

**Effects of Food Motivation
on Stereotypies and
Aggression in Group Housed Sows**

Promotor: **Dr. P. R. Wiepkema**

Hoogleraar in de Ethologie

Co-promotor: **Dr. W.G.P. Schouten**

Universitair docent Ethologie bij het departement Dierwetenschappen

Dr. S.A. Edwards

Senior Pig Specialist bij de Animal Biology Division van SAC, Aberdeen

1000.2414

**Effects of Food Motivation
on Stereotypies and
Aggression in Group Housed Sows**

Hermanus A.M. Spoolder

Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van de Landbouwniversiteit Wageningen,
dr. C.M. Karssen,
in het openbaar te verdedigen
op vrijdag 3 april 1998
des namiddags te vier uur in de aula.

wn 953923

Spoolder, H.A.M. 1998. Effects of food motivation on stereotypies and aggression in group housed sows (Effecten van voerniveau op stereotypieën en agressie in groepen zeugen). Group housing of dry sows is generally believed to provide a higher degree of welfare than individual housing, because it allows the animal greater behavioural freedom. However, group housing does not eliminate behaviours such as stereotypies, and it may promote occurrence of agonistic behaviour. The present thesis addresses these undesirable behaviours and their relationship with food level and straw provision. Also, it looks at the possibility of early identification of animals likely to develop these behaviours. The results suggest that chronic food motivation in sows fed just above maintenance increased levels of foraging behaviour, and may in the absence of a foraging substrate have lead to an increase in stereotypic behaviour. No elevation of ACTH induced salivary cortisol levels were found in response to food level or straw provision treatments. Levels of aggression in large dynamic groups of sows were not affected by food level, but primarily by the introduction of new animals to the group. It is speculated that the deep straw bed mitigated some of the hunger related frustration. The spatial organisation data of these groups suggests that the bond between animals introduced together was still strong when pigs were taken out for farrowing. Young gilts show consistent behavioural responses to a number of challenges. These responses could however not be used as predictors for the subsequent development of excessive aggression or stereotypic behaviour.

Ph.D. thesis, Department of Animal Husbandry, Agricultural University, PO Box 338, 6700 AH Wageningen, The Netherlands.

voor Wilma

CONTENTS

	Page
GENERAL INTRODUCTION	11
CHAPTER 1 Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows.	15
CHAPTER 2 Effects of food level and straw bedding during pregnancy on sow performance and responses to an ACTH challenge.	31
CHAPTER 3 Effects of food level on performance and behaviour of sows in a dynamic group housing system with electronic feeding.	43
CHAPTER 4 Spatial organisation of dynamic groups of sows on two different food levels.	61
CHAPTER 5 Intra- and inter-situation consistency in behavioural responses to different challenges in gilts.	81
GENERAL DISCUSSION	97
SUMMARY	111
SAMENVATTING	115
LIST OF PUBLICATIONS	121
DANKWOORD / ACKNOWLEDGMENTS	123
CURRICULUM VITAE	128

Stellingen

1. Het ontwikkelen van stereotiep gedrag door chronisch hongerige zeugen wordt met name bepaald door de aan- of afwezigheid van een manipuleerbaar substraat.
(Dit Proefschrift)
2. In een dynamische groep dragende zeugen vindt volledige ruimtelijke integratie van dieren die op verschillende tijdstippen geïntroduceerd zijn nooit plaats.
(Dit Proefschrift)
3. Bij de aanwezigheid van stro leidt het voeren net boven onderhoudsniveau van dynamische groepen zeugen niet tot een meetbare verhoging van agressiviteit, in vergelijking met een veel hoger voerniveau.
(Dit Proefschrift)
4. Hessing's (1993) stelling, dat in een stressvolle situatie het gemiddelde dier niet bestaat, berust op een beperkte definitie van het begrip 'stress'.
(Hessing, M.J.C. 1993. Proefschrift Landbouwwuniversiteit Wageningen)
(Dit Proefschrift)
5. Het gegeven, dat het zuiggedrag van kalveren de vertering van voedsel in het maagdarmkanaal bevordert, suggereert dat appetitieve gedragspatronen meer zijn dan ethologische 'luxe'.
(De Passillé, A.M., Christopherson, R.J. and Rushen, J. 1993. Physiology & Behaviour, 54: 1069-1073)
6. Het feit, dat de Nederlandse welzijnswet voor dieren als 'Gezondheids- en welzijnswet voor dieren' wordt aangeduid, geeft aan dat de Nederlandse wetgever welzijn nog steeds primair vanuit de veterinaire hoek benaderd.
7. Groepshuisvesting om welzijnsredenen is alleen zinvol als het dier eventuele agressie ook kan ontwijken.
8. Het verbeteren van de technische resultaten van een varkensbedrijf door het veranderen van de houding van de dierversorger ten opzichte van zijn dieren (Hemsworth, 1997), heeft meer te maken met de werkmotivatie van de versorger, dan met de stressfysiologie van het varken.
(Hemsworth, P.H. 1997. In: Animal Welfare (Appleby & Hughes, Eds.), CAB International)
9. Een tevreden varken is een produktief varken, maar een produktief varken is niet noodzakelijkerwijs ook een tevreden varken.
10. "Ik denk dus ik besta" is de uitdrukking van een intellectueel die kiespijn onderschat.
(Kundera, M. 1990. Onsterfelijkheid. Ambo)
11. Geloof nooit iemand die uitgebreid de tijd neemt je te vertellen hoe druk hij het heeft.

H.A.M. Spoolder

Effects of food motivation on stereotypies and aggression in group housed sows.
Wageningen, 3 April 1998.

Stellingen

1. The development of stereotypic behaviour in chronically food motivated sows is mainly determined by the presence or absence of a manipulable substrate.
(This Thesis)
2. In dynamic groups of pregnant sows complete spatial integration of all animals introduced on different days never takes place.
(This Thesis)
3. A food level just above maintenance requirements does, in the presence of straw bedding, not lead to increased aggression in groups of pregnant sows, compared with sows on a much higher food level.
(This Thesis)
4. Hessing's (1993) stelling that "the average animal does not exist in a stressful situation", is based on a narrow definition of the word "stress".

(Hessing, M.J.C. 1993. PhD Thesis, Wageningen Agricultural University, The Netherlands)
(This Thesis)

5. The observation that suckling behaviour by calves improves the secretion of digestive hormones, suggests that appetitive behaviour patterns are more than behavioural "luxuries".
(De Passillé, A.M., Christopherson, R.J. and Rushen, J. 1993. Physiology & Behaviour, 54: 1069-1073)
6. The fact that the Dutch Welfare law is called the "*Health* and Welfare law", indicates that the Dutch legislator still addresses welfare primarily from a veterinarianian angle.
7. Group housing of pigs to improve welfare is only justified if the animal can also avoid potential aggression.
8. The improvement of pig performance through changes in the attitudes of the stock people towards their animals (Hemsworth, 1997), is related to the work ethic and motivation of the individual, rather than the stress physiology of the pig.

(Hemsworth, P.H. 1997. In: Animal Welfare (Appleby & Hughes, Eds.), CAB International)

9. A happy pig is a productive pig, but a productive pig is not necessarily a happy pig.
10. "I think therefore I am" is the statement of an intellectual who underrates toothache.
(Kundera, M. 1990. Onsterfelijkheid. Ambo)
11. Never believe anyone who spends a lot of time explaining how busy he is.

H.A.M. Spoolder.

Effects of food motivation on stereotypics and aggression in group housed sows.
Wageningen, 3 April 1998.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Legislative Background

In 1991 the European Union (then: European Economic Community) agreed Council Directive 91/630/EEC, laying down minimum standards for the protection of pigs. One of the most controversial articles in the directive stipulates that from January 2006 onwards it will be illegal to tether pregnant sows. This article is an obvious compromise between the industry's perceived need for individual housing, and public (and therefore political!) concerns about the well being of individually housed sows: the industry will have wanted to keep the option of tethering and stall housing open, the animal welfare lobby will have insisted on compulsory group housing.

Most European Union countries have implemented the tether ban in domestic legislation without imposing additional requirements. However, the United Kingdom's Welfare of Livestock Regulations 1994, went further than EU's directive on two counts. Firstly, the date of the ban was brought forward by 7 years to January 1999, and secondly, stall housing was banned in addition to tethers, which effectively meant that from that date pregnant sows will have to be group housed in the UK. The immediate and primary concern of the UK pig industry was that their influential supermarkets would source cheap pig meat from countries which had not adopted the same welfare standards. This concern was relieved as one major chain after the other issued statements confirming they would only buy pork and bacon reared to UK welfare standards.

The Dutch government did not implement additional measures on dry sow housing compared to the EU directive, in their "Varkensbesluit" (1994). However, recent developments in the Dutch pig industry, notably the disastrous outbreak of Classical Swine Fever, resulted in calls for the sector to undergo radical changes in the way it operates. A government White Paper, read out in parliament in July 1997, suggested the Dutch industry will have to reduce pig numbers, in order to improve the environment as well as health and welfare of the animals. Changes in the Dutch welfare legislation to underpin this strategy have recently been presented. They include conversion to group housing systems for dry sows.

Group Housing and Sow Welfare

Group housing of dry sows is generally believed to provide a higher degree of welfare than individual housing (e.g. Fraser and Broom, 1990; Webster, 1994). The UK Farm Animal Welfare Council suggested in their report on farm animal welfare (1993) that adequate welfare for domestic animals is only ensured when they are offered all of five basic freedoms: freedom from thirst, freedom from hunger and malnutrition, freedom from discomfort, freedom from pain, injury and disease, freedom from fear and distress and the freedom to express normal behaviour (FAWC, 1993). Current husbandry techniques together with good quality stockmanship ensure that the first four of these freedoms are met. The last of the five freedoms, which ensures the animal's ability to perform normal behaviour, is the one used primarily by those arguing against stalls and tethers. Intuitively one assumes that normal behaviour in sows is promoted by housing the animals in groups: group housing increases the area available for recreation and allows (more) opportunity for social interactions. However, group housing systems often not only fail to eliminate behavioural abnormalities seen in individually housed animals (such as stereotypies; Terlouw, 1991), they also potentially add another: aggression (e.g. Edwards, 1992). Behavioural "freedom" is by no means

guaranteed by simply grouping sows. Other factors are involved, and this thesis addresses two of them: food level and straw provision.

Contents of this Thesis

Chapter 1 discusses how food level and bedding influence the behaviour of pigs in groups of six. It concentrates on the development of stereotypies: behaviours which are relatively invariant, repetitive and lack an obvious function (Ödberg, 1978). Stereotypic bar biting and chain chewing in pigs have in the past primarily been associated with tethering (e.g. Edwards, 1992). Cronin (1984) speculated in his thesis on the development of stereotypies that a less restrictive environment allowing social interaction would avoid stereotypies. This was put to the test by Terlouw (1991), who compared group housed and individually housed pregnant sows, and found food motivation to be a major factor contributing to the development of chain chewing and bar biting. Chapter 1 takes this work one step further, by asking whether it is not just the motivation to feed, but the motivation to perform appetitive foraging behaviour which results in behaviour being directed towards pen components. Chapter 2 investigates whether performance parameters and stress hormone responses were linked to the frustrated feeding and/or foraging motivation of the pigs in Chapter 1. It tests the hypothesis that pigs which are both chronically food motivated, as well as unable to use straw as a foraging substrate, will show higher levels of cortisol in their saliva in response to an acute endocrinological challenge of the adrenal cortex.

Chapters 3 and 4 look at behaviour of sows housed in dynamic groups of 30. Dynamic groups have a constant throughput of sows, with recently served animals entering and pre-partum sows leaving, often on a weekly basis. In these groups, the social hierarchy has to be re-established constantly (e.g. Brouns and Edwards, 1992; Burfoot *et al.*, 1994), potentially resulting in high levels of aggression. The study described in these two chapters again addresses the level of food motivation of the animals. Work by Buré (1991) and Svendsen *et al.* (1990) suggests that sows on low food levels are more likely to show aggressive behaviour towards pen mates than sows on a higher nutritional plane. Buré (1991) speculates this may be related to frustrated feeding motivation, similar to observations in other species (Duncan, 1971). Chapter 3 investigates the effects of the two food levels on aggressive behaviour and the performance of the sows. Chapter 4 looks in details at the spatial organisation of these groups, primarily addressing the way food level influences the use of the space available, and the integration of newly introduced animals to the large groups.

The final chapter deals with individual behavioural differences. Behavioural responses to environmental challenges show a wide range in variation between individuals (e.g. Manteca and Deag, 1993). Although challenging housing conditions, such as low food levels or lack of foraging substrate, may result in an average increase of certain behaviours for a given group of pigs, variation within the group is often large and can not be easily accounted for by looking at previous experiences. Similar to other species (e.g. mice and rats; Benus *et al.*, 1987), different pigs do not necessarily cope in the same way (Hessing, 1994). Chapter 5 attempts to categorize individuals on the basis of their behavioural characteristics in response to a number of test situations. Developing a standard test to identify pigs which are unlikely to cope with subsequent challenges, whether they are nutritional, environmental or social, would be of great use to the pig industry. This is especially true for an industry which is moving away from individual control of dry sows, by housing them in groups.

The discussion concentrates on some of the practical implications of this thesis. It attempts to put the issues of stereotypes, aggression and individual behavioural differences in the context of group housing and makes suggestions for further research in this field. Finally, it contains some recommendations for the management and housing of dry sows in groups, based on the work presented in this thesis.

References

- Benus, R.F., Koolhaas, J.M. and Oortmerssen, G.A. van 1987. Individual differences in behavioural reaction to a changing environment in mice and rats. *Behaviour*, 100: 105-122.
- Brouns, F. and Edwards, S.A. 1992. Future prospects for housing of non-lactating sows. *Pig News and Information*, 13: 47N-50N.
- Buré, R.G. 1991. The influence on vulva biting of supplying additional roughage in an electronic sow feeder. Proceedings of the 42nd annual meeting of the EAAP, Berlin 1991.
- Burfoot, A., Kay, R.M. and Simmins P.H. 1994. Level of skin damage in sows when mixed in groups in early pregnancy. *Animal Production* 58: 438.
- Cronin, G.M. 1985. The development and significance of abnormal stereotyped behaviours in tethered sows. PhD Thesis, University of Wageningen.
- Duncan, I.J.H. and Wood-Gush, D.G.M. 1971. Frustration and aggression in the domestic fowl. *Animal Behaviour*, 19: 500-504.
- Edwards, S.A. 1992. Scientific perspectives on loose housing systems for dry sows. *Pig Veterinary Journal*, 28: 40-51.
- Farm Animal Welfare Council 1993. Second report on priorities for research and development in farm animal welfare. MAFF, Tolworth.
- Fraser, A.F. and Broom, D.M. 1997. Farm animal behaviour and welfare. CAB International, Wallingford. pp. 437.
- Hessing, M.J.C. 1994. Individual behavioural characteristics in pigs and their consequences for pig husbandry. PhD thesis, Wageningen Agricultural University, The Netherlands.
- Manteca, X. and Deag, J.M. 1993. Individual differences in temperament of domestic animals: a review of methodology. *Animal Welfare*, 2: 247-268.
- Ödberg, F.O. 1978. Abnormal behaviours: (stereotypies) Proceedings of the 1st World Congress on Ethology Applied to Zootechnics, Madrid 1978: 475-480.
- Svendsen, J., Andersson, M., Olsson, A.C., Rantzer, D. and Lundqvist, P. 1990. Group housing of sows in gestation in insulated and uninsulated buildings. Swedish University of Agricultural Sciences, LBT report 66.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W. 1991. Influences of feeding level and physical restriction on development of stereotypes in sows. *Animal Behaviour*, 42: 981-991.
- Webster, J. 1994. *Animal Welfare. A cool eye towards Eden*. Blackwell Science Ltd, Oxford. pp.273.

Chapter 1

PROVISION OF STRAW AS A FORAGING SUBSTRATE REDUCES THE DEVELOPMENT OF EXCESSIVE CHAIN AND BAR MANIPULATION IN FOOD RESTRICTED SOWS

Hans A.M. Spoolder^{1,2}, Jackie A. Burbidge^{1,2}, Sandra A. Edwards²,
P. Howard Simmins^{1†} and Alistair B. Lawrence²

¹ ADAS Terrington, Terrington St. Clement, King's Lynn, Norfolk PE34 4PW, UK

² SAC, West Mains Road, Edinburgh, EH9 3JG, UK

[†] Present address: Rhône-Poulenc Animal Nutrition, 42 Avenue Aristide Briand,
BP100, 92164 Antony, France.

Published in: *Applied Animal Behaviour Science* (1995) 43: 249-262.

Reproduced by permission of Elsevier Science Publishers B.V.[©]

PROVISION OF STRAW AS A FORAGING SUBSTRATE REDUCES THE DEVELOPMENT OF EXCESSIVE CHAIN AND BAR MANIPULATION IN FOOD RESTRICTED SOWS

H.A.M. Spoolder, J.A. Burbidge, S.A. Edwards, P.H. Simmins, and A.B. Lawrence

ABSTRACT

Pregnant sows fed at commercial levels remain highly food motivated for most of the day. The inability to express this behaviour appropriately may under certain conditions result in the development of abnormal oral activities, such as stereotypic chain and bar manipulation. Ninety six gilts, all between 1 and 3 weeks post service, were entered into a 2 x 2 factorial design comparing food level (L=low 1.8kg/23MJ day⁻¹; H=high 3.2kg/40MJ day⁻¹) and the provision of a foraging substrate (S=straw, N=no straw). The gilts were loose housed in groups of 6 with individual stalls. A 70 cm chain loop was attached to the front of each stall. The sows were fed at 09:00 hours during which time S sows received straw (approximately 1.5kg sow⁻¹). Behaviour was recorded over the first two parities, by time sampling for the 2 and 6 hours after the start of feeding and over 24 hours using video recordings. Activity levels were highest just after feeding, with L sows being more active than H sows (L v H: 79 v 49% for the second hour after the start of feeding, $F_{1,12}=41.5$, $P<0.001$). Most of the postprandial activity consisted of manipulating substrates. In LN sows, particularly in parity 2, this behaviour was mainly directed towards chains and bars, resulting in levels 3 to 4 times higher than in other groups (26, 7, 4 and 4% for the second hour after feeding for LN, LS, HN and HS respectively; Tukey's HSD, $P<0.05$). LS sows directed their foraging behaviour mainly towards the straw. It is concluded that in food restricted pregnant sows abnormal high levels of chain and bar manipulation can be prevented by providing straw which apparently acts as a foraging substrate.

INTRODUCTION

Chain and bar manipulation in pregnant sows are often regarded as stereotypic behaviours (e.g. Jensen, 1988; Terlouw *et al.*, 1991b), as they are relatively invariant, repeated frequently and without an apparent goal (Ödberg, 1978). What causes stereotypies to develop in pigs is the subject of much current research, but a number of contributing factors such as physical restriction (Cronin, 1985), general lack of stimulation (Mason, 1991) and individual characteristics (Terlouw *et al.*, 1990) have been identified.

Recently, Lawrence and Terlouw (1993) suggested that food restriction and the inability to express resulting foraging behaviour is one of the main causes for the development of stereotypies in sows. They argue that in food restricted sows the positive feedback effects of feeding in the early stages of a meal (Wiepkema 1971) overrules the negative feedback from ingestion of nutrients. This may result in higher levels of feeding motivation after the meal than before it, which would be expressed in higher levels of appetitive foraging behaviour. In an environment where this behaviour cannot be performed in a satisfactory way, where the animal's movements are restricted or where there is simply no available foraging substrate, the behaviour may be performed repetitively with a less appropriate substrate. This "channelling" of complex behaviour into a few repeated sequences

less appropriate substrate. This "channelling" of complex behaviour into a few repeated sequences could be an important prerequisite stage in the sensitisation of underlying neural elements (Dantzer, 1986), which would allow stereotypies to be more easily elicited and maintained.

Lawrence and Terlouw (1993) hypothesise that there are two methods of preventing stereotypies from developing: by reducing the level of feeding motivation, or by allowing the expression of more complex behaviours to prevent the channelling process. The present study was designed to investigate this hypothesis. It compared the effects of food level and the presence of a foraging substrate (straw) on the development of behaviours in gestating sows during their first and second pregnancy. The effects on production parameters will be the subject of a report which is currently in preparation.

The sows' behaviour was observed over three different periods during the day. First, the two hours after the start of feeding were studied, as activity levels should be highest during this period (Rushen, 1985; Jensen, 1988; Terlouw *et al.*, 1991b) and the onset of stereotypic behaviour is triggered by food ingestion (Jensen, 1988; Terlouw *et al.*, 1993). These scans may indicate how stereotypies develop over the two parities. Second, data were collected over a longer period during the day. Although stereotypies peak in the postprandial period, they are often sustained subsequently (Terlouw *et al.*, 1991a). As food restricted sows are food motivated throughout most of the day (Lawrence *et al.*, 1988), differences between treatments could be expected to be maintained in levels of foraging and other manipulative behaviours. Third, 24 hour video recordings were sampled for the sows' posture, location and drinking behaviour. Posture was used to test the hypothesis that activity levels, indirectly measured as "standing", are highest just after feeding (Rushen, 1985; Jensen, 1988; Terlouw *et al.*, 1991b), and influenced by food level. The preference for bedding in the dunging area (Fraser, 1975) was tested by comparing the use of the stall and dunging area between treatments. Finally, Terlouw *et al.* (1991b) recorded drinking levels in food restricted sows which they considered abnormal. By estimating the levels of drinking behaviour over 24 hours this study aimed to investigate whether drinking behaviour can be influenced by the food and straw treatments.

MATERIALS AND METHODS

Animals

Ninety six nulliparous sows (PIC Camborough; weight 147.7, SD 10.5kg; age 238.3, SD 16.4 days.) entered the experiment in 16 groups of 6 at a rate of 2 groups per month. All animals had been in their groups for at least 2 months, and were between 1 and 3 weeks post service.

Treatments

The experiment was a 2 x 2 factorial design, comparing food level (high (H) 3.2kg / 40MJ day⁻¹ v low (L) 1.8kg / 23MJ day⁻¹) and the provision of straw as a foraging substrate (straw (S) v no straw (N)). Groups were randomly assigned to one of the four treatments. The straw treatment started on entry to the building: S sows received approximately 1.5kg of fresh long barley straw in their stalls during feeding. The straw was usually removed from the dunging passage during cleaning the following day. The food treatment started in both parities after a preliminary habituation period of 2 weeks, during which all the sows received the same daily ration of 2.4kg / 30MJ.

Housing and Care

The sows were loose housed in a solid floor pen (3.6 x 4.1m), consisting of 6 free-access stalls raised 15cm above a communal dunging area (3.6 x 2.0m). Each stall had a ground level trough and a 70cm loop of chain which was attached to the front bars. The animals had access to 2 drinkers and 2 additional chains (70cm in length) in the dunging area. They were shut in the stalls between 09.00 and 10.00 hours every morning, to allow for the daily cleaning out of the dunging passage. Feeding started at 09.00 hours using a semi-automatic feeder which dispensed fixed rations of the same gestation diet to each individual. Chemical analyses of the diet indicated an average content of 151g protein, 55g oil, 60g neutral detergent fibre, 64g ash, and 6.9g lysine per kg. The digestible energy content calculated from proximate analyses using a standard prediction equation was 12.6MJ per kg. Any food left in the trough at 10.00 hours was removed and weighed.

Pregnancy was tested for in both parities, around day 28 and 42 after service. Oestrus detection was carried out daily by examination of the vulva. Any animal which returned for service was served, but sows which had expected farrowing dates more than 30 days later than the rest of the group were rejected from the experiment after the rest of the group had moved to the farrowing house.

Sows were taken to the farrowing house one to two weeks prior to their expected farrowing date. The building had a controlled environment and solid floor farrowing crates. Chopped straw was provided to all sows every day after cleaning out. The animals were fed 2 kg of a lactation diet (184g protein, 87g oil, 54g fibre, 71g ash, 9.7g lysine and a calculated digestible energy of 13.8 MJ per kg) twice a day. After farrowing the daily ration was increased by 0.5kg per piglet born alive to a maximum of 8.0kg.

Weaning occurred at 24±2 days. Sows were taken to the service house and reunited in their original groups. They were housed in solid floor straw pens with 6 individual feeders, and fed a daily ration of 3.0kg (41MJ) of the lactation diet until service. Eight sows in three groups had their services delayed by three weeks to allow for synchronisation of their reproductive cycle with other group members. After service, sows received 3.0kg (38MJ) of the pregnancy diet.

Two to five days after the last animal had been served the group was moved back to the experimental building, where they returned to their experimental food levels 2 weeks later.

Behavioural Observations

All sows in a group were marked with a sprayed pattern to facilitate identification. The sows' behaviour was recorded over both pregnancies using three different methods.

Two hour time sampling

The sows were observed on 3 days evenly spaced over each pregnancy, at approximately 3, 7 and 11 weeks after entry to the experimental building. The observation periods started at 09.00 hours (feeding time) and finished at 11.00 hours, an hour after the sows had been released from their stalls. Every 5 minutes an observer recorded posture, behaviour and the substrate used for each sow. A description of the behavioural categories used can be found in Table 1. Data were recorded on to an Atari portfolio computer (Atari Co, Sunnyvale, CA 94086, USA), using the data collection program Keybehaviour (Deag, 1990)

Table 1

List of behavioural categories used for 2 and 6 hour time sampling.

Standing	Body supported by all four legs.
Other postures	Lying, sitting or kneeling.
Feeding	Chewing and ingesting feed or licking the inside of the trough while food still in trough.
Sleeping	Lying with eyes closed without apparently performing any behaviour.
Inactive	Lying, sitting or standing with eyes open, without apparently performing any other behaviour.
Drinking	Drinking water from the drinker nipples in the dunging area.
Oral activities	Non-manipulative oral activity (as described by Cronin & Wiepkema 1984): vacuum chewing (continuous and rhythmical chewing in the absence of any substrate or feed in the mouth), tongue sucking (apparent sucking and subtle jaw movements with the cheeks slightly involutioned and the front of the lower lip drawn in a V-shape) and mouth stretching (continues and rhythmical mouth opening and closing with the emphasis on stretching the lower jaw whilst open, rather than on chewing).
Manipulating substrates	Nosing, chewing, rooting, biting, lifting or licking any available substrate in the stalls or dunging area other than feed or pen mates.
Chains	Nosing, chewing, rooting, biting, lifting or licking the chain loops in the feeding stalls or in the dunging area.
Bars	Nosing, rooting, biting or licking any of the bars of the stalls.
Trough	Nosing, rooting or licking any part of the feeding trough.
Floor	Nosing or licking any part of the floor in the feeding stalls or the dunging area.
Straw	Nosing, chewing or rooting straw, either in the stalls or in the dunging area.
Other	Manipulating any other substrate (e.g. pen mates, walls, drinkers).
Other behaviours	Any other behaviours (e.g. excretion, locomotion, agonistic).

Six hour time sampling

Sows were observed for a total of six hours after the start of feeding on 5 days evenly spaced over each pregnancy (approximately 3, 5, 7, 9 and 11 weeks after entry to the experimental building). The interval between samples was 20 minutes, resulting in 18 samples for each animal per observation day. The ethogram and data collection program used were similar to those given above.

Twenty-four hour time sampling

Around day 50 of pregnancy a 48 hour video recording was made of each group's behaviour using a video camera (Ikegami ICD-42E, Ikegami Tsushinki Co., 5-6-16 Ikegami, Ohta-ku, Tokyo, Japan) with a wide angled lens and a time lapse video recorder (Panasonic AG6720, Matsushita Electric Industrial Co., Osaka, Japan) set on 72 hour recording mode. An uninterrupted 24 hour section was then selected off the tape and for each sow its posture (lying, kneeling / sitting or standing), use of area (dunging area or stalls) and drinker activity (using the drinker or not) were recorded every ten minutes.

Statistical Methods

The percentages of time each sow spent in the different behavioural categories was estimated. As feeding behaviour was performed over a relatively large part of the first hour, the levels of all other behaviours during this hour were calculated as a percentage of the observation period minus the time spent feeding. This correction was not applied to data of the 6 and 24 hour scans. Feeding time (in minutes) in the first hour of the two hour scans was estimated as the number of times a sow was observed feeding multiplied by five. Feeding rate (in grams per minute) was calculated by dividing the ration by the feeding time. Data were tested for treatment effects using Genstat 5 (1987), by analyses of variance for repeated measures (nested for pig and group) with two factors (food and straw). Data on straw directed behaviour were tested in S groups only, with one factor (food). Where data could not be normalised, the Mann-Whitney test was used (Minitab 9 for Windows, 1993), with only one factor (food or straw). Three factors (food, straw and parity number) were used where data were tested for effect of parity. Time of day effects were tested for per parity, by analysis of variance, using feed, straw and hour as factors. Tukey's HSD (Minitab 9 for Windows, 1993) was used for pairwise comparison of the means of the four treatments (or of the 6 hours, when time of day effects were tested for) but only after an interactive effect or time of day effect had been found. Regression analysis was used to investigate effects of stage of pregnancy on development of behaviours. Where appropriate angular, square root or logarithmic transformations were used.

RESULTS

Out of the original 96 sows that started on the treatments, 95 sows completed the first parity and 79 the second. This was mainly due to the large number of sows which no longer had synchronous reproductive cycles with their group mates due to returns to service. Rejected sows came from all 4 treatments, and were regarded as missing values in the data analyses.

Effects of Parity and Time of Day

Levels of standing increased on all treatments before feeding (Figure 1). Over the six hours following the start of feeding the level of standing decreased (Parity 1: $F_{5,460}=238.3$, $P<0.001$; parity 2: $F_{5,375}=138.1$, $P<0.001$) as well as the level of substrate manipulation (Figure 2; Parity 1: $F_{5,460}=55.0$, $P<0.001$; parity 2: $F_{5,375}=43.9$, $P<0.001$). Levels of sleeping and inactive (Parity 1: $F_{5,460}=144.3$, $P<0.001$; parity 2: $F_{5,375}=120.3$, $P<0.001$) increased.

Levels of standing over the 24 hour day were higher in the second than in the first parity (Table 2; $F_{1,77}=10.5$, $P=0.002$), and so were levels of drinking (Table 2; $F_{1,77}=7.7$, $P=0.007$). The 6 hour data confirms this (Table 3; standing: $F_{1,75}=45.2$, $P<0.001$; drinking: $F_{1,75}=14.9$, $P<0.001$). It also shows an increase in chain and bar manipulation (Table 3; $F_{1,75}=45.2$, $P<0.001$), and a decrease in sleeping and inactive (Table 3; $F_{1,75}=9.1$, $P=0.003$) in parity 2 relative to parity 1. Average feeding rates were higher in parity 2 than in parity 1 ($F_{1,77}=39.8$, $P<0.001$).

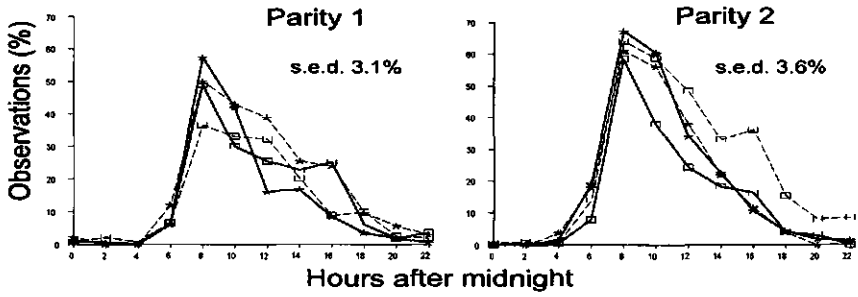


Figure 1

The percentage of observations spent standing. Values shown are treatment means with standard errors of the differences of means (SED) over all four treatments: LN (open squares and dashed line), HN (open squares and solid line), LS (asterisks and dashed line) and HS (asterisks and solid line).

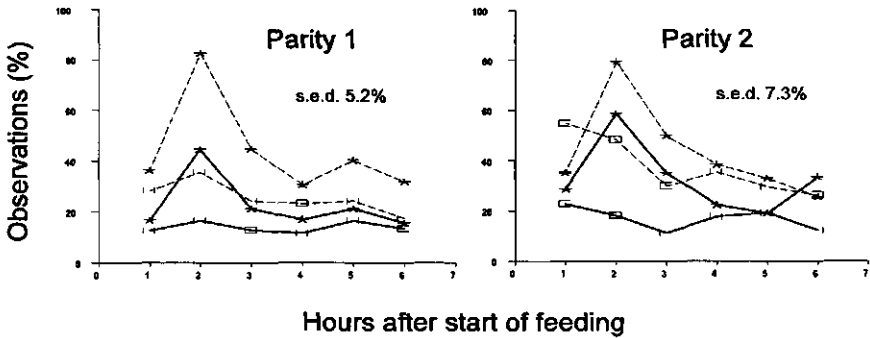


Figure 2

The percentage of observations spent manipulating substrates. Values shown are treatment means with standard errors of the differences of means (SED) over all four treatments: LN (open squares and dashed line), HN (open squares and solid line), LS (asterisks and dashed line) and HS (asterisks and solid line).

Table 2

Analyses of variance on the percentages of time treatment groups spent standing, drinking and in the dunging area across parities 1 and 2 (24 hour data).

	Parity 1							Parity 2						
	Means per treatment				SED			Means per treatment				SED		
	LN	LS	HN	HS	F	S	FxS	LN	LS	HN	HS	F	S	FxS
Standing	13	18	15	12	3.1	0.538	0.555	24	20	14	16	3.6	0.091	0.787
Dunging area	7	18	8	37	7.4	0.080	<0.001	8	32	8	18	8.8	0.079	<0.001
Drinking	1	0	1	2	0.6	0.033	0.813	2	1	2	2	0.4	0.528	0.472
														0.965

Values in bold indicate significant effects at $P < 0.05$.

* Data could not be normalised. The statistical test used was Mann-Whitney for Food and Straw effect.

