THE DEVELOPMENT OF UNRESTRICTED, GROUP FARROWING SYSTEMS FOR SOWS

by

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A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

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Seale-Hayne Faculty

July 1998

ABSTRACT

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This thesis examines the activities of four groups of four sows, allocated to one of two space allocations, in a novel farrowing system design, over parturition and during lactation. The two pen configurations provided 13.4m^2 (L) and 8.6m^2 (S) per sow, respectively. A lactation diet providing 14MJ/kg DE and 18% CP was supplied *ad libitum* via a sow operated feeder, adapted to facilitate the calculation of individual feed intakes. The influence of environmental, physical, management and production factors upon the way in which sows allocated their time to different activities, suckling behaviour, feed intakes and feeding and drinking strategies was investigated.

Sows in the small pen area were generally less active than those housed in the large pen configuration. During the first week of lactation, significantly more time was spent lying down ($P<0.05$) and fewer transitions were made between postures ($P<0.001$) in the reduced space allocation. Sows in the S pen configuration suckled their piglets significantly more frequently than sows in the L pen area ($P<0.001$). However, similar daily piglet weight gains were achieved in both the L and S pen configurations.

Daily feed intakes of 7.69 kg (s.e. 0.31) and 7.72 kg (s.e. 0.35) were achieved during lactation, by sows in the L and S pen configurations, respectively. This was accomplished by sows taking a series of small feeds throughout the day. Sows in the S pen area made fewer visits to the feeder and spent less time per day feeding, compared with sows in the L pen area. However, more feed was consumed per visit by the S sows, resulting in similar daily feed intakes in both treatment groups.

A marked increase in activity during the 24 hours prior to parturition was followed by a sharp reduction during day 1 of lactation in both treatment groups. Thereafter, activity levels increased gradually during week 1 of lactation. Most piglet deaths occurred in early lactation, 65.0% and 67.9% of which were during days 1 to 3 following birth in the L and S pen areas, respectively. Mortality of live-born piglets was unacceptably high at 19.6% in the L and 24.6% in the S pen areas.

The relative advantages and disadvantages to sows and piglets within the novel farrowing system are considered in the general discussion.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

Abstr.	abstract
ADAS	Agricultural Development and Advisory Service
av.	average
CP	crude protein
cm	centimetre
cm^3	cubic centimetre
DE	digestible energy
DIAS	Danish Institute of Agricultural Science
DWG	daily liveweight gain
E_m	energy for maintenance
E_h	energy for thermogenesis
E_l	energy for lactation
ECT	evaporative critical temperature
FAL	Bundesforschungsanstalt für Landwirtschaft
g	gramme
IMAG-DLO	Institute for Agricultural and Environmental Engineering
kg	kilogramme
kJ	kilojoule
km	kilometre
L	large pen configuration
L2	replicate 2 in L pen area
LCT	lower critical temperature
m	metre
ml	millilitre
mm	millimetre
m^2	square metre
MAFF	Ministry of Agriculture, Fisheries and Food
ME	metabolisable energy
MJ	megajoule
MLC	Meat and Livestock Commission
na.	none available
NL	Netherland
no.	number
P	probability
RSD	residual standard deviation
R-sq(adj)	adjusted coefficient of multiple determination
S	small pen configuration
S1	replicate 1 in S pen area
S2	replicate 2 in S pen area
s.d.	standard deviation
s.e.	standard error
SE_D	standard error of the difference
SLU	Swedish University of Agricultural Sciences
Suppl.	Supplement
T	ambient temperature
T_c	lower critical temperature
T_c	effective ambient temperature
UK	United Kingdom
USA	United States of America
V_e	measure of insulation effects
V_f	measure of flooring effects
vs.	versus
W	weight
$W^{0.75}$	metabolic weight
wt	weight
μ	mean vector
^{0}C	degree centigrade

ACKNOWLEDGEMENTS

I would like to thank Prof Peter Brooks for his expert supervision and guidance during the completion of this research project. His encouragement and enthusiasm were invaluable and greatly appreciated. I am also indebted for the support, advice and encouragement given by Dr John Kirk and Dr John Eddison in their capacity as supervisors.

I am very grateful for the support of the John Oldacre Foundation in providing funding towards the research project.

I would especially like to thank Dr Bill Budenburg of Tracksys Ltd. for his patience and invaluable assistance whilst I was learning to cope with the peculiarities of the Observer software programme.

Grateful thanks to Patrick Bugg for building the farrowing system and setting up the video cameras and recording equipment. Thank you to Peter Russell for his advice and calm manner in which he helped me cope with problems which arose along the way. In particular, I would like to thank Cathryn Caveney for her assistance with the sows and litters.

My thanks also go to Richard Newington for providing the sows from the Seale-Hayne Pig Unit for the research project. Special thanks to Nikki Hodgkiss for her assistance with the sows, particularly the ones with slightly more aggressive tendencies and for making me laugh.

I wish to thank the library staff at Seale-Hayne Faculty for their assistance and cheerfulness, which were greatly appreciated.

A warm thank you to Niki and Claire for their enthusiasm and encouragement of my work and finally a big thank you to Eddie for listening, for cups of tea and spaghetti bolognaise, but mainly for just being there.

AUTHOR'S DECLARATION

I hereby certify that this thesis has been written by me and that the contents are the results of my own investigations. The results presented here have not previously been submitted for any degree or qualification.

This study was financed with the aid of sponsorship from the John Oldacre Foundation.

Publications:

Brooks, P.H. and Burke, J. 1998. Behaviour of sows and piglets during lactation. In: Verstegen, M., Moughan, P. and Schrama, J., *The Lactating Sow,* Wageningen Pers, Wageningen, NL. 301-338.

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Burke, J. 1996. *An investigation of experimental and commercial non-confinement and group farrowing systems in the Netherlands, Germany, Denmark, Sweden and Norway.* Seale-Hayne Faculty, University of Plymouth, Newton Abbot. pp 60.

Poster publications

Burke, J., Brooks, P.H., Kirk, J.A. and Eddison, J.C. 1998. *Suckling frequency of group housed sows in two different space allocations.* Proceedings of the British Society of Animal Science 1998, Scarborough.

Burke, J., Brooks, P.H., Kirk, J.A. and Eddison, J.C. 1997. *Daily feed intakes of group housed sows fed ad libitum from 5 days before parturition until day 17 of lactation.* Progress in Pig Science, University of Nottingham, 58th Easter School in Agricultural Science. Sutton Bonnington.

Conferences attended:

1998: British society of Animal Science Winter Meeting, Scarborough

1997: International Society for Applied Ethology, UK/EIRE Winter Meeting, The Royal Veterinary College, London.

Progress in Pig Science, 58th Easter School in Agricultural Science, University of Nottingham

British Society of Animal Science Winter Meeting, Scarborough

1996: Animal Choices Conference, joint meeting of the International Society for Applied Ethology and the British Society of Animal Science, Leeds University

British Society of Animal Science Winter Meeting, Scarborough

Developments in Animal Welfare from Farmgate to Slaughter, Meat and Livestock Commission, Coventry

1995: International Society for Applied Ethology UK/Ireland Regional Meeting, Royal Veterinary College, London

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29th International Congress of the International Society for Applied Ethology, University of Exeter

British Society of Animal Science Winter Meeting, Scarborough

Awards:

1996: The British Society of Animal Science Braude Travel Scholarship

1996: The Royal Bath and West Show Society special award for travel and study of research into development of farrowing systems in Europe

1996: Funding in support of travel and study in Europe from the Cornwall Education and Research Trust

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Research Institute for Pig Husbandry, Rosmalen, Netherlands

Institute of Agricultural and Environmental Engineering (IMAG-DLO), Wageningen, Netherlands

Experimental Farm (IMAG-DLO), Maartensdijk, Netherlands

The Agricultural University of Wageningen, Netherlands

Experiment Farm for Pig Husbandry, Raalte, Netherlands

Federal Agricultural Research Centre, Braunschweig, Germany

Danish Institute for Animal Science, Research Centre Bygholm, Horsens, Denmark

Danish Institute for Animal Science, Research Centre Foulum, Viborg, Denmark

Swedish University of Agricultural Sciences, Lund, Sweden

Swedish University of Agricultural Sciences, Skara, Sweden

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Dr Finn Møller, Dr Lise Dybjær, Anne Olsen	D.I.A.S., Bygholm
Karen Thodberg, Mette Herskin	D.I.A.S., Viborg
Dr Jørgen Svendson, Dr Anne-Charlotte Olsson	S.L.U., Lund
Prof Per Jensen, Prof Bo Algers, Dr Linda Keeling, Dr Barbro Mattsson	S.L.U., Skara
Prof Knut Bøe, Inger-Lise Furuhaug	Agricultural University of Norway
Dr Jeremy Marchant, Dr Harry Bradshaw	University of Cambridge
Dr Han Spoolder, Dr Xanthe Whittaker	A.D.A.S., Terrington
Dr Pinder Gill	M.L.C.
Dr Violet Beattie	Agricultural Research Inst., N. Ireland

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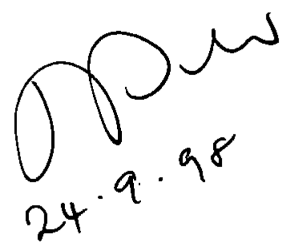
Date



INTRODUCTION

Housing systems based on the farrowing stall or crate were developed in order to reduce piglet deaths from crushing by the sow and began to replace traditional straw bedded farrowing pens in the early 1960s (Robertson, Laird, Hall, Forsyth, Thomson and Walker-Love 1965; Cronin and Smith 1992a). As pig units became more intensive and buildings more specialised, increasing numbers of sows were housed in crates over parturition and during lactation (Baxter 1981; Blackshaw, Blackshaw, Thomas and Newman 1994; McGlone, Salak-Johnson, Nicholson and Hicks 1994). In addition to affording piglet protection, the farrowing crate allows observation, treatment and individual feeding of the sow and litter. The system provides protection and ease of control for the stockperson and enables separate thermal environments to be provided for sow and piglets to cater for the wide difference in their respective lower critical temperatures. For these reasons, the farrowing crate has become a valuable management tool, which makes very efficient use of space and as a result, over 90% of sows in indoor units in the UK, are housed in the farrowing crate over parturition and during lactation (Edwards and Baxter 1989; Baldwin 1996).

Opponents of the farrowing crate argue that it restricts the natural movements of the sow and prevents pre-farrowing nest building activity. There is also some evidence that confinement in the crate may cause prolonged parturition times which result in an increased number of stillbirths (Baxter 1980; Arey and Petchey 1992). Even with the protection of the farrowing crate crushing and trampling by the sow have continued to be the major cause of mortality of live born piglets (English and Wilkinson 1982; Dyck and Swierstra 1987; Edwards 1987; Arey and Petchey 1992).

The perceived welfare of farm livestock is of increasing importance as, through concern about food animal production methods, consumers and powerful pressure groups continually press for changes to production systems which they judge to compromise animal welfare (Bennett 1994; Bennett 1996). Public opinion increasingly requires the consideration of more welfare oriented approaches to animal production. Against such a background, certain husbandry systems must inevitably change, particularly in intensive areas such as farrowing accommodation. Following their success in persuading legislators in the UK to ban sow stalls and tether systems for gestating sows (MAFF 1991), the animal welfare lobby mounted a new campaign to prevent the use of the farrowing crate and allow the sow more freedom whilst rearing her young (D'Silva 1993; Anon. 1995b; Anon. 1997).

Communal farrowing systems would appear to be more compatible with loose housing of dry sows, as the accommodation change at farrowing time would be less profound than a move to the confinement of farrowing crates and cause less disruption of social activity within established groups of animals (den Hartog, Backus and Vermeer 1993). It is however, vitally important to ensure that, whenever changes are made to improve the welfare of animals in one part of the production cycle, the alterations do not detract from that welfare in another area (Olsson, Svendsen and Reese 1994; Marchant 1997).

There is a need therefore, to investigate the possibility of economically viable alternatives to the farrowing crate which

* are compatible with loose housing of dry sows
* facilitate expression of the full behavioural repertoire of sows of suitable temperament
* provide protection for the piglets
* incorporate a safe working environment for the stockperson

in anticipation of further Government legislation and changes to buying specifications of major food retailers which discriminate against existing systems.

1. LITERATURE REVIEW

1.1 INTRODUCTION

A great deal of research on the behaviour of pigs in the wild including that of Graves (1984), Robert, Dancosse and Dallaire (1987) and Mauget (1981) has aimed to broaden our understanding of what constitutes natural behaviour and provide an insight into the wellbeing of pigs in modern intensive production systems. Knowledge of the potential range of behaviour would be limited if study was confined to production environments (Dawkins 1989; Gonyou 1995). Nevertheless, Veasey, Waran and Young (1996) argue that improved welfare of domestic species is not dependent upon the presence of the full range of behaviours exhibited by wild conspecifics. This was in accordance with the findings of Stolba and Wood-Gush (1984) in their work identifying key features which need to be present in pig housing for the stimulation of important behavioural sequences and the enhancement of welfare. They considered that the complex natural environment could be simplified, as only a few key stimuli and main behavioural elements were required to safeguard the welfare of domestic livestock.

In this literature review, the maternal behaviour of wild boar and domestic sows kept in semi-natural environments is described and comparisons are made with experimental and commercial production systems. Where possible, the relevance to unrestricted, group farrowing systems is discussed. Following this, the development of suckling and the behaviour of sows and piglets during lactation is discussed. The final part of this chapter examines the factors which influence the feed intake and water use of the lactating sow and their relationship with productivity.

1.2 THE SOCIAL ORGANISATION OF SOWS

Wild and feral swine live in matriarchal groups consisting of a number of sows and their offspring. The groups vary in size and make-up as illustrated by a number of reports (Table 1.1). Adult boars often remain solitary, (Hanson and Karstad 1959; Gundlach 1968; Kurz and Marchinton 1972; Fradrich 1974; Mauget 1981; Graves 1984) only joining groups of sows for breeding. In contrast, domestic pigs kept in semi-natural enclosures 1.16 and 1.14 hectares in size, formed sub-groups which included an adult boar and a number of sows (Stolba and Wood-Gush 1984, 1989). Gundlach (1968) noted that in a confined space, the normal social organisation does not develop and adult boars stayed with the sows and their young. He goes on to say that this was never seen in larger enclosures or in the wild. It may be that the relatively small size of the enclosures in the study by Stolba and Wood-Gush (1989) prevented the boar from separating himself from the sows and litters successfully, resulting in the group structure and spatial organisation reported.

no. of sows	*no. of offspring*	*total group size*	*reference*
1 - 4	2 - 12	3 - 16	(Gundlach 1968)
1 - 4	1 - 19	2 - 23	(Graves 1984)
2+	na	na	(Fradrich 1974)
2 - 4	na	na	(Mauget 1981)
1+	na	<10	(Signoret, Baldwin, Fraser and Hafez 1975)
2 - 3	2 - 15	4 - 18	(Kurz and Marchinton 1972)*

* feral pigs

Table 1.1 Numbers of wild boar and feral sows and offspring reported to form matriarchal groups

Commercially operated communal farrowing systems are a rarity and generally involve the housing of larger groups of sows than would occur in natural conditions. Examples include

* the Swedish Thorstensen system in which groups of ten or more sows and their litters were housed in a farrowing room providing $8m^2$ per sow over parturition and during a 6 week lactation period (Algers 1991)

* Norwegian fully integrated systems in which stable groups of thirty sows were housed together throughout the production cycle (Bøe 1993; Bøe 1994)

The number of sows catered for and the environment provided in experimental group farrowing systems has varied (Table 1.2).

1.3 BEHAVIOUR OF THE PERI-PARTURIENT SOW

A few days before farrowing wild boar sows (Stegeman 1938; Fradrich 1965; Gundlach 1968; Fradrich 1974; Mauget 1981) and free-ranging domestic sows (Jensen 1986; Stolba and Wood-Gush 1989) became solitary, left the matriarchal group and became increasingly aggressive towards their previous years offspring (Gundlach 1968; Mauget, Campan, Spitz, Dardaillon, Janeau and Pepin 1984). During this time the sow selected a suitable site in which to build the farrowing nest. Nest sites were generally in well protected places, for example, in gullies, in undergrowth on the forest edge or surrounded by tall grasses in meadows (Gundlach 1968; Stolba and Wood-Gush 1984).

Stolba and Wood-Gush (1984) and Jensen (1989) found that the nest sites of domestic sows in semi-natural environments tended to be protected on at least one side. Similarly, Graves (1984) observed that nests of wild and feral pigs were often made at the base of a tree, or by a log or rock.

System	*No.of Sows*	*Housing features*	*Occupation time*	*Difficulties*	*reference*
Edinburgh Family Pen	4 to 5	enriched pens with straw bedded nest, heated piglet creep, activity and peat rooting areas, for sows and progeny	production cycle	poor use of creep area, 30% piglet mortality	(Kerr, Wood-Gush, Moser and Whittemore 1988) (Arey 1994)
Group farrowing system	6	oval pen with individual farrowing compartments, chopped straw bedding, partitions removed after 1 week to form common lying area, heated piglet creep	to weaning	cross suckling fighting, injuries, infections in piglets, disturbed sows	(van de Burgwal 1993)
Freedom Farrowing System	6	individual farrowing enclosures in which turning by sow prevented, restraining bar to confine sow, little chopped straw bedding, inwardly sloping wall and piglet escape tunnel to prevent crushing, piglets confined until 2 to 3 weeks of age, heated piglet creep	28 days	25% piglet mortality, damage to fittings by sows, discomfort due to flooring, sows preferred to lie outside enclosures	(Baxter 1991)
Integrated Farrowing System	32	dry sow accommodation, electronic gate to farrowing section, individual farrowing pens in which piglets confined, straw provided before farrowing, heated piglet creep	production cycle	only 70-80% of sows farrowed in pens, sows left piglets for prolonged periods	(Houwers, Buré and Koomans 1992)

Table 1.2 Summary of sow numbers, housing features, occupation time and difficulties encountered in experimental group farrowing systems reported in the literature

Interestingly, a number of studies of sow behaviour around farrowing, in a variety of experimental housing situations, demonstrated that a degree of enclosure and protection appeared to be an important feature of a farrowing site for sows (Table 1.3). Furthermore, the presence of sufficient manipulable substrate with which to build a nest also influenced the choice of farrowing site by sows (Arey, Petchey and Fowler 1992).

1.3.1 Nest building in wild and semi-natural environments

The preparation of the nest was an elaborate process, the first phase of which involved the sow in hollowing out a depression in the earth with the snout. In some cases this nest hollow was the only preparation performed (Kurz and Marchinton 1972), but more usually sows then proceeded to gather nest materials with which to line the hollow (Fradrich 1965; Gundlach 1968; Jensen 1986; Stolba and Wood-Gush 1989; Meynhardt 1991).

Dry grass, foliage and small twigs were collected from within a radius of 20-50 metres around the earth hollow (Gundlach 1968; Jensen 1986; Stolba and Wood-Gush 1989; Meynhardt 1991). The choice of material collected depended on availability and ranged from pine straw (Kurz and Marchinton 1972), to green plants or just foliage and thin branches (Gundlach 1968). The sow carried bundles of material in her mouth and placed them either in or on the edge of the nest hollow (Gundlach 1968; Fradrich 1974; Jensen 1986; Stolba and Wood-Gush 1989).

The sow then lined the nest by pushing the bundles of bedding material to the sides whilst continually turning round within the hollow (Gundlach 1968; Jensen 1986). Leaves and grass outside the nest were scraped in with the forelegs and finally the sow pressed the materials down with the underside of her head. This activity continued until the nest edge was visibly raised and the hollow completely lined and filled with material (Gundlach 1968). Loose housed domestic sows have been observed to create similar nest structures out of straw during the 24 hours prior to parturition (Arey, Petchey and Fowler 1991).

Housing features	*No. of sows tested*	*Preferred farrowing site*	*Reference*
Individually housed sows given choice of farrowing ark, bare concrete floor, straw on concrete and Profort pig nest	20	11 sows chose the ark, 3 the nest box and 6 chose sites against a side wall, ark or nest box	(Hunt and Petchey 1987)
Individually housed sows given choice of a single wall, a corner, a cul-de-sac and an enclosed area with an entrance	32	14 sows chose the enclosed area, 11 the cul-de-sac, 2 the corner and 2 chose the single wall	(Hunt and Petchey 1989)
Individually housed sows given choice of parallel walls, 2m long and spaced 0.55, 0.95 and 1.35m apart	48	21 sows farrowed between walls 0.55m apart, 14 between walls 0.95m apart, 6 between walls 1.35m apart and 7 farrowed outwith these areas	(Petchey 1991)
Sows housed individually in a 6.5 x 7m test arena with a 2 x 2m pen in one corner	24	14 farrowed in small pen, 10 in the test arena. All but 1 sow farrowed with their backs against a wall or fence, or across a corner	(Haskell and Hutson 1994)

Table 1.3 Summary of the types of enclosure and protection which influenced the farrowing site choice of sows in experimental housing systems, reported in the literature

Gundlach (1968) pointed out that individual differences of particular animals, weather conditions and the nature of the available vegetation influenced the exact sequence of actions and the eventual nest structure. This is in agreement with studies of free-ranging domestic sows (Jensen 1989; Jensen, Vestergaard and Algers 1993) and borne out by the fact that wild boar sows observed by Meynhardt (1991) stopped building at this point and settled in the nest approximately 2 hours prior to parturition. In contrast, wild boar sows studied by Gundlach (1968) continued their nest preparation by building a roof over the nest.
To facilitate this, thicker branches approximately 2 metres in length, were added to the nest and covered by more grasses and finer material (Gundlach 1968). The finished nest consisted of several layers of material, up to 1 metre in height, through which the sow slowly burrowed (Gundlach 1968; Meynhardt 1991). Once inside the nest the sow was almost completely covered by the structure. According to Pullar (1950) the nests of feral sows are also often large and well camouflaged, up to six or eight feet in diameter.

Studies conducted by Jensen (1986) revealed that domestic sows in a semi-natural environment moved between 2.5 and 6.5km whilst selecting a nest site, then spent 1.2 to 3.0 hours collecting material and nest building in the 15 to 24 hours leading up to farrowing.

1.3.2 Pre-farrowing behaviour of sows housed in pens and crates

Baxter (1991) reported that sows housed in 5m^2 pens, moved approximately 30km during the 20 hours prior to parturition. In a study conducted by Haskell and Hutson (1993), sows housed in a 49m^2 pen, walked a mean distance of 677.7 (s.e. 132.3) metres during the 15 hours prior to farrowing. More recently, Haskell, Hutson, Dickenson and Palmer (1997) demonstrated that sows required to lift a lever to gain access to a 45.5m^2 test arena, travelled over 400 metres in the 24 hours leading up to parturition. Although estimates of distances travelled vary, it is clear that sows are strongly motivated to move around and investigate their surroundings prior to farrowing.

A number of studies have reported that nest building activity of sows housed individually in loose pens and in farrowing crates began within 24 hours and peaked between 6 and 12 hours before parturition (Widowski and Curtis 1990; Arey, Petchey and Fowler 1991; Castren, Algers, de Passille, Rushen and Uvnas-Moberg 1993b). Recently Castren *et al.* (1993b) demonstrated that blood plasma levels of the hormone prolactin had begun to rise above baseline concentrations, but had not reached maximum concentrations when nest building began. Furthermore, nest building ended as oxytocin levels began to rise and the timing of the end of nesting was correlated with the oxytocin concentration 8 hours before parturition.

Over 90% of sows in modern commercial pig production in UK (Edwards and Baxter 1989; Baldwin 1996) are housed in farrowing crates from about one week before parturition to weaning when piglets are three to four weeks of age. Confinement in this often bare environment restricts movement and frustrates nest building behaviour (Baxter 1980; Arey and Petchey 1992). This restriction frequently results in increased restlessness, vacuum nest building activity, including pawing and rooting at concrete floors and increased investigation and manipulation of pen fixtures in the hours leading up to parturition (Baxter 1980; Lammers and de Lange 1986; Arey *et al.* 1991; Cronin and Smith 1992a; Haskell and Hutson 1993; Jensen 1993).

There is evidence that the stress related to restrictions on sow movement and a lack of nest building substrate at this time leads to prolonged parturition times and an increased number of stillbirths (Baxter 1980; Arey and Petchey 1992; Cronin, Smith, Hodge and Hemsworth 1994). However, Fraser, Phillips and Thompson (1997) demonstrated that the provision of more space and nest building material did not consistently reduce farrowing times and the incidence of stillbirths and suggested that pre-farrowing activity levels might be more important in reducing these piglet losses.

1.3.3 Sow behaviour during farrowing

Close observation of wild boar sows during farrowing proved to be difficult and dangerous. Meynhardt (1991) found that the sow would leave the nest during farrowing to attack if he approached closer than 20 metres. Gundlach (1968) reported that farrowing wild boar are very sensitive to any disturbance and would attack any intruders if a certain critical distance from the farrowing nest was not observed. He went on to say that if a piglet was threatened, its squeals brought other sows with young, in the vicinity to its defence.

As a rule, the young were born while the sow was in lateral recumbency (Gundlach 1968; Fradrich 1974; Jensen 1986). Gundlach (1968) observed that during the birth of the piglets the sow stood repeatedly and changed position. According to Meynhardt (1991) she also repaired and reassembled the nest structure from time to time, covering the young. Domestic sows in semi-natural environments also stood to sniff their piglets, carefully rooted in the nest material and turned to lie on the other side or in the opposite direction during farrowing (Jensen 1986; Petersen, Recen and Vestergaard 1990).

In commercial pig production many sows become very disturbed and angry when their offspring are handled by the stockperson, but if confined in a farrowing crate, they are unable to affect the situation and essential litter tasks may be carried out in safety. A study conducted by Castren, Algers, De Passille, Rushen and Uvnas-Moberg (1993a) revealed that sows with the higher peaks of oxytocin during farrowing had higher baseline levels of the circulating hormone and were more likely to be aggressive towards intruders and very protective of their litters. Although a degree of aggression can be a sign of strong mothering motivation, sows which are extremely aggressive created management difficulties, particularly in loose housing systems (Marchant 1997). Their rapid movements are often a danger to their piglets, as they react vigorously to any perceived danger.

Wide individual variation in temperament both within and between breeds and its influence on maternal success is acknowledged (Meunier-Salaun and Schouten 1991; Sinclair, Edwards, Hoste and McCartney 1995; Wattanakul, Sinclair, Stewart, Edwards and English 1997) and there is interest in developing tests to aid the selection of sows with suitable attributes for loose housed systems (Thodberg, Jensen and Herskin 1997). In addition to sow characteristics, the qualities and skills of the stockperson affect the way sows react to human interference around farrowing time and in early lactation (Seabrook 1984). The variation in the behaviour and reproductive performance of sows was linked to the variation in handling by stockpersons in both experimental and commercial conditions (Hemsworth, Brand and Willems 1981; Hemsworth, Barnett and Hansen 1986a; Hemsworth, Barnett, Hansen and Winfield 1986b; Hemsworth, Barnett, Coleman and Hansen 1989; Hemsworth, Barnett and Coleman 1993). Furthermore, pigs did not discriminate between good and bad handlers on the basis of their previous experience, so that in similar handling situations, the behavioural response to a bad handler was likely to extend to other stockpersons (Hemsworth, Coleman, Cox and Barnett 1994).

1.4 THE NEONATAL PIG

Newly born wild boar are almost entirely covered in hair and have typical lengthwise stripes from birth (Gundlach 1968). Foley, Seerley, Hansen and Curtis (1971) demonstrated that this pelage contributed greatly to the resistance to cold of neonatal wild piglets, but even so wild piglets huddled together, close to the sow, for warmth, during the initial days of life (Gundlach 1968). It is considered that the need to retain body heat forced the young boar to stay within the nest during their first 3 to 4 days of life and that the sow remained in close contact with the young during this time in order to warm and protect them (Gundlach 1968; Fradrich 1974; Mauget *et al.* 1984).

Algers and Jensen (1990) investigated the thermal micro-climate within the nests of free ranging domestic pigs during a Scandinavian winter. The nest structures and lining materials afforded considerable protection for the young domestic piglets against the outside climate. The results of the study revealed that when outside temperatures averaged -1.5^{0}C, temperatures inside the nests, 5cm from the piglets, averaged 20.3°C. It was suggested that the nest material acted as insulation against the outside cold and retained the heat generated by the sow and piglets, enabling them to maintain a suitable micro-climate within the nest.

Domestic breeds of neonatal piglets chill rapidly as they have low energy reserves, sparse pelage and a poorly developed subcutaneous adipose layer which provides only minimal insulation (Dividich and Noblet 1981). Hypothermic piglets become lethargic and may not suckle successfully (Edwards, Smith, Fordyce and MacMenemy 1994). These piglets are more susceptible to disease and to crushing by the sow. In most commercial farrowing systems newborn piglet survival is aided by the provision of a protected, heated creep area for the piglets, which often incorporates some form of insulated flooring material. Even so, up to 30% of all piglets alive at parturition do not survive until weaning (Edwards and Furniss 1988). The majority of these perish within the first three days after birth (Dividich and Noblet 1981). The provision of straw will reduce conductive heat loss to the floor. Using the relationship between oxygen consumption of new born piglets and the ambient temperature, Stephens (1971) demonstrated that a straw covered floor at 10°C was equivalent to a concrete floor at 18°C in terms of thermal demand upon the piglet. This benefit was revealed by placing piglets on top of the straw and could reasonably be expected to be greater if piglets were covered by straw as would occur in a nest constructed by a sow.

1.5 SOW AND PIGLET BEHAVIOUR IN EARLY LACTATION

Spitz (1986) reported that wild boar sows remain in or close to the nest for between 2 and 4 days after birth, whereas Gundlach (1968) observed one sow and her piglets move a short distance from the nest on the day following birth. It is thought that this period of isolation allowed a close attachment to form between mother and young (Petersen, Vestergaard and Jensen 1989) and ensured that milk was only produced in the regularly used teats (Newberry and Wood-Gush 1984). The timing of trips out from the nest and the length of stay outside it were determined by weather conditions, but once they had ventured out, the sow and litter wandered further away and stayed out of the nest for longer periods of time on each subsequent occasion (Gundlach 1968; Jensen 1986; Stolba and Wood-Gush 1989). Upon returning to the nest, sows scraped the nest material together, before burrowing in and carefully lying down, avoiding crushing the young and reacting immediately by changing position in response to any piglet squeals (Gundlach 1968). Gundlach (1968) observed that whenever the sow left the nest she would eliminate and feed. This is similar to the behaviour observed in domestic sows in semi-natural conditions (Stangel and Jensen 1991). In commercial farrowing accommodation sows are unable to leave the farrowing site to eliminate and particularly when confined in a crate are forced to soil the 'nest'. Stangel and Jensen (1991) suggested that this may be stressful to sows housed in intensive pig units.

The modern domestic sow has a greater mature body size and is considerably longer in the body than her wild boar counterpart (Baxter 1991; Whittemore 1994; Marchant and Broom 1997). Baxter (1991) and Marchant and Broom (1997) studied lying down and standing movements of sows in detail and suggested that larger animals had greater difficulty in standing up and lying down than smaller animals. Although sows in individual loose farrowing pens tended to root through the bedding with their snout and lay down carefully, most often they were observed to flop straight down directly from a standing position on other occasions (Blackshaw and Hagelso 1990). Marchant and Broom (1997) considered that the degree of muscular control possessed by sows during lying down was influenced by the activity levels permitted by the dry sow housing environment.

Following parturition, the maternal behaviour and the responsiveness of sows to their piglets was improved with the provision of a degree of comfort and environmental stimuli for the sow (Cronin and van Amerongen 1991; Herskin, Jensen and Thodberg 1997). Investigations conducted by Edwards (1987) and Edwards and Furniss (1988) revealed that sows in farrowing crates, provided with straw performed less posture changes over farrowing and during the first 48 hours of lactation, than sows confined without straw. This result is in agreement with that of Herskin *et al.* (1997) who found that lactating sows on a sand floor performed fewer posture changes than sows on concrete.

1.6 NEST LEAVING AND INTEGRATION OF SOWS AND LITTERS

Estimates of when the farrowing site was finally abandoned by the wild boar sow and litter ranged from between 3 and 4 days (Mauget *et al.* 1984) 2 to 4 days (Spitz 1986) and 7 to 14 days after birth (Gundlach 1968). This is in accordance with findings of Jensen and Redbo (1987), which revealed that nest leaving in domestic sows in semi-natural surroundings occurred between 3 and 16 after farrowing. Delcroix, Mauget, Signoret and Jouventin (1995) observed that although the average length of time taken for wild boar sows to regroup after farrowing was 7 days (range 2 to 18 days), strict isolation was limited to the first few hours post partum.

Domestic sows in group farrowing accommodation were reported to encourage their piglets to climb out of the nest enclosures at around 7 days of age. If unsuccessful in coaxing the litters away from the farrowing site at this time, or if the system prevented the piglets leaving, many sows failed to return to the nests and abandoned their piglets (Bøe 1993; Bøe 1994). In other commercial group farrowing systems piglets readily escaped their nest enclosures at between 7 and 10 days of age (Algers 1991; Marchant 1997) whereas in farrowing crate systems, sows and litters are confined to the farrowing quarters throughout a three or four week lactation.

Once the farrowing nest had been vacated the litters of wild boar piglets mixed gradually as the sow group reformed (Gundlach 1968; Graves 1984; Meynhardt 1991; Gonyou 1995). The mixing of wild boar sows and their piglets took place with little or no aggression (Fradrich 1965). Similarly, Petersen *et al.* (1989) observed that there was little or no aggression when litters of free ranging domestic piglets mingled.

The integration of sows and litters was simulated in some commercial production systems by the formation of multisuckling groups when litters were approximately two weeks of age. Although most piglet deaths occurred in the first few days following birth (Dyck and Swierstra 1987; Rudd 1994; Holyoake, Dial, Trigg and King 1995), the disruption that mixing caused to suckling patterns and the aggression displayed amongst piglets was reported to cause another peak of deaths at the start of this multisuckling phase (Sinclair, Edwards, Cruikshank and English 1993; Marchant 1997; Wattanakul *et al.* 1997). Newberry and Wood-Gush (1986) suggested that the absence of aggression between domestic piglets in a semi-natural environment was because the young piglets met others in an unconfined area, in the presence of their litter mates and their dam. Swedish researchers, led by Professor Bo Algers and Professor Per Jensen at the Swedish University of Agricultural Sciences compared two different ways of introducing sows and litters to multisuckling pens (Marchant 1997). One treatment was to put all sows and litters together at the same time and the second, to move the litters first and the sows one hour later. The preliminary findings were that although there was less fighting amongst piglets when sows were present, the level of aggression among the piglets of each treatment group equalised over time. The presence of the sows only served to delay the onset of aggressive encounters between piglets.

1.7 SUCKLING BEHAVIOUR OF SOWS AND PIGLETS

1.7.1 Suckling development of the neonatal piglet

The development of a regular suckling routine follows a distinct pattern which is similar for wild boar, domestic pigs in semi-natural conditions and pigs in commercial farrowing units (Fraser 1980; Jensen 1988; Delcroix *et al.* 1995) (Figure 1.1).

Within minutes of birth young piglets are mobile and make their way towards the udder of the sow. If not already severed during birth, the umbilical cord is broken at this stage, easing progress as piglets nose and nuzzle along the body of the sow, towards the vicinity of the udder (Hartstock and Graves 1976). Once piglets establish contact and suckle from a teat they move along the udder, suckling from several teats in succession (Randall 1972a and b;

Petersen *et al.* 1990). Hartstock and Graves (1976) classified this behaviour, occurring at between 2 and 6 hours after parturition, as the teat sampling phase of suckling development. The energy reserves of newborn piglets, in the form of liver glycogen, are rapidly depleted after birth, leaving piglets highly susceptible to chilling, hypoglycaemia, weakness and death from crushing by the sow (Dividich and Noblet 1981; Moser 1983). In addition, the neonatal piglet has only low levels of immunoglobulins for protection from disease (de Passillé, Rushen and Pellether 1988). Colostrum is the source of dietary energy which also contains immunoglobulins which can be absorbed intestinally by piglets for up to 36 hours after birth, prior to 'gut closure' (Hartstock and Graves 1976; de Passillé *et al.* 1988). The speedy acquisition of colostrum by the piglet soon after birth is therefore essential to provide the energy and antibody protection necessary for survival. During farrowing and in the first few hours of lactation colostrum may be expressed relatively easily from the sow's teats.

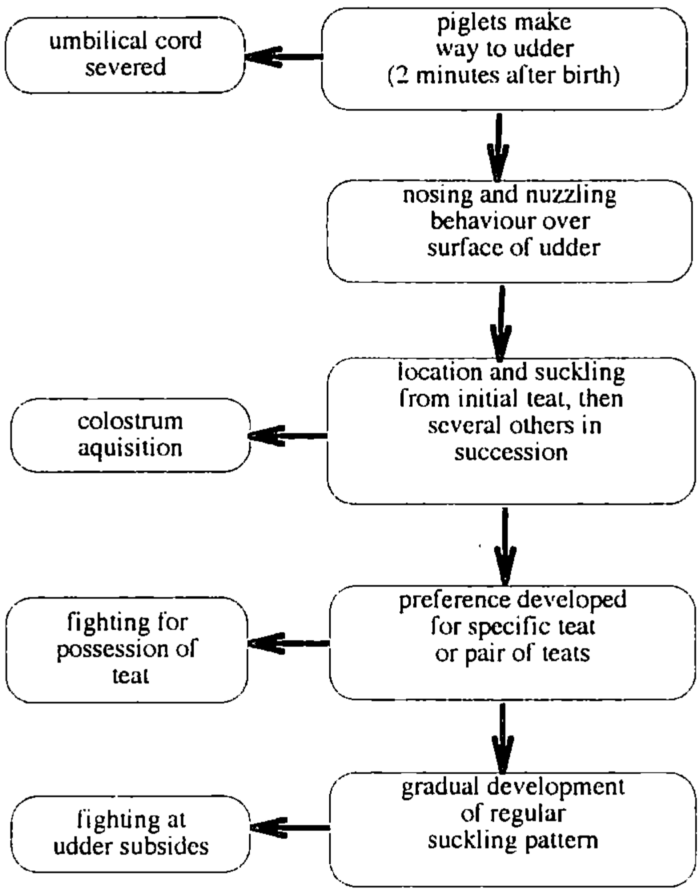


Figure 1.1 The development of nursing behaviour in piglets

However Fraser (1984) demonstrated that after 15 minutes yield declined sharply after which colostrum could be collected during