Nielsen *et al.* (1996) who found that group-housed pigs, when subsequently housed individually, showed only a small increase in the number of visits. They concluded on the basis of this result that feeding patterns in the pig, once established are resistant to change. However, it is possible that grouping pigs puts constraints on their feeding patterns that are different from those imposed by a restricted feeding regime. A further indication of the flexibility in the pigs' feeding behaviour is shown by their ability to adapt over a short time after the restriction was removed.

When the period of restriction was imposed the pigs showed only a slow adaptation to the new conditions in terms of daily food intake, which did not attain the levels seen in the controls, even after 14 days. In Period 1 the pigs occupied the feeders for about 60 min out of the 24 h available but in period 2, even though they had a full 120 min available for feeding, they did not use this amount of time for this

purpose. The mean feeder occupation time was only 35.9 min. However, it was evident that some pigs took a mouthful of food from the trough and then backed away to chew it, thereby ending the visit. So the feeder occupation time does not equate to the total chewing (feeding) time. The method of Tolcamp *et al.* (1998) was used to collapse the sequence of feeder visits by each pig into meals. The mean number of daily visits which was 34.0 then became 4.0 (s.e. 0.58) meals with a total eating time of 45.7 (s.e. 5.27) min, again far short of the 120 min available. Thus it is apparent that, although the pigs were hungry, they could not spend the full time available in feeding activity. In the first couple of days this may have been due to the pigs not expecting the restriction but they would have learnt this quickly and would be expected to maximize the time available to eat. That they did not do this is likely to be a consequence of the limitation of stomach capacity to process large quantities of food in a short time. Food intake is controlled in part by the rate of gastric emptying (Rayner and Gregory, 1989). Kyriazakis and Emmans (1995) found that food intake was immediately depressed in pigs that were switched from a standard cereal-based food to a bulky food. However there was an adaptation over time as food intake recovered and this response was also seen here as food intake approached that of the controls after 14 days.

Time budgets

Analysis of the mean proportion of observed time spent in each behaviour indicated that when all the observation sessions were taken in to account there was little difference between the restricted and control pigs or between periods. However, when individual observation times were analysed in detail more disruption was revealed as described below.

Over all three periods, pigs slept more, and rooted less between 09:30 h and 10:30 h (session 1), than between 13:30 h and 14:30 h (session 3) indicating that all pigs were more active in observation session 3 compared with observation session 1. However, when observation session 1 was compared between periods 1 and 2, restricted pigs spent less time sleeping and more time rooting than the control pigs. Furthermore, the restricted pigs spent a larger proportion of time making feeding attempts in session 1 compared with session 3. These results are consistent with work by Savory and Maros (1993) who found that broiler breeder chickens given food at a restricted level were more active than birds given food *ad libitum* and activities that seemed to reflect feeding motivational state were walking before feeding time, and drinking and pecking the floor litter and sitting after feeding time. In addition, work

by Terlouw *et al.* (1993a) on meal-fed pigs found that the pigs demonstrated an anticipatory response in the form of a decrease in blood glucose level up to 1 h prior to the delivery of food. Therefore, in the present experiment, the pigs may have been anticipating food expressed by an increase in time spent active and alert, and showing frustration by attempting to gain access to the feeder in observation session 1 in period 2.

Contrary to what might be expected, some pigs continued to make feeding attempts in session 3 after they had had access to food. However, Lawrence and Illius (1989) found that the commercial level of food restriction for sows resulted in high levels of operant response suggesting that food restriction gives rise to high and sustained levels of feeding motivation throughout the day. Hence, it could be that by being allowed access to food for only a relatively short period of time these pigs were still hungry, and eating a small amount of food increased their feeding motivation. Indeed, Rushen (1985) reported that sows demonstrated increased stereotypic rooting and drinking in the post-feeding period and Terlouw *et al.* (1993b) found frequency of stereotypic behaviour increased after a small ration of food was provided. This may have been due to an increase in feeding motivation caused by positive feedback in the early stages of a meal. If an animal is not allowed to eat until satiation then this positive feedback overrules the negative feedback effects of the food ingested (Wiepkema, 1971). Therefore if the pigs did not take full advantage of the 2-h feeding slot, as discussed previously, then they would still be left with a strong motivation to eat and hence continue to make feeding attempts even after access to food. Alternatively, pigs could have been attempting to adhere to the feeding pattern they used successfully in period 1 when they had 24-h access to food.