Table 3

Analyses of variance on the percentages of time treatment groups spent in different behavioural categories across parities 1 and 2 (6 hour data)

	Parity 1							Parity 2						
	Means per treatment				SED			Means per treatment				SED		
	LN	LS	HN	HS	F	S	FxS	LN	LS	HN	HS	F	S	FxS
Standing	36	49	26	35	4.6	0.002	0.005	52	54	32	46	7.5	0.024	0.142
Feeding	5	5	9	9	1.3	0.001	0.984	3	5	8	8	0.9	<0.001	0.053
Sleeping + Inactive	50	41	59	54	3.8	0.001	0.023	42	38	57	47	6.3	0.017	0.131
Drinking	3	1	4	4	0.9	0.018	0.127	4	4	6	5	1.5	0.360	0.478
Oral activities	4	1	1	0	1.4	0.021	0.005*	3	2	1	1	1.2	0.333	0.064*
Manipulating substr.	27	45 ^c	15	23	4.4	<0.001	0.180	41	44	18	33	6.2	0.002	0.054
Man. Straw	-	32	-	14	3.6	0.003	-	-	33	-	19	3.5	0.045	-
Man. Trough + Floor	14 ^b	7 ^a	8 ^a	6 ^a	1.4	0.003	0.027	15 ^b	5 ^a	10 ^a	7 ^a	2.1	0.384	0.002
Man. Bar + Chain	8	4	3	2	2.3	0.049	0.253	22 ^b	6 ^a	5 ^a	6 ^a	4.2	0.019	0.096
														0.014

Values in bold indicate significant effects at $P < 0.05$. Means of a category within each parity with different superscripts differ significantly (Tukey, $P < 0.05$).

* Data could not be normalised. The statistical test used was Mann-Whitney for Food and Straw effect.

Table 4

Analyses of variance on the percentages of time treatment groups spent in different behavioural categories (corrected for feeding time) across Hours 1 and 2 after the start of feeding (2 h data)

	Hour 1										Hour 2									
	Means per treatment					P-values					Means per treatment					P-values				
	LN	LS	HN	HS	SED	F	S	FxS			LN	LS	HN	HS	SED	F	S	FxS		
<i>Parity 1</i>																				
Standing	35	41	21	28	8.0	0.029	0.280	0.986			50	88	32	53	9.9	0.002	0.001		0.001	0.247
Sleeping + Inactive	48	43	64	54	7.1	0.019	0.133	0.614			41	8	55	40	8.0	0.001	<0.001		<0.001	0.147
Drinking	-	-	-	-	-	-	-	-			8	5	9	11	3.0	0.140	0.756		0.756	0.227
Oral activities	7	3	1	2	2.4	0.065	0.475*	-			5	0	1	0	2.1	0.049	0.002*		0.002*	-
Manipulating substr.	38	43	26	33	8.7	0.106	0.374	0.922			32 ^b	80 ^c	20 ^a	40 ^b	6.4	0.001	<0.001		<0.001	0.010
Man. Straw	-	14	-	12	5.3	0.724*	-	-			-	75	-	30	8.2	0.002	-		-	-
Man. Trough + Floor	24	22	17	19	4.8	0.171	0.947	0.561			18	4	12	7	2.3	0.802	<0.001*		<0.001*	-
Man. Bar + Chain	9	9	4	1	3.9	<0.001	0.438*	-			6	1	3	1	1.1	0.247	<0.001*		<0.001*	-
<i>Parity 2</i>																				
Standing	71	56	31	40	13.3	0.005	0.686	0.142			79 ^{cb}	89 ^c	34 ^a	68 ^b	7.4	0.001	0.002		0.002	0.040
Sleeping + Inactive	20	30	52	47	8.3	0.002	0.636	0.250			17 ^{ab}	9 ^a	52 ^c	26 ^b	5.4	<0.001	<0.001		<0.001	0.030
Drinking	-	-	-	-	-	-	-	-			14	7	10	10	2.8	0.981	0.121		0.121	0.105
Oral activities	4	4	5	1	2.7	0.640	0.185*	-			4	2	2	0	1.2	0.235	0.008*		0.008*	-
Manipulating substr.	71	60	36	41	8.5	0.001	0.575	0.215			51	79	21	49	10.0	0.001	0.002		0.002	0.924
Man. Straw	-	12	-	7	3.8	0.252	-	-			-	67	-	39	10.5	0.034	-		-	-
Man. Trough + Floor	27	24	22	21	6.3	0.409	0.725	0.821			21	5	12	5	2.7	0.368	<0.001*		<0.001*	-
Man. Bar + Chain	43	21	8	13	8.6	0.006	0.197	0.053			26	7	4	4	5.2	0.001	0.011*		0.011*	-

Values in bold indicate significant effects at $P < 0.05$. Means of a category within each hour with different superscripts differ significantly (Tukey, $P < 0.05$).

* Data could not be normalised. The statistical test used was Mann-Whitney for Food and Straw effect.

Effects of Food Level

The high fed sows spent more time feeding in both parities (parity 1: H v L: 30.9 v 14.9 min, $F_{1,12}=47.4$, $P<0.001$; parity 2: H v L: 24.8 v 11.1 min, $F_{1,12}=63.4$, $P<0.001$). Feeding rates in high fed sows averaged 112g min⁻¹ in parity 1, with no significant change over pregnancy. Regression analyses showed that low fed sows increased their rate of feeding from 115g min⁻¹ in the first month to 151g min⁻¹ at the end of parity 1 ($T=4.3$, $P<0.001$). By the end of parity 1 average feeding rates differed significantly between the two food treatments ($F_{1,12}=7.8$, $P=0.017$), a difference that was maintained in parity 2 (L v H: 181 v 133g min⁻¹, $F_{1,12}=5.5$, $P=0.037$).

Levels of standing over the 24 hour day did not differ between the food treatments in parity 1, but, in parity 2, low fed sows tended to spent more time standing than high fed animals (Table 2; $F_{1,12}=3.4$, $P=0.091$). High fed sows spent more time drinking than low fed animals in parity 1, an effect which was absent in parity 2 (Table 2; parity 1: $F_{1,12}=5.5$, $P=0.033$; parity 2: $F_{1,12}=0.4$, $P=0.528$). During the first six hours after the start of feeding L sows spent more time standing (Table 3; parity 1: $F_{1,12}=14.9$, $P=0.002$; parity 2: $F_{1,12}=6.7$, $P=0.024$) and manipulating substrates (Table 3; parity 1: $F_{1,12}=28.9$, $P<0.001$; parity 2: $F_{1,12}=15.2$, $P=0.002$) than H sows, both in the first and in the second parity. They spent less time feeding, and less time sleeping or inactive. Data from the first two hours after feeding are summarised in Tables 4a and 4b. In both parity 1 and 2 levels of standing and bar and chain manipulation are higher in the L sows than in the H sows (e.g. Table 4; bar and chain manipulation, second hour: Mann-Whitney $W=1667.5$, $P=0.001$). Straw manipulation was higher in L than in H sows in the second hour after feeding (Table 4; parity 1: $F_{1,6}=29.7$, $P=0.002$; parity 2: $F_{1,6}=7.5$, $P=0.034$). Trough and floor manipulation was not influenced by food level.

Effects of Straw Provision

Over the 24 hour period sows on straw spent more time in the dunging area than sows without straw (Table 2; parity 1: $F_{1,12}=19.1$, $P<0.001$; parity 2: Mann-Whitney $W=895.5$, $P<0.001$). No effect of straw was found on standing over the 24 hour day. During the 6 hours post feeding in parity 1, sows on straw stood more than sows without (Table 3; $F_{1,12}=11.7$, $P=0.005$). In both parities S sows also manipulated substrates more than N sows (Table 3; parity 1: $F_{1,12}=17.6$, $P=0.001$; parity 2: $F_{1,12}=4.6$, $P=0.054$) but spent less time manipulating pen components such as trough and floor (Table 3; parity 1: $F_{1,12}=19.0$, $P<0.001$; parity 2: $F_{1,12}=16.4$, $P=0.002$). In the first hour immediately following the start of feeding no effects of straw were apparent (Table 4). In the second hour however, standing and manipulating substrates were higher in S than in N sows (e.g. Table 4; standing: $F_{1,12}=17.9$, $P=0.001$). S sows spent less time performing oral activities, and less time manipulating substrates other than straw (e.g. Table 4, second hour; oral activity: Mann-Whitney $W=2531.5$, $P=0.002$).

Interactive Effects of Food Level and Straw Provision.

Interactive effects of food and straw were found during the 6 hours post feeding in the levels of chain and bar manipulation (Table 3; parity 2: $F_{1,12}=8.3$, $P=0.014$) and trough and floor manipulation (Table 3; parity 1: $F_{1,12}=6.4$, $P=0.027$; parity 2: $F_{1,12}=5.8$, $P=0.033$). LN sows spent more time performing these behaviours than sows on the other 3 treatments (Figure 3, Tukey,

$P < 0.05$). Chain and bar manipulation in the 2 hour data was non-parametrically distributed, and a straw \times food interaction could not be tested for. However, average levels of chain and bar manipulation were up to 4 times higher in LN sows than in any of the other groups (Table 4), but there was a large variation between individual sows (Figure 4).

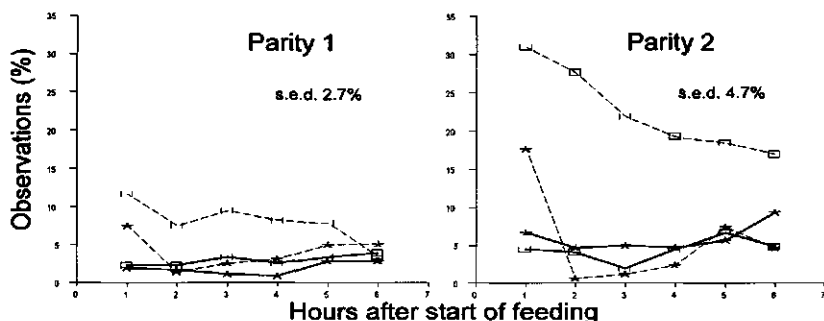


Figure 3

The percentage of observations spent manipulating bars and chains. Values shown are treatment means with standard errors of the differences of means (SED) over all four treatments: LN (open squares and dashed line), HN (open squares and solid line), LS (asterisks and dashed line) and HS (asterisks and solid line).

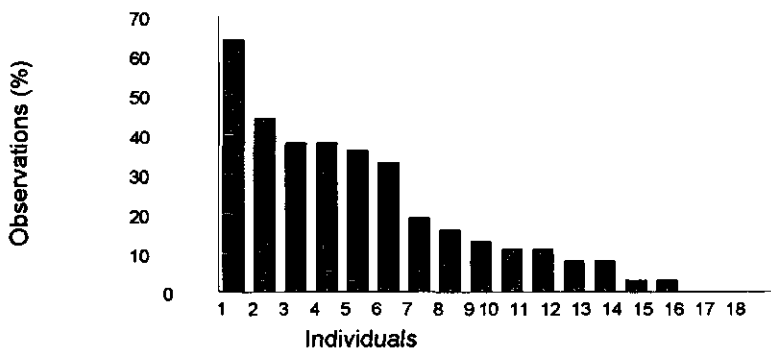


Figure 4

The percentage of observations in which individual NL sows were engaged in chain manipulation during the second hour after feeding in Parity 2.

DISCUSSION

This study demonstrates that activity in food restricted group housed sows peaks during and just after feeding and that sows on a low feed level are more active than sows on a high feed level. Most of the active time was spent manipulating straw and other pen components, straw being the preferred substrate. In its absence, levels of chain and bar manipulation increased significantly between parities 1 and 2 in low fed animals.

High activity levels of pregnant sows in the periods immediately post feeding are also reported by other authors (Rushen, 1985; Jensen, 1988; Terlouw *et al.*, 1991b). The present study (6 hour data) shows a more gradual decline in levels of standing in the first six hours after feeding than Terlouw *et al.* (1991b) and Rushen (1985) who worked with individually confined sows. The data, particularly in the second parity, are more comparable with Jensen (1988), who observed the sows confined in stalls during feeding. The relatively sustained levels of activity in the present experiment may, therefore, have been caused by the release of the sows from their feeding stalls, by the positioning of the drinkers in the dunging passage and also by the novelty factor of the fresh straw for those groups receiving straw.

Le Magnen and Devos (1980) found a positive correlation between feeding rate and duration of food deprivation in rats, *Rattus norvegicus*. The present study showed an increase in average feeding rate in parity 1 in the low fed sows, but not in the high fed sows. Terlouw *et al.* (1991b), who found similar results, suggests that the increase over time in feeding rate in low fed sows may be caused by increasing feeding motivation. In addition, the present study found average feeding rates to remain higher for L than for H sows throughout parity 2. A possible explanation for this difference may be that given a constant decline in feeding rates during any meal, shorter meals would result in higher average feeding rates compared to longer ones. Evidence in rodents suggests however, that feeding rates show an initial increase in intake, rather than a constant decrease. Wiepkema (1971) found that mice, *Mus musculus*, increase the length of their feeding bouts during the initial stages of a meal. This would suggest that ingestion of food has positive effects on feeding motivation, which in later stages of the meal is overruled by the negative effects of increasing satiety. In the present study the sows on the low fed treatments received a meal insufficient to induce satiation (Lawrence *et al.*, 1988; Lawrence and Illius, 1989) and the positive feedback of the meal ingested may have left them with a stronger motivation to feed after, than before the meal. This could explain the differences in activity levels found in the postprandial period, when food restricted sows were significantly more active than the high fed sows. This effect of food restriction on post feeding activity has also been reported by other authors (e.g. Appleby and Lawrence, 1987; Terlouw *et al.*, 1991b). In this study, most of the activity was directed towards the available substrates, with a preference for straw: low fed sows on straw rooted and chewed straw for over 70% of the time they were manipulating substrates. Low fed sows without straw directed their manipulative behaviour towards other pen components, such as bars and chains. The recording method did not allow for a detailed assessment of these behaviours. However, the occurrence of bar and chain manipulation in parity 2 was very frequent in low fed sows that weren't provided with straw, and individuals could often be identified by their behavioural routines. Together with the absence of an apparent goal, this suggests that, at least in these animals, chain and bar manipulation were performed stereotypically.

The provision of straw did not have an effect on the 24 hour levels of activity as measured through levels of standing, but it did alter the time spent in the dunging area with sows on straw spending significantly less time in their stalls than sows without straw. During the course of the day most of the straw went from the stalls into the communal dunging area, providing it with a thicker bedding than the stalls. The difference in use of the two areas was consistent over the day, suggesting that the straw in the dunging area was not only used as a foraging substrate (during the active hours of the day), but also preferred for lying.

Sows on a high food level drank significantly more in parity 1 in the first 6 hours after feeding, as well as measured over the 24 hour day, probably reflecting an increased physiological water requirement due to their higher food intake (Agricultural Research Council, 1981). However,

in parity 2, levels of drinking in L sows rose to a value similar to that in the high fed sows, although the differences in food intake remained the same, suggesting that normal regulatory mechanisms were not operating. Terlouw *et al.* (1991b) found levels of drinking in low fed gilts rising beyond those in high fed animals, and considered the excessive drinking stereotypic. The levels reported here were well below the 12 and 10% Terlouw *et al.* (1991b) found in their loose-housed low-fed gilts in months 1 and 3 of gestation, respectively. However, the positioning of the drinkers in their experiment (above the trough in the feeding stalls) may well have facilitated the development of excessive drinking in sows who spent about 92% of the day in stalls (average of the non-straw groups in the present study: 24 hour data).

Similar to the results in the present experiment, Fraser (1975) found that straw was preferred to chains and bars, and that provision of straw reduces stereotypic manipulation of these pen components. This preference can at least in part be explained by comparing the decrease after feeding of the two behaviours. Between 14.00 and 15.00 hours second parity LS sows only manipulated straw at 20% of the peak time levels, whereas LN sows still manipulated chains at over 50%. Thus, on the one hand use of straw, the preferred substrate, declines rapidly, whereas chain and bar manipulation, which is less preferred, is more persistent. The most likely factors to explain the more rapid decline in fresh straw manipulation are the decreasing novelty factor due to exploration, and the reduced foraging motivation due to ingestion. The latter is not easy to support as Lawrence and Illius (1989) found that ingestion of straw did not reduce operant responding for food. Both factors however, suggest the presence of a purpose, which is by definition absent in stereotypic behaviour.

Whether the development of stereotypies, reflected in excessive levels of drinking or manipulation of pen components, constitutes a welfare problem is still a matter of considerable debate. Mason (1991) concludes in her review that animals develop stereotypies when the environment is inadequate, and therefore presumably aversive. It is unclear, however, if this means that the animal is under stress (Dantzer and Mittelman, 1993) or suffering. Although some authors suggest that the performance of abnormal behaviours indicates that an animal is suffering (e.g. Fraser, 1984), Dantzer (1986) argues that stereotyping animals temporarily suspend the use of their higher nervous functions. This view would make the question of suffering irrelevant, but "it provides no excuse for the design and use of facilities that result in such abnormal behavior" (Dantzer, 1986).

Enriching the sows environment with straw appears to reduce the performance of stereotypies. However, straw manipulation itself may be of a very compulsive nature, and provision may not necessarily improve the sow's well-being. Further investigation into the motivations of manipulating straw, for example by separating the time of feeding and the time of fresh straw provision, and closer analysis of the manipulative behaviour involved, are required to reveal the extent to which straw provision provides real improvement to sow welfare.

CONCLUSION

In their review, Lawrence and Terlouw (1993) suggest that the development of stereotypies in food restricted sows is largely based on an inability to express foraging behaviour. The present study supports this conclusion, and offers a practical solution. It was found that higher levels of manipulative behaviour (appetitive foraging behaviour) were observed in low fed gilts. This behaviour was, in the absence of straw, channelled towards relatively invariant pen components like

bars and chains and over a period of time, abnormal high levels of chain and bar manipulation resulted. Where straw was present however, equally food motivated animals did not show a dramatic increase in overall levels of manipulative behaviour between parities, and levels of chain and bar manipulation remained comparable to those in the high fed animals. Therefore, daily provision of fresh straw may represent a simple and effective means of preventing the development of abnormal levels of chain and bar manipulation in food restricted group-housed sows.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of the Ministry of Agriculture, Fisheries and Food. SAC receives financial support from the Scottish Office Agriculture and Fisheries Department. We would also like to thank Francis Brouns for assisting in analysing the data, and Piet Wiepkema and Mike Mendl for valuable comments on the manuscript.

REFERENCES

- Agricultural Research Council, 1981. Requirements for water. In: *The nutrient requirement of pigs*, Commonwealth Agricultural Bureaux, Slough, 299-304.
- Appleby, M.C. and Lawrence, A.B., 1987. Food restriction as a cause of stereotypic behaviour in tethered gilts. *Animal Production*, 45: 103-110.
- Cronin, G.M. and Wiepkema, P.R., 1984. An analyses of stereotyped behaviour in tethered sows. *Annales Recherche Veterinaire*, 15: 263-270.
- Cronin, G.M., 1985. The development and significance of abnormal stereotyped behaviours in tethered sows. PhD thesis, Univ. of Wageningen.
- Dantzer, R., 1986. Behavioral, physiological and functional aspects of stereotyped behavior: a review and a re-interpretation. *Journal of Animal Science*, 62: 1776-1786.
- Dantzer, R. and Mittleman, G., 1993. Functional consequences of behavioural stereotypy. In: A.B. Lawrence and J. Rushen (Editors), *Stereotypic animal behaviour: fundamentals and applications to animal welfare*. C.A.B.I. Wallingford, U.K., 147-172.
- Deag, J.M., 1990. Keybehaviour - a program for recording data on an Atari Portfolio Computer. Copyright John M. Deag, 10 Fletcher Grove, Penicuik EH26 0JT, UK 46 pp.
- Fraser, D., 1975. The effect of straw on the behaviour of sows in tether stalls. *Animal Production*, 21: 59-68.
- Fraser, A.F., 1984. The behaviour of suffering in animals. *Applied Animal Behaviour Science*, 13: 1-6.
- Genstat 5 Reference Manual, 1987. Oxford University Press, Oxford. 749 pp.
- Jensen, P., 1988. Diurnal rhythm of bar-biting in relation to other behaviour in pregnant sows. *Applied Animal Behaviour Science*, 21: 337-346.
- Lawrence, A.B., Appleby, M.C. and Macleod, H.A., 1988. Measuring hunger in the pig using operant conditioning: the effect of food restriction. *Animal Production*, 47: 131-137.
- Lawrence, A.B. and Illius, A.W., 1989. Methodology for measuring hunger and food needs using operant conditioning in the pig. *Applied Animal Behaviour Science*, 24: 273-285.

- Lawrence, A.B. and Terlouw, E.M.C., 1993. A review of behavioral factors involved in the development and continued performance of stereotypic behaviors in pigs. *Journal of Animal Science*, 71: 2815-2825.
- Le Magnen, J. and Devos, M., 1980. Parameters of the meal pattern in rats: their assessment and physiological significance. *Neuroscience and Biobehavioural Reviews*, 4, 1-11.
- Mason, G.J., 1991. Stereotypy: a critical review. *Animal Behaviour*, 41: 1015-1037.
- Minitab Inc., 1993. *Minitab Reference Manual*. Sowers Printing Company, Lebanon, PA.
- Ödberg, F., 1978. Animal behaviours: stereotypies. In: *Proceedings of the 1st World Congress on Ethology Applied to Zootechnics*, Madrid, 475-480.
- Rushen, J.P., 1985. Stereotypies, aggression and the feeding schedules of tethered sows. *Applied Animal Behaviour Science*, 14: 137-147.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W., 1990. The roles of feeding regime, housing and individuals 'temperament' in the development of stereotypic behaviour in pregnant sows. *Animal Production*, 50: 567-568.
- Terlouw, E.M.C., Lawrence, A.B., Ladewig, J., De Passille, A.M., Rushen, J.P., 1991a. Relationship between plasma cortisol and stereotypic activities in pigs. *Behavioural Processes*, 25: 133-153.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W., 1991b. Influences of feeding level and physical restriction on development of stereotypies in sows. *Animal Behaviour*, 42: 981-991.
- Terlouw, E.M.C., Wiersma, A., Lawrence, A.B. and Macleods, H.A., 1993. Ingestion of food facilitates the performance of stereotypies in sows. *Animal Behaviour*, 46: 939-950.
- Wiepkema, P.R., 1971. Positive feedbacks at work during feeding. *Behaviour*, 39: 266-273.

Chapter 2

EFFECTS OF FOOD LEVEL AND STRAW BEDDING DURING PREGNANCY ON SOW PERFORMANCE AND RESPONSES TO AN ACTH CHALLENGE

Hans A.M. Spoolder^{1,2}, Jackie A. Burbidge^{1,2}, Sandra A. Edwards²,
P. Howard Simmins^{1†} and Alistair B. Lawrence²

¹ ADAS Terrington, Terrington St. Clement, King's Lynn, Norfolk PE34 4PW, UK

² SAC, West Mains Road, Edinburgh, EH9 3JG, UK

[†] Present address: Rhône-Poulenc Animal Nutrition, 42 Avenue Aristide Briand,
BP100, 92164 Antony, France.

Published in: Livestock Production Science (1996) 47: 51-57.
Reproduced by permission of Elsevier Science Publishers B.V.®

EFFECTS OF FOOD LEVEL AND STRAW BEDDING DURING PREGNANCY ON SOW PERFORMANCE AND RESPONSES TO AN ACTH CHALLENGE

H.A.M. Spoolder, J.A. Burbidge, S.A. Edwards, P.H. Simmins and A.B. Lawrence

ABSTRACT

The interactive effects of straw provision and food level during pregnancy on performance, and the adrenal response to a challenge with ACTH (as a measure of chronic physiological stress) were studied over two parities. Ninety six gilts were allocated to a 2 x 2 factorial experiment comparing food level (L=1.6-1.8 kg (20-23 MJ DE) day⁻¹; H= 3.0-3.2 kg (38-40 MJ DE) day⁻¹) and the provision of straw (S=straw, N=no straw) during pregnancy. All gilts were loose housed in groups of 6 with individual feeding stalls. Significantly more N sows failed to start the second parity than S sows. H sows gained more weight and back fat over both pregnancies than L sows. There was a tendency for LS sows to gain more weight and back fat over both pregnancies than LN sows. Litter performance was not influenced by the straw treatment. HN sows had the highest concentration of basal cortisol, but no treatment effects were found in increase of salivary cortisol concentrations in response to the ACTH challenge in second parity sows. It is concluded that provision of straw may buffer the adverse effects of a low food level on weight and back fat gain in group-housed pregnant sows, but has no effect on reproductive performance. The cortisol data suggest differences between treatments to be of an acute, rather than a chronic nature.

INTRODUCTION

In commercial practice, almost all pregnant sows are fed on restricted feeding regimes. Operant conditioning studies suggest that this results in the animals being food motivated for most of the day (Lawrence *et al.*, 1988), a behavioural state which, in relatively barren environments, has been associated with the development of abnormal stereotypic behaviour (Terlouw *et al.*, 1991; Spoolder *et al.*, 1995). Stereotypies are generally considered to be signs of chronic stress (e.g., Mason, 1991; Dantzer, 1991), which potentially affects the health and performance of the animal performing the behaviour. Chronic food motivation in sows has, to our knowledge, not been linked to physiological stress indicators, such as activation of the Hypothalamic-Pituitary-Adrenal axis. However, Dantzer *et al.* (1980) showed that in growing pigs in the short term, frustration over an absent food reward will result in increased plasma cortisol concentrations.

Straw might mitigate the adverse effects of low food level in a number of ways. Behaviourally, it has been shown to reduce the effect of low food level on the development of excessive chain and bar manipulation in pregnant sows (Spoolder *et al.*, 1995). Benefits of straw provision to the energy balance of low fed animals can also be expected, as work in growing pigs estimated that the lower critical temperature of pigs on straw is 5-6 °C lower than pigs on concrete (Bruce and Clark, 1979). Also, Cole (1990) estimated that straw contributes about 2 MJ DE per day to the sow's diet, depending on supply, freshness and frequency of feeding. This would suggest that under similar environmental conditions, sows on straw would have lower nutritional requirements (Simmins *et al.*, 1994), or suffer less nutritional restriction when subjected to a low food level.

under similar environmental conditions, sows on straw would have lower nutritional requirements (Simmins *et al.*, 1994), or suffer less nutritional restriction when subjected to a low food level.

The present study investigates the interactive effects of food level and straw provision on adrenal response to a challenge with ACTH (as a measure of physiological stress) and on physical performance.

MATERIALS AND METHODS

Animals and Management

Ninety-six nulliparous sows (PIC Camborough; weight 147.7, s.d. 10.5 kg; age 238.3, s.d. 16.4 days.) entered the experiment in 16 groups of six, at a rate of two groups per month. All animals were between one and three weeks post-service and were housed in groups with individual feeding stalls. The study was a 2 x 2 factorial experiment, comparing food level (high (H) 3.2 kg (40 MJ DE day⁻¹) v. low (L) 1.8 kg (23 MJ day⁻¹)) and the provision of straw (straw (S) v. no straw (N)). Groups were randomly assigned to one of the four treatments for two consecutive parities. The straw treatment started on entry to the building: each S sow received approximately 1.5 kg of fresh long barley straw in its stall every morning during feeding. The food treatment started in both parities after a preliminary habituation period of two weeks, during which all the sows received the same daily ration of 2.4 kg (30 MJ DE). After the first eight groups had started their treatment it was decided that the food levels had to be adjusted, as gilts on the high food levels often did not finish their rations. The second series of eight groups therefore, was offered a reduced food level: 3.0 kg (38 MJ DE) for high and 1.6 kg (20 MJ DE) for the low fed animals, maintaining the differential between the two treatments. Chemical analyses of the diet indicated an average content of 151g crude protein, 55g oil, 60g neutral detergent fibre, 64g ash, and 6.9g lysine per kg. The DE content, calculated from proximate analyses using a standard prediction equation (MAFF, 1993), was 12.6 MJ DE per kg.

The sows were loose-housed in a solid floor pen (3.6 x 4.1m), consisting of six free-access stalls, with insulated concrete flooring, raised 15cm above a communal dunging area (3.6 x 2.0m). The walls and ceiling were insulated, and an automatically controlled natural ventilation system (ACNV) was used, set to maintain room temperature at 20°C. Oestrus detection was carried out daily by examination of the vulva and behavioural signs. Animals which returned to oestrus were served. Sows were taken to the farrowing house one to two weeks prior to their expected farrowing date. The building had a controlled environment and solid floor farrowing crates. Chopped straw was provided to all sows daily after cleaning out. The animals were fed 2 kg of a lactation diet (184 g protein, 87 g oil, 54 g fibre, 71 g ash, 9.7 g lysine; calculated DE of 13.8 MJ per kg) twice a day. After farrowing, the daily ration was increased to a level determined by litter size (2 kg + 0.5 kg per piglet per day, to a maximum of 8.0 kg per day). Piglets were not offered creep feed. Weaning occurred at 24±2 days. Sows were reunited in their original groups and served at first oestrus. Two to five days after the last animal had been served, the group was moved back to the experimental building, where they returned to their experimental food levels two weeks later.

Sow and Litter Performance

Sows were weighed and their back fat was measured at the P2 position using a Meritronics Ultrasonic Scanner (Meritronics Ltd, Otterden Place, Eastling, ME13 0BU). Weights and P2 were taken during both parities on transfer to the experimental building, at day 100 of pregnancy and after weaning. Sows which had expected farrowing dates more than 30 days later than the rest of the group were rejected from the experiment after the rest of the group had moved to the farrowing house. Piglets were weighed at birth and at weaning. All piglets that died during suckling were also weighed, as well as any piglets fostered on or off a litter.

ACTH Challenge

Approximately one week prior to first service (before any treatments were imposed), and around day 100 of the second pregnancy, each animal was subjected to an adrenocorticotrophic hormone challenge test to examine pituitary-adrenal activity (e.g., Broom, 1988; Mendl *et al.*, 1992). The animals were weighed on the day before testing. On the test day, a dose of 1 iu kg⁻¹ live weight was prepared for each pig of a 50 iu ml⁻¹ solution of synthetic ACTH (Sigma Chemical, Poole, Dorset, UK). This dose was administered by injection into an ear vein, while the animal was being restrained using a noose, usually between 11.00 and 12.00 hours. Prior to injection (generally between 10.00 and 11.00 hours), and at 80, 95 and 110 minutes post injection, saliva samples were taken by allowing the animal to chew on a cotton bud. This non-invasive technique was shown to be a valid alternative to collecting blood by jugular puncture (Parrott *et al.*, 1989). Between 1 and 1.5 ml of saliva was obtained from most animals. The cotton buds were stored in a closed test tube on ice, and saliva was removed from the buds within 60 min after collection, by centrifugation (1800 rpm, 5 min, 4 °C). The saliva was then aliquoted into 0.5 ml quantities, and stored in a freezer at -20 °C. Salivary cortisol was measured using an enzyme-linked immunosorbent assay (ELISA; Cooper *et al.*, 1989).

Statistical Analysis

Data were tested for treatment effects using Genstat 5 (Genstat 5 Committee, 1987), by analyses of variance for repeated measures (blocking for pig and group) with two factors (food and straw). An extra factor (parity) was added to the model to test for parity effects, and interactions between food, straw and parity. Pre-treatment cortisol concentrations in saliva were tested for differences between treatments, to identify any non random allocation of animals. Parity 2 saliva samples were tested for treatment effects whilst blocking for day of analysis and group. They were also tested by using the pre-treatment cortisol concentrations as a covariate, to eliminate pre-treatment differences between animals. Treatment effects on proportions of sows rejected per group were tested using the Mann -Whitney test (Minitab, 1993). Individual birth weights were analysed with litter size as a covariate. Piglet weight gain over lactation was analysed with litter size and weaning age as covariates. An angular, square root or logarithmic transformation of the data was used where appropriate.

RESULTS AND DISCUSSION

Ninety-five sows completed the first parity of which 85 were retained to start the second. Of the 10 sows that were rejected, four were out of synchrony with their group members, two had uterine prolapses and four were rejected because of lameness. More N sows were rejected than S sows (N v. S: 0.19 v. 0.04, Mann-Whitney test, $P<0.05$). All four sows which farrowed late were out of synchrony because their first observed return to service occurred 30 days or more after other members of the group had been served. All sows rejected for lameness had been on the non-straw treatments, and three out of four on the high food level. Both prolapses occurred in H sows. Parity two was completed by 69 sows, most of the rejections being caused by animals that returned to service (12). Two sows died, one aborted and one was rejected because of lameness. No treatment effects were found.

Sows on the H treatment gained more weight in pregnancies one and two than L sows, and lost more weight during lactation. They also gained more back fat during pregnancy (Table 1). In the L groups, sows that were given straw tended to have higher back fat increases in parity one ($F_{1,6}=6.49$, $P=0.06$) and more weight gain during parity two ($F_{1,6}=5.37$, $P=0.08$). In sows on the high food levels, HN sows gained more weight during parity two ($F_{1,6}=6.7$, $P<0.05$). This interactive effect of food level and straw on pregnancy weight gain was significant in parity two (Table 1), and a similar trend could be seen in parity one, where it was not significant due to greater variation within treatments. Statistical analyses showed differences between parities. Animals in parity 2 were heavier at day 100 of pregnancy (Parity 1 v. 2: 193.3 v. 211.3 kg, $F_{1,92}=108.5$, $P<0.001$) than first parity animals, but they had less back fat (Parity 1 v. 2: 22.6 v. 20.4 mm, $F_{1,92}=29.1$, $P<0.001$) on average. For both variables there was a strong interactive parity x food effect ($P<0.001$): L animals were about 10 kg heavier at the end of pregnancy two than pregnancy one, this difference was 27 kg for H animals. High fed animals had similar back fat levels at the end of pregnancy one and two, but L animals lost back fat: at the end of pregnancy two they had about 4 mm less than at the end of pregnancy one.

Table 1

Effect of treatment on live weight and back fat change of sows in parities 1 and 2[†]

Parity 1	Treatments				s.e.d.	Level of significance		
	LN	LS	HN	HS		Food	Straw	FxS
LW change in pregnancy (kg)	20.9	30.3	69.0	62.2	6.3	***	NS	NS
Back fat change in preg. (mm)	0.8	2.4	6.2	3.9	0.8	***	NS	**
LW change in lactation (kg)	-12.5	-13.2	-37.4	-34.4	8.8	**	NS	NS
Back fat change in lact. (mm)	-5.3	-5.0	-6.5	-6.1	1.6	NS	NS	NS
Parity 2								
LW change in preg. (kg)	16.6	26.9	64.2	52.9	4.4	***	NS	**
Back fat change in preg. (mm)	-0.11	-0.13	5.1	5.3	1.0	***	NS	NS
LW change in lact. (kg)	-3.5	-14.4	-31.3	-23.8	8.4	**	NS	NS
Back fat change in lact. (mm)	-2.6	-3.3	-4.4	-5.5	2.0	NS	NS	NS

[†]Treatments were: High (H) and Low (L) food level and Straw (S) and No Straw (N) as bedding. Levels of significance are: *, ** and ***, for $P<0.05$, $P<0.01$ and $P<0.001$, respectively. For parity effects please refer to text.

No treatment effects were found in litter performance, except for a positive effect of food level on individual piglet weight at birth (Table 2). This agrees with other work (e.g. Hard and Anderson, 1979) which suggests that food level does not influence litter size and that nutrient intake has only a small effect on the development of foetuses (Verstegen *et al.*, 1987). Matte *et al.* (1993) found an interactive effect of parity and diet composition on total litter weight, and concluded that, when examining the effects of food on litter performance, more than one parity should be considered. Unfortunately, in the present experiment, the number of piglets born alive in parity two was adversely affected by an outbreak of Porcine Reproductive and Respiratory Syndrome (PRRS). The litter performance results of parity two (Table 2) will therefore have to be treated with caution.

Table 2
Effect of treatment in parity 1 and 2 on litter performance¹

Parity 1	Treatments					Level of significance		
	LN	LS	HN	HS	s.e.d.	Food	Straw	FxS
Total number born	11.7	12.9	13.9	13.2	0.9	NS	NS	NS
Number born alive	10.7	11.5	11.7	12.0	0.9	NS	NS	NS
Mean piglet weight (kg)	1.3	1.4	1.6	1.6	0.1	*	NS	NS
Piglet gain (g/day)	195	181	174	181	13.8	NS	NS	NS
Number weaned	9.5	7.7	9.0	9.6	1.9	NS	NS	NS
Parity 2								
Total number born	11.1	10.4	9.9	10.6	1.9	NS	NS	NS
Number born alive	9.1	9.8	8.4	9.5	1.8	NS	NS	NS
Mean piglet weight (kg)	1.6	1.6	1.7	1.7	0.1	NS	NS	NS
Piglet gain (g/day)	206	212	234	233	23.7	NS	NS	NS
Number weaned	7.9	8.1	6.0	7.5	1.7	NS	NS	NS

¹Treatments were: High (H) and Low (L) food level and Straw (S) and No Straw (N) as bedding. Litter performance in parity 2 was badly affected by an outbreak of PRRS, and data from this parity will have to be treated with caution. Levels of significance are: *, ** and ***, for $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively.

The effects of the food levels on the sows' body condition were as expected. Greater weight and back fat gains over pregnancy and greater losses over lactation in sows on a high food level have also been found by other authors (Agricultural Research Council, 1981; Yang *et al.*, 1989). In trying to explain this effect three factors have to be considered: sow intake during lactation, sow output (in terms of piglet weight reared and maintenance) and food conversion efficiency. Sow output during lactation was calculated by subtracting total litter birth weight from total litter weight at weaning. Differences between food level on the increase in litter weight were not found (e.g. Parity 1: H v. L: 33.7 v. 39.5 kg, $F_{1,80} = 0.02$, NS). However, sow maintenance during lactation was calculated to be higher for H sows than for L sows. In parity 1 the average H sow required nearly 25 MJ DE on entry to the farrowing house and the L sow 22 MJ DE for maintenance (parity 1: H v. L: 208.9 kg v 177.8 kg live weight; 430 kJ ME / kg metabolic weight, 1 ME = 0.95 DE (TCORN Report, 1990)). Since food level during lactation was based on litter size, and as litter size did not differ between treatments, H sows would lose on average 3 MJ DE more through maintenance than L sows. This can not account totally for the difference in weight loss during lactation between the two food treatments. Greater weight loss during lactation in H sows must therefore be due to reduced food

intake, or poorer utilisation. No data are available for sow food refusals in the farrowing house (and therefore none for conversion efficiency).

The interaction between the effects of food and straw on growth and back fat thickness were strong in parity 1, as was the interaction on live weight change in parity 2. Provision of straw had a negative effect on weight gain in high fed animals. Low fed animals appeared to gain more weight and back fat when given straw. Spoolder *et al.* (1995) found in their analyses of the behavioural data from the present experiment, that low fed animals without straw developed high levels of stereotypies, which according to Cronin *et al.* (1986) could lead to higher energy loss through heat output. However, general activity levels were equally high in low fed sows that were given straw, due to high levels of straw manipulation (Spoolder *et al.*, 1995). Differences in the performance of stereotypies are, therefore, unlikely to have caused this treatment effect on sow weight and back fat gain. Higher gut fill in low fed sows on straw may have been a contributing factor in the weight gain difference between the S and the N treatments (Just, 1982), but it cannot account for the greater increase in back fat thickness in sows on straw. However, the digestion of straw may have contributed. Cole (1990) estimated that sows consumed about 0.5 kg wheat straw daily, which would contribute 2 MJ DE per day to the sow's diet. Although levels of straw ingestion in the present study were not measured, it is reasonable to assume that the highly food motivated LS animals consumed an amount close to or above the level estimated by Cole (1990). If the energy cost of live maternal gain is in the region of 25 MJ DE/kg (Verstegen *et al.*, 1987) the 2 MJ DE would contribute about 80 g in gain per day (or 8 kg at day 100 of gestation). A further contribution to the differences found could have been made by the thermal effect of straw. The calculated Low Critical Temperature value (LCT) for an average sow of 200 kg on the high food level would be around 15.9°C (calculations based on a deterministic model by Bruce and Clark, 1979). The animals on the low food levels however, would have had an LCT of 20.7°C, thus benefiting from any additional thermal insulation from the straw if the building was maintaining set temperature (20°C). This confirms a suggestion by Simmins *et al.* (1994), that straw buffers the adverse effects of low food levels.

Table 3 shows the effects of the treatments on cortisol concentrations before and after a challenge with ACTH, at the end of the second parity. The peak in ACTH response appeared to lie before or near the moment the first sample was taken (at 80 min post injection) (Parrott *et al.* 1989). The responses show a clear effect of straw provision, with N sows having higher concentrations of salivary cortisol. There were, however, significant effects of both food and straw treatment on baseline cortisol concentrations (food: $F_{1,18}=7.8$, $P=0.012$; straw: $F_{1,18}=12.7$, $P=0.002$), with sows on high food level and without straw showing the highest concentrations of salivary cortisol. These baseline differences seemed to be responsible for the effects found on the responses to ACTH. Although the increases from baseline to response values appear to be higher in N sows, they were not significantly different (Table 3). To investigate whether these baseline differences reflect individual variation between animals, or an acute response to the saliva samples being taken, the baseline values at the end of pregnancy 2 were retested whilst correcting for differences that existed prior to the treatments being imposed (by including the baseline taken prior to pregnancy 1 as a covariate). The correction was marginal on food effects (covariance efficiency = 0.77) and negligible on straw effects (covariance efficiency = 1.0), resulting in similar levels of significance for treatment effects. The results suggest that the treatments had not led to a long-term change to the response of the adrenal gland, indicative of chronic stress. The differences between the treatments in baseline values can most likely be attributed to differences in response to the experimenter taking saliva

samples (J. Ladewig, personal communication). Differences in behaviour patterns post-feeding had developed at the time of the challenge, with the HN pigs spending a lot of time inactive or asleep in the feed stall, as opposed to the other three treatment groups, which were more active immediately post-feeding (Spoolder *et al.*, 1995). It can be speculated, therefore, that the collection of saliva was perceived as more stressful by the HN animals than by the others. In hindsight, serial samples could have been taken over a longer period before injection with ACTH, and a record kept of the animal's behaviour during sampling, to deny or confirm the hypothesis of a relationship between behavioural and cortisol response.

Table 3

Effect of treatment¹ at day 100 of second pregnancy on salivary cortisol concentrations (nM l⁻¹), prior to intra venous injection with ACTH (baseline) and 80, 95 and 110 min. post injection (first, second and third sample respectively)[‡]

	Treatments				Level of significance		
	LN	LS	HN	HS	Food	Straw	FxS
Baseline	4.3	2.0	9.0	3.8	**	***	NS
First	12.1	6.5	19.1	5.5	NS	**	NS
First minus Baseline	11.8	5.4	15.2	3.5	NS	NS	NS
Second	8.4	6.9	16.7	5.2	NS	*	NS
Second minus Baseline	5.9	5.1	17.2	7.1	NS	NS	NS
Third	7.9	4.9	18.3	3.6	NS	**	NS
Third minus Baseline	7.5	3.9	15.5	2.2	NS	NS	NS

¹Treatments were: High (H) and Low (L) food level and Straw (S) and No Straw (N) as bedding.

[‡](logarithmic) transformations and back-transformations were used as appropriate, resulting in the loss of additive properties between rows per column. Levels of significance are: *, ** and ***, for $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively.

CONCLUSION

It can be concluded that provision of straw as bedding to pregnant sows has only limited effects on their performance, although previously published behavioural data (Spoolder *et al.*, 1995) suggests it significantly modifies their behaviour. Acute differences in cortisol release may be influenced by the provision of bedding, but no long term physiological effects are apparent as measured by an ACTH challenge test. However, there is an indication that straw may reduce the incidence of lameness in high fed sows, and that it can result in improved sow weight and back fat gain during pregnancy when animals are fed at low levels.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of the Ministry of Agriculture, Fisheries and Food. SAC receives financial support from the Scottish Office Agriculture and Fisheries Department. We would also like to thank Sue Kirkpatrick for her help in analysing the saliva samples, and Piet Wiepkema, Willem Schouten, Mike Mendl and Jan Ladewig for useful discussions and valuable comments on the manuscript.

REFERENCES

- Agricultural Research Council, 1981. Energy requirements. In: The nutrient requirement of pigs, CAB, Slough, pp. 299-304.
- Broom, D.M., 1988. The scientific assessment of animal welfare. *Applied Animal Behaviour Science*, 20: 5-19.
- Bruce, J.M. and Clark, J.J., 1979. Models of heat production and critical temperature for growing pigs. *Animal Production*, 28: 353-369.
- Cole, D.J.A., 1990. Nutritional strategies to optimize reproduction in pigs. *Journal of Reproduction Fertility*, 40: 67-82.
- Cooper, T.R., Trunkfield, H.R., Zanella, A.J. and Booth, W.D., 1989. An enzyme-linked immunosorbent assay for cortisol in the saliva of man and domestic farm animals. *Journal of Endocrinology*, 123: R13-R16.
- Cronin, G.M., van Tartwijk, J.M.F.M., van der Hel, W. and Verstegen, M.W.A., 1986. The influence of degree of adaptation to tether-housing by sows in relation to behaviour and energy metabolism. *Animal Production*, 42: 257-268.
- Dantzer, R., Arnone, M. and Mormede, P., 1980. Effects of frustration on behaviour and plasma corticosteroid levels in pigs. *Physiology Behaviour*, 24: 1-4.
- Dantzer, R., 1991. Stress, stereotypies and welfare. *Behavioural Processes*, 25: 95-102.
- Genstat 5 Committee, 1987. *Genstat 5 Reference Manual*. Oxford University Press, Oxford. 749 pp.
- Hard, D.L. and Anderson, L.L., 1979. Maternal starvation and progesterone secretion, litter size and growth in the pig. *American Journal of Physiology*, 273: E273-278.
- Just, A., 1982. The influence of ground barley straw on the net energy value of diets for growth in pigs. *Livestock Production Science*, 9: 717-729.
- Lawrence, A.B., Appleby, M.C. and Macleod, H.A., 1988. Measuring hunger in the pig using operant conditioning: the effect of food restriction. *Animal Production*, 47: 131-137.
- MAFF, 1993. PB 1285: Prediction of the energy value of compound feeding stuffs for farm animals. MAFF Publications, London, pp. 7.
- Mason, G.J., 1991. Stereotypy: a critical review. *Animal Behaviour*, 41: 1015-1037.
- Matte, J.J., Robert, S., Girard, C.L., Farmer, C. and Martineau, G.P., 1993. Influence de diètes à haute teneur en fibres sur les performances de reproduction de truies nullipares et primipares. *Journées Recherche porcine en France*, 25: 203-208.
- Mendl, M., Zanella, A.J. and Broom, D.M., 1992. Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour*, 44: 1107-1121.
- Minitab Inc., 1993. *Minitab Reference Manual*. Sowers Printing Company, Lebanon, PA.
- Parrott, R.F., Misson, B.H. and Baldwin, B.A., 1989. Salivary cortisol in pigs following adrenocorticotrophic hormone stimulation: comparison with plasma levels. *British Veterinary Journal*, 145: 362-366.
- Simmins, P.H., Edwards, S.A. and Spechter, H.H., 1994. Growth and body condition of sows given different feeding regimes during the rearing stages and through eight parities when housed in groups with straw bedding. *Animal Production*, 58: 271-283.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1995. Provision of a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. *Applied Animal Behaviour Science*, 43: 249-262.

-
- TCORN Report, 1990. The nutrient requirement of sows and boars. In: Nutrition Abstracts and Reviews (Series B), 60: 384-406.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W., 1991. Influences of feeding level and physical restriction on development of stereotypies in sows. *Animal Behaviour*, 42: 981-991.
- Verstegen, M.W.A., Verhagen, J.M.F. and den Hartog, L.A., 1987. Energy requirements of pigs during pregnancy: a review. *Livestock Production Science*, 16: 75-89.
- Yang, H., Eastham, P.R., Phillips, P. and Whittemore, C.T., 1989. Reproductive performance, body weight and body condition of breeding sows with differing body fatness at parturition, differing nutrition during lactation, and differing litter size. *Animal Production*, 48: 181-201.

Chapter 3

EFFECTS OF FOOD LEVEL ON PERFORMANCE AND BEHAVIOUR OF SOWS IN A DYNAMIC GROUP HOUSING SYSTEM WITH ELECTRONIC FEEDING

Hans A.M. Spoolder^{1,2}, Jackie A. Burbidge^{1,2}, Sandra A. Edwards²,
Alistair B. Lawrence² and P. Howard Simmins^{1†}

¹ ADAS Terrington, Terrington St. Clement, King's Lynn, Norfolk PE34 4PW, UK

² SAC, West Mains Road, Edinburgh, EH9 3JG, UK

[†] Present address: Rhône-Poulenc Animal Nutrition, 42 Avenue Aristide Briand,
BP100, 92164 Antony, France.

Published in: *Animal Science* (1997) 65: 473-482.

EFFECTS OF FOOD LEVEL ON PERFORMANCE AND BEHAVIOUR OF SOWS IN A DYNAMIC GROUP HOUSING SYSTEM WITH ELECTRONIC FEEDING

H.A.M. Spoolder, J.A. Burbidge, S.A. Edwards, A.B. Lawrence and P.H. Simmins

ABSTRACT

Evidence from studies of group housed sows in unbedded systems indicates that hunger may be a cause of increased aggression between animals. The present study aimed to investigate the effects of food level on performance, aggression and skin damage in a deep straw system. Sixteen groups of 5 gilts were introduced over 8 months to 1 of 2 dynamic groups in a deep straw yard ($2.35\text{m}^2 \text{ sow}^{-1}$) receiving different food levels from an electronic sow feeding system: High (H: $3.0\text{kg}/38\text{MJ day}^{-1}$) and Low (L: $1.6\text{kg}/20\text{MJ day}^{-1}$). Seventy second parity sows were returned to the same treatments in the same subgroups. The behaviour of the animals was recorded throughout both pregnancies using a time sampling technique. Severity of skin damage was recorded as a number from 1 to 4 for each of 9 areas, the average of which being the "damage score". The total number of animals in each dynamic group was maintained at around 30, through the use of additional sows. As expected, H sows were heavier than L sows, but no effect of food treatment was found on litter size or performance. L sows were more active (L v. H; standing: 41 v. 31% of total observation time respectively, $F_{1,14}=7.65$, $P=0.015$) and showed more straw manipulation than H sows (L v. H: 17 v. 10% respectively, $F_{1,14}=18.4$, $P<0.001$). No differences between treatments were found in number of aggressive interactions (L v. H: 3.6 v. 3.8 interactions per sow per observation day, $F_{1,14}=0.82$, NS), nor in damage score (L v. H: 0.24 v. 0.28; $F_{1,14}=0.27$; NS). However, introduction of new animals did influence aggression, with pigs being more involved in aggressive interactions on the day they were introduced, than on other pig's introduction days and no introduction days (Tukey, $P<0.05$). Average skin lesions per experimental sow were also higher in the days immediately following introduction. It can be concluded that in a sequential feeding system with plentiful straw, aggression is not influenced by the level of feeding. In these systems, the major factor giving rise to aggression is the introduction of new animals to the resident group.

INTRODUCTION

Aggression in group housed sows is often related to competition for food. Sequential feeding (e.g. Electronic Sow Feeding (ESF)) avoids confrontations at the trough, but may replace them with interactions at the feeder entrance (e.g. Hunter *et al.* 1988; Brouns and Edwards, 1992). Levels of aggression in groups of sows may, amongst other things, be influenced by food level: Svendsen *et al.* (1990) found an association between injury scores and sow condition in their survey of 21 Swedish herds. This would agree with work by Buré (1991) which also suggests a link between level of food offered and agonistic behaviours in sows. There are a number of possible reasons why such a link may exist.

Firstly, frustrated feeding motivation may be redirected aggressively towards pen mates. Wiepkema (1971) found that in mice, *Mus musculus*, the length of the feeding bouts increased

during the early stages of a meal. This could mean that initially there is a positive feedback of ingestion on food motivation. Therefore, animals which are fed small meals are potentially more motivated to feed at the end of their meal, than they were before it, resulting in increased levels of frustration (see Lawrence *et al.* 1988). Frustration induced aggression has been observed in a number of species, such as domestic fowl (*Gallus gallus*, Duncan and Wood-Gush, 1971) and rats (*Rattus norvegicus*, Thompson and Bloom, 1966). In pigs, Dantzer *et al.* (1980) concluded that feeding frustration did not elevate aggression by itself, but increased the probability of its occurrence if stimuli which can elicit aggression were present. In pigs, Buré (1991) found a higher incidence of vulva biting after small meals terminated by the ESF station rather than the sow, compared to larger meals. The mere presence of another individual near the feeder may be sufficient to initiate an aggressive interaction.

A second argument for expecting a relationship between food level and aggressive interactions relates to the occupation of the area near the feeder entrance. Dominant sows may return to the feeder frequently, even after the allocated ration has been consumed, can be frequent (e.g.: Hunter *et al.*, 1988; Ritter and Weber, 1989; Weber *et al.*, 1993). This behaviour is likely to be motivated by hunger and may be reinforced by the occasional find of food left in the trough by other pigs. Restriction of the daily food allowance may result in a higher incidence of dominant sows attempting to re-enter the feeder station, and thus a larger number of aggressive encounters at the feeder entrance.

Thirdly, food level and level of activity have been shown to be related. Terlouw *et al.* (1991) and Spoolder *et al.* (1995) found that pigs fed just above maintenance requirement spent more time standing in the post prandial period than pigs which were fed up to two times maintenance. In sequentially fed animals the start of the post feeding period differs between animals. Therefore, any differences in activity levels between food treatments can be expected to last for most of the day, potentially resulting in an increased number of social encounters between active and non-active pigs.

The objective of the current experiment was to test the hypothesis that a relationship exists between level of food and the incidence of aggressive behaviour in dynamic groups of sows, receiving food through a sequential feeding system.

MATERIAL AND METHODS

Animals

Eighty nulliparous sows (PIC Camborough; weight 136.2, SD 8.72 kg; age 234.3, SD 21.2 days) entered the experiment in 16 groups (n=5) at a rate of 2 groups per month. All animals had been in their groups for at least 2 months, and were between 1 and 3 weeks post service.

Treatments

The experiment compared 2 food levels: high (H; parity 1: 3.0 kg / 37.8 MJ DE day⁻¹, parity 2: 3.2 kg / 40.3 MJ DE day⁻¹) and low (L; parity 1: 1.6 kg / 20.2 MJ DE day⁻¹, parity 2: 1.8 kg / 22.7 MJ DE day⁻¹). Sows were subjected to the same treatment during their first two pregnancies. Chemical analyses of the feed indicated an average content of 151 g protein, 55g oil, 60 g neutral

detergent fibre, 64 g ash and 6.9 g lysine per kg. The digestible energy content calculated from proximate analyses using a standard prediction equation (MAFF, 1993) was 12.6 MJ DE per kg.

Housing and Care

Sub-groups of pigs were entered into one of two dynamic groups in a deep strawed building, with a lying area allowing 2.35 m² per sow. Each group was fed from a Pig Code Electronic Sow Feeder (ESF) station (Quality Equipment, Heath Road, Woolpit, IP30 9RN, UK). The ESF stations both had a front exit gate with a 2.5 m exit race leading to an outside dunging area with drinkers. The feeders were sow operated: the entry gate opened automatically on exit of a sow from the feeder, thus allowing the next sow to enter. All sows carried an electronic identification device on a collar, which was read by an aerial in the front of the trough. The sow's identity was communicated to the computer, instructing the feeder to drop approximately 100 grams of food every 40 seconds until the animal's daily allocation had been dispensed. If a sow left the station before finishing her ration, food dispensing stopped and the sow could return later in the day to receive the remaining food. The feeding cycle started at 18.00 h when the new daily ration for each sow became available. Any food remaining at the end of the cycle was not carried over to the next one, but instances where animals left part of their allocation were extremely rare.

All gilts spent the first week after introduction to the experimental building in a separate pen (3 x 15 m) in their group of 5. During this period the animals were trained to use the ESF system, between 13.00 and 16.00 hours every day. During this period all sows were offered a daily ration of 2.0 kg (25.2 MJ DE). After the training week the animals were entered into their treatment groups and put on their H or L food rations.

Pregnancy was tested for in both parities, around day 28 and 42 after service. Any animal which returned for service was served, but sows which had expected farrowing dates more than 30 days delayed from the rest of the group were rejected from the experiment after the rest of the group had moved to the farrowing house.

Sows were taken to the farrowing house one to two weeks prior to their expected farrowing date. The building had a controlled environment and solid floor farrowing crates. Chopped straw was provided to all sows every day after cleaning out. The animals were fed 2 kg of a lactation diet (184 g protein, 87 g oil, 54 g fibre, 71 g ash, 9.7 g lysine and a calculated digestible energy of 13.8 MJ DE per kg) twice a day. After farrowing, the daily ration was increased to a level determined by litter size (2 kg + 0.5 kg per piglet per day, to a maximum of 8.0 kg per day). Piglets were not offered creep feed.

Weaning occurred at 24±2 days. Sows were taken to the service house and reunited in their original subgroups, or, if they were 1 cycle behind their subgroup members, in the next subgroup of the same treatment. They were housed in solid floor straw pens with 6 individual feeders, and fed a daily ration of 3.0 kg (41 MJ DE) of the lactation diet until service. After service, sows received 3.0 kg (37 MJ DE) of the pregnancy diet.

Two to five days after the last animal was served the group was moved back to the experimental building and penned in the training pen for one week prior to re-entering the experimental groups.

Sow and Litter Performance

Sows were weighed and their back fat was measured at the P2 position using a Meritronics Ultrasonic Scanner (Meritronics Ltd, Otterden Place, Eastling, ME13 0BU). Weights and P2 were taken during both parities on transfer to the experimental building, at day 100 of pregnancy and after weaning. Piglets were weighed at birth and at weaning. All piglets that died during suckling were also weighed, as well as any piglets fostered on or off a litter.

Behavioural Observations

All sows were marked with a sprayed pattern to facilitate identification. The sows' behaviour was recorded over both pregnancies, using two different methods, and by scoring levels of skin damage.

Assessment of behavioural time budgets

Time budgets were assessed using a time sampling technique. Sows were observed for a total of six hours on five observation days evenly spaced over each pregnancy: the day of introduction to the dynamic groups, and at approximately 2, 4, 6 and 8 weeks from thereafter. Approximately every other observation day was used to introduce new animals to the dynamic group. The observation periods started at 09.00 hours, the time new animals to the groups were introduced. Every 20 minutes, posture, behaviour and substrate used were recorded, resulting in 18 time samples for each animal per observation day. A description of the behavioural categories used can be found in Table 1. Data were recorded on to an Atari portfolio computer (Atari Co., Sunnyvale, CA 94086, USA), using the data collection program Keybehaviour (Deag, 1990).

Table 1
List of behavioural categories used for time sampling.

Standing	Body supported by all four legs.
Other postures	Lying, sitting or kneeling.
Sleeping	Lying with eyes closed without apparently performing any behaviour.
Inactive	Lying, sitting or standing with eyes open, without apparently performing any other behaviour.
Aggression	Biting, snapping, shoulder pushing at and of other pigs in the pen.
Manipulating substrates	Nosing, chewing, rooting, biting, lifting or licking any available substrate (straw, other pen components, pen mates) other than feed.
Other behaviours	Any other behaviours (e.g. feeding, drinking, excretion, locomotion).

Aggressive interactions

In addition to general behaviour time sampling, all incidences of aggressive interactions involving experimental animals were recorded using an *ad libitum* sampling technique (Martin and Bateson, 1993). Each record identified the time, the severity of the interaction, the animals involved and the winner. Severity was measured on a scale from 1 to 4: 1= a threat without physical contact; 2= one or two bites followed by the immediate retreat of the receiving animal; 3= a series of bites

and / or a chase by the aggressor without significant retaliation from the receiver; and 4= a fight involving aggression from both animals. An animal's "success rate" in aggressive social interactions was defined as the percentage of interactions it was engaged in, from which it emerged as the winner.

Skin lesion scoring

Skin lesions of all experimental animals were scored regularly throughout both pregnancies: on the day before introduction to the groups (day -1), on the first day after introduction (day 1), 3 days after, 7 days after, 14 days after and then at fortnightly intervals until the animal was taken out for farrowing. Damage was assessed for each of nine areas on the pig's body: 1= face, 2= ears, 3= neck / throat, 4= shoulders, 5= sides, 6= rump, 7= tail, 8= buttocks and 9= vulva. It was measured on a scale from 0 to 4: 0= no damage, 1= redness, 2= minor scratches / redness, 3= several scratches and / or small wounds, 4= severe wounds. No attempt was made to age the lesions. The detailed assessments of the nine areas were then grouped into 3 main body parts (Front: face, ears, neck / throat and shoulders, Middle: sides and rump, Back: tail, buttocks and vulva) by averaging the scores of the detailed assessments for each body part. A total score per pig was also calculated by averaging the total of all nine areas.

Statistical Methods

The percentages of observations each sow spent in the different behavioural categories was calculated. Data were tested for treatment effects using Genstat 5 (1987), by analyses of variance for repeated measures (nested for pig and group) with two factors (parity and food level). Where data could not be normalised, by using angular, square root or logarithmic transformations, the Mann-Whitney test was used (Minitab 9 for Windows, 1993). Time of day effects were tested for per parity, by analysis of variance, using food level and hour as factors. Tukey's HSD (Minitab 9 for Windows, 1993) was used for pairwise comparison of means but only after an interactive effect or time of day effect had been found.

Aggression data were analysed using two factors (parity number and food level), in an analysis of variance design for repeated measures (nesting sows in group). Transformations were used as appropriate. Effects of stage of pregnancy was examined using three factors: parity, food level and observation day (1 to 6).

Treatment effects on skin lesion scores were tested for per body part, using analyses of variance for repeated measures, with two factors (parity number and food level) and nesting pig within group. Effects of stage of pregnancy were examined by using the average of the body area scores (the total score), nesting pig within group, using three factors (parity number, food level and recording day). Tukey's HSD (Minitab 9 for Windows, 1993) was used for pairwise comparison if significant effects were found.

RESULTS

Performance

Out of the original 80 gilts, 74 (93%) completed the first parity (36 on the L and 38 on the H treatment), of which 70 were retained to start the second. Of the sows which failed to start parity two, five were out of synchrony with their group sub-members: their first observed return to service occurred 30 days or more after other members of the sub-group had been served. The other five had to be rejected for various other reasons (e.g. cervical/vaginal prolapse). Parity two was completed by 62 sows (78% of original 80 sows, 31 sows on either treatment), all of the rejections being caused by animals which returned to service. There were no effects of treatment on the rejection of sows from the experiment.

Sows on the H treatment gained more weight in pregnancies one and two than L sows. They also gained more back fat during pregnancy (Table 2). Statistical analyses showed differences between parities. Animals in parity 2 were heavier at day 100 of pregnancy than first parity animals (Parity 1 v. 2: 165.8 v. 194.6 kg, $F_{1,78}=333.03$, $P<0.001$), but there was no difference in back fat (Parity 1 v. 2: 17.8 v. 17.2 mm, $F_{1,78}=1.26$, NS) on average.

No treatment effects were found on litter performance. Average piglet weight at birth in parity 2 was higher than in parity 1, and so was daily live weight gain (Table 3).

Table 2

Effect of treatment on live weight and back fat change of sows fed a high or a low food level in parities 1 and 2.

Food level	Parity 1		Parity 2		s.e.d.	Level of significance		
	Low	High	Low	High		Food	Parity	FxP
LW change in pregnancy (kg)	23.6	35.8	20.3	44.6	3.53	***		**
Back fat change in preg. (mm)	-0.66	2.61	0.92	7.83	1.22	***	***	**
LW change in lactation (kg)	-14.06	-19.5	-18.1	-19.8	4.80			
Back fat change in lact. (mm)	-5.03	-6.87	-5.46	-7.66	1.32			

Levels of significance are: *, ** and ***, for $P<0.05$, $P<0.01$ and $P<0.001$ respectively.

Table 3

Effect of treatment in parity 1 and 2 on litter performance

Food level	Parity 1		Parity 2		s.e.d.	Level of significance		
	Low	High	Low	High		Food	Parity	FxP
Total number born	11.9	12.0	11.4	11.0	0.81			
Number born alive	10.9	11.1	10.9	10.1	0.86			
Mean piglet weight (kg)	1.24	1.27	1.44	1.48	0.05		***	
Piglet gain (g/day)	178	194	220	229	13.5		***	
Number weaned	9.0	9.4	9.8	9.6	0.83			

Levels of significance are: *, ** and ***, for $P<0.05$, $P<0.01$ and $P<0.001$ respectively.

Behaviour

Behavioural time budgets

Over both parities animals in the L group were more active, as measured by the percentage of time they spent standing, than H animals (L v. H: 41 v. 31%, $F_{1,14}=7.65$, $P=0.015$; Table 4). They spent more time manipulating substrates (L v. H: 28 v. 20%, $F_{1,14}=12.27$, $P=0.004$) than the animals on the higher food level, which was a reflection of a greater time spent manipulating straw in the L v. H groups (16.6 v. 9.5% (back-transformed values), $F_{1,14}=18.4$, $P<0.001$). Pen components other than straw were manipulated at similar levels on both treatments (L v. H: 8.0 v. 7.8%, $F_{1,14}=0.03$, NS). Second parity animals were less active (Sleeping: 1st v. 2nd: 48.3 v. 54.6%, $F_{1,68}=16.6$, $P<0.001$) than animals in parity 1, but they manipulated straw and other pigs significantly more (back-transformed values: Straw: 1st v. 2nd: 12.0 v. 13.7%, $F_{1,67}=4.7$, $P=0.034$; Other pigs: 1st v. 2nd: 1.0 v. 1.7%, $F_{1,67}=10.6$, $P=0.002$). Levels of agonistic behaviour were low with no measurable differences between treatments or parities.

Table 4
Effects of treatment and parity on behavioural time budgets. Values are percentages of total number of observations.

Food level	Parity 1		Parity 2		s.e.d.	Level of significance		
	Low	High	Low	High		Food	Parity	FxP
Standing	42	29	39	33	3.9	*		
Sleeping	44	53	52	57	3.4	*	***	
Inactive	11	14	6	6	1.0		***	**
Aggression [†]	0.01	0.01	0.02	0.00	-			
Manipulating substrates	28	17	27	22	2.6	**		*
- straw [†]	16	8	16	11	-	***	*	
- other pen components	8	7	8	8	1.2			
- other pigs [†]	1	1	1	2	-		**	*

[†]Data had to be transformed prior to analyses. Means are the back-transformed values, resulting in an absence of additive properties between rows per column. Standard errors could not be calculated.

Levels of significance are: *, ** and ***, for $P<0.05$, $P<0.01$ and $P<0.001$ respectively.

Ad libitum sampling of aggressive interactions

No effects of treatment were found on the average number of aggressive interactions, or the success rate (Low v. High: Interactions: 3.6 v. 3.8, $F_{1,14}=0.82$, NS; Success rate: 41 v. 39%, $F_{1,14}=0.1$, NS; Table 5). However, there were differences between parities (Parity 1 v. 2: Interactions: 3.5 v. 3.9, $F_{1,878}=4.38$, $P=0.037$; Success rate: 29 v. 51%, $F_{1,878}=100.3$, $P<0.001$). An interactive effect of food and parity number was found on success rate, but Tukey's HSD only showed a difference between parities.

Table 5

Effect of treatment and parity number on average number of aggressive interactions per pig per day, and average success rate.

Food level	Parity 1		Parity 2		s.e.d.	Level of significance		
	Low	High	Low	High		Food	Parity	FxP
Average number of interactions [†]	3.6	3.4	3.6	4.3	-		*	
Success rate (%)	33	25	49	53	7.06		***	**

[†]Data had to be transformed prior to analyses. Means are the back-transformed values. Standard errors could not be calculated.

Levels of significance are: *, ** and ***, for $P < 0.05$, $P < 0.01$ and $P < 0.001$ respectively.

The severity of the interaction was generally lower in the second parity than it was in the first (Table 6). Parity 2 animals were more engaged in interactions restricted to threats and bites (e.g. bites: Parity 1 v. 2: 1.54 v. 2.42; $F_{1,78}=23.56$; $P < 0.001$), and less in prolonged interactions (e.g. attacks: Parity 1 v. 2: 0.55 v. 0.28 (back-transformed values); $F_{1,78}=21.83$; $P < 0.001$). Success rates were higher for pigs in parity 2 than for pigs in parity 1, when comparing the outcome of all types of interactions (e.g. bites: Parity 1 v. 2: 28 v. 52%; $F_{1,78}=76.56$; $P < 0.001$). Over time, the average number of interactions per animal changed in both parities (Figure 1).

Table 6

Effect of treatment and parity number on average number of aggressive interactions per pig per day by severity of interaction.

	Food level	Parity 1		Parity 2		s.e.d.	Level of significance		
		Low	High	Low	High		Food	Parity	FxP
Average number:									
1. Threat [†]	0.39	0.41	0.79	0.64	0.30		***		
2. Bite	1.40	1.68	2.40	2.43			***		
3. Attack [†]	0.51	0.60	0.23	0.33			***		
4. Fight [†]	0.21	0.21	0.05	0.08			***		
Success rate:									
1. Threat	35	27	52	47	0.08		***		
2. Bite	32	24	45	60	0.08		***	***	
3. Attack	26	28	43	57	0.10		***		
4. Fight	39	47	61	31	0.11			***	

[†]Data had to be transformed prior to analyses. Means are the back-transformed values, resulting in the loss of additive properties. Standard errors could not be calculated.

Levels of significance are: *, ** and ***, for $P < 0.05$, $P < 0.01$ and $P < 0.001$ respectively.

The presence of newly introduced animals in the group had an effect on overall levels of aggression. The data in Table 7 shows the average level of interactions in three different circumstances: on the day animals were introduced ("Own"), on days other animals were introduced ("Other") and on days no animals were introduced ("No"). Number of interactions involving an animal were highest on the day it was introduced, and lowest on no introduction days (Tukey, $P < 0.05$). An interactive effect was found of Food level and Introduction day on Success rate: H

animals had similar success rates on own, other and no introduction days, whereas L animals show a significantly lower rate of success on days they were introduced (Tukey, $P < 0.05$).

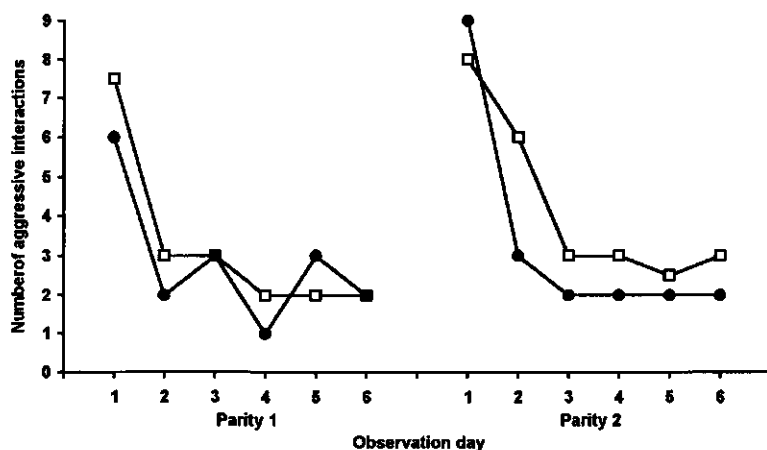


Figure 1
Median number of aggressive interactions per animal in first and second parity, per observation day, for animals on the High (□) and Low food level (●).

Table 7
Effect of treatment and introduction of animals on average number of aggressive interactions per pig per day and average success rate.

Food level	Low			High			s.e.d.	Level of significance		
	Own	Other	No	Own	Other	No		Food	Intro	FxI
Introduction day [†]										
Average number of interactions [‡]	7.1	1.9	1.5	7.5	2.2	1.6			***	
Success rate (%)	22	40	42	33	35	33	0.07		**	**

[†]Introduction days were classed as "own" on the day an animal was introduced, "other" on the day other animals were introduced and "no" on days no animals were added to the existing group.

[‡]Data had to be transformed prior to analyses. Means are the back-transformed values. Standard errors could not be calculated.

Levels of significance are: *, ** and ***, for $P < 0.05$, $P < 0.01$ and $P < 0.001$ respectively.

Skin lesion scores

No effects of the food treatments on the skin lesion score of the three main body parts were found (Total Score: Low v. High: 0.052 v. 0.060; $F_{1,14} = 0.27$; NS; Table 8). A parity effect was found, with second parity animals showing lower lesion scores than first parity animals (e.g. Total Score: parity 1 v. parity 2: 0.113 v. 0.028; $F_{1,1326} = 108.1$; $P < 0.001$). Skin lesion scores changed over pregnancy ($F_{8,1326} = 81.44$; $P < 0.001$; Figure 2). They were highest during the first few days after introduction in both parity 1 and 2 (Tukey, $P < 0.05$).

Table 8

Effect of treatment and parity number on the average lesion score per body part[†]: front (snout, throat, ears, shoulders), middle (sides and rump) and back (tail, buttocks and vulva).

Food level	Parity 1		Parity 2		s.e.d.	Level of significance		
	Low	High	Low	High		Food	Parity	FxP
Front	0.112	0.095	0.020	0.028	-		***	
Middle	0.034	0.056	0.012	0.014	-		***	
Back	0.0017	0.0018	0.0013	0.0014	-		***	
Total	0.116	0.126	0.025	0.033	-		***	

[†]Data had to be transformed prior to analyses. Means are the back-transformed values, resulting in an absence of additive properties between rows per column. Standard errors could not be calculated.

Levels of significance are: *, ** and ***, for $P < 0.05$, $P < 0.01$ and $P < 0.001$ respectively.

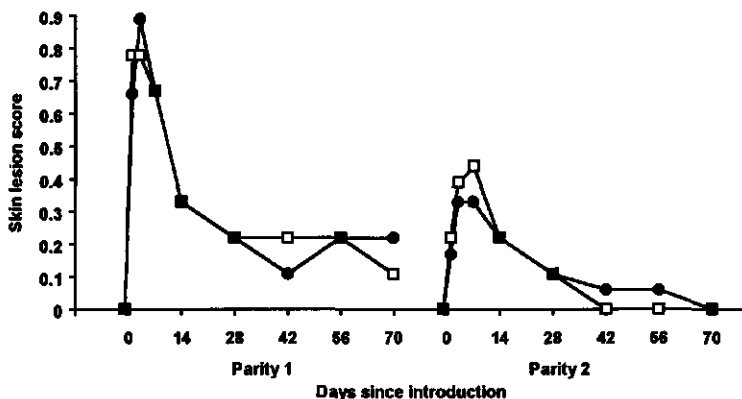


Figure 2

Median total skin lesion score per animal in first and second parity, in relation to time of introduction (day 0), for animals on the High (□) and Low food level (●).

DISCUSSION

Performance

As expected, sows on the high food level gained more weight and back fat during pregnancy than sows on the low food treatment. Other studies (ARC, 1981; Yang *et al.*, 1989; Spoolder *et al.*, 1996) show the reverse is generally true during subsequent lactation, but in the present study this was not confirmed. No effects were found of the food treatments on litter performance, in concordance with suggestions by Hard and Anderson (1979) that food level during pregnancy does not influence litter size, and Verstegen *et al.* (1987) that nutrient intake only has a small effect on the development of foetuses. Piglets born from second parity sows were heavier and grew faster. Other studies have also found a relationship between parity number and birth weight (Gatel *et al.*, 1987;

Kirkwood *et al.*, 1988), although significant increases in birth weight between first and second parity litters are less frequently seen (Gatel *et al.*, 1987). Parity effects on birth weight may reflect the requirement of the (immature) gilt for relatively higher levels of maternal growth during pregnancy. The higher growth rate in the second parity litters compared to first parity litters may be a result of increased milk production in second parity sows (e.g.: ARC 1981; Yang *et al.* 1989). Once again, the underlying physiological mechanism is possibly related to the gilt's immaturity compared to the sow.

Behaviour

Behavioural time budgets

Levels of activity, measured as standing, differed significantly between the two food treatments: low fed sows spent more time active than high fed sows. In simultaneously fed sows, increased levels of activity are common in the post-prandial period (Rushen, 1985; Jensen, 1988), and appear to be further increased in animals which are on restricted feeding levels (Terlouw *et al.*, 1991; Spoolder *et al.*, 1995). However, statistically significant differences between food levels disappeared when activity was measured over the 24 hour day (Spoolder *et al.*, 1995). The present experiment compared groups of sows which were fed *sequentially*, and therefore almost any observation period will include animals which have, and animals which have not fed. Therefore, the present study suggests that in sequentially fed animals, activity levels are influenced by food level, with a larger proportion of sows being active on the restricted food level, even when measured about 15-20 hours after the start of the feeding cycle.

On both treatments, about two thirds of the active time (as measured by percentage of time spent standing) was taken up by manipulative behaviours, with straw being the preferred object. Other studies also showed straw to be preferred over other pen components (e.g. Fraser, 1975; Arey, 1993), and that provision of straw reduces the incidence of abnormal behaviours such as stereotypies (Fraser, 1975; Spoolder *et al.*, 1995). In the present experiment, food level had a significant effect on the level of straw manipulation, but not on manipulation of pen components such as bars, walls or the feeders. Therefore, straw appears to have a more important role in satisfying the need to forage than other pen components.

In parity two, levels of substrate manipulation increased in the high fed animals, but not in the animals on the low food level. Part of the reason for this interactive effect between food and parity number may be that the increased food level in parity two (2.5 MJ DE per day for both L and H pigs) may have been sufficient to support the higher maintenance requirement of the sows on the low food level, but not on the high food level. At the end of pregnancy two H sows weighed on average 208.0 kg, compared to 181.2 kg for L sows (compared to 175.7 kg and 156.0 kg for H and L respectively in parity 1). Maintenance requirements (based on 430 kJ ME / kg metabolic weight and 1 ME = 0.95 DE; TCORN Report, 1990) have increased by 2.4 MJ DE per day for L fed sows, but by 3.0 MJ DE per day for the H fed sows. A marginal difference, but perhaps sufficient to increase foraging motivation relative to the first pregnancy. An additional reason for the interactive effect may be that foraging behaviour in L pigs reached a ceiling level in parity 1, whereas it did not in H pigs.

Food levels were fixed by treatment and parity, and were not adjusted individually for weight differences between sows. It can be argued that maintenance requirements will have been different within treatments as a result of differences in live weight, potentially causing a degree of overlap in feeding motivation between the two treatment groups. However, a comparison at the end of parity

two of the daily energy levels available after maintenance, of the lightest low-fed second parity sow (151 kg) with the heaviest of the (multiparous) sows which were used to keep the group size at 30 (hypothetically set at 350 kg) suggests no overlap exists: weight: 151 v. 350 kg; maintenance requirement; 19.5 v. 36.6 MJ DE; energy intake 22.7 v. 40.3 MJ DE; difference: 3.2 v. 3.7 MJ DE). Therefore, all sows on the low food treatment, even the lightest ones at the end of parity two, will have experienced higher levels of feeding motivation compared to the heaviest sows on the high food level.

Ad lib sampling of aggressive interactions and skin lesion scores

The incidence and severity of aggressive interactions were not influenced by the food treatments, and neither was the level of skin lesions. This appears to contradict work by Buré (1991) which suggests that agonistic behaviours, such as vulva biting, are a symptom of frustrated feeding motivation. A possible explanation for the apparent difference in results, lies in the availability of straw both as bedding material, and as a foraging substrate. Straw bedding reduces heat loss to the floor and lowers the LCT, potentially resulting in lower maintenance requirements. In addition, Spoolder *et al.* (1995) showed in a previous study that sows housed in small stable groups without straw bedding, developed a higher level of stereotypic chain and bar manipulations when they were fed a restricted as opposed to a relatively high food level. However, in the presence of straw, levels of stereotypies in both high and low fed animals were similar to those of high fed sows without straw. Therefore, straw provision may help to satisfy a behavioural need associated with an increased level of food motivation, thereby reducing the frustration resulting from this state (Weber *et al.* 1993). To support this, both Van Putten and Van de Burgwal (1990) and Buré (1991) report that providing additional roughage to their sows (which were housed in unbedded ESF systems) reduced the incidence of aggressive interactions. Therefore, in the present experiment, thermal and behavioural effects of straw may have helped to mitigate the effects of increased food motivation on aggression.

An effect of parity number was found on the level of aggression and the resulting skin lesions. Gilts were significantly more involved in severe interactions than second parity sows, although average number of all interactions was greater in the latter. Gilts also sustained more fighting injuries than sows, and had a lower success rate during interactions. These parity effects can in part be explained by the difference in size and experience of first and second parity animals: there is sufficient evidence to support the hypothesis that older and heavier pigs rank higher in the social hierarchy (e.g. Ritter and Weber, 1989; Brouns and Edwards, 1994). However, this does not explain why gilts are involved in more severe interactions, such as fights, compared with second parity animals. Work by Dingemans *et al.* (1993) suggests this may be due to inexperience in competitive situations. In their study, 5 month old gilts were challenged by mixing them at weekly intervals with other unfamiliar individuals over a seven week period. As the animals gained experience over the weeks, the level of skin lesions following mixing was reduced: the gilts learned to avoid fights, and thus diminish the aggressive outcome of a social interaction (Jensen, 1982). The results of the present experiment showed a significant interaction of parity number and food level on success rates: L sows won proportionally more aggressive interactions on days other animals were introduced and on days no animals were introduced, than on days they were introduced themselves. No such effect was found on the H treatment. It can be hypothesised that although food level may not influence the number of social encounters which result in aggressive interactions, low food levels may increase a pig's motivation to win, and therefore the outcome of an interaction, once it is engaged in a fight.

Number of aggressive interactions and level of skin lesions were both influenced by the introduction of animals to the dynamic group. Skin lesions were highest in the first weeks after introduction and tailed off towards the end of the gestation period. Similarly, the day of introduction gave rise to the highest level of aggressive interactions involving the newly introduced animals. Both effects have been found in several other studies (e.g. Burfoot, *et al.*, 1994; Bokma and Kersjes, 1988). Over time newly introduced animals integrate with resident sows, resulting in reduced aggression and inter-individual distance between animals of different original sub-groups (Moore, *et al.*, 1993; Spoolder, *et al.*, 1996). The average level of interactions per sow on days when *other* animals were introduced did not differ significantly from days that *no* animals were introduced. At first this may sound contradictory, as newly introduced animals are most likely to have had interactions with sows other than the ones in their own subgroup. However, since at almost any point during the experiment the number of resident sows was about five times the number of newly introduced animals, the effects on average number of interactions per resident sow may well have been diluted to the point of statistical insignificance.

CONCLUSIONS

The present study suggests that in a sequential feeding system with plentiful straw, food level may influence body weight and back fat levels, but not aggressive behaviour. In these systems, the main factor giving rise to aggression is the introduction of new animals to the resident group. Comparison of the results of the present study with work done on unstrawed systems suggest further research is needed to investigate the mitigating effect straw may have on levels of aggression in sequential feeding systems.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of the Ministry of Agriculture Fisheries and Food. SAC also receives financial support from the Scottish Office Agriculture Environment and Fisheries Department. We would like to thank Francis Brouns for her help in analysing the data, and Piet Wiepkema and Willem Schouten for valuable comments on the manuscript.

REFERENCES

- Agricultural Research Council 1981. The nutrient requirement of pigs. Commonwealth Agricultural Bureaux, Slough., UK.
- Arey, D.S. 1993. The effect of bedding on the behaviour and welfare of pigs. *Animal Welfare* 2: 235-246.
- Bokma, S. and Kersjes, G.J.K. 1988. The introduction of pregnant sows in an established group. *Proceedings of the International Congress on Applied Ethology in Farm Animals, Skara 1988*: 166-169.
- Brouns, F. and Edwards, S.A. 1992. Future prospects for housing of non-lactating sows. *Pig News and Information* 13: 47N-50N.

- Brouns, F. and Edwards, S.A. 1994. Social rank and feeding behaviour of group-housed sows fed competitively or ad libitum. *Applied Animal Behaviour Science* 39: 225-235.
- Buré, R.G. 1991. The influence on vulva biting of supplying additional roughage in an electronic sow feeder. Paper presented at the 42nd annual meeting of the EAAP, Berlin 1991.
- Burfoot, A., Kay, R.M. and Simmins, P.H. 1994. Level of skin damage in sows when mixed in groups in early pregnancy. *Animal Production* 58: 438.
- Dantzer, R., Arnone, M. and Mormede, P. 1980. Effects of frustration on behaviour and plasma corticosteroid levels in pigs. *Physiology and Behavior* 24: 1-4.
- Deag, J.M., 1990. Keybehaviour - a program for recording data on an Atari Portfolio Computer. Copyright John M. Deag, 10 Fletcher Grove, Penicuik EH26 0JT, UK 46 pp.
- Dingemans, E.C.F.M., Buré, R.G. and Van Putten, G. 1993. The influence of rearing conditions on social behaviour of sows in groups [De invloed van opfokomstandigheden op het sociale gedrag van zeugen in groepen]. IMAG-DLO report 93-21, IMAG, Wageningen, The Netherlands.
- Duncan, I.H.J. and Wood-Gush, D.G.M. 1971. Frustration and aggression in the domestic fowl. *Animal Behaviour* 19: 500-504.
- Fraser, D. 1975. The effect of straw on the behaviour of sows in tether stalls. *Animal Production* 21: 59-68.
- Gatel, F., Castaing, J. and Lucbert, J. 1987. Changes in productivity and culling rate according to pregnancy feed intake and litter parity. *Livestock Production Science* 17: 247-261.
- Genstat 5 Reference Manual, 1987. Oxford University Press, Oxford. 749 pp.
- Hard, D.L. and Anderson, L.L. 1979. Maternal starvation and progesterone secretion, litter size and growth in the pig. *American Journal of Physiology* 273: E273-E278.
- Hunter, E.J., Broom, D.M., Edwards, S.A. and Sibly, R.M. 1988. Social hierarchy and feeder access in a group of 20 sows using a computer-controlled feeder. *Animal Production* 47: 139-148.
- Jensen, P. 1982. An analyses of agonistic interaction patterns in group-housed dry sows - aggression regulation through an "avoidance order". *Applied Animal Ethology* 9: 47-61.
- Jensen, P. 1988. Diurnal rhythm of bar-biting in relation to other behaviour in pregnant sows. *Applied Animal Behaviour Science* 21: 337-346.
- Kirkwood, R.N., Mitaru, B.N., Gooneratne, A.D., Blair, R. and Thacker, P.A. 1988. The influence of dietary energy intake during successive lactations on sow prolificacy. *Canadian Journal of Animal Science* 68: 283-290.
- Lawrence, A.B. and Illius, A.W. 1988. Measuring hunger in the pig using operant conditioning: the effect of food restriction. *Animal Production*, 47: 131-137.
- MAFF, 1993. Prediction of the energy value of compound feeding stuffs for farm animals. MAFF Publication 1285, London, pp. 7.
- Martin, P.R. and Bateson, P.P.G. 1993. Measuring behaviour. Cambridge University Press. pp 222.
- Minitab Inc., 1993. Minitab Reference Manual. Sowers Printing Company, Lebanon, PA.
- Moore, A.S., Gonyou, H.W. and Ghent, A.W. 1993. Integration of newly introduced and resident sows following grouping. *Applied Animal Behaviour Science* 38: 257-267.
- van Putten, G. and van de Burgwal, J.A. 1990. Vulva biting in group-housed sows: preliminary report. *Applied Animal Behaviour Science* 26: 181-186.
- Ritter, E. and Weber, R. 1989. Social rank order of sows and occupation of the feeder station with two different types of computerised feeding systems [Soziale Rangordnung von Zuchtsauen und belegung der Futterstation bei zwei verschiedenen Abruffütterungsanlagen]. *KTBL-schrift* 336: 132-141.

- Rushen, J.P. 1985. Stereotypies, aggression and the feeding schedules of tethered sows. *Applied Animal Behaviour Science* 14: 137-147.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A. 1995. Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. *Applied Animal Behaviour Science* 43: 249-262.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B. Edwards, S.A. and Simmins, P.H. 1996. Social recognition in gilts mixed into a dynamic group of sows. *Animal Science* 62: 630.
- Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Simmins, P.H. and Lawrence, A.B. 1996. Effects of food level and straw bedding during pregnancy on sow performance and responses to an ACTH challenge. *Livestock Production Science*, 47: 51-57.
- Svendsen, J., Andersson, M., Olsson, A.C., Rantzen, D. and Lundqvist, P. 1990. Group housing of sows in gestation in insulated and uninsulated buildings [Grupphållning av dräktiga suggor i isolerade och oisolerade stallar]. Report 66 of the Swedish University of Agricultural Sciences.
- TCORN Report, 1990. The nutrient requirement of sows and boars. In: *Nutrition Abstracts and Reviews (Series B)* 60: 384-406.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W. 1991. Influences of feeding level and physical restriction on development of stereotypies in sows. *Animal Behaviour* 42: 981-991.
- Thompson, T. and Bloom, W. 1966. Aggressive behaviour and extinction-induced response rate increase. *Psychonomic Science* 5: 335-336.
- Verstegen, M.W.A., Verhagen, J.M.F. and Hartog, L.A. den. 1987. Energy requirements of pigs during pregnancy: a review. *Livestock Production Science* 16: 75-89.
- Weber, R., Friedli, K., Troxler, J. and Winterling, Ch. 1993. The influence of computerized individual feeding system on the behaviour of sows. In *Livestock Environment IV* (ed. E. Collins and C. Boon), pp. 495-501, St Joseph, Michigan, USA.
- Wiepkema, P.R. 1971. Positive feedbacks at work during feeding. *Behaviour* 39: 266-273.
- Yang, H., Eastham, P.R., Phillips, P. and Whittemore, C.T. 1989. Reproductive performance, body weight and body condition of breeding sows with differing body fatness at parturition, differing nutrition during lactation, and differing litter size. *Animal Production* 48: 181-201.

Chapter 4

SPATIAL ORGANISATION OF DYNAMIC GROUPS OF SOWS ON TWO DIFFERENT FOOD LEVELS

Hans A.M. Spoolder^{1,2}, Alistair B. Lawrence², Sandra A. Edwards²,
P. Howard Simmins^{1†} and Tony W. Armsby¹

¹ ADAS Terrington, Terrington St. Clement, King's Lynn, Norfolk PE34 4PW, UK

² SAC, West Mains Road, Edinburgh, EH9 3JG, UK

[†] Present address: Rhône-Poulenc Animal Nutrition, 42 Avenue Aristide Briand,
BP100, 92164 Antony, France.

Submitted to : Applied Animal Behaviour Science

SPATIAL ORGANISATION OF DYNAMIC GROUPS OF SOWS ON TWO DIFFERENT FOOD LEVELS

H.A.M. Spoolder, A.B. Lawrence, S.A. Edwards, P.H. Simmins and A.W. Armsby

ABSTRACT

The spatial organisation of large groups of domestic pigs is regulated primarily through (the avoidance of) agonistic behaviour. Aggressive behaviour in group housed pigs increases shortly after the introduction of new animals, but has also been suggested to be influenced by food level. The present study investigated the effects of these two factors on the long term spatial organisation of groups of 30 sows. Sixteen subgroups of 5 gilts were introduced over 8 months to 1 of 2 dynamic groups in a deep straw yard, each group receiving a different food level from an electronic sow feeding system. Seventy second parity sows were returned to the same treatments in the same subgroups. The spatial organisation of the animals was recorded throughout both pregnancies on a floor plan of the building at fortnightly intervals. From these a range of spatial parameters were calculated. Food level only influenced the proportion of time drinker and feeder areas were used. The time since introduction of a new subgroup did affect spatial organisation, with the average inter-individual distance between resident and new animals decreasing, and that within subgroups increasing. However, social integration appeared to be a staged progress, starting off with a peak in agonistic behaviour, followed by an increased use of the same areas of the pen. The final stage, which involved a random sharing of the immediate area around an individual, was not achieved before pigs were taken out of the group for farrowing.

INTRODUCTION

The spatial organisation of captive animals living in social groups is influenced by a number of aspects which are absent or irrelevant in the wild conspecific. Groups of domestic pigs are subjected to factors such as group size, group structure (age, sex) and space allowance, without the ability to influence them. As a result, territoriality (the defense of a fixed part of the total available area by one or more individuals; McBride, 1971) which is absent in wild pigs (Graves, 1984), can be seen in groups of domestic pigs when competition for available lying space is high (Moore *et al.*, 1993). It can be hypothesised that under these circumstances, territoriality is most likely to be influenced by individuals defending a degree of personal (portable) space (McBride, 1971). This space, or the distance to the nearest neighbour, has been shown to be related to the social status of the animals involved (McCort and Graves, 1982). More recently, the level of familiarity has been suggested as a factor determining inter-individual proximities, and therefore spatial organisation, in groups of domestic pigs (Petersen *et al.*, 1989; Spoolder *et al.*, 1996).

Agonistic behaviour is one of the main tools regulating the social and spatial structure of a group of pigs. The introduction of a new group of unfamiliar pigs to a larger group of resident animals (for example in so-called "dynamic" sow housing systems), inevitably results in an increase in aggressive interactions whilst the social hierarchy is being re-established. These temporary peaks in

aggressive behaviour generally last about one to two days (Bokma and Kersjes, 1988; Spoolder *et al.*, 1997), but the integration of the newly introduced animals, as measured using spatial parameters, may take much longer (Moore *et al.*, 1993; Spoolder *et al.*, 1996). It has been suggested that the level of aggression in pigs is influenced by their food level (Svendsen *et al.*, 1990; Buré, 1991): low levels of food which result in chronic food motivation may give rise to frustration at or near the food source (Duncan and Wood-Gush, 1971). Spoolder *et al.* (1997) failed to confirm this hypothesis in dynamic groups of sows housed on straw: pigs on a food level just above maintenance did not have significantly higher levels of aggression or skin lesions compared with pigs on a substantially higher nutritional plane. Instead, they identified the introduction of unfamiliar animals as the main cause of increased agonistic behaviour.

The present paper, which investigates spatial data obtained during the study described by Spoolder *et al.* (1997), addresses the impact the different degrees of food motivation may have had on the integration of new animals into the larger groups, by closely examining the spatial organisation of the animals.

METHODS

Full details of methods used in this experiment were presented in Spoolder *et al.* (1997). The following is a summary description, with additional information provided where necessary.

Subjects, Housing and Care

Eighty nulliparous sows (PIC Camborough; weight 136.2, SD 8.72 kg; age 234.3, SD 21.2 days) entered the experiment in 16 groups ($n=5$) at a rate of 2 groups per month. All animals had been in their groups for at least 2 months, and were between 1 and 3 weeks post service. They were introduced to one of two groups managed commercially as part of a dynamic system. In these systems, recently served sows enter, and sows about to farrow leave the group on a regular basis. The total number of animals in each dynamic group was maintained at around 30 through the use of additional sows, which were introduced at least one week clear of days when experimental animals were introduced. For the sake of clarity, from here onwards, the sixteen groups of five familiar pigs which entered the larger dynamic groups will be referred to as "subgroups", the two larger dynamic groups (containing introduced subgroups and additional non experimental sows) as "groups".

Both dynamic groups were housed in a naturally ventilated deep strawed building, with a lying area allowing 2.35 m² per sow. Figure 1 shows a floor plan of the building. Each group was fed from a Pigcode Electronic Sow Feeder (ESF) station (Quality Equipment, Heath Road, Woolpit, UK). The feeding cycle started at 1800 hours when the new daily ration for each sow became available. Water was provided *ad libitum* from drinkers situated in the Outside area.

All sows spent the first week after introduction to the experimental building in a separate pen (3 x 15 m; "training pen", see Fig. 1) in their subgroup. During this period the animals were trained to use the ESF system, between 1300 and 1600 hours every day. Sows in the dynamic groups were denied access to the ESF feeders during the hours new pigs were being trained. The daily ration offered during the training period was 2.0 kg (25.2 MJ DE). After the training week the animals were entered into their treatment groups. Sows which were to be introduced to the group on the left hand side of the building spent the final training day in a "holding pen" (Fig. 1) and were trained

from there that day whilst all other animals were held back into their lying area. A maximum of one subgroup occupied the training or the holding pen at any time. Both the training pen and the holding pen were strawed and water was provided ad libitum. No physical contact was possible with pigs in the dynamic groups.

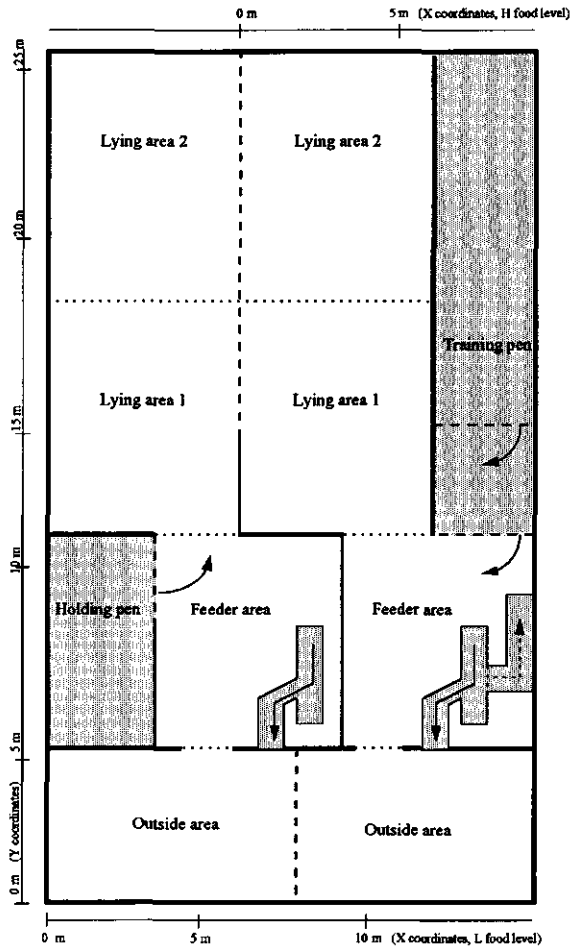


Figure 1
Floor plan of experimental building. Sows which were housed in the left half of the building were on the Low food treatment (L), sows on the right on the High food treatment (H).

Sows were taken to the farrowing house one to two weeks prior to their expected farrowing date. The building had a controlled environment and solid floor farrowing crates. Chopped straw was provided to all sows every day after cleaning out. The animals were fed 2 kg of a lactation diet (13.8

MJ DE per kg) twice a day. After farrowing, the daily ration was increased to a level determined by litter size.

Weaning occurred at 24±2 days. Sows were taken to the service house and reunited in their original subgroups, or, if they were 1 cycle behind their subgroup members, in the next subgroup of the same treatment. They were housed in solid floor straw pens with 6 individual feeders, and fed a daily ration of 3.0 kg (41 MJ DE) of the lactation diet until service. After service, sows received 3.0 kg (37 MJ DE) of the pregnancy diet. Two to five days after the last animal was served the group was moved back to the experimental building and penned in the training pen for one week, prior to re-entering the experimental groups as second parity sows.

Treatments

The experiment compared 2 food levels: high (H; parity 1: 3.0 kg / 37.8 MJ DE day⁻¹, parity 2: 3.2 kg / 40.3 MJ DE day⁻¹) and low (L; parity 1: 1.6 kg / 20.2 MJ DE day⁻¹, parity 2: 1.8 kg / 22.7 MJ DE day⁻¹). Sows were subjected to the same treatment during both pregnancies.

Behavioural Observations

All sows were marked with a sprayed pattern on days prior to observation days, to facilitate identification. The group's spatial behaviour was recorded over both pregnancies on six observation days evenly spaced over each pregnancy: the day of introduction to the dynamic groups, and at approximately 2, 4, 6, 8 and 10 weeks thereafter. However, observation days needed to coincide with the introduction of new subgroups. Due to the temporal fluctuations in the pattern of natural services, and subsequent delays in the introduction of the subgroups, the fortnightly pattern of observation days could not be strictly adhered to. During observation days the location and identity of each experimental animal was recorded on a floor plan similar to Fig. 1, every hour from 0900 to 1500 hours. Location of non-experimental sows were also recorded, but they were not identified individually. A total of nearly 400 floor plans were collected during the 14 month trial period. The floor plans were digitised using Mapdata software (Mapdata Management Ltd, Carnforth, Lancashire, UK), recording the position of the head and the tail of all individuals (relative to the plan of the building), their posture, and the date and time of observation. These data were stored in a dBASE IV database file (Borland, Scotts Valley, California, USA).

Data Collation and Statistical Methods

Data files were interrogated using dBASE IV to identify a) the average daily location of each pig (in X and Y coordinates), b) the use of particular areas of the pen, c) the average daily inter-individual distance between any two pigs in the group, d) the proportion of observations during which two pigs were seen within two meters of each other and e) the average daily distance to the nearest neighbour. Although there was a degree of overlap between first and second parity animals being entered to the dynamic groups, data sets were kept separate: no attempt was made to determine spatial associations between first and second parity animals.

Average location

Data on the average location of the animals were calculated to allow a longitudinal assessment of "migration" of the animals in their pens, via linear regression (Excel for Windows 1995) on the X and the Y coordinates separately. The model used was $L = a + b \cdot T$, with L being the X or Y coordinate (in m) and T being the time since introduction to the group (in days). In addition, a one way analysis of variance was used to test for time effects with time period as treatment factor (Genstat 5 1987), with individual pig data nested in subgroups. Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days, 5: 43-56 days, 6: 57-70 days and 7: 71+ days. Tukey's HSD (Minitab 9 for Windows 1993) was used for pairwise comparison if significant effects were found.

Use of different pen areas

The proportion of observations the animals were recorded in the four functionally different areas of the pen were calculated on a daily basis. The areas were (see Fig. 1): Outside area, Feeding area, Lying area 1 (the half of the Lying area nearest to the feeders) and Lying area 2 (the second half, furthest from the feeders). One way analysis of variance was used to test for time effects with time period as treatment factor (Genstat 5 1987; time periods defined in previous section). Tukey's HSD (Minitab 9 for Windows 1993) was used for pairwise comparison if significant effects were found.

Average inter-individual distance

Daily averages of inter-individual distances between experimental animals (head to head) were calculated, resulting in symmetrical matrices varying in size from 5 x 5 (1 subgroup) to 15 x 15 pigs (3 subgroups). These matrices were used to assess changes over time in the spatial relationship between consecutively introduced pairs of subgroups. For example, spatial data from subgroups A and B were analysed together (both within and between subgroups) on the day subgroup B was introduced (subgroup A having been entered to the main group a month before), a fortnight later on the next observation day, and so on, until subgroup A was removed for farrowing. Matrices for observation days with three subgroups were split up into smaller matrices involving only two, e.g. on the day subgroup C was introduced (with A and B being part of the resident group), three smaller matrices involving A + B, A + C and B + C were calculated and analysed.

For first parity data, these matrices were analysed using two methods. Firstly, the smaller matrices involving only two subgroups were compared with a hypothesis matrix using the non parametric Mantel test (Manly, 1986). A computational example by Schnell *et al.* (1985) was used to write a Genstat 5 programme (Genstat 5, 1987) which automated the statistical analysis. The hypothesis matrix reflected a spatial organisation in which individuals have closer proximity to subgroup members than to non-subgroup members. It contained zeroes on the diagonal (suggesting no distance between an animal and itself), it contained fours in cells pairing individuals from the same subgroup (suggesting close within subgroup proximity), and nines in cells formed by individuals from different subgroups (suggesting large between group proximity). The values in the hypothesis matrix were based on the medians of inter-individual distances found on the day of introduction of a subgroup. The test calculates a *t*-value, which can be compared against the standard normal distribution (at infinite degrees of freedom). A *t*-value > 1.96 suggests the hypothesis and the data matrix are similar in structure at the $P < 0.05$ probability level.

Secondly, the elements of each data matrix were categorised as representing within or between subgroup proximities. Time since introduction of members of different subgroups to each other (which was equivalent to the time since the last subgroup entered the large dynamic group) was then categorised using the time periods described in the previous section. For each of the 7 time periods, distances between and within subgroup members were then compared using the non-parametric Mann-Whitney test (Minitab 9 for Windows, 1993). Significant differences confirmed the hypothesis that distances between members of different subgroups were larger than between members from the same subgroup.

Parity 2 data were not analysed using the Mantel test for two reasons. In parity 2 numbers of pigs in each subgroup varied from 2 (one subgroup) to 5 (four subgroups), with most subgroups (eight) consisting of 4 animals. This was caused by 17 sows having to be rejected from the experiment, mainly due to returns to service which resulted in a lack of synchrony with subgroup members. Data matrices were therefore highly variable in size and composition, which warranted a different hypothesis matrix for nearly every observation day. In addition, the parity 1 results obtained from the Mann-Whitney test were highly comparable with those from the Mantel test (see later). Parity two data were therefore analysed using the Mann-Whitney test only.

Observations within 2 m

The fourth main category of spatial information aimed to estimate the proportion of time animals spent within 2 meters of each other. Once again, matrices were developed per observation day. Each cell represented the proportion of observations a pair of sows were seen within 2 meters of each other (distances measured from head to head). The variables thus calculated were on an ordinal scale, and analysis was done in two ways using non-parametric techniques, as described in the previous section.

Nearest neighbour

Finally, the distance from each experimental animal to its nearest neighbour was calculated per scan. For each scan, the identity of the nearest neighbour was also established, and categorised as being either a subgroup member or not. Non-subgroup members included all pigs from other experimental subgroups (including those from a different parity) and all non-experimental animals. Daily averages of distances to the nearest neighbour were calculated per experimental animal, for nearest neighbours who were subgroup members, and nearest neighbours who were non-subgroup members separately. In addition, the proportion of observations per day that a nearest neighbour was a subgroup member was calculated. Both nearest neighbour parameters were then averaged per time period described above, and differences between "within" and "between" subgroup nearest neighbour distances were tested for using the Mann-Whitney test (Minitab 9 for Windows, 1993).

RESULTS

The performance and general behaviour data (with emphasis on agonistic behaviour) were presented in Spoolder *et al.* (1997).

Average Location

For both food treatments, and in both first and second parity sows, average location during the hours of observation showed a significant change over the gestation period, in the X as well as the Y orientations of the building (e.g. L sows, parity 1: correlation between time spent in the group (days) and migration along the Y axis (m): $r_s=0.70$; $n=230$; $P<0.001$). Averages of the seven time periods were significantly different, and showed a migration of the sows towards the top end and left hand side of their pen (Fig. 2).

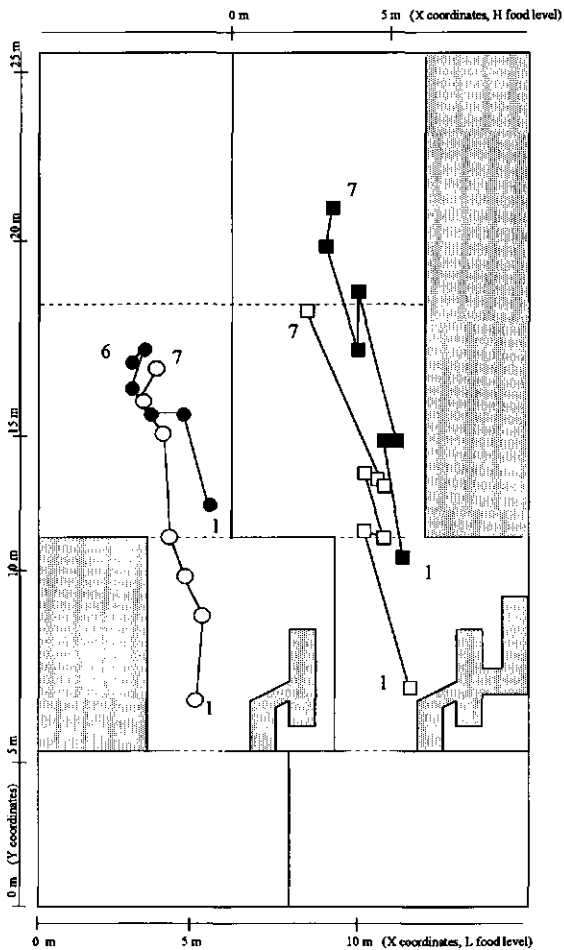


Figure 2
Average location of animals in the experimental building, per time period[†], per parity and on both food treatments.
[†] Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days, 5: 43-56 days, 6: 57-70 days and 7: 71+ days post introduction. Legend: Low Food level, parity 1: ○, parity 2: ●, High Food level, parity 1: □, parity 2: ■.

For both food treatments, migration along the Y axis appeared to be a stepped process (e.g. L sows, parity 1: average Y-axis location: 6.3^a, 8.8^b, 9.7^b, 11.1^b, 14.3^c, 15.4^c and 16.3^c, for time periods 1-7 respectively; different superscripts indicate significantly different means, Tukey, $P < 0.05$). L sows progressed from just inside the Feeder area, via the top of the Feeder area to the top end of Lying area 1. In parity two they set off just inside Lying area 1, to progress towards the top end of it. In contrast, H sows (although starting off at a similar location in parity 1 as the L pigs), spent the vast majority of the time periods around the bottom part of Lying area 1. In parity 2 they moved away from the feeders considerably quicker, and settled just inside Lying area 2 (Fig. 2).

Use of Different Areas

During both the first and the second parity the proportion of observations sows were seen in the outside dunging area decreased, and the time spent in the back of the lying area increased (Fig. 3a and 3b). In parity 1, sows spent significantly more time in the outside area on their introduction day, compared to subsequent days (e.g. L-sows: proportion of scans in outside area: 0.30^a, 0.16^{bc}, 0.20^{ac}, 0.08^{bc}, 0.06^b, 0.08^{bc} and 0.08^{bc}, for time periods 1-7 respectively; different superscripts indicate significantly different means, Tukey, $P < 0.05$). Use of the front of the lying area initially increased, peaking in the 3rd period (15-28 days), and then decreasing (e.g. L-sows: proportion of scans in lying area 1: 0.04^a, 0.24^{bc}, 0.35^c, 0.31^c, 0.30^c, 0.25^{bc} and 0.11^{ab} for time periods 1-7 respectively; different superscripts indicate significantly different means, Tukey, $P < 0.05$).

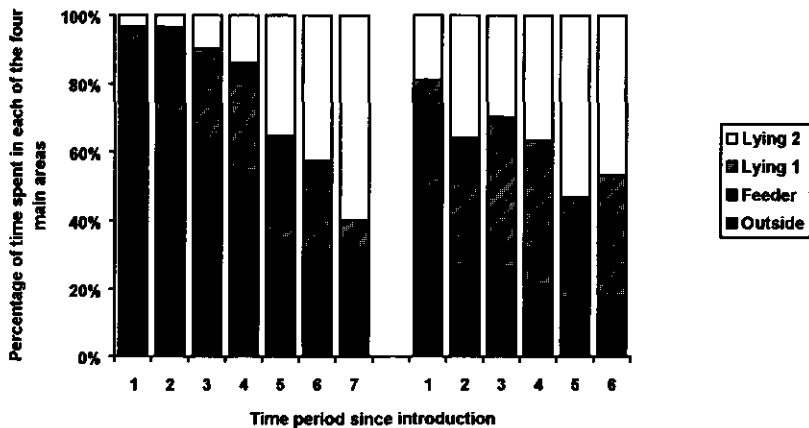


Figure 3a

Percentage of time spent by Low fed sows in the four main areas of the pen, during the first and second parity. Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days, 5: 43-56 days, 6: 57-70 days and 7: 71+ days post introduction.

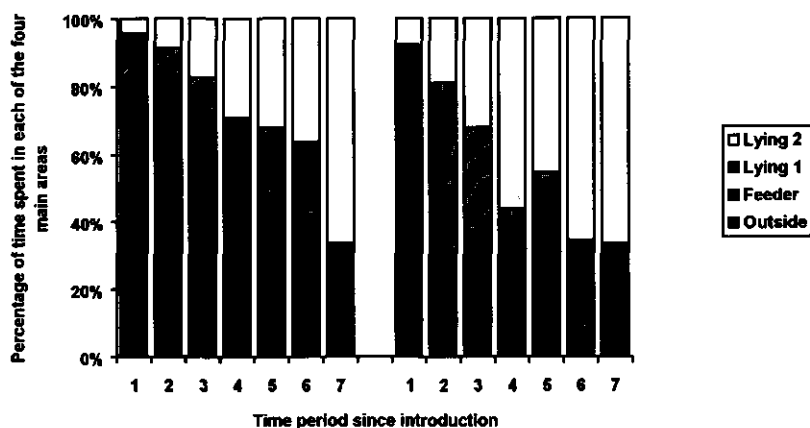


Figure 3b

Percentage of time spent by High fed sows in the four main areas of the pen, during the first and second parity. Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days, 5: 43-56 days, 6: 57-70 days and 7: 71+ days post introduction.

Occupation of the back of the lying area increased from almost none (introduction day) to a level of about 30% during and after the fourth period (days 29-42), in parity 1. In parity 2 this level was reached earlier, possibly during the second period (days 7-17). Towards the end of the observation period (days 71+) sows were observed in the back of the lying area for over 50% of the time. Food treatment effects were only found for the Outside area and the Feeder area during parity 1 (Outside: 0.20 vs. 0.15, H vs. L. respectively; $t=2.41$, $P<0.05$; Feeder: 0.33 vs. 0.38, H vs. L respectively, $t=2.16$, $P<0.05$).

Average Inter-Individual Distance

Average daily inter-individual distances increased over time in sows belonging to the same subgroup, after introduction to a larger dynamic group. Proximity between animals of different, unfamiliar subgroups decreased over time (Fig. 4). In dynamic groups of pigs on a high food level, average daily proximity between animals of unfamiliar subgroups remained significantly higher than between animals of the same subgroup until approximately 28 days after introduction of a subgroup. On the low food level they remained higher until at least 74 days post introduction (Table 1). The results of the Mantel tests (comparing pairs of subgroups for within and between subgroup proximities) are plotted in Fig. 5. Each data point in these figures represents a critical value W , calculated when testing the hypothesis that for a given pair of subgroups the daily average "within" distance is smaller than the "between" distance, i.e. the subgroups are spatially separated. A t -value smaller than 1.96 means the hypothesis has to be rejected at $P=0.05$. Linear regression of the t -values on time since introduction to the dynamic group suggests subgroups are no longer spatially different from day 29 in L sows, and from day 23 in H sows, as measured using averaged daily proximities. Significant effects of food treatment were found (Table 1) but were not very consistent.

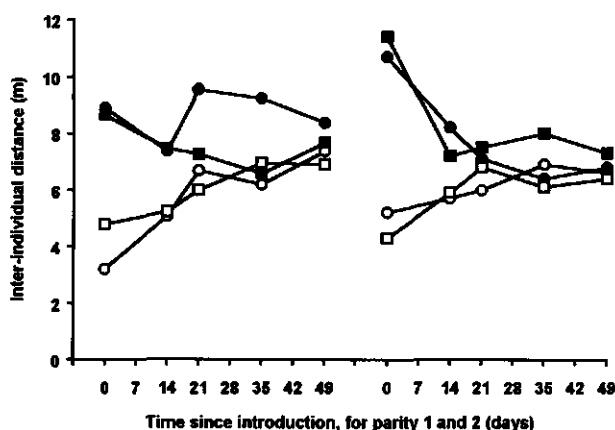


Figure 4

Medians of inter-individual distances (m) between individuals *within* subgroups (introduced at the same time) and *between* subgroups, relative to the day of introduction of the last subgroup, per food treatment and per parity. Legend: Low Food level, Within subgroups: ○, Between subgroups: ●, High Food level, Within subgroups: □, Between subgroups: ■.

Table 1

Medians of inter-individual distances (m) between individuals *within* subgroups (introduced at the same time) and *between* subgroups, per time period[†], for both food treatments and per parity

Period [†]	Median of inter individual distance				Level of significance [‡]			
	Low		High		Subgroup effects (by food level)		Food effects (by subgroup status)	
	within	between	within	between	Low	High	within	between
Parity 1								
1	3.2	8.9	4.8	8.7	***	***	***	NS
2	5.1	7.4	5.3	7.5	***	***	NS	NS
3	6.7	9.6	6.0	7.3	***	***	*	***
4	6.2	9.3	7.0	6.6	***	NS	NS	***
5	7.4	8.4	6.9	7.7	*	NS	NS	NS
Parity 2								
1	5.2	10.7	4.3	11.4	***	***	***	*
2	5.7	8.2	5.9	7.2	***	*	NS	***
3	6.0	7.1	6.8	7.5	**	*	NS	NS
4	6.9	6.4	6.1	8.0	NS	***	NS	**
5	6.6	6.8	6.4	7.3	*	NS	NS	NS

[†]Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days and 5: 43-56 days post introduction.

[‡]Differences between Low and High food treatment, and between and within subgroups were tested using the Mann-Whitney test

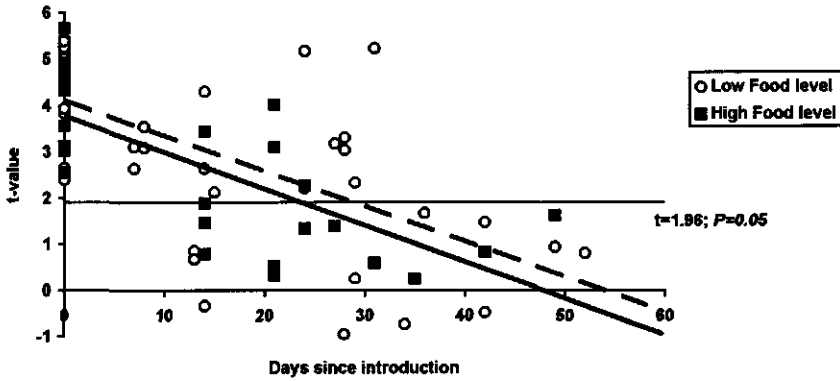


Figure 5

Degree of difference between average Within subgroup distances and average Between subgroup distances, per food level, expressed using the t-statistic calculated by the Mantel test (for explanation see text). The dashed line of best fit relates to the Low food level, the solid line to the High food level.

Observations within Two Meters

Significant differences were found in the proportion of daily observations sows, which belonged to the same subgroup, were observed within two meters of each other, compared with sows belonging to different subgroups (Table 2).

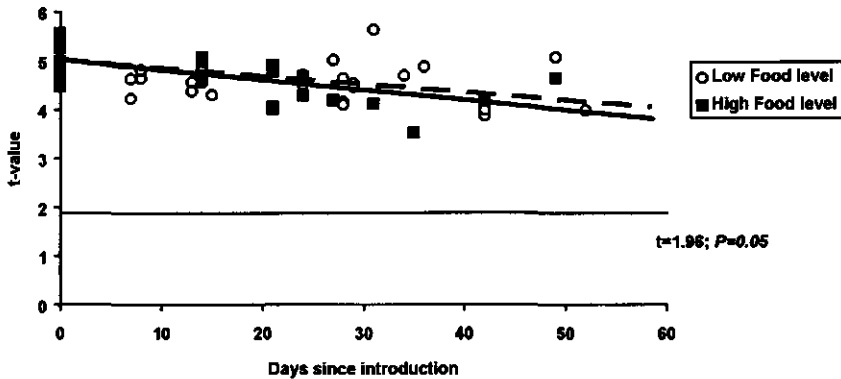


Figure 6

Degree of difference between proportion of time spent within 2 meters of a subgroup member and proportion of time spent within 2 meters of a non-subgroup member, per food level, expressed using the t-statistic calculated by the Mantel test (for explanation see text). The dashed line of best fit relates to the Low food level, the solid line to the High food level.

These differences existed on both food treatments for the whole of the duration in which relationships could be measured between resident experimental sows and newly introduced animals (approximately 56 days). Figure 6 shows the change in *t*-value over time, calculated in Mantel tests comparing a matrix of proportions, with a hypothesis matrix stating that *within* subgroups proportions should be greater than *between* subgroups. The *t*-values were highly significant for all of the matrices tested. Linear regression suggested a level of decline of the *t*-value sufficiently low for it to remain above the $P=0.05$ significance level for the duration of the subgroup's stay in the dynamic group.

Differences between the two food treatments were found (Table 2), but were very inconsistent.

Table 2

Medians of proportions of daily observations spent within two meters of each other for individuals *within* subgroups (introduced at the same time) and *between* subgroups, per time period[†], for both food treatments and per parity.

Period [†]	Median of inter individual distance				Level of significance [‡]			
	Low		High		Subgroup effects (by food level)		Food effects (by subgroup status)	
	within	between	within	between	Low	High	within	between
Parity 1								
1	0.33	0.00	0.17	0.00	***	***	*	NS
2	0.17	0.00	0.17	0.00	***	***	**	*
3	0.17	0.00	0.17	0.00	***	***	NS	NS
4	0.17	0.00	0.17	0.00	***	**	NS	*
5	0.00	0.00	0.17	0.00	*	***	**	NS
Parity 2								
1	0.17	0.00	0.33	0.00	***	***	*	*
2	0.00	0.00	0.17	0.00	***	***	*	NS
3	0.00	0.00	0.17	0.00	NS	***	NS	**
4	0.17	0.00	0.17	0.00	*	***	NS	NS
5	0.17	0.00	0.17	0.00	***	***	NS	NS

[†] Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days and 5: 43-56 days post introduction.

[‡] Differences between Low and High food treatment, and between and within subgroups were tested using the Mann-Whitney test.

Nearest Neighbour

Nearest neighbours were significantly more often non-subgroup members than subgroup members (e.g. L sows, Parity 1: 0.71 vs. 0.29, for Between and Within subgroups respectively, $t=10.9$, $P<0.001$). In general, subgroup members were identified as nearest neighbours in 20 - 30% of observations (Table 3). Chance expectation of a nearest neighbour being a subgroup member was 4 out of 29 (14%). Median distances to nearest neighbours who are subgroup members appeared to be lower than to non-subgroup members, although statistical significance was not achieved in all time periods tested (Table 4). No difference was found between the two food treatments (Table 4).

Table 3

Effect of time since introduction on the proportion of nearest neighbours which are subgroup members, for first and second parity sows.

	Time periods [†]						
	1	2	3	4	5	6	7
Parity 1							
Low	0.58	0.29	0.23	0.27	0.19	0.20	0.19
High	0.48	0.37	0.25	0.20	0.24	0.25	0.24
Parity 2							
Low	0.38	0.30	0.33	0.28	0.21	0.16	-
High	0.47	0.33	0.27	0.31	0.19	0.22	0.21

[†] Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days, 5: 43-56 days, 6: 57-70 days and 7: 71+ days post introduction.

Table 4

Median daily inter-individual distances (m) for nearest neighbours if they were a subgroup member ("within") and if they were not ("between"), per time period[†], food treatment and parity.

Period [†]	Median of inter individual distance				Level of significance [‡]			
	Low		High		Subgroup effects (by food level)		Food effects (by subgroup status)	
	within	between	within	between	Low	High	within	between
Parity 1								
1	1.50	1.99	1.69	2.07	*	*	NS	NS
2	1.00	1.76	1.31	1.67	***	*	NS	NS
3	1.09	1.51	1.40	1.63	***	*	NS	NS
4	1.16	1.46	1.06	1.67	*	***	NS	NS
5	1.34	1.50	1.32	1.78	NS	***	NS	NS
6	1.11	1.45	0.89	1.55	*	***	NS	NS
7	1.22	1.47	0.82	1.51	NS	*	NS	NS
Parity 2								
1	1.47	2.26	1.51	2.32	**	***	NS	NS
2	1.40	2.01	1.13	1.79	**	***	NS	NS
3	1.39	1.72	1.51	1.84	NS	NS	NS	NS
4	1.55	1.86	1.42	1.61	NS	NS	NS	NS
5	1.38	1.88	1.19	1.70	NS	**	NS	NS
6	1.15	1.56	0.85	1.65	**	**	NS	NS
7	-	-	1.23	1.60	-	NS	-	-

[†] Time periods were: 1: introduction day, 2: day 7 - 17 post introduction, 3: 15-28 days, 4: 29-42 days, 5: 43-56, 6: 57-70 days and 7: 71+ days post introduction.

[‡] Differences between Low and High food treatment, and between and within subgroups were tested using the Mann-Whitney test.

DISCUSSION

Effects of Time Since Introduction and Parity Number

Average location

The average daily position (measured between 0900 and 1500 hours) changed during gestation with pigs on treatments moving towards the part of the lying area furthest away from the feeding and dunging areas. Second parity animals "started" further away from the lying area than first parity animals. This shift of average location towards the quieter areas of the building may be caused by one (or a combination) of two factors. Firstly, the feeding order in electronic sow feeder systems is mainly determined by the relative social ranking of the animals (e.g. Hunter *et al.*, 1988; Tanida *et al.*, 1993). In the present study this meant that dominant sows would have fed shortly after the start of the food cycle at 1800 hours. As a result, they would have spent more time *on average* in the lying area away from the feeder during the day time observation periods, than subordinate animals. A second explanation assumes that the quieter areas (where least disturbance can be expected from sows walking to and from the feeding and dunging areas) contain the preferred lying places. Dominant animals will be able to claim and defend these areas more readily. Several studies have shown that social rank in dynamic groups (measured using feeding orders) is not just related to the age of the animal, but also to the stage of pregnancy (Hunter *et al.*, 1989; Bressers *et al.*, 1993). Sows which have spent longer in the dynamic group may therefore be more successful in competing for access to food, as well as defend preferred lying areas.

Spatial association between individuals

The different spatial parameters used in the present study appear to give different answers to the question of social integration. When comparing average distances between animals of the same subgroup with those of different subgroups, both Mann-Whitney tests as well as Mantel tests suggest within-subgroup distances to be smaller than between-subgroup distances at least until day 28 post introduction. After that the comparisons become inconsistent: L subgroups appear to remain segregated for the duration of their stay in the group when data is tested using the Mann-Whitney test, but not when using the Mantel test. For H subgroups the two statistical tests are in agreement (i.e. integration established by the end of period 3). Spoolder *et al.* (1996) found average distances between previously unfamiliar pigs not to be significantly different from distances between familiar pigs after 21 days. In contrast, in the present study, the proportion of time sows spent within two meters of each other is significantly higher for sows from the same original subgroup compared with sows from different subgroups, throughout the whole of their stay in the main group (71 days +). The Nearest Neighbour data from this study backs this up, albeit that the differences (particularly in parity 2) are less consistent.

This suggests firstly, that calculating and comparing average distances is not sufficient to assess spatial integration. An obvious explanation for the differences between the methods is that average distances are influenced by distances too high to have social significance. A large proportion of all distances measured fall outside the range within which individual animals can exert a degree of control. All these distances may be classified as similar by the animal, but the effect of different distances on the average (the mean, or to a lesser extent the median) may be significant. In theory, the Nearest Neighbour distances calculated in our study are similarly affected by this. Moore *et al.* (1993) also looked at a measure of spatial organisation indirectly related to distance, when studying

the integration of newly introduced animals into resident groups for 21 days post-introduction. They calculated the proportion of subgroups with new as well as resident sows (their definition of a subgroup being "all pigs which lie directly or indirectly in contact with each other"), and found that random subgroup formation had only been achieved by the end of their study in one of their three replicates. Again, the lack of control an animal has over who it is spatially related to (using the above definition) may be partly to blame for the lack of consistency in Moore *et al.*'s (1993) results.

The second conclusion which can be drawn from the data on spatial associations is that, based on the Proportion data and the percentage of nearest neighbours which are subgroup members, complete assimilation of newly introduced sows is not achieved by the end of gestation. From the data presented here, as well as results presented previously, it appears that in commercially housed pigs, the integration of new animals is a staged process. The first stage involves a rapid decrease in overt aggression between familiar and unfamiliar animals during the first few days (Bokma and Kersjes, 1988; Spoolder *et al.*, 1997) through the establishment of social hierarchies (or "avoidance orders" - Jensen, 1982). The second stage involves an increased sharing of the same pen areas. Moore *et al.* (1993) found a disproportionate amount of newly introduced animals were still using the dunging area for resting at the end of their study (21 days post introduction). However, their stocking density (total area available: 1.45 m² per pig) was relatively high compared to that in the current study (2.35 m² per pig *excluding* Dunging and Feeding area). Sows in the present experiment showed a gradual migration towards preferred locations, after the initial sharp drop (before day 7) in the use of the Outside area. A better indicator of the degree to which areas are shared may be the apparent lack of differences between average distances within subgroups and between subgroups from approximately 25 days onwards, as discussed before. The third and final stage is completed when within a relatively close range of an individual, previously unfamiliar and familiar animals can be found randomly distributed. The Proportion data of the present study suggests this stage was not achieved in our groups of dynamic sows.

Space allowance plays an important part in determining the level of spatial integration. At high stocking rates, dominant animals will have a greater level of control over the spatial organisation of the group as a whole. Very low stocking rates may also affect social integration negatively. Studies of sheep by Dwyer and Lawrence (1997) suggest spatial segregation of two breeds is far more pronounced when they were grazed in a large field compared to a small one. Individual preferences, as opposed to social control by a part of the population, is likely to be an increasingly important factor influencing spatial organisation when stocking rates decrease.

Effects of Food Level

Average location

During parity 1, sows on the Low food level spent significantly less time Outside, and significantly more time in the Feeder area, compared to H sows. The data on average location of the animals confirm this to a certain extent: the L sows occupy an average location situated in the Feeder area up to approximately day 28. This effect of food level was not found in parity 2. A possible explanation would be that high fed sows will spend more time near the drinkers (situated outside) because their higher food intakes will increase their requirement for drinking water (Friend, 1973). L sows will have had a lower physiological need for water, but the level of food they were offered meant they were highly food motivated for most of the day (Lawrence *et al.*, 1988), possibly more so immediately after feeding than before (Wiepkema, 1971) resulting in prolonged periods of interest

in the feeder. In parity 2 sows will have been more experienced and they are more likely to have fed during the night (unpublished data from this experiment), reducing the differences in area use between the two food treatments.

Spatial association between individuals

Differences between food levels were either absent, or highly inconsistent. Average distances between animals from different subgroups, for example, were significantly higher on the L treatment during part of parity 1 (approximately 15 - 42 days), compared with the H group. This potentially indicated that the more food motivated L sows chose to associate less with unfamiliar animals for a longer period of time after introduction compared to H sows. However, this effect of food level was not repeated in parity two. Also, low fed sows did not appear to keep a greater average distance to their nearest neighbours, compared to H sows. Therefore, the present study does not provide sufficient data to support the hypothesis that food motivation in domestic sows is related to the amount of personal space claimed by the animals. As discussed in Spoolder *et al.* (1997) a potential explanation for the apparent discrepancies in behavioural responses to food motivation may lie in the provision of a foraging substrate. Weber *et al.* (1993) suggested that the provision of a deep litter on commercial units reduced the level of skin lesions in ESF fed sows. Buré (1991) and Van Putten and Van De Burgwal (1990) both found that provision of additional fibre reduces the incidence of aggressive behaviour. It can be speculated therefore that the presence of a deep straw bed in the current experiment helped to buffer some of the frustration due to the chronic food motivation the animals were subjected to. Potentially this may have resulted in less behavioural differences between the two food treatments, than would have been found in a more barren, unstrawed environment.

CONCLUSIONS

The data suggest that any food level effects on the spatial organisation of domestic sows housed in large groups is primarily related to feeding motivation, with hungry sows spending more time near the feeder. Food level does not appear to influence inter-individual distances *per se*. The integration of new animals into a resident group is a staged process, of which the final stage (random distribution of previously familiar and unfamiliar animals within a 2 meter radius of any one pig) may not have been achieved 71+ days after introduction.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of the Ministry of Agriculture Fisheries and Food. SAC also receives financial support from the Scottish Office Agriculture Environment and Fisheries Department. We would like to thank Jackie Burbidge for her help in collecting the data, Dave Hunt for setting up the structure of the Mapdata file, Steve Malkin and Paul Bowden for entering all individual sow locations on the computer and Wilma Spoolder for endless patience during earlier attempts to transfer the data manually.

REFERENCES

- Bokma, S. and Kersjes, G.J.K. 1988. The introduction of pregnant sows in an established group. In: *Proceedings of the International Congress on Applied Ethology in Farm Animals, Skara 1988* (Ed. by J. Unshelm, G. van Putten, K. Zeeb and I. Ekesbo), pp. 166-169. Darmstadt: KTBL.
- Bressers, H.P.M., te Brake, J.H.A., Engel, B. and Noordhuizen, J.P.T.M. 1993. Feeding order of sows at an individual electronic feed station in a dynamic group-housing system. *Applied Animal Behaviour Science*, 36: 123-134.
- Bure, R.G. 1991. The influence on vulva biting of supplying additional roughage in an electronic sow feeder. In: *Proceedings of the 42nd annual meeting of the European Association for Animal Production, Berlin 1991* (Ed. by Commission on Animal Management and Health), pp. 1-5. Darmstadt: KTBL.
- Duncan, I.J.H. and Wood-Gush, D.G.M. 1971. Frustration and aggression in the domestic fowl. *Animal Behaviour*, 19: 500-504.
- Dwyer, C.M. and Lawrence, A.B. 1997. Social relationships between ewes of two breeds. In: *Animal Choices*, BSAS Occasional Publication No. 20 (Ed. by J.M. Forbes, T.L. Lawrence, R.G. Rodway and M.A. Varley), pp. 92-93. Edinburgh: British Society of Animal Science.
- Friend, D.W. 1973. Self-selection of feeds and water by unbred gilts. *Journal of Animal Science*, 37: 1137-1141.
- Genstat 5 Committee, 1987. *Genstat 5 Reference Manual*. Oxford: Oxford University Press.
- Graves, H.B. 1984. Behavior and ecology of wild and feral swine (*Sus scrofa*). *Journal of Animal Science*, 58: 482-492.
- Hunter, E.J., Edwards, S.A. and Simmins, P.H. 1989. Social activity and feeder use by a dynamic group of 40 sows using a sow-operated computerised feeder. In: *Proceedings of the Winter Meeting of the British Society of Animal Production*, (Ed. by BSAS). Edinburgh: British Society of Animal Science.
- Jensen, P. 1982. An analyses of agonistic interaction patterns in group-housed dry sows - aggression regulation through an "avoidance order". *Applied Animal Ethology*, 9: 47-61.
- Lawrence, A.B., Appleby, M.C. and Macleod, H.A. 1988. Measuring hunger in the pig using operant conditioning: the effect of food restriction. *Animal Production*, 47: 131-137.
- Manly, B.F.J. 1986. *Multivariate statistical methods. A primer*. London: Chapman and Hall.
- McBride, G. 1971. Theories of animal spacing: the role of flight, fight and social distance. In: *Behavior and Environment*, pp. 53-68. New York: Plenum Press.
- McCort, W.D. and Graves, H.B. 1982. Social dominance relationships and spacing behavior of swine. *Behavioural Processes*, 7: 169-178.
- Microsoft Excel, 1992. *Excel User Guide*. Redmond: Microsoft Corporation.
- Minitab Inc., 1993. *Minitab Reference Manual*. Lebanon: Sowers Printing Company.
- Moore, A.S., Gonyou, H.W. and Ghent, A.W. 1993. Integration of newly introduced and resident sows following grouping. *Applied Animal Behaviour Science*, 38: 257-267.
- Petersen, H.V., Vestergaard, K. and Jensen, P. 1989. Integration of piglets into social groups of free-ranging domestic pigs. *Applied Animal Behaviour Science*, 23: 223-236.
- van Putten, G. and van de Burgwal, J.A. 1990. Vulva biting in group-housed sows: preliminary report. *Applied Animal Behaviour Science*, 26: 181-186.
- Schnell, G.D., Watt, D.J. and Douglas, M.E. 1985. Statistical comparison of proximity matrices: applications in animal behaviour. *Animal Behaviour*, 33: 239-253.

- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B. Edwards, S.A. and Simmins, P.H., 1996. Social recognition in gilts mixed into a dynamic group of sows. *Animal Science*, 62: 630.
- Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Lawrence, A.B. and Simmins, P.H., 1997. Effects of food level on performance and behaviour of sows in a dynamic group-housing system with electronic feeding. *Animal Science*, 65: 473-482.
- Svendsen, J., Andersson, M., Olsson, A.C., Rantzen, D. and Lundqvist, P. 1990. Group housing of sows in gestation in insulated and uninsulated buildings [Grupphållning av dräktiga suggor i isolerade och oisolerade stallar]. In: Report 66 of the Swedish University of Agricultural Sciences. Lund: Swedish University of Agricultural Sciences.
- Tanida, H., Motooka, A., Seki, K., Tanaka, T. and Yoshimata, T. 1993. The feeding behavior of group-housed pigs using a computerized individual feeding system. *Animal Science and Technology*, 64: 455-461.
- Wiepkema, P.R. 1971. Positive feedbacks at work during feeding. *Behaviour*, 39: 266-273.
- Weber, R., Friedli, K., Troxler, J. and Winterling, Ch. 1993. The influence of computerized individual feeding system on the behaviour of sows. In: *Livestock Environment IV*, (Ed. by E. Collins and C. Boon), pp. 495-501. St Joseph Michigan: American Society of Agricultural Engineers.

Chapter 5

INDIVIDUAL BEHAVIOURAL DIFFERENCES IN PIGS: INTRA- AND INTER-TEST CONSISTENCY

Hans A.M. Spoolder^{1,2}, Jackie A. Burbidge^{1,2}, Alistair B. Lawrence²,
P. Howard Simmins^{1†} and Sandra A. Edwards²

¹ ADAS Terrington, Terrington St. Clement, King's Lynn, Norfolk PE34 4PW, UK

² SAC, West Mains Road, Edinburgh, EH9 3JG, UK

[†] Present address: Rhône-Poulenc Animal Nutrition, 42 Avenue Aristide Briand,
BP100, 92164 Antony, France.

Published in: Applied Animal Behaviour Science (1996) 49: 185-198.
Reproduced by permission of Elsevier Science Publishers B.V.®

INDIVIDUAL BEHAVIOURAL DIFFERENCES IN PIGS: INTRA- AND INTER-TEST CONSISTENCY

H.A.M. Spoolder, J.A. Burbidge, A.B. Lawrence, P.H. Simmins and S.A. Edwards

ABSTRACT

Individual differences in behavioural responses are of increasing interest in the behavioural sciences. There could be enormous benefits for animal husbandry if a test could be developed that would identify categories or types of individuals unlikely to cope with subsequent challenges. The present study compared the behavioural responses of two series of 16 groups ($n = 6$ or 7 gilts) under 4 different circumstances: Situation 1: an open field with a novel stimulus (bucket or human); Situation 2: individual access to food for 15 minutes after a 20 hour period of food deprivation; Situation 3: competition for food after food deprivation; Situation 4: general activity and feeding behaviour in a group over a 24 hour period. Situations 1 and 2 were assessed 4 and 3 times over a 2 and 1 week period, respectively. Both showed high levels of consistency in the behavioural responses of the gilts. Principal components analyses was used to reduce the number of variables per test situation and facilitate measurement of consistency across test situations. The amount of variation explained by the first component was generally more than twice that explained by any subsequent components. The only significant correlation between factor scores calculated from the first components was found between Situation 1 and 2 in the first series. None of the calculated factor scores showed bi- or multimodal distributions. We conclude that, whilst over a short period of time gilts respond consistently to a specific challenge, they do not display the same consistency when challenged in a different context. This lack of inter-situation correlations, plus the absence of multimodal distributions, fails to support the view that behavioural "types" of gilts exist.

INTRODUCTION

Individual differences in behavioural responses between animals are of increasing interest in the behavioural sciences (e.g. Mendl and Harcourt, 1988; Manteca and Deag, 1993; Kerr and Wood-Gush, 1987). There could be enormous benefits for animal husbandry if a simple test could be developed that would identify animals that have difficulty in adapting to challenges in later life. The possibility of identifying stable behavioural characteristics would also aid understanding of the origins of individual differences in behaviour, giving insight into behavioural mechanisms.

The study of individual differences has so far examined a number of individual behavioural characteristics, such as the position in the social hierarchy (Schjelderup-Ebbe, 1922), attack latencies in mice and rats (Van Oortmerssen 1985, Benus *et al.*, 1987), timidity in goats (Lyons *et al.*, 1988) and responses to handling in pigs (Lawrence *et al.*, 1991) and dairy cattle (Dickson *et al.*, 1970).

These studies have been largely based on within-test consistency (i.e. the consistency in behavioural response over time to an identical or similar test situation: e.g. Lyons *et al.*, 1988; Kerr and Wood-Gush, 1987). The existence of behavioural categories within a species would be strengthened by evidence showing consistency in responses over several test situations: different

"types" of animals would be expected to respond differently in a range of circumstances. There have been few studies of consistency of behavioural responses in different tests or situations, and these studies have so far given conflicting evidence. Lawrence *et al.* (1991) and Jensen *et al.* (1995) failed to find any correlations between responses to social and non-social challenges in pigs. In dairy cattle, Dickson *et al.* (1970) did not find any correlation between temperament and social dominance. However, Benus *et al.* (1987) found significant correlations between responses to a changing environment and attack latency in mice and rats. In their experiments they identified "active" and "passive" copers. They conclude that active copers in general have short attack latencies and more easily develop routine-like behaviour, whereas passive copers have longer latencies of attack and more readily adapt their behaviour to a changing environment. More recently, Hessing *et al.* (1993) found correlations between the responses of piglets being manually restrained on their backs and their responses to social encounters. He argued that (young) pigs can also be classified as active or passive responders.

The present experiment was designed to investigate the existence of categories or types of pigs, by studying the correlation between behavioural responses to a series of different situations. The underlying assumption was that if distinct categories of animals exist, they will respond differently to different test situations, and correlations within animals between situations will become apparent. Each of the studies was repeated if possible, to also investigate within situation consistency. This report is part of a larger study to investigate if behavioural responses of young gilts to different challenges predicts subsequent behavioural development and physical performance over two parities.

MATERIALS AND METHODS

Animals and Care

The first series of studies used 112 gilts (PIC Camborough; weight 55.9, sem 0.7kg; age 104.6, sem 0.7 days) which arrived monthly on the experimental unit in groups of 14 after a quarantine period of 3 weeks on an isolated part of the farm. On introduction to the experimental building the gilts were weighed and their back fat was measured. Each group was subsequently split into 2 groups of 7, keeping the variation in weight and back fat thickness within each new group to a minimum. The gilts were then housed in a strawed and kennelled area. They were given *ad libitum* access to water and feed (containing on average 151g protein, 55g oil, 60g fibre, 64g ash, 6.9g lysine and 12.6 MJ DE per kg), and allowed to settle for 2 weeks before testing started. One gilt died during the settling period and was not replaced.

The second series of studies, almost identical to the first, started 2 months after the first finished. For this series 96 new gilts were used (weight: 62.2, sem 0.6kg; age: 114.3, sem 1.5 days), arriving monthly in groups of 12, each split into 2 groups of 6.

Test Situations

The studies took place over a period of 18 months. Experimental conditions were standardised throughout, although some environmental parameters (e.g. temperature) may have fluctuated.

Response to novelty

The first study to be carried out after the 2 week habituation period was aimed at investigating the individual animals' responses to a novel stimulus in an open field situation. This was the only study to be changed between the first and the second series.

First series. This study was carried out 4 times over 2 weeks, with 2 different novel stimuli: a bright yellow bucket and a person wearing a clean pair of white disposable overalls. The stimuli were presented alternately on different days, starting with the bucket. The experimental pen consisted of 2 normal pens (one of the kennels was blocked off, Figure 1) with the separating gate removed, and measuring 2.6 x 6.2 for the dunging area and 1.2 x 3.1 m for the kennel.

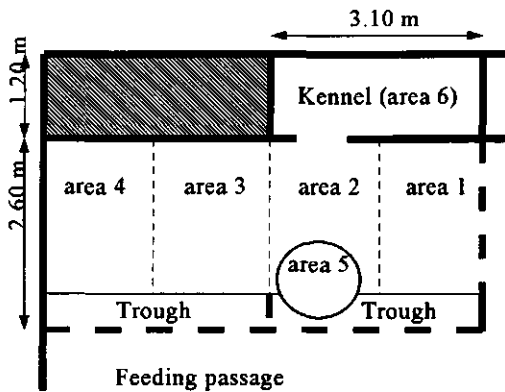


Figure 1

The test pen used during the novel stimulus studies. Area 5 had a radius of 0.5 m and contained the novel object.

The dunging area was provided with fresh long straw at the start of each test day. Both stimuli were positioned in front of the kennel door, the bucket being suspended from the ceiling approximately 20cm above the straw. An observer sat behind a wooden panel in front of the pen; only the observer's head was in view of the animal. During testing no visual or tactile contact was possible between the test gilt and the rest of her group.

Individual gilts were separated in a random order from their group and allowed a 5 minute habituation period in the kennel of the experimental pen. The observation period started with the opening of the sliding kennel door. Continuous behavioural records were made of behaviour directed towards the novel stimulus (observing; in contact; neither) and the area of the pen being used (kennel; within 0.5m of the stimulus; other). Data were recorded using an Atari portfolio computer (Atari Co., Sunnyvale, CA 94086, USA) and the data collection programme Keybehaviour (Deag, 1990). Each gilt was observed for 5 minutes, after which time it was returned to the home pen.

Second series. In the second series the study was modified by removing the human stimulus and increasing the number of tests with the bucket to three. The focal sampling technique was replaced by instantaneous sampling: the behaviour, any substrates used, the vocalisations and the location of the gilt were recorded every 20 seconds during the 5 minutes observation period (Table 1). From this, the proportion of time the animal spent performing the various behaviours was estimated.

Table 1

List of behavioural categories used during the second series of Responses to Novelty studies.

Observing the object	Observation of the object
Locomotion	Any locomotory activity
Manipulating substrates	Rooting, licking, chewing, nosing, biting or lifting any available substrate in the pen
Manip. straw	As above, for straw
Manip. entry/exit gate	As above, for the entry / exit gate
Manip. bucket	As above, for the bucket
Manip. other pen comp.	As above, for pen components other than straw, gate or bucket
No vocalisation	No vocalisations for 5 seconds prior to the scan being sampled
Grunting	Grunting during the 5 seconds prior to the scan being sampled
Squealing/screaming	Squealing or screaming during the 5 seconds prior to the scan being sampled
Near entry/exit gate	The head of the animal was within 1 m of the entry / exit gate of the pen
Near object	The head of the animal was within 50 cm of the bucket
In kennel	The head of the animal was in the kennel.

Food motivation

The gilt's motivation to feed after a set period of food deprivation was studied during the third week following habituation. The *ad libitum* hoppers were removed at 17.00 hours on day 1 and all animals group fed between 16.00 and 17.00 hours on day 2. The gilt's responses were then observed on days 3, 4 and 5 of that week. All gilts were group fed until satiation after each test, and the hoppers were replaced at the end of day 5.

Gilts were tested in a random order every day between 14.00 and 16.00 hours. Individuals were taken out of their groups, entered into a pen similar to their home pen and presented with 1.5 kg of food. Continuous behavioural records were taken for 15 minutes from the start of feeding. Observations were made using three categories of behaviour: feeding (gilt chewing food and head within 50cm of the trough), chewing (gilt chewing food but head more than 50cm from trough) and any other behaviour. These behaviours were chosen as they reflect the level of interest which is shown towards the food in comparison with the relatively new environment of the test pen: an animal which interrupted its feeding behaviour less often was presumed to be more motivated to feed and less responsive to its surroundings. The remainder of the food was weighed back after the animal was returned to its home pen.

For each of the 3 behavioural categories total time and number of bouts were calculated. In addition the length of the first feeding bout was calculated as well as the total amount eaten.

Social status

The position of the gilts in the social hierarchy was tested during the fourth week after habituation. The hoppers were removed at 17.00 hours of day 1. Observations were carried out on

days 2 to 5, and lasted 30 minutes each. As in the Food Motivation situation animals were fed until satiation after testing, and the ad libitum hoppers were replaced at the end of day 5.

All gilts in the group were given a back number to aid identification. The studies commenced mid afternoon by putting a small amount of food in the trough, so that a maximum of 3 gilts could feed at any one time. All aggressive interactions, resulting in a clear winner and loser, were recorded, stating the aggressor, the receiver and the outcome of the interaction. In addition, the identity of any gilts feeding was recorded every 5 minutes.

The data from all four observation periods were combined, and from this a dominance score (DS) was calculated based on a method originally described by Reinhardt and Reinhardt (1975). Dominance was assigned to a member of a dyad where there were at least 2 active competitive encounters with the same outcome. Where reversals were present, a ratio of at least 3:1 was required to assume dominance of one member of the dyad. The dominance score for each animal was then calculated as the number of group members dominated divided by the total number of relationships established. The feeding success (FS) of the gilts was calculated as the number of times a gilt was observed feeding, divided by the total number of time samples.

Activity score

General activity levels in the group were measured over 24 hours during the latter part of the test weeks. A video camera (Ikegami ICD-42E, Ikegami, Ohta-ku, Tokyo, Japan) was used with a wide angled lens and a time lapse video recorder (Panasonic AG6720, Matsushita Electric Industrial Co., Osaka, Japan) set on a 72 hour recording mode. An uninterrupted 24 hour section was selected of the tape, and for each gilt location (kennel or strawed dunging area), posture (standing, sitting, kneeling or lying), any behavioural activity (yes or no) and, more specifically, feeding (yes or no) were recorded every 15 minutes. Behaviour of gilts in the kennel could not be recorded, and they were assumed to be lying, inactive and not feeding. All activities were then calculated as a proportion of the total observation time.

Statistical Analyses

Data from the first and the second series of studies were analysed separately. Kendall's coefficient of concordance was used to determine individual behavioural consistency between replicates of the Food Motivation and the Response to Novelty situations, following the procedure described by Siegel and Castellan (1988). Friedman's two-way analysis of variance by ranks (Siegel and Castellan, 1988) was used to test for overall differences (e.g. due to habituation) between the three replicates of the Food Motivation study in both series and the Response to Novelty study in the second series. In the Response to Novelty study in the first series a Wilcoxon signed ranks test was used to test for differences over the two replicates of the study (Siegel and Castellan, 1988).

The variables from the different test situations were compared using the Spearman rank-order correlation coefficient (Minitab Inc., 1993), resulting in a large number of correlations. Principal components analysis (PCA), generally used to explain the biological relationship between variables, was subsequently used to reduce the number of variables within each test situation. A detailed description of the two main steps involved, the calculation of the "components" and the resulting "factor scores" can be found in Huntingford *et al.* (1976) and McGregor (1992) respectively. Factor scores were calculated when the component's Eigen value was greater than 1. This cut-off was used for mathematical reasons: components with Eigen values > 1 explain more variation than a single

standardised original variable (Manly 1986, p.65). The biological significance of the components retained this way was not always easy to interpret.

All factor scores were tested for Normality, using Minitab 9 for Windows (Minitab Inc., 1993), which uses a test essentially similar to that of Shapiro and Wilk (1965). Any factor scores which were not normally distributed were analysed by creating histograms, with at least ten classes, to be able to score subjectively for bi- or multi-modality. The factor scores for different test situations were compared using the Spearman rank-order correlation coefficient (Minitab Inc., 1993).

RESULTS

Intra-Test Consistency

Response to Novelty, first series

Some differences were found in the averaged responses to the bucket and the human situations: latency to contact the human was lower (Wilcoxon's $T+ = 1349$, $z = -6.76$, $P < 0.001$), and total time in contact longer ($T+ = 785$, $z = -9.42$, $P < 0.001$) than the bucket. Within objects, there was a level of adaptation, which was especially clear in the gilts' observation of the stimuli: e.g. latency to observe was longer ($T+ = 2019$, $z = -2.70$, $P < 0.01$), and time spent observing shorter ($T+ = 801$, $z = -7.25$, $P < 0.001$) in the second replicate of each situation compared with the first. The behaviour of each gilt was consistent however, relative to the other animals that were being tested. Over all four studies, most of the 11 variables obtained showed significant levels of within-animal consistency (Table 2). The only inconsistencies found were in the frequency of kennel visits and in the "observe" variables.

Table 2

Mean frequency (number of bouts), latency to first occurrence (s) and proportion of total time spent performing the behavioural activity (out of 300 s) in the first series of the Response to Novelty studies. Kendall's coefficient of concordance (W; a test of individual consistency of response over the four replicates) is also given.

Variable	Replicate				W	χ^2	
	Bucket 1	Human 1	Bucket 2	Human 2			
Freq. in kennel	1.5	1.4	1.4	1.3	0.252	110.1	***
Time in kennel	0.07	0.05	0.05	0.04	0.489	213.5	***
Lat. near stimulus	40.2	29.8	35.7	19.2	0.418	182.5	***
Freq. near stimulus	5.1	4.1	3.8	3.9	0.405	176.6	***
Time near stimulus	0.22	0.29	0.15	0.29	0.449	191.6	***
Lat. to observe	18.8	16.0	37.4	33.8	0.284	124.2	
Freq. observing	7.3	7.4	3.6	4.1	0.259	113.2	
Time observing	0.07	0.07	0.03	0.04	0.309	135.1	*
Lat. to contact	49.9	33.8	43.5	24.0	0.393	171.5	***
Freq. of contact	4.9	5.0	3.0	4.3	0.396	172.9	***
Time in contact	0.11	0.18	0.05	0.17	0.436	190.5	***

A PCA was carried out on the results of the two Novel Stimuli separately. Both resulted in 4 components with Eigen values greater than 1. The pattern of loadings on the first components was highly consistent, and components two and three were also very similar. Component 4 differed between the two situations.

Given the strong indications of consistency between the tests, the results were averaged, and a principal components analysis on the means per sow was carried out. PCA of the test resulted in 4 components with Eigen values greater than 1 (Table 3). Together they represented 0.77 of the variation. The first component, which accounted for 39% of the variation explained, showed negative loadings for frequency and time spent near the novel stimuli, and frequency and time spent in contact with the stimuli. Animals scoring low on this component can therefore said to be less fearful than animals scoring high. The behavioural meaning of the other three components, which were all mathematically significant contributors, was less easy to explain.

Table 3

First four components for the 11 analysed variables in the first series of the Response to Novelty studies, plus their Eigen value and the proportion of the total variation they explain (for explanation see text).

	Component			
	1	2	3	4
Eigen value	4.27	1.77	1.37	1.03
Propor. variance	0.388	0.161	0.124	0.093
Freq. in kennel	0.182	-0.103	-0.279	0.718
Time in kennel	0.356	-0.122	0.117	0.354
Lat. near stimulus	0.405	-0.086	0.185	0.163
Freq. near stimulus	-0.345	-0.165	-0.246	0.276
Time near stimulus	-0.330	-0.280	0.456	0.117
Lat. to observe	0.098	0.344	0.506	0.114
Freq. observing	0.132	-0.583	-0.244	-0.123
Time observing	0.177	-0.550	0.143	-0.342
Lat. to contact	0.369	-0.113	0.240	0.076
Freq. of contact	-0.398	-0.115	-0.027	0.224
Time in contact	-0.309	-0.273	0.459	0.202

The normal probability plots and the test for normality did not show a deviation from a normal distribution in any of the four sets of factor scores. The correlation coefficients between the normal scores and the original factor scores were 0.964, 0.990, 0.974 and 0.976 for the first four sets of factor scores respectively.

Response to Novelty, second series

Most of the behavioural categories analysed were consistent over the three replicates (e.g. proportion of "no vocalisation": 0.66, 0.60 and 0.71; Kendall's $W = 0.736$, $\chi^2=192.0$, $P<0.001$). Categories that were not consistent included manipulation of the bucket and presence within 0.5m of it. Some behaviours showed a significant downward or upward trend (e.g. proportion of time spent manipulating straw: 0.18, 0.26 and 0.32, Friedman's $Fr = 24.27$, $P<0.01$) suggesting a degree of habituation to the test object.

The principal components analysis identified five components with Eigen values greater than 1. Together they explained 0.81 of the variation, of which the first component explained 0.38. The loadings of the first component were positive for behaviours and locations that could be associated with restlessness: time spent near the entrance/exit gate, alertness, walking and vocalisations. Negative loadings were found for behaviours associated with exploration. The biological meaning of the other four components was less obvious. The factor scores calculated from the first five components were normally distributed: correlations between factor scores and their Normal scores were 0.988, 0.990, 0.995, 0.992 and 0.997 respectively.

Food Motivation

In both the first and the second series the animals were very consistent in their response to the test situation (e.g. Series 1: average proportion of time spent feeding for replicates 1, 2 and 3 respectively: 0.83, 0.80 and 0.76; Kendall's $W = 0.664$; $\chi^2 = 189.3$; $P < 0.001$). The results of each series were therefore averaged over the three replicates.

PCA resulted in very similar components for both series. Two were found to have Eigen values greater than one. The first component in each series attributes positive loadings to time spent feeding, length of the first feeding bout and the total amount eaten, and negative coefficients for all the other variables: animals with a high factor score for this component were more food motivated and less distracted by their environment than animals with a low score. In series 1 and 2 these first components explained 0.69 and 0.63 of the variation respectively. The second component highlights behaviours other than chewing and feeding, possibly accentuating a second behavioural axis relating to inquisitiveness. They each explained 0.19 of the variation.

The test for normality showed correlations between the factor scores and their Normal scores ranging from 0.970 to 0.994. All four calculated factor scores were therefore presumed to be normally distributed.

Social Status

The total number of interactions per 30 minute replicate periods averaged 27.1 (std=17.9), and was not sufficient to determine the relationships between individuals in their groups. Data from the four periods were therefore combined. In the first series 52% (std=10.6%) of all possible relationships could be identified, and 59% (std=10.4%) in the second. There were no typically clear or unclear groups. In general 1 animal in each group was dominant in all the relationships established, and 2 or 3 animals either did not engage in any aggressive interactions, or were subordinate in every dyad.

The four variables tested with PCA were number of interactions lost (IL), number of interactions won (IW), the dominance score based on the number of dominance relationships (DS) and the proportion of scans the animal was observed feeding (FS). In each series only one component had an Eigen value greater than 1 (0.53 and 0.63 of variation explained). The emphasis in both was on dominance, with IL showing strong negative loadings, whereas the other variables showed strong positive loadings.

The Normal scores and the factor scores had a correlation of 0.975 and 0.984 respectively. Both histograms of the factor scores showed a skewed distribution, with the positive factor scores (the more "dominant" animals) having a longer tail than the negative ones (Figure 2).

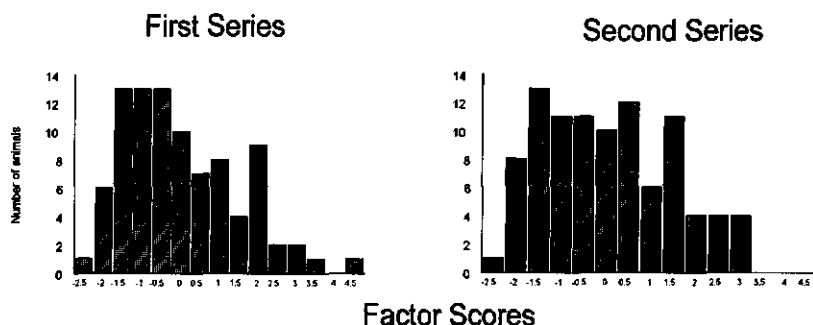


Figure 2
The distribution of the factor scores calculated using the first components of the social status studies in Series 1 and 2 (for explanation see text).

Activity Score

Time spent in kennel, total time standing, time spent feeding and total time active were analysed by PCA. Two components in the first, and 1 component in the second series had Eigen values over 1. The loadings for the first components in both series were similar (variation explained: 0.69 and 0.63 respectively), and only negative for the time spent in the kennel (where the animal was presumed to be inactive, lying and not feeding). The second component of the first series emphasised feeding behaviour, but the amount of variation explained was substantially lower (0.19).

Inter-Situation Consistency

The Spearman rank correlations between all the variables in each of the four situations were calculated and in general they were very low. Of the 250 possible correlations between variables of different situations only 42 (17%) were significant at the 5% level in the first series, and 5 (2%) in the second series. The majority of the significant correlations in the first series (33) were found between the Response to Novelty and the Food Motivation studies. Variables associated with a higher motivation to feed were correlated positively with less time in the kennel and more in the proximity of the novel stimuli. In the second series these findings were not repeated. The only significant correlations that were found in both series were those between Feeding Success in the Social Status study and some Food Motivation variables (e.g. Feeding Success with Time Spent Feeding: $r=0.252$, $P<0.05$ and $r=0.238$, $P<0.05$, for series 1 and 2 respectively).

The factor scores, in which the study variables were effectively condensed, were correlated between situations in both series (Table 4). Because of the large number of correlations a significance level of $P<0.01$ was used.

Table 4

Spearman rank order correlations between the factor scores derived from the different test situations for both the first and the second series. Correlations in bold are statistically significant ($P < 0.01$).

	NS 1	NS 2	NS 3	NS 4	FM 1	FM 2	SS 1	AC 1
<i>1st series</i>								
Novel Stimulus (NS) 2	-							
Novel Stimulus 3	-	-						
Novel Stimulus 4	-	-	-					
Food Motivation (FM) 1	-0.309	0.204	0.168	-0.016				
Food Motivation 2	-0.153	0.102	0.014	-0.095	-			
Social Status (SS) 1	-0.051	0.144	-0.076	-0.228	0.188	-0.069		
Activity (AC) 1	-0.195	0.071	-0.223	-0.016	0.053	-0.002	0.160	
Activity 2	-0.048	-0.079	-0.084	-0.008	-0.076	0.022	0.014	-
	NS 1	NS 2	NS 3	NS 4	NS 5	FM 1	FM 2	SS 1
<i>2nd series</i>								
Novel Stimulus 2	-							
Novel Stimulus 3	-	-						
Novel Stimulus 4	-	-	-					
Novel Stimulus 5	-	-	-	-				
Food Motivation 1	0.094	-0.033	-0.067	-0.073	0.085			
Food Motivation 2	0.054	0.049	0.042	0.280	-0.056	-		
Social Status 1	-0.045	-0.191	-0.038	0.128	-0.152	0.005	0.110	
Activity 1	-0.032	-0.001	-0.031	0.005	-0.022	0.175	-0.032	-0.089

Some significant, but weak correlations were found. The strongest correlation is the one between the first components of the Response to Novelty and the Food Motivation studies in the first series ($r = -0.309$, $P < 0.01$). It suggests that animals which show high levels of food motivation are more likely to investigate the novel stimulus; positive values for the first component of the Food Motivation study corresponded with high food motivation, and positive values for the first Response to Novelty component with a tendency to stay away from the object (Table 3). Any significant values found were however not confirmed in the other series.

DISCUSSION

Both the Response to Novelty and the Food Motivation studies showed that gilts respond consistently to specific challenges, at least over the short term: although there was a degree of adaptation, the relative ranking of the animals' responses did not change. The condensed results, obtained using principal components analyses, highlighted the main response variables within each situation. Only relatively small levels of correlation were found between different factor scores calculated using the components. None of the factor scores showed a deviation from the Normal distribution.

The consistency of the behavioural responses was measured over a relatively short period. Long-term investigations in individual differences have only been reported by a few authors, and generally involved less animals. Lyons *et al.* (1988) found stable differences in timidity in goats

various behaviours in rats to be significantly correlated between two tests 30 days apart. Finally Mendl *et al.* (in press) report consistency in dominance ranking between female pigs tested over 4 pregnancies. The present results do not contradict these findings, but suggests that prepubertal gilts show consistent individual differences in behavioural responses to specific tests.

Individual differences in pigs have very rarely been compared across different motivational systems, and the few results that are available give conflicting evidence. Lawrence *et al.* (1991) and Jensen *et al.* (1995) compared social and non-social challenges, and failed to find a relationship. Meese and Ewbank (1973) did not find any correlation between leadership and exploration in growing pigs kept outdoors. In contrast, Hessing *et al.* (1993) found correlations between escape behaviour from piglets manually restrained on their backs and responses to social encounters.

The main problems in correlating across different test situations are the number of possible correlations *between* situations, resulting in correlation tables which are often difficult to interpret. Furthermore, if there is a high level of consistency *within* situations, there will be a high degree of dependency between variables. In the present report all variables within each of the two series have been correlated pair wise, but only a small proportion of correlations reached a significant level. These significant correlations were not evenly distributed across pairs of studies. General conclusions on the relationships between the main motivational systems under investigation in each situation were therefore difficult to make.

Lyons *et al.* (1988) used a multivariate technique to reduce the number of variables in their study of fear responses in goats. The variables in their tests were highly correlated and were used to produce one component, which explained 76% of the variance. The factor scores calculated using the first component, the "Timidity score", were then correlated with other (physiological) variables. The present experiment went one step further and correlated the factor scores from one test with those of others. This reduced the total number of correlations *between* situations, and allowed for a balanced condensation of the highly correlated variables *within* situations.

The first component in all test situations showed a relatively high proportion of variation explained (typically more than twice the proportion in the second component). Each situation therefore highlighted one behavioural dimension, plus a small number of less prominent ones. If gilts could be classified into a small number of behavioural "types", a high level of correlation would be expected between responses to different challenges. However, only two first component factor scores correlated significantly at the $P < 0.01$ level: Food Motivation and Response to Novelty of the first series. In the second series this correlation was not found. It is very likely that the change of emphasis from object orientated behaviour in the first series to a more general ethogram in the second series, has resulted in different aspects of behaviour being highlighted.

There could be at least three reasons why Hessing *et al.* (1993) found different types and the present study does not. Firstly, the present study was not sensitive enough to identify response categories. This is possible, although consistency within test situations was found, suggesting sufficient data were collected to identify individual differences. Secondly, the piglet's individual character erodes as it gets older: differences in responses become more subtle and may start to differ between situations. The result is not a limited number of categories, but a range of responses within and between challenges. Thirdly, Hessing *et al.*'s method of categorising is, although repeatable, not indicative of the existence of behavioural types. Strictly speaking, different categories or classes only exist if the data is bimodally or multimodally distributed. Based on histogram information, no indication of non-continuous distributions, resulting in a limited number of classes, were found in any of the responses to the present study. Providing there is a degree of intra-test consistency there are

advantages to creating artificial class limits: for example when an intermediate group does not respond in the same way to a different situation as the two extremes (e.g. Mendl *et al.*, 1992). Jensen *et al.* (1994) on the other hand highlights the main problem with artificial classifications: the limits of the categories have been set on an arbitrary basis, and do not constitute any biological differences between individuals on either side of them. The critical question here is whether categories have a predictive value: they may be useful when associations between extreme behavioural responses and, for example, physiology are to be investigated. They can however not be used as proof for the existence of different types of animals within a species.

CONCLUSIONS

The present study aimed to investigate consistency and individuality in behavioural responses of prepubertal pigs to a number of different situations, in order to establish the existence of different behavioural "types". Although our gilts showed consistent behavioural differences, no specific categories were apparent. The data suggests therefore that if categories do exist, they are very likely to be numerous, rather than restricted to two or three. Consistent individual differences in pigs are therefore exactly what they say they are: consistent, but very individual.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of the Ministry of Agriculture, Fisheries and Food. SAC receives financial support from the Scottish Office Agriculture and Fisheries Department. We would also like to thank Francis Brouns for assisting in analysing the data, and Mike Mendl, Piet Wiepkema and Willem Schouten for valuable comments on the manuscript.

REFERENCES

- Benus, R.F., Koolhaas, J.M. and Oortmerssen, G.A. van, 1987. Individual differences in behavioural reaction to a changing environment in mice and rats. *Behaviour*, 100: 105-122
- Deag, J.M., 1990. Keybehaviour - a program for recording data on an Atari Portfolio Computer. Copyright John M. Deag, 10 Fletcher Grove, Penicuik EH26 0JT, UK 46 pp.
- Dickson, D.P., Barr, G.R., Johnson, L.P. and Wieckert, D.A., 1970. Social dominance and temperament of Holstein cows. *Journal of Dairy Science*, 53: 904-907
- Hessing, M.J.C., Hagelso, A.M., Beek, J.A.M van, Wiepkema, P.R., Schouten, W.G.P. and Krukow, R., 1993. Individual behavioural characteristics in pigs. *Applied Animal Behaviour Science*, 37: 285-295
- Huntingford, F.A., 1976. An investigation of the territorial behaviour of the three-spined stickleback (*Gasterosteus aculeatus*) using principal components analysis. *Animal Behaviour*, 24: 822-834
- Jensen, P., Forkman, B., Thodberg, K. and Kostner, E., 1995. Do pigs show consistent behavioural strategies? *Applied Animal Behaviour Science*, 44: 245-256.
- Jensen, P., 1994. Individual variation in behaviour - noise or functional strategies? In: *Proceedings of the 28th Congress of the ISAE, Denmark 1994*. pp. 93-101.

- Kerr, S.C. and Wood-Gush, D.G.M., 1987. Development of behaviour patterns and temperament in dairy heifers. *Behavioural Processes*, 15: 1-16.
- Lawrence, A.B., Terlouw, E.M.C. and Illius, A.W., 1991. Individual differences in behavioural responses of pigs exposed to non-social and social challenges. *Applied Animal Behaviour Science*, 30: 73-86.
- Lyons, D.M., Price, E.O. and Moberg, G.P., 1988. Individual differences in temperament of domestic dairy goats: constancy and change. *Animal Behaviour*, 36: 1323-1333.
- Manly, B.F.J. 1986. *Multivariate statistical methods. A primer*. Chapman and Hall, London.
- Manteca, X. and Deag, J., 1993. Individual differences in temperament of domestic animals: a review of methodology. *Animal Welfare*, 2: 247.
- McGregor, P.K., 1992. Quantifying responses to play back: one, many, or composite multivariate measures? In: *Playback and studies of animal communication*, P.K. McGregor (Ed.), Plenum Press, New York.
- Meese, G.B. and Ewbank, R. 1973. Exploratory behaviour and leadership in the domesticated pig. *British Veterinary Journal*, 129: 251-259.
- Mendl, M. and Harcourt, R. 1988. Individuality in the domestic cat. In: *The domestic cat. The biology of its behaviour* (Eds. D.C. Turner and P. Bateson). Cambridge University Press, Cambridge. pp 41-54.
- Mendl, M., Zanella, A.J. and Broom, D.M., 1992. Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour*, 44: 1107-1121.
- Mendl, M., Zanella, A.J., Broom, D.M. and Whittemore, C.T. Maternal social status and birth sex ratio in domestic pigs: an analysis of mechanisms. In press, *Animal Behaviour*.
- Minitab Inc., 1993. *Minitab Reference Manual*. Sowers Printing Company, Lebanon, PA.
- Negrao, N. and Schmidek, W.R., 1987. Individual differences in the behavior of rats (*Rattus norvegicus*). *Journal of Comparative Psychology*, 101: 107-111.
- Oortmerssen, G.A. van, Benus, I. and Dijk, D.J., 1985. Studies in wild house mice: genotype - environment interactions for attack latency. *Netherlands Journal of Zoology*, 35: 155-169.
- Reinhardt, V. and Reinhardt, A., 1975. Dynamics of social hierarchy in a dairy herd. *Tierpsychologie*, 38: 315-323.
- Schjelderup-Ebbe, T., 1922. Beitrage zur Socialpsychologie des Haushuhns. (Contributions to the social psychology of the domestic chicken) *Zeitschrift Psychologie* 88: 225-252.
- Shapiro, S.S. and Wilk, M.B., 1965. An analysis of variance test for normality (complete samples). *Biometrika* 52: 591-611.
- Siegel, S. and Castellan Jr., N.J., 1988. *Nonparametric statistics for the behavioural sciences*. McGraw-Hill, New York.

GENERAL DISCUSSION

GENERAL DISCUSSION

Introduction

The present thesis addresses the occurrence of two types of behaviours in group housed sows which can be classed as "undesirable": stereotypes (which are generally associated with a poor environment), and aggressive behaviour (which in excessive levels is detrimental to the well being of all pigs involved). Stereotypes were increased in pigs on low food levels without a foraging substrate. In the presence of straw, general activity went up, but stereotyped chain and bar directed behaviours did not increase significantly. Aggression in large groups of sows was not affected by food level, but comparisons with other studies in situations where straw was absent, suggest that the availability of straw may have mitigated the level of aggressive social interactions. The thesis went on to investigate behavioural characteristics which pre-determine gilts to exhibit undesirable behaviours in adult life. However, analyses of gilt responses to a number of test situations failed to identify a common behavioural parameter between test situations, although responses within situations were consistent.

This discussion highlights some of the observations in the preceding chapters which have not yet been addressed in detail, and aims to discuss practical implications of the present thesis, as well as provide suggestions for further research. It is broadly divided into the three main topic areas: "stereotypes in small groups", "aggression in large dynamic groups" and "individual behavioural responses".

Food Motivation and Stereotypic Behaviour in Small Groups of Sows

Group housing may help to improve pig welfare through a reduction of undesirable behaviours, such as oral stereotypes (Vermeer *et al.*, 1996). However, these behaviours, which are generally associated with an inadequate environment (Mason, 1991), are not necessarily eliminated by the provision of more complex social circumstances. Terlouw *et al.* (1991) suggest that the development of stereotypic behaviour is potentially more influenced by the level of food offered to a pig, than by its social situation. The hypothesis proposed by these researchers (see Lawrence and Terlouw, 1993) that the development of stereotypes in chronically food motivated sows is primarily the result of the inability to perform appetitive behaviours, was tested in the study described in Chapter 1 of this thesis. The results indicate that the proposed relationships between food level, foraging substrate and stereotypic behaviour are largely correct. However, a number of areas still need addressing.

Firstly, group housing as such does reduce stereotypes: not only Vermeer *et al.* (1996), but also Terlouw *et al.* (1991) showed a decrease in stereotypic behaviours in group housed sows compared to individually housed pigs. Straw was not provided in either study. It seems therefore logical that the increased complexity of the social environment in conjunction with the total space available, resulted in satisfaction of (part of) the motivation which predisposes stereotypic behaviour. The present thesis indicates that the ability to manipulate straw results in a dramatic decrease in stereotypes, which points towards foraging motivation as a primary drive in explaining the development of stereotypic behaviour (Lawrence and Terlouw, 1993). Although this seems very likely, the ability to explore and interact with other pigs also increases the complexity of the

environment. This reduces the chance that behaviour elements are fixated towards a limited number of pen components, "channelling" them into stereotypic patterns.

Secondly, the idea that the *association* with feeding can provide stimuli which facilitate the start of a bout of stereotypic activity. Terlouw *et al.* (1993) demonstrated elegantly that the ingestion of food can trigger a sequence of stereotypic behaviour. However, Chapter 1, as well as a number of other studies (e.g. Cronin, 1984), suggest that although stereotypic behaviour peaks in the post-prandial period, stereotyping sows will exhibit their behavioural routines for many hours of the day. Unpublished observations of sows in the study described in Chapter 1 point towards a strong relationship between stereotypies and the feeding stalls: the chains provided in the dunging area were very rarely observed to be manipulated for more than a brief period, and never in a stereotypic fashion. The present study, which provided drinkers in the dunging area, also failed to find levels of adjunctive drinking comparable to those found by Terlouw *et al.* (1991), who provided their sows with drinking nipples in the feeder stalls. Clearly, the potential "reward" for drinking water (i.e. a feeling of satiation) is the same whether the drinkers are in the feeder stalls (Terlouw *et al.*, 1991) or in the communal dunging area (Chapter 1, this thesis). However, the accessibility of the drinkers in the period immediately post feeding in the study by Terlouw *et al.* (1991), affected the "choice" of stereotypic routine considerably. It could be argued therefore, that preventing access to areas or pen components which the animal associates with feeding, may further reduce the chance that manipulative oral stereotypies are developed (Lawrence, pers. comm.). A simple experiment, in which groups of sows are being removed to a different pen after feeding, and other groups remain in their home pen, will test this hypothesis.

Thirdly, the question whether straw is the only substrate which reduces the levels of chain and bar directed behaviours, needs addressing. There is sufficient data to suggest that not only stereotypies, but also other behavioural vices such as tail biting, can be reduced by the provision of straw (e.g. McKinnon *et al.*, 1989; Fraser *et al.*, 1991; Beattie *et al.*, 1993). However, approximately 20% of the UK herd (Sheppard, 1996) and nearly all Dutch pig units have either part or fully slatted dry sow accommodation, which are incompatible with straw provision. Limited work has been done on the effectiveness of alternative substrates to modify sow behaviour. Walker and Kilpatrick (1994) showed some effects on the use of pen areas when comparing sows with access to straw, a slatted dunging area or a sawdust-based compost bed. They found that more time was spent in pen areas where substrates were provided, but could not compare straw vs. compost, since straw was provided in the kennels (and the compost was not). Durrell *et al.* (1997) provided spent mushroom compost to their sows and found a reduction in aggression and injuries, compared to sows without a substrate. Data on environmental enrichment in finishing pigs are more widely available. They suggest that not all alternatives are equally successful in reducing levels of pen mate manipulation. A trough with earth has been found to stimulate rooting behaviour in some studies (Wood-Gush and Beilharz, 1983), but was found to be inadequate in the long term in others (Appleby and Wood-Gush, 1983). Peat has been used quite successfully (Beattie *et al.*, 1995), but its use on a large scale can have serious health and environmental implications. The same research group also investigated the provision of spent mushroom compost (Sneddon and Beattie, 1995), and found it to reduce behaviours directed towards pen mates. They found that when given the choice, growing pigs will prefer peat and mushroom compost as foraging and bedding material, compared to straw. Ladewig and Matthews (1996) also investigated pig preferences. They tested the relative efforts pigs are willing to make to get access to different commodities (substrates) in a series of operant conditioning tests, and also looked at the time pigs spent using them. They found that although pigs were willing

to go through a similar level of effort to get access to straw, as they did for sawdust and wood shaving, straw was accessed for longer periods of time. However, Ladewig and Matthews (1996) point out that the results of these tests are not only dependent on, for example, ambient temperature, they also do not tell us anything about the long term behavioural needs of the animals. Further research is needed to a) assess what properties straw has which make it effective in reducing behavioural vices, b) determine what alternatives are equally suitable, and can be used in commercial situations where straw is not an option.

Food Motivation, Aggression and Spatial Organisation in Dynamic Groups

Group housing of dry sows allows the animals more total space and the possibility to interact with conspecifics. As an almost inevitable result, it will involve an element of competition. Pigs which have to share resources, whether they are (access to) food or a comfortable lying place, will compete for them, resulting in an increase in aggression (e.g. Bokma 1990; Edwards, 1992; Svendsen and Svendsen, 1997). These fights are potentially highly detrimental to the welfare of the animals involved. The losing animal generally suffers most, possibly sustaining severe skin damage, abscesses, locomotor problems (Svendson *et al.* 1990; Burfoot *et al.* 1995; Chapter 3, this thesis) and acute psychological stress resulting in an increase in heart rate (Marchant *et al.*, 1995) and cortisol levels (Mendl *et al.*, 1992) during and after the fight. In addition, there are indications that social stress during the early stages of pregnancy may result in decreased fertility (Bokma, 1990; Burfoot, 1997), while aggression incurred at weaning reduces the expression of subsequent oestrus behaviour (Pedersen, 1993). In situations where available resources are limited, lower ranking animals may fail to cope with their social environment entirely and suffer severe weight loss, or in extreme cases, death.

Although fighting between sows potentially has quite serious consequences, the social hierarchy is usually established within two days after introduction of new animals, resulting in a dramatic decrease in aggression (e.g. Bokma and Kersjes, 1988; Leuscher *et al.*, 1990; Chapter 3, this thesis). Generally, this is followed by a comparatively stable period in which the relative social position of individuals facilitates the organisation of the whole group, for example through the development of feeding orders (e.g. Hunter *et al.*, 1988; Bressers *et al.*, 1993) and / or lying patterns (Moore *et al.*, 1993; Chapter 4, this thesis). In contrast, stalled sows have been observed to maintain a degree of aggressiveness towards their neighbours for prolonged periods of time, possibly because they are physically prevented from resolving any dispute satisfactorily (Vestergaard and Hansen, 1984; Barnett *et al.*, 1987).

In dynamic group housing systems the social organisation of the group needs to be re-established every time recently served animals enter the group, and prepartum sows leave. This results in several peaks of aggression during the gestation period of any one sow (e.g. Burfoot *et al.*, 1994), and in a highly unsettled spatial organisation of the group (Chapter 4, this thesis). Minimising (the impact of) this continuous social unrest is a prerequisite to improving the welfare of sows in these systems. The factor investigated in the present thesis, food motivation, does not appear to have any influence on either the levels of aggression or the use of space in dynamic groups of sows. This in itself appears to contradict findings in (unstrawed) Dutch circumstances (Buré, 1991). Chapter 3 therefore speculates as to whether aggression in dynamic groups of sows can be mitigated through the presence of straw. Commercially housed sows, who are generally fed only once per day, have been shown to be chronically food motivated for most of the time (Lawrence *et al.*, 1988). In the

presence of straw, low fed animals will manipulate this substrate significantly more than animals on a higher nutritional plane (Chapter 3, this thesis). Kelley *et al.* (1980) found that straw did not reduce aggressive behaviour among finishing pigs that were fed *ad libitum*, but tended to reduce aggression among fasted pigs ($P < 0.1$). Straw therefore potentially serves as a buffer for frustration arising from a state of chronic food motivation: in its absence, sows may redirect their behaviour towards pen mates.

This immediately raises questions on the viability of dynamic group housing systems in the absence of a substrate. Vermeer *et al.* (1996) report that in a dynamic electronic sow feeder (ESF) system welfare and production was "far worse" than in an individual housing system. In the same paper they conclude that welfare in a stable ESF group was no different from that in stalls: sows in the ESF group had higher injury scores (perhaps because these "stable" groups were mixed mid-pregnancy), but showed lower oral stereotypies. Bokma (1990) who investigated welfare and performance of sows on a Dutch commercial unit also concluded that dynamic group housing on slats is "not yet an acceptable system". Van Putten and Van de Burgwal (1990) concluded in their discussion of a novel pig husbandry system, that not offering roughage to a dynamic group of sows fed via an ESF feeder is a "very risky affair because of vulva biting and lameness". Practical experience in the UK suggest that dynamic groups on slats place a high demand on the quality of the feeder. There are several examples of early attempts to operate rear-entry rear-exit ESF feeders under these housing conditions, all of which lead to high levels of vulva biting and other agonistic behaviour (Brade, pers. comm.). More recent experiences in Northern Ireland seem to indicate that operating these systems is not impossible, but that the provision of some straw is still preferred (Donnelly, pers. comm.). Therefore, pig housing consultants in both the Netherlands (H. Vermeer - P.V. Rosmalen) and the UK (M. Brade - ADAS) advise against operating dynamic groups on slats.

The results from Chapter 3 indirectly imply that the frequency with which new animals are introduced to a dynamic group should be kept to a minimum. In practice this means that from a welfare point of view a number of smaller, "semi-dynamic" groups are preferred over one large dynamic group. Semi-dynamic grouping effectively spreads the days new sows are introduced over different groups. For example, consider a 300 sow unit, weaning an average 13 sows per week. Sows are introduced to the dynamic group after pregnancy diagnosis at 28 days post service, and taken out for farrowing one week before expected parturition. Therefore, each sow would spent approximately 80 days in the dry sow group. A conventional dynamic group on this unit would consist of around 160 sows and a 12 week cycle, with 13 pregnant animals being introduced, and 13 removed for farrowing on a weekly basis. In a situation with two semi-dynamic groups of 80 dry sows each, the introduction (and removal) of sows would take place over a six week period in each group. After each dynamic six week period, a relative stable six weeks follow (during which animals are being introduced and removed in the other group). Technically, the number of semi-dynamic groups, the number of animals in each group and the duration of introduction and stable periods depend primarily on the number of sows a producer weans each week. In the above example the ideal number of subgroups is 12: one for each week's weaning, effectively resulting in stable groups of 13 sows. Practically, for financial reasons, the number of groups is kept to a minimum (with "one" being the ideal), as extra groups mean extra pen partitionings, extra feeders or food dispensers and more labour.

After an initial period of increased social interactions following the introduction of new sows to an existing group, the spatial organisation of individuals or subgroups within a group, appears to be used as a tool in minimising further aggression (Chapter 4, this thesis). The experimental groups

described in this thesis are relatively small: commercially, group sizes of several hundred sows exist. Only limited data are available on what happens spatially in groups of this size. Beckett *et al.* (1986) found that individual animals in a group of 400 sows will show a preference for certain parts of the lying area, although animals did appear to be using all parts of the pen. Eddison (1992) found that sows prefer certain feeders. It seems a fair assumption that in these extremely large groups individual sows will fail to recognise, let alone form a (stable) social relationship, with every other animal in the group. When given the opportunity, they will voluntarily restrict themselves to using certain parts of the pen, thereby minimising the risk of encounters with unfamiliar other pigs. Attempts have been made to further develop this idea of a "home range" for subgroups. Burfoot (unpublished data) looked at dynamic groups of 30 sows, fed in free access feeder stalls. They isolated subgroups of new animals in stalls for several hours prior to releasing the pigs into the dynamic group. Every introduced subgroup had their own set of stalls, and showed a tendency to return to these stalls at feeding times for several days after introduction. Studies in the Netherlands also indicate that the home range concept can be used effectively. The former "Welfare Farm" successfully used a dry sow lying area divided into three parts, one of which was used to introduce newcomers into, before allowing them to mix with the rest of the group (Anonymus, 1990). Van Putten and Van de Burgwal (1990) tested a dry sow accommodation for groups of 40 sows. One week before introduction of a new subgroup (of 10 pigs) a quarter of the pen was closed to other sows. New sows were introduced in this area, and the partition between them and the rest of the pen was removed 24 hours later. *Ad libitum* water and additional roughage (maize silage) was provided to the subgroups in these areas. The authors conclude that some vulva biting only occurred when sows were trespassing in other territories.

The development of feeding orders (e.g. Hunter *et al.*, 1988; Bressers *et al.*, 1993) helps to reduce agonistic behaviour at the feeder entrance through a reduction of average number of sows waiting for access to food. Feeding orders in dynamic groups of sows fed from a sequential feeding system are consistent but transient: sows gradually move up the hierarchy during their stay in the dry sow accommodation (unpublished results from the study described in Chapter 4 of this thesis). Subordinate or newly introduced sows spent a larger proportion of their time near the feeder than more established animals (Chapter 4, this thesis), in part because they have to rely on lack of competition for access to the feeder if they want to get food. By positioning the feeder so that its entrance is clearly visible, the number of animals which need to wait near it will be reduced, and as a consequence, so will the likelihood of potentially aggressive encounters.

Individuals in a Challenging Environment

The average number of pigs per unit steadily increased over the last decades, and aided by the continued automation of the industry, this has meant that it is now common for one person to look after several hundred animals (Nix, 1997). As a consequence, "uniformity" of pigs has become the standard. Outliers are considered a nuisance, whether they are part of a large newly born litter, a group of bacon pigs ready to be sold or a group of dry sows using a trickle feeder system. Under these circumstances it is often easily forgotten that animals are individuals, each responding to the environment in its own way. The behavioural characteristics of sows are most obvious in stalled or tethered animals, as is their physical performance. Tending to the individual needs of sows in these systems is far easier than to those of group housed sows. Consequently, a lack of "control" over individual needs of group housed sows has become one of the main concerns for those UK

producers having to convert their stall and tether systems (Baynes, pers. comm., based on Cambac JMA survey).

Although individually housed sows may express different behavioural characteristics, their personalities or "temperament" can not physically affect other pigs. However, observations on stereotyping sows suggest that their behaviour is influenced by the behaviour of their neighbours: Appleby *et al.* (1989) showed that there is a significant relationship between standing behaviour and between repetitive behaviours of neighbouring sows. Barnett *et al.* (1987) observed elevated concentrations of free-corticosteroids in stall housed sows, and suggests this was caused by the failure of neighbouring sows to resolve disputes. In group housed animals the effects of behavioural differences between pigs are much more important, and largely determined by factors such as relative social rank. Dominance rankings have been shown to be closely linked to feeding orders in sequential feeding systems, for example (Hunter, 1988; Bressers *et al.*, 1993). Similarly, the use of particular areas of the pen may be influenced by rank (Chapter 4, this thesis). However, social rank, although possibly influenced by a pig's temperament, is probably mainly linked to factors such as weight, age and experience (e.g. Beilharz and Cox, 1967; Sambraus, 1981). Hessing (1994) described a different dimension of individuality, by suggesting that pigs can broadly be classified as "active" or "passive" responders, depending on the way they cope with stressful situations. These observations follow in the footsteps of Benus (1987), who suggested such a behavioural dichotomy in dealing with stressful situations in mice and rats. Hessing's work has been criticised mainly because it fails to show satisfactorily that a bimodal distribution in piglet behavioural responses exists: Jensen *et al.* (1995) argue that bimodality was a premise of the study, rather than a conclusion. However, Hessing's observation that groups of finishing pigs which consist of a combination of behavioural types will perform better, compared to groups consisting solely of one type (Hessing, 1994), is very interesting to say the least.

Consistent behavioural characteristics can be measured in early life. Hessing's (1994) bimodality may have been questioned, the consistency of the behavioural responses of his piglets never was. The present study (Chapter 5) investigated behavioural responses of approximately 4 month old gilts to a number of distinct challenges, over a relatively short time period (approximately 7 weeks). Again, responses to tests which could be repeated showed a significant degree of consistency. Principal components analysis of each test resulted in one or more independent sets of factor scores: each representing a condensed set of behavioural variables. The lack of correlation between factor scores of different tests suggests the lack of one single overriding response to the tests: pigs behaved consistently in the face of each challenge, but behaviour in one test did not predict the response in another (Chapter 5, this thesis). It appears therefore that an individual pig's personality is a point in a multidimensional space of character traits, each of which are different, but not necessarily perpendicular to each other (and therefore not necessarily independent). The number of personality traits has been investigated by many researchers, mainly through the use of factor analysis, resulting in any number of factors or traits being proposed (Czeschlik, pers. comm.). In one of the most recent literature reviews of the subject, Buss and Plomin (1984) suggested that there is sufficient evidence for at least three inherited traits in both animals and humans: Emotionality, Activity and Sociability. Emotionality would cover things like fear, approach-withdrawal, irritability and intensity of reactions. It possibly covers the observations on piglets by Hessing (1994) and mice by Benus *et al.* (1987). Activity refers to motor activity, ambulation, restlessness, and Sociability refers to gregariousness and the need for friendship and affiliation. The tests described in Chapter 5 of this

thesis may well have tested for (combinations of) different traits, resulting in the absence of an overall agreement.

The lack of correlation between different tests not only questions the existence of a single behavioural trait which allows for the typecasting of all subjects, it also casts doubts on the possibility of developing tests which will identify animals likely to develop behavioural vices. If the response to one challenge does not predict the response to a different challenge in a relatively short period of time, what chance has a test got which is aiming to predict individual characters over a longer period of time? Spoolder *et al.* (1994) found a relationship between fearfulness in a Response to Novelty test before puberty (First Series, see Chapter 5) and the performance of chain directed behaviours in pregnancy two (correlation between "touching the object" and "chain directed behaviour": $r_s=0.495$; $n=24$; $P<0.05$), but failed to repeat that finding in a subsequent study (Second Series, see Chapter 5). The relationship between the factor scores calculated in Chapter 5 and behaviour patterns observed in parities 1 and 2 does not show a clear predictive value of the pre-pubertal tests (Spoolder - unpublished data). Possible predictors of a sow's likelihood to develop stereotypies have been identified by others. Schouten and Wiepkema (1991) found that heart rates of tethered sows which they classed as "high stereotypers" were lower before (when they were loose housed) as well as during tethering, compared to "low stereotypers". Pre-tethering heart rates were recorded during the month prior to tethering. Terlouw *et al.* (1990) found a relationship between the relative social status of gilts and their propensity to develop excessive drinking. In their experiment, gilts were ranked according to the number of pen mates they dominated in a group feeding test (cf. social status test in Chapter 5) just prior to entering the experimental treatments at approximately eight months of age. No significant relationship between social rank and chain directed behaviours were found, but higher ranking animals were more likely to develop excessive drinking behaviour during gestation. In both studies, the predictors were measured relatively shortly before the environmental challenges were imposed. Increasing the time gap between measuring predictors and determining individual responses to stressors, will inevitably lead to a loss of predictive value. This is mainly due to the fact that behavioural characteristics are not only determined by the genetic make-up of the individual, but also -as time goes on- to an increasing extent by its environment (Whimbey and Denenberg, 1967). Therefore, attempting to identify predictors in 4 month old gilts of behavioural responses to stressful situations which start developing when the animals are about 8 months, was perhaps a little ambitious.

Conclusions and Practical Implications

Stereotypic behaviour in group housed sows, measured as chain and bar manipulation, is affected by food level. Straw provision appears to satisfy a need to forage, and reduces the level of chain and bar directed behaviours in the immediate post-feeding period to less than a third. The "freedom to express normal behaviour", and, as a result, the "freedom from abnormal behaviours" will therefore benefit from the presence of a foraging substrate.

Agonistic behaviour and the spatial organisation of dynamic groups of sows on straw are not affected by food level. However, spacing behaviour of sows in dynamic systems suggests that complete integration of introduced subgroups is not achieved by the time individuals are taken out for farrowing. To facilitate the social organisation of the group and promote a harmonious environment, proper building lay-out and management techniques are essential. Areas to consider

include the visibility of the feeder entrance(s) from the lying area, and the provision of barriers creating spatially separated lying areas.

Dynamic group housing systems subject sows to recurring aggression each time new animals are introduced. The frequency of introduction should therefore be kept to a minimum, for example by establishing semi-dynamic groups. Straw potentially acts as an aggression "buffer", redirecting behaviour away from pen mates. Therefore, dynamic systems in the absence of straw can, at present, not be recommended as a high welfare alternative to individual housing.

Pigs show measurable and repeatable individual behavioural differences. The pig's individuality expresses itself in a number of dimensions, which collectively determine the way in which the animal responds to, and copes with, challenges during its life. To date there is insufficient evidence to base a strategy on which would allow selection of behavioural types, and alleviate problem behaviours in groups of sows. Therefore, group housing systems demand a higher degree of supervision and handling skills from the stock person, compared to individual housing systems.

References

- Anonymous 1990. Welfare farm: a progress report. *Pig International*, October 1990: 32-37.
- Appleby, M.C., Lawrence, A.B. and Illius, A.W. 1989. Influence of neighbours on stereotypic behaviour of tethered sows. *Applied Animal Behaviour Science*, 24: 137-146.
- Appleby, M.C. and Wood-Gush, D.G.M. 1988. Effect of earth as an additional stimulus on the behaviour of confined piglets. *Behavioural Processes*, 17: 83-91.
- Barnett, J.L., Hemsworth, P.H. and Winfield, C.G. 1987. The effects of design of individual stalls on the social behaviour and physiological responses related to the welfare of pregnant pigs. *Applied Animal Behaviour Science*, 18: 133-142.
- Beattie, V.E., Sneddon, I.A. and Walker, N. 1993. Behaviour and productivity of the domestic pig in barren and enriched environments. In *Livestock Environment IV*, ed. E. Collins and C. Boon, 43-50, St Joseph Michigan: American Society of Agricultural Engineers.
- Beattie, V.E., Walker, N. and Sneddon I.A. 1995. Effect of rearing environment and change of environment on the behaviour of gilts. *Applied Animal Behaviour Science*, 46: 57-65.
- Beckett, M.P. 1986. Electronic identification and individual feeding of sows in a very large group. *Animal Production*, 42: 468.
- Beilharz, R.G. and Cox, D.F. 1967. Social dominance in swine. *Animal Behaviour*, 15: 117-122.
- Benus, R.F., Koolhaas, J.M. and Oortmerssen, G.A. van 1987. Individual differences in behavioural reaction to a changing environment in mice and rats. *Behaviour*, 100: 105-122.
- Bokma, S. and Kersjes, G.J.K. 1988. The introduction of pregnant sows in an established group. *Proceedings of the International Congress on Applied Ethology in Farm Animals*, Skara 1988: 166-169.
- Bokma, S. 1990. Housing and management of dry sows in groups in practice: partly slatted systems. *Proc. of an International Symposium on Electronic Identification in Pig Production*, RASE Stoneleigh, 23-26 Sep. 1990, pp. 37-45.
- Bressers, H.P.M., Brake, J.H.A. te, Engel, B. and Noordhuizen, J.P.T.M. 1993. Feeding order of sows at an individual electronic feed station in a dynamic group-housing system. *Applied Animal Behaviour Science*, 36: 123-134.

- Bure, R.G. 1991. The influence on vulva biting of supplying additional roughage in an electronic sow feeder. Proceedings of the 42nd annual meeting of the EAAP, Berlin 1991.
- Burfoot, A., Kay, R.M. and Simmins P.H. 1994. Level of skin damage in sows when mixed in groups in early pregnancy. *Animal Production* 58: 438.
- Burfoot, A., Kay, R.M. and Corning, S. 1995. A scoring method to assess damage caused by aggression between sows after mixing. *Animal Science* 60: 564.
- Burfoot, A., Kay, R.M. and Corning, S. 1997. Reproductive performance and aggression between sows re-mixed into small stable groups at different stages during the embryo implantation period following initial mixing at weaning. Proceedings of the British Society of Animal Science, Scarborough, March 1997: 107.
- Buss A.H. and Plomin, R. 1975. A temperament theory of personality development. New York, Wiley.
- Buss A.H. and Plomin, R. 1984. Temperament: Early developing personality traits. Hillsdale (N.J.), Earlbaum.
- Cronin, G.M. 1985. The development and significance of abnormal stereotyped behaviours in tethered sows. PhD Thesis, Wageningen Agricultural University, The Netherlands.
- Durrell, J., Sneddon, I.A. and Beattie, V.E. Effects of enrichment and floor type on behaviour of voluntary cubicle loose-housed dry sows. *Animal Welfare*, 6: 297-308.
- Eddison, J.C. 1992. Sows display individual preferences for electronic feeding stations. *British Veterinary Journal*, 148: 157-159.
- Edwards, S.A. 1992. Scientific perspectives on loose housing systems for dry sows. *Pig Veterinary Journal*, 28: 40-51.
- Fraser, D., Phillips, P.A., Thompson, B.K. and Tennessen, T. 1991. Effect of straw on the behaviour of growing pigs. *Applied Animal Behaviour Science*, 30: 307-318.
- Hessing, M.J.C. 1994. Individual behavioural characteristics in pigs and their consequences for pig husbandry. PhD thesis, Wageningen Agricultural University, The Netherlands.
- Hunter, E.J., Broom, D.M., Edwards, S.A. and Sibly, R.M. 1988. Social hierarchy and feeder access in a group of 20 sows using a computer-controlled feeder. *Animal Production*, 47: 139-148.
- Hunter, E.J. 1988. Social hierarchy and feeder access in a group of sows using a computerized feeder. *Applied Animal Behaviour Science*, 21: 372-373.
- Jensen, P., Rushen, J. and Forkman, B. 1995. Behavioural strategies or just individual variation in behaviour? - A lack of evidence for active and passive piglets. *Applied Animal Behaviour Science*, 43: 135-139.
- Kelley, K.W., McGlone, J.J. and Gaskins, C.T. 1980. Porcine aggression: measurement and effects of crowding and fasting. *Journal of Animal Science*, 50: 336-341.
- Ladewig, J. and Matthews, L.R. 1996. The role of operant conditioning in animal welfare research. *Acta Agricultura Scandinavica. Sect A, Animal Science Supplement* 27: 64-68.
- Lawrence, A.B., Appleby, M.C. and Macleod, H.A. 1988. Measuring hunger in the pig using operant conditioning: the effect of food restriction. *Animal Production*, 47: 131-137.
- Lawrence, A.B. and Terlouw, E.M.C. 1993. A review of behavioral factors involved in the development and continued performance of stereotypic behaviors in pigs. *Journal of Animal Science*, 71: 2815-2825.
- Luescher, U.A., Friendship, R.M. and McKeown, D.B. 1990. Evaluation of methods to reduce fighting among regrouped gilts. *Canadian Journal of Animal Science*, 70: 363-370.

- Marchant, J.N., Mendl, M.T., Rudd, A.R. and Broom, D.M. 1995. The effect of agonistic interactions on the heart rate of group-housed sows. *Applied Animal Behaviour Science*, 46: 49-56.
- Mason, G.J. 1991. Stereotypy: a critical review. *Animal Behaviour*, 41: 1015-1037.
- McKinnon, A.J., Edwards, S.A., Stephens, D.B. and Walters, D.E. 1989. Behaviour of groups of weaner pigs in three different housing systems. *British Veterinary Journal*, 145: 367-372.
- Mendl, M., Zanella, A.J. and Broom, D.M. 1992. Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour*, 44: 1107-1121.
- Moore, A.S., Gonyou, H.W. and Ghent, A.W. 1993. Integration of newly introduced and resident sows following grouping. *Applied Animal Behaviour Science*, 38: 257-267.
- Nix, J. 1997. Farm management pocket book, 27th edition. University of London, Wye College Press.
- Pedersen, L.J., Rojkittikhun, T., Einarsson, S. and Edqvist, L.-E. 1993. Postweaning grouped sows: effects of aggression on hormonal patterns and oestrus behaviour. *Applied Animal Behaviour Science*, 38: 25-39.
- Putten, G. van and Burgwal, J.A. van de 1990. Pig breeding in phases. *Proc. of an International Symposium on Electronic Identification in Pig Production*, RASE Stoneleigh, 23-26 Sep. 1990, pp. 115-120.
- Samraus, H.H. 1981. Social behaviour of group housed sows [Das Sozialverhalten von Sauen bei Gruppenhaltung]. *Züchtungskunde*, 53: 147-157.
- Schouten, W.G.P. and Wiepkema, P.R. 1991. Coping styles of tethered sows. *Behavioural Processes*, 25: 125-132.
- Sheppard, A. 1996. The structure of pig production in England and Wales - Results of a national survey of pig production systems. *Agricultural Economics Unit, University of Exeter*.
- Sneddon, I.E. and Beattie, V.E. 1995. Improving the welfare of pigs. *Irish Journal of Psychology*, 16: 418-425.
- Spooler, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A. 1994. The relationship between individual temperament and the development of abnormal oral stereotypies in food restricted sows. In: *Proceedings of the 28th International Congress of the International Society for Applied Ethology*, Foulum, Denmark, 1994. p. 120.
- Svendsen, J., Andersson, M., Olsson, A.C., Rantzer, D. and Lundqvist, P. 1990. Group housing of sows in gestation in insulated and uninsulated buildings. *Swedish University of Agricultural Sciences, LBT report 66*.
- Svendsen, J. and Steen Svendsen, L. 1997. Intensive (commercial) systems for breeding sows and piglets to weaning. *Livestock Production Science*, 49: 165-179.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W. 1991. Influences of feeding level and physical restriction on development of stereotypies in sows. *Animal Behaviour*, 42: 981-991.
- Terlouw, E.M.C., Lawrence, A.B. and Illius, A.W. 1990. The roles of feeding regime, housing and individuals 'temperament' in the development of stereotypic behaviour in pregnant sows. *Animal Production*, 50: 567-568.
- Terlouw, E.M.C., Wiersma, A., Lawrence, A.B. and Macleods, H.A., 1993. Ingestion of food facilitates the performance of stereotypies in sows. *Animal Behaviour*, 46: 939-950.
- Vermeer, H.M., Backus, G.B.C., Blokhuis, H.J., Metz, J.H.M., van Putten, G., Schouten, W.G.P., Smeets, J.J.J. and Verheijden, J.H.M. 1996. Welfare assessment in four housing systems for dry sows. In: *Proceedings of the International Congress of the International Society for Applied*

-
- Ethology, I.J.H. Duncan, T.M. Widowski and D.B. Haley (Editors). Guelph 1996. Centre for the Study of Animal Welfare.
- Vestergaard, K. and Hansen, L.L. 1984. Tethered versus loose sows: ethological observations and measures of productivity. I. Ethological observations during pregnancy and farrowing. *Annales Recherche Veterinaire*, 15: 245-256.
- Walker, N. and Kilpatrick, D.J. 1994. A study of spatial behaviour of pregnant sows housed in pens with various feeding and dung disposal systems. *Animal Welfare*, 3: 97-105.
- Whimbey, A.E. and Denenberg, V.H. 1967. Experimental programming of life histories: the factor structure underlying experimentally created individual differences. *Behaviour*, 29: 296-314.
- Wood-Gush, D.G.M. and Beilharz, R.G. 1983. *The enrichment of a bare environment for animals in confined conditions*. *Applied Animal Ethology*, 10: 209-217.

SUMMARY

SUMMARY

Changing legislation and consumer attitudes towards the welfare of farm animals means that individual housing of dry sows will soon be illegal in the United Kingdom. Other European countries, and in particular those for whom the UK is an important export market (such as The Netherlands), are under pressure to follow suit. Group housing is generally believed to provide a higher degree of welfare than individual housing, because it allows the animal greater behavioural freedom. However, group housing does not eliminate behaviours such as stereotypies, which are associated with an inadequate environment and have long been the cornerstone of the (ethological) argument against individual dry sow housing. Also, group housing promotes the occurrence of agonistic behaviour, potentially reducing the welfare of most, if not all animals in the group. The present thesis addresses these undesirable behaviours in group housed sows, and investigates the role food level and the provision of straw may have to play in trying to reduce them. It also looks into the possibility of developing tests to identify gilts which are likely to develop these behaviours during their adult life, by assessing individual behavioural responses to a number of challenges before the animals reach puberty.

In Chapter 1 the hypothesis was tested that food motivated pregnant sows need a substrate, for example straw, to express foraging behaviour. The absence of a suitable substrate may under certain conditions result in the development of abnormal oral activities, such as stereotypic chain and bar manipulation. The study described used 96 gilts, all between 1 and 3 weeks post service, which were entered into a 2 x 2 factorial design comparing food level (Low 1.8 kg/23 MJ day⁻¹ and High 3.2 kg/40 MJ day⁻¹) and the provision of a foraging substrate (Straw and No straw). The gilts were loose housed in groups of 6 with individual stalls. Behaviour was recorded over the first two parities, by time sampling for the 2 and 6 hours after the start of feeding and over 24 hours using video recordings. The results show that activity levels were highest just after feeding, with low fed sows being more active than high fed sows. Most of the postprandial activity consisted of manipulating substrates. In low fed sows without straw, particularly in parity 2, this behaviour was mainly directed towards chains and bars, resulting in levels 3 to 4 times higher than in other groups. Low fed sows with straw directed their foraging behaviour mainly towards the straw. Chapter 1 concludes that in food restricted pregnant sows abnormal high levels of chain and bar manipulation can be prevented by providing straw which apparently acts as a foraging substrate.

The second chapter described how the treatments applied in Chapter 1 affected the performance of the animals as well as their chronic and acute physiological stress responses. The latter was tested by injecting the pigs at the end of their second pregnancy with adrenocorticotrophic hormone, ACTH (1 iu kg⁻¹ live weight), which induces the adrenal cortex to release all available cortisol. Saliva samples were taken before and after the ACTH challenge, and baseline and response levels of salivary cortisol were assessed. The results emphasise the importance of straw: significantly more non-straw sows failed to start the second parity than straw sows. Food level showed expected differences in weight gain, with high fed sows gaining more weight and back fat over both pregnancies than low fed sows. Low fed animals with straw tended to gain more weight and back fat over both pregnancies than low fed sows without straw. Litter performance was not influenced by the straw treatment. High fed sows without straw were found to have the highest concentration of basal cortisol, but no treatment effects were found in increase of salivary cortisol concentrations in

response to the challenge with ACTH. The chapter concludes that provision of straw may buffer the adverse effects of a low food level on weight and back fat gain in group-housed pregnant sows, but that it has no effect on reproductive performance. The results of the ACTH challenge tests suggest that physiological differences between treatments are most likely to be of an acute nature, rather than a chronic one.

In Chapter 3, the focus of attention is moved towards large groups of dynamic sows. It addresses the hypothesis that hunger may be a cause of increased aggression between animals. For this study, sixteen groups of 5 gilts were introduced over 8 months to 1 of 2 dynamic groups in a deep straw yard. Sows in each group were receiving a different level of food from an electronic sow feeding system: High (3.0 kg / 38 MJ day⁻¹) and Low (1.6 kg / 20 MJ day⁻¹). The behaviour of the animals was recorded throughout both pregnancies using a time sampling technique. The total number of animals in each dynamic group was maintained at around 30, through the use of additional sows. The results indicate, as expected, that food level affects body weight: high fed sows were heavier than low fed sows. However, no effect of the food treatment was found on litter size or litter performance. Behaviour observations showed a low fed sows to be more active and manipulating the straw more than H sows. However, food level did not affect the number of aggressive interactions, or the level of skin damage on the sows. In contrast, the introduction of new animals to the groups did: pigs were more involved in aggressive interactions on the day they were introduced, than on other pig's introduction days and no introduction days. Average skin lesions per experimental sow were also higher in the days immediately following introduction. The conclusion of Chapter 3 is that in a sequential feeding system with plentiful straw, aggression is not influenced by the level of food. In these systems, the major factor giving rise to aggression is the introduction of new animals to the resident group.

In Chapter 4 the spatial organisation of the dynamic groups of pigs used in the previous chapter was investigated more closely. Although Chapter 3 suggested that food level does not have an overriding effect on aggression, an increased food motivation may well affect the use of the pen by the animals, through changes in personal space requirements and / or the "defense" of particular areas. In order to do this, the spatial organisation of the animals was recorded throughout both pregnancies on a floor plan of the building, at fortnightly intervals. From these a range of spatial parameters were calculated: the frequency of visiting predetermined pen areas, the average location of the pig in the pen, the average inter individual distance, the distance and identity of the nearest neighbour and the proportion of observations an animal spends within a two meter range of another animal. The effects of food level were restricted to an increased use of the drinker area by high fed sows, and an increased use of the feeder area by low fed sows. The time since introduction of a new subgroup affected all spatial parameters, with the average inter-individual distance between resident and new animals decreasing, and that within subgroups increasing. The chapter concludes that social integration appears to be a staged progress, starting off with a peak in agonistic behaviour, followed by an increased use of the same areas of the pen. The final stage, which involves a random sharing of the immediate area around an individual, was not achieved before pigs were taken out of the group for farrowing.

The fifth chapter described an investigation into the consistency of a gilt's behavioural responses between and within test situations, aiming to relate them to the development of

undesirable behaviours in the group housed adult animal. To achieve this, behavioural responses of gilts were tested under 4 different circumstances. Gilts were housed in two series of 16 groups each ($n=6$ or 7 gilts per group). The test situations were: Situation 1: an open field with a novel stimulus (bucket or human); Situation 2: individual access to food for 15 minutes after a 20 hour period of food deprivation; Situation 3: competition for food after food deprivation; Situation 4: general activity and feeding behaviour in a group over a 24 hour period. Situations 1 and 2 were assessed 4 and 3 times over a 2 and 1 week period, respectively. Both showed high levels of consistency in the behavioural responses of the gilts. Principal components analyses was used to reduce the number of variables per test situation and facilitate measurement of consistency across test situations. The amount of variation explained by the first component was generally more than twice that explained by any subsequent components. The only significant correlation between factor scores calculated from the first components was found between Situation 1 and 2 in the first series. None of the calculated factor scores showed bi- or multimodal distributions. The chapter concludes that, whilst over a short period of time gilts respond consistently to a specific challenge, they do not display the same consistency when challenged in a different context. This lack of inter-situation correlations, plus the absence of multimodal distributions, fails to support the view that behavioural "types" of gilts exist.

The General Discussion addresses the practical implications of the findings in Chapters 1 to 5 in three parts. Part 1 suggests that group housing may result in reduced development of stereotypic behaviour, even though factors such as food level and straw provision may have an even greater effect. It also queries the relationship between the feeder area and the development of abnormal repetitive behaviour: does the association with food reinforce of this area reinforce the behaviour? Finally, on the subject of stereotypes, it highlights the need for continued research into alternative substrates which can be used in circumstances where straw is not an option. In Part 2, the discussion on large dynamic groups starts off by highlighting the fear of many producers who have to convert to group housing, that aggressive behaviour will dramatically reduce the welfare of the animals. It suggests that dynamic group housing systems, in which aggression is an inevitable consequence of the constant restructuring of the social organisation, should preferably not be operated in the absence of a substrate. Further more, the frequency of introducing sows to an existing group should be kept to a minimum, for example by operating semi-dynamic groups. In the final section of Part 2, the stability of the subgroup is discussed, and the concept of incorporating separate lying areas supported. Part 3 reaffirms that pigs are individuals, and that their individuality might be based on differences in a range of underlying character traits. It questions the feasibility of identifying gilts unable to "cope" with challenges in adult life, although it may well be possible to identify behavioural or physiological predictors of undesirable behaviour shortly before they start developing. Finally, it acknowledges the fact that individual behavioural differences between pigs are both unavoidable as well as desirable, but that they do demand a higher level of stockmanship if sows are kept in groups, compared to individually housed animals.

SAMENVATTING

SAMENVATTING

De toenemende mate waarin het publiek zich bezorgd maakt over het welzijn van landbouwhuisdieren heeft in het Verenigd Koninkrijk geleid tot wetswijzigingen die het houden van varkens in aanbindstallen of ligboxen binnenkort verbiedt. Andere Europese landen, met name die landen voor wie Groot Britannië een belangrijk afzetmarkt vormt (waaronder Nederland), staan onder druk dit voorbeeld te volgen. Groepshuisvesting wordt over het algemeen geacht het welzijn van het varken te verbeteren, omdat het het dier een grotere mate van vrijheid geeft zijn natuurlijke gedrag uit te voeren. Het optreden van stereotiep gedrag in individuele huisvestingssystemen, hetgeen lange tijd een van de belangrijkste ethologische argumenten was tegen deze vorm van varkenshouderij, lijkt echter niet volledig vermeden te worden door de dieren in groepen te houden. Daarnaast leidt groepshuisvesting over het algemeen tot een verhoging van de agressiviteit, hetgeen het welzijn van de dieren in de groep schaadt. Dit proefschrift onderzoekt deze ongewenste gedragingen in groepen zeugen, en vraagt zich af welke bijdragen stro en het voerniveau aan de verbetering van het welzijn van deze dieren kunnen leveren. Verder wordt er in dit proefschrift ingegaan op het voorkomen van individuele gedragsverschillen tussen varkens. Deze verschillen kunnen in een vroeg stadium misschien aangeven welke dieren voortbestemd zijn om later afwijkende sociale en stereotype gedragingen te gaan vertonen.

In hoofdstuk 1 wordt de hypothese getoetst dat chronisch hongerige zeugen een geschikt substraat nodig hebben om daarmee in een behoefte aan fourageer gedrag te kunnen voorzien. De afwezigheid van zo'n substraat kan onder bepaalde omstandigheden leiden tot de ontwikkeling van abnormale orale gedragingen, zoals stereotiep stang- en kettingbijten. Voor deze proef werden 96 gelten gehouden op een hoog of een laag voerniveau (1.8 kg / 23 MJ per dag of 3.2 kg / 40 MJ per dag), in een stal met of zonder stro. Alle gelten werden gehuisvest in groepen van zes met individuele voerligboxen en een gezamenlijke mestgang. Het gedrag van de dieren werd geobserveerd gedurende de eerste twee pariteiten. De resultaten tonen aan dat de dieren het actiefst waren in de periode direct na het voeren, en dat zeugen op een laag voerniveau actiever waren dan dieren op een hoog voerniveau. De gedragingen uitgevoerd in de periode onmiddellijk na het voeren waren voornamelijk gericht op het manipuleren van het substraat. Bij zeugen zonder stro op een laag voerniveau, was dit gedrag voornamelijk gericht op de aanwezige kettingen en stangen, die ze 3 tot 4 maal zo vaak manipuleerden als in de andere groepen. Door de zeugen op een laag voerniveau met stro werd dit gedrag voornamelijk met het aanwezige stro uitgevoerd. Geconcludeerd wordt dat stereotiep gedrag in zeugen op een laag voerniveau grotendeels vermeden kan worden door de dieren toegang te geven tot een substraat waarop hun fourageer gedrag voldoende uitgevoerd kan worden.

Het tweede hoofdstuk beschrijft hoe de behandelingen omschreven in Hoofdstuk 1 de technische resultaten en fysiologische stress respons beïnvloeden. De stress respons werd getest door de dieren te injecteren met ACTH (adrenocorticotrophic hormone, 1 iu per kg levend gewicht), hetgeen de bijnier aanzet tot de afgifte van cortisol. Speekselmonsters werden genomen zowel voor als na de toediening van ACTH, om rust- en reactieniveaus te kunnen meten. De technische resultaten benadrukken de voordelen van stro: er waren significant meer dieren zonder dan met stro, die om diverse redenen niet aan de tweede dracht begonnen. Het voerniveau was, zoals verwacht, positief gerelateerd aan gewichtstoename en spekdikte. Er was een tendens voor dieren op een laag

voerniveau zonder stro tot een geringere groei en spekdikte in vergelijking met dieren op een laag voerniveau met stro. Grootte, gewicht en uitval van de toom werden niet beïnvloed door de behandelingen. Zeugen op een hoog voerniveau met stro vertoonden het hoogste cortisol gehalte voor de toediening van ACTH, maar er was geen effect van de behandelingsmethoden op de toename in cortisol na ACTH verstrekking. Geconcludeerd wordt dat verstrekking van stro een bufferwerking kan hebben tegen de negatieve effecten van een laag voerniveau, maar dat het de toom kenmerken niet beïnvloed. De resultaten van de ACTH test wijzen op een acute response op de testsituatie, niet op een chronisch effect van de behandelingen.

Hoofdstuk 3 beschrijft een experiment waarin de aandacht verschuift van kleine stabiele groepen naar grote dynamische groepen, en wordt onderzocht of het voerniveau van invloed kan zijn op agressief gedrag. Het bespreekt een proef waarin 16 subgroepen van 5 gelten geïntroduceerd worden in twee dynamische groepen over een periode van 8 maanden. Het grootste deel van de twee hokken was bedekt met een diepe laag stro (30-50 cm). Zeugen in de ene groep ontvingen een hoog voerniveau (3.0 kg / 38 MJ per dag), in de andere groep een laag voerniveau (1.6 kg / 20 MJ per dag). Het gedrag van de dieren werd gedurende beide pariteiten geobserveerd door gebruik te maken van scans. De groepsgrootte werd rond de 30 dieren gehouden door extra dieren aan de dynamische groep toe te voegen wanneer nodig. De resultaten toonden zoals verwacht een positief verband tussen voerniveau en gewichtstoename, maar toomkenmerken werden niet beïnvloed. Zeugen op een laag voerniveau waren actiever, en manipuleerden het stro meer dan zeugen op een hoog voerniveau. Agressie en huidbeschadigingen werden echter niet door het voerniveau beïnvloed. Daarentegen leidde de introductie van nieuwe dieren aan de groep tot een significante verhoging van beide kenmerken: zeugen waren vaker betrokken bij agressieve interacties op dagen dat ze geïntroduceerd werden dan op dagen dat andere dieren geïntroduceerd werden of geen dieren werden geïntroduceerd. De gemiddelde huidbeschadigingsscore was het hoogst gedurende de eerste dagen na introductie. De conclusie van dit hoofdstuk luidt dat in een systeem waarin zeugen niet tegelijkertijd kunnen vreten maar waar voldoende stro aanwezig is, agressie niet wordt beïnvloed door het voerniveau. In deze huisvestingssystemen is de toevoeging van nieuwe dieren aan de bestaande groep de voornaamste reden voor het uitbreken van agressief gedrag.

In hoofdstuk 4 wordt in detail gekeken naar de ruimtelijke organisatie van de groepen zeugen uit Hoofdstuk 3. Gedurende de duur van de proef (omschreven in Hoofdstuk 3) werden op plattegronden van de stal de exacte posities van alle dieren zes maal tijdens elk van de veertiendaagse observatie dagen aangegeven. Met behulp van deze data werden een aantal ruimtelijke parameters bepaald: de mate waarin bepaalde delen van de stal gebruikt werden, de "gemiddelde" positie van elk dier, de gemiddelde afstand tussen twee dieren, de afstand en identiteit van het dichtstbijzijnde andere varken en het aantal malen dat twee individuen binnen twee meter van elkaar waargenomen werden. Het voerniveau bleek opnieuw de resultaten nauwelijks te beïnvloeden: zeugen op een hoog voerniveau werden vaker gezien in het deel van het hok waar de drinknippels waren gesitueerd, en de dieren op een laag voerniveau vaker in de buurt van het voerstation. Daarentegen had de tijd na introductie van een nieuwe groep een belangrijk effect op alle ruimtelijke kenmerken: de gemiddelde afstand tussen dieren van verschillende subgroepen werd kleiner, en de gemiddelde afstand tussen dieren van dezelfde subgroepen groter naarmate subgroepen langer in de dynamische groep waren. Hoofdstuk 4 besluit met de conclusie dat sociale integratie een stapsgewijs proces is, beginnend met een piek in agressiviteit, waarna een periode aanbreekt waarin alle dieren dezelfde delen van het hok

in toenemende mate gaan gebruiken. De laatste stap, die een volledige willekeurige verdeling van voormalig aan elkaar bekende of onbekende dieren ten opzichte van elkaar impliceert, werd in de onderzochte groepen niet bereikt: voor dat moment waren de dieren uit de dynamische groep al verwijderd om naar de kraamstal te gaan.

Het vijfde hoofdstuk beschrijft een onderzoek naar de herhaalbaarheid van het gedrag van individuele gelten binnen zowel als tussen verschillende teststatuities. Het doel was deze gedragsverschillen vervolgens te kunnen relateren aan de ontwikkeling van ongewenst gedrag in een later stadium. Hiertoe werden de gelten aan een viertal testsituaties onderworpen, in twee series van elk 16 groepen. Elke groep bestond uit zes of zeven dieren. De situaties waren: 1: een "Open Field" test met een onbekend stimulus (emmer of mens); 2: toegang tot voer voor een individu gedurende 15 minuten na 20 uur voerdeprivatie, 3: toegang tot een beperkte hoeveelheid voer in een groepssituatie na 20 uur voerdeprivatie, 4: gedrag gedurende 24 uur in een standaard groepssituatie. Situaties 1 en 2 werden meerdere malen uitgevoerd. Beide suggereerden een hoge mate van herhaalbaarheid. Principle Components Analysis (PCA) werd gebruikt om het aantal test variabelen per situatie te reduceren, en om de interpretatie van de relatie tussen de verschillende situaties te vergemakkelijken. De hoeveelheid variatie die verklaard werd door de eerste component van de PCA was over het algemeen meer dan het dubbele van die van de andere componenten. De enige significante relatie tussen componenten werd gevonden voor situaties 1 en 2 in de eerste serie groepen. Geen van de componenten resulteerde in variabelen die bimodaal verdeeld waren. Geconcludeerd wordt, dat hoewel gelten over een relatief korte tijd consistent zijn in de manier waarop ze reageren op dezelfde situaties, deze herhaalbaarheid niet noodzakelijkerwijs *tussen* verschillende situaties geldt. Mede vanwege de afwezigheid van bimodaliteit van de gekozen gedragsvariabelen, kan het bestaan van een beperkte groep van gedrags "typen", met deze data niet worden bevestigd.

De algemene discussie behandelt de praktische implicaties van het voorgaande. Deel 1 suggereert dat hoewel groepshuisvesting een bijdrage kan leveren aan het verminderen van stereotiep gedrag, factoren als voerniveau en substraat voorziening mogelijk belangrijker zijn. Verder wordt besproken of de associatie van de omgeving van de voerbak of voergoot met vreetgedrag, het optreden van stereotypieën stimuleert. Tot slot wordt het belang van verder onderzoek naar alternatieve substraten, die verstrekt kunnen worden op bedrijven waar strogebruik onmogelijk is, benadrukt. Deel 2 bespreekt de agressiviteit tussen zeugen in zowel groepshuisvesting als individuele huisvesting. Het benadrukt het gegeven dat in dynamische systemen de sociale structuur van de groep voortdurend onder druk staat door de toevoeging van nieuwe en vaak onbekende dieren. Het ontraadt het gebruik van deze systemen in de afwezigheid van stro (of een ander vergelijkbaar substraat). Bovendien wordt ervoor gepleit de frequentie waarmee nieuwe dieren aan de dynamische groep toegevoegd worden tot een minimum te beperken. Dit kan bijvoorbeeld door een semi-dynamisch systeem te gebruiken waarbij dieren gedurende een paar opeenvolgende weken aan een groep toegevoegd worden, waarna deze groep met rust gelaten wordt. Gedurende deze rustperiode worden nieuwe zeugen toegevoegd aan een volgende semi-dynamische groep, etc. Andere huisvestingsmethoden, zoals het verstrekken van afzonderlijke ligruimtes voor subgroepen, kunnen ook de rust in de stal bevorderen. Deel 3 tot slot bevestigt dat varkens individuen zijn. Wel plaatst het vraagtekens bij de mogelijkheid om al op jonge leeftijd te kunnen meten of deze individuen succesvol zijn in het omgaan met hun volwassen milieu. Dit kan wellicht wel op een later tijdstip

voorspeld worden. Tot slot wordt er op gewezen dat de aanwezigheid van "individuen" in een groepshuisvestingssysteem meer vereist van het vakmanschap van de verzorger, dan dat in een individueel huisvestingssysteem het geval is.

LIST OF PUBLICATIONS

Papers

- Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Simmins, P.H. and Lawrence, A.B., 1995. Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. *Applied Animal Behaviour Science*, 43: 249-262.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1996. Individual behavioural differences in pigs: intra- and inter-test consistency. *Applied Animal Behaviour Science*, 49: 185-198.
- Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Simmins, P.H. and Lawrence, A.B., 1996. Effects of food level and straw bedding during pregnancy on sow performance and responses to an ACTH challenge. *Livestock Production Science*, 47: 51-57.
- Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Lawrence, A.B. and Simmins, P.H., 1997. Effects of food level on performance and behaviour of sows in a dynamic group housing system with electronic feeding. *Animal Science*, 65: 473-482.
- Spoolder, H.A.M., Lawrence, A.B., Edwards, S.A., Simmins, P.H. and Armsby, A.W. Spatial organisation of dynamic groups of sows on two different food levels (submitted).
- Whittaker, X., Spoolder, H.A.M., Edwards, S.A., Lawrence, A.B. and Corning, S. The influence of dietary fibre and the provision of straw on the development of stereotypic behaviour in food restricted pregnant sows (submitted).

Abstracts

- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H., Edwards, S.A. and Terlouw, E.M.C., 1993. Characterisation of behavioural types in pigs: The relationship between feeding behaviour and social rank. *Animal Production*, 56: 439.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1993. Straw substitutes for a chain as a stimulus for post feeding activity in food restricted sows. *Applied Animal Behaviour Science*, 41: 279.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1994. Characterisation of behavioural types in pigs: The relationship between feeding behaviour and social rank. *Animal Production*, 58: 473.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1995. The effects of food level on general activity and aggression in dynamic groups of 30 sows. *Animal Science*, 60: 517.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Edwards, S.A. and Simmins, P.H., 1996. Social recognition in gilts mixed into a dynamic group of sows. *Animal Science*, 62: 630.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Edwards, S.A. and Simmins, P.H., 1996. Effects of food level and straw provision during pregnancy on sow performance and responses to an adrenocorticotrophic hormone challenge. *Animal Science*, 62: 675.
- Whittaker, X., Spoolder, H.A.M., Corning, S., Edwards, S.A. and Lawrence, A.B., 1996. The effect of *ad libitum* feeding of a high fibre diet on the reproductive performance of gilts. *Animal Science*, 62: 660.

Proceedings of Conference Presentations

- Burbidge, J.A., Spoolder, H.A.M., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1993. The effect of feeding regime and the provision of a foraging substrate on the development of behaviours in group-housed sows. In: Proceedings of the International Congress of the International Society for Applied Ethology, M. Nichelmann, H.K. Wierenga and S. Braun (Editors). Berlin 1993. KTBL, Darmstadt. pp. 104-107.
- Kemp, B., Jansen, R.G., Spoolder, H.A.M., Lende, T. Van Der and Soede, N.M., 1992. The influence of boar stimulation after insemination on embryonic diversity during early pregnancy in individually housed gilts. In: Proceedings of the 12th International Congress on Animal Reproduction, 1249-1251.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1994. The relationship between individual temperament and the development of abnormal oral stereotypies in food restricted sows. In: Proceedings of the 28th International Congress of the International Society for Applied Ethology, Foulum, Denmark, 1994. p. 120.
- Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H. and Edwards, S.A., 1995. Intra- and inter-test consistency in behavioural responses of gilts to different challenges. In: Proceedings of the 29th International Congress of the International Society for Applied Ethology, Exeter, U.K., 1995. p. 55-56.
- Spoolder, H.A.M., Corning, S. and Edwards, S.A. 1997. A comparison of methods of specifying stocking density for welfare and performance of finishing pigs on different floor types. In: Proceedings of the British Society of Animal Science, Scarborough, March 1997: 43.
- Spoolder, H.A.M., Corning, S. and Edwards, S.A. 1998. Welfare of finishing pigs after mixing in kennelled or unkennelled accommodation. In: Proceedings of the British Society of Animal Science, Scarborough, March 1998.
- de Vries, H.L., Spoolder, H.A.M. and Marchant, J.N. 1998. Food competition tests between pigs: differences in heart rates of "winners" and "losers" prior to testing. In: Proceedings of the British Society of Animal Science, Scarborough, March 1998.
- Whittaker, X., Spoolder, H.A.M., Edwards, S.A., Corning, S. and Lawrence, A.B., 1995. The effect of *ad libitum* feeding of a high fibre diet on aggressive interactions in pregnant sows following dynamic grouping. In: Proceedings of the International Society for Applied Ethology regional meeting, London, 29 November 1995.
- Whittaker, X., Spoolder, H.A.M., Edwards, S.A., Corning, S., and Lawrence, A.B. 1997. The effect of high fibre diet and the provision of a foraging substrate on the development of stereotypic behaviour in group housed sows. In: Proceedings of the British Society of Animal Science, Scarborough, March 1997: 45.
- Whittaker, X., Spoolder, H.A.M., Edwards, S.A., Corning, S. and Lawrence, A.B. 1997. The foraging behaviour of *ad libitum* compared with restricted fed sows housed in dynamic groups. In: Proceedings of the 31st International Congress of the International Society for Applied Ethology, Prague, August 1997: 243.
- Whittaker, X., Edwards, S.A., Spoolder, H.A.M., Corning, S. and Lawrence, A.B. 1998. Levels of aggression in floor fed sows: effects of straw bedding and high fibre diets. In: Proceedings of the British Society of Animal Science, Scarborough, March 1998.

DANKWOORD / ACKNOWLEDGMENTS

DANKWOORD

In 1991 begonnen Jackie Burbidge en ik aan het project dat uiteindelijk tot dit proefschrift leidde. Ik vroeg tijdens één van onze eerste bijeenkomsten aan Sandra Edwards of de drie jaar die ervoor stonden genoeg zouden zijn om naast het "gewone" werk een proefschrift te schrijven. Haar (typische) antwoord was: "Dat ligt eraan hoeveel slaap je denkt nodig te hebben!". Het feit dat het na zeven jaar toch gelukt is en ik in die tijd (meestal) redelijk goed geslapen heb, is voor een belangrijk deel te danken aan de hulp die ik heb gehad van een groot aantal mensen.

Allereerst natuurlijk mijn promotor, Piet Wiepkema en co-promotor Willem Schouten. Beiden waren jullie vanaf het begin betrokken bij het project en ondanks de afstand Terrington - Wageningen zagen we elkaar regelmatig om de voortgang van de verschillende hoofdstukken te bespreken. Voor alle tijd die jullie in die discussies en het lezen van mijn artikelen staken, maar vooral voor de steun en aanmoediging die ik telkens tijdens deze besprekingen ontving, wil ik jullie graag bedanken.

Op de tweede plaats Sandra Edwards en Alistair Lawrence, mijn begeleiders gedurende het project. Sandra, je scherpe analyses van ingewikkelde problemen, je opbouwende kritiek op manuscripten die ik bijna altijd per omgaande ontving, je geduld wanneer mijn basiskennis van veevoeding of statistiek weer eens bijgespijkerd moest worden, dat alles heb ik altijd enorm gewaardeerd. Alistair, een belangrijk deel van de ideeën die in dit proefschrift aangedragen worden, zijn het resultaat van de vele discussies die ik met jou had over de ethologie van het varken. Daarnaast was je als mijn 'line manager' altijd in de eerste plaats geïnteresseerd in mijn eigen welzijn vóór dat van het project. Jullie bijdrage was zonder twijfel de belangrijkste voor mijn training als zelfstandig onderzoeker. Bedankt.

Jackie Burbidge, met wie ik het project op de proefboerderij van ADAS Terrington uitvoerde. Samen hebben we vele uren varkens geobserveerd, bloed getapt en speekselmonsters verzameld. Je enthousiasme, maar vooral de manier waarop je je in de 'gedachtengang' van onze dieren wist te verplaatsen was onnavolgbaar. Ik heb bovendien nog nooit iemand ontmoet die zoveel verschillende varkens aan hun gezicht kon herkennen. Bedankt voor je gezelschap en al je hulp!

De ADAS Pig Team managers met wie ik tot nog toe in Terrington samengewerkt heb: Howard Simmins, Sue Corning en Tony Walker. Howard, je was team-manager in de jaren dat Jackie en ik het project uitvoerden. Aan jou ben ik onder meer dank verschuldigd voor het geduld dat je toonde toen ik mijn eerste wankele stapjes zette op het pad van het 'Wetenschappelijk Engels'. Sue en Tony, jullie hebben vanaf het moment dat ik bij ADAS begon te werken gezorgd dat niet al mijn schrijfwerk in de avonduren hoefde te gebeuren. Zonder jullie positieve instelling ("Problemen bestaan niet: het leven bestaat uit uitdagingen en kansen!") waren deze laatste loodjes een stuk zwaarder geweest.

Alle (ex-) collega's op de proefboerderij van ADAS Terrington, en met name Tony Armsby, Carl Widdows, Steve Malkin, Roger Kay, Roger Stiles, Steve Jackson, John Billington, Bill Downey, Simon Ash, Liz Moore, Andrew Rudd, Eunice Everitt, Janet Stiles, Paul Kenneally en John Ward. Bedankt voor al jullie hulp.

Wilma's ouders, Sinie en Antoon, die hun dochter zagen vertrekken naar Engeland. In het buitenland wonen en werken is niet iets dat je zomaar doet. Maar jullie ondersteuning, op allerlei manieren, heeft Wilma (en mij!) al door menig "dieptepunt" heen geholpen. Bedankt.

Een bijzonder woord van dank aan mijn eigen ouders. Zeven kinderen opvoeden kan niet altijd gemakkelijk geweest zijn. Toch hebben wij, mijn broers, zussen en ik, door jullie harde werk en goede zorgen altijd de kans gekregen de richting te kiezen die ons het meest aansprak. Voor jullie steun de afgelopen zeven jaren en al die jaren daarvoor, ben ik jullie heel dankbaar.

En tot slot Wilma, mijn vrouw, aan wie ik dit werk heb opgedragen. De beslissing eind 1990 om naar Engeland te verhuizen was waarschijnlijk de moeilijkste die we ooit gemaakt hebben. Je liet een goede baan en al je familie en vrienden achter om mij de kans te geven dit doel te bereiken. Bedankt voor je hulp als ik weer eens handen tekort kwam, voor je droge humor die me met beide benen op de grond hield, voor het herinneren van al die dingen als mijn geheugen weer eens zo lek bleek als een zeef, maar vooral bedankt, omdat je er *bent*.

ACKNOWLEDGMENTS

In 1991 Jackie Burbidge and I started working on the project which forms the basis of this thesis. Initially, writing a PhD thesis was only an option in addition to the ongoing project work. During one of our first meetings, I asked Sandra Edwards whether three years would be enough to complete a PhD. Her (typical) answer was: "that depends on how much sleep you need!". It may have taken seven years, but I slept well most nights during this time, and that was only possible because I had the support from a large number of people to whom I owe my thanks.

Firstly to my promotor, Piet Wiepkema, and co-promotor Willem Schouten. You were both involved with the project right from the start, and despite the distance between Wageningen and Terrington we managed to meet regularly to discuss the progress of the various chapters in my thesis. I would like to thank you both for all the time you put into reading my drafts, but especially for all the support and encouragement I received every time we met.

Secondly to Sandra Edwards and Alistair Lawrence, my joint PhD supervisors. Sandra, thank you for your sharp analysis of complicated problems, your constructive criticism on my drafts which I usually received by return mail and your endless patience when basic nutritional or statistical principles needed explaining (again...!). Alistair, an important part of the ideas which are put forward in this thesis are the result of the many discussions I had with you on pig behaviour. For this, and for the fact that as my line manager you would always place my "welfare" before that of the project, I am very grateful. Your joint efforts have without doubt been the most important contribution to my training as a researcher.

Jackie Burbidge, my co-worker, with whom I carried out the project at ADAS Terrington. Together we spent many hours observing pigs, collecting blood samples and sticking cotton buds up pigs' mouths. Your enthusiasm, but especially the way in which you always managed to put yourself in the mind of our pigs was impressive. And, I've never known anyone who could recognise so many sows by their face! Thanks for your company and all your help.

The succession of ADAS Pig Team managers with whom I worked at Terrington: Howard Simmins, Sue Corning and Tony Walker. Howard, you were the team manager during the years Jackie and I did our project. Thanks, among many other things, for your patience when I made my first steps on the road to "writing scientific English". Sue and Tony, your support meant I didn't have to do all the writing in the evening hours once I joined ADAS. Also, without the positive way

in which you ran the team ("Problems don't exist, only challenges and opportunities!") the final hurdles would have been a lot higher.

All colleagues and ex- colleagues on the ADAS Terrington experimental farm, who were in some way involved with the project: Roger Stiles, Steve Jackson, John Billington, Bill Downey, Simon Ash, Liz Moore, Andrew Rudd, Eunice Everitt, Janet Stiles, Paul Kenneally, John Ward, and in particular Tony Armsby, Carl Widdows, Steve Malkin and Roger Kay. Thank you all for your help.

A special word of thanks to my parents. Raising seven children was not easy. However, through hard work and dedication they made sure that each one of us could pursue our own ambitions in life. For your support and encouragement these past seven years, as well as all those years before that, I am very grateful.

And finally Wilma, my wife, to whom I dedicate this thesis. The decision at the end of 1990 to move to England was probably the most difficult one we have ever had to make. You left a job, your family and many friends behind to give me the chance to achieve this aim. Thanks for your help at times when one pair of hands (or one brain) wasn't enough, for reminding me of all those little things I keep forgetting and for making me laugh with your dry sense of humour. But most of all, thank you for just *being here*.

Yours

CURRICULUM VITAE

Hermanus Antonius Maria Spoolder werd geboren op 6 oktober 1965 in Nijverdal (Ov.). In 1984 behaalde hij het VWO diploma aan het Pius X College in Almelo, en begon in september van dat jaar met de studie Zoötechniek aan de toenmalige Landbouwhogeschool in Wageningen. In Augustus 1990 studeerde hij af met als afstudeervakken Ethologie en Vruchtbaarheid en Voortplanting.

In januari 1991 werd hij aangesteld als Assistant Scientific Officer bij de Scottish Agricultural College in Edinburgh, Schotland. In die functie werkte hij gedurende ruim drie jaar aan een project met als titel "The relationship between foraging behaviour, feeding regime and the welfare of the pregnant sow" op het varkens proefbedrijf van ADAS Terrington, King's Lynn, Engeland. Het onderzoek uitgevoerd gedurende deze periode vormt de basis voor dit proefschrift. In april 1994 volgde een aanstelling als Scientific Officer bij SAC. In deze hoedanigheid leidde hij op de proefboerderij van ADAS gedurende een jaar een project getiteld "Welfare of pregnant sows when fed *ad libitum*". In maart 1995 werd hij aangesteld als Pig Research Consultant voor ADAS, met als primaire taak het ondersteunen van het gedragsonderzoek op de proefboerderij in Terrington.