The number of feeding attempts made by the restricted pigs in period 2 was very variable between pigs. However, in general, the proportion of observed time spent making feeding attempts was greatest on the second day of restriction. On day 1, the pigs had no previous experience of the restricted feeding regime and so could not anticipate when the feeder shutters would be removed. In addition, once the shutters had been removed, they had no concept that the shutters might be replaced in 2 h time. Therefore any feeding attempts made would more likely be due to feeding motivation and frustration and not to anticipation. By day 2 of restriction pigs would have been increasingly more hungry and might also have started anticipating and learning when food would be available so the proportion of observed time spent making feeding attempts was at

its highest. On subsequent days, feeding attempts decreased slightly but the extent to which this happened varied between pigs. Anticipation rather than hunger or frustration may have been more causal in the performance of feeding attempts later in period 2.

The variability of timing and number of feeding attempts made by individual pigs could have been indicative of individual differences between pigs and different abilities to cope with the change in time of access to food. This is consistent with work by Kostal *et al.* (1992) who investigated individual variation in behaviour of broiler breeders given food at a restricted level and found that greatest variation between birds was shown in stereotyped pecking at the drinker, empty feeder and walls and in resting. In addition different birds specialized in stereotyped pecking at the drinker or feeder. Birds which showed the most stereotyped behaviour also had lower plasma corticosterone concentrations and this points to a decrease in stress levels in these birds. Moreover, Terlouw *et al.* (1991) suggested that group feeding competition tests and long-term restrictive feeding and housing regimes induced variable behavioural responses indicating individual differences between pigs.

It is difficult to gauge the level of stress and frustration of the pigs during the period of restriction. Stress-susceptible pigs have been found to spend more time manipulating their environment than normal animals (Robert and Dallaire, 1986). Hence, the increase in proportion of time spent rooting in session 1, period 2 by the restricted pigs could be an indication of elevated stress levels. Although feeding attempts were observed, no other abnormal behaviours such as persistent rooting at the same spot, or excessive drinking which may have indicated increased stress levels (Robert and Dallaire, 1986), or unsatisfied feeding motivation (Lawrence and Terlouw, 1993) were detected. It could be that the restricted feeding regime imposed was not severe enough to induce such behaviours, alternatively, the provision of straw may have provided alternative stimulation. Indeed, work by Wittaker *et al.* (1998) showed that the provision of straw reduced levels of stereotypies in food-restricted pregnant sows. Finally, it is possible that the period of restriction was not long enough for stereotypic behaviours to develop. Vocalizations were not recorded, however, some restricted pigs did appear to vocalize more than others, particularly in the observation session before access to food in period 2 and this could have been an indication of anticipation, frustration or stress.

By comparing periods 1 and 3 it was possible to determine the effects of the period of food restriction on the behaviour of the pigs. There were no treatment or treatment by period interactions, even though there had been differences between treatments in period 2. It can be assumed therefore, that the change in time of access to food in period 2 did not affect how pigs behaved in Period 3 and hence their time budgets were flexible. There were some differences between periods but these occurred for all pigs and were probably a consequence of increasing age and size. This is consistent with the conclusions from the feeding data.

Conclusions

The results from this experiment suggest that feeding patterns are flexible in the pig in response to a period of restricted feeding. Their patterns were similar before and after restriction. The pigs with restricted access to food did not achieve the same food intake as the controls, probably due to physical constraints in dealing with the food in a short time. However, it is unlikely that pigs would suffer from stress if they are prevented from displaying their desired pattern provided feeding is not restricted to a period that is insufficient for them to eat to their requirements. Furthermore, the time budgets also appear to have been resilient across periods, suggesting that behaviours other than feeding pattern are also flexible in the face of an enforced period of restricted feeding. Individual differences between pigs were observed in terms of changes in feeding patterns, time budgets and performance of feeding attempts. This suggests that pigs have differing abilities to cope with a change in time of access to food and could indicate that some pigs are better at adapting to new situations than others. This might have implications when pigs are mixed into groups in that those which are more flexible should adapt more quickly and be less stressed if they cannot adhere to their preferred feeding pattern. However, as previously discussed, it is possible that the effect of a physical restriction in the form of a reduction in time of access to the feeder may have different effects on the feeding behaviour of pigs than a restriction imposed by group mates in a social situation.

Acknowledgements

The authors wish to thank Mr D. Allcroft (Biomathematics and Statistics Scotland) for his statistical advice. H. L. I. Bornett was supported by a BBSRC research studentship. The experiment was funded by the Scottish Office Agriculture, Environment and Fisheries Department.

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(Received 7 May 1999—Accepted 30 November 1999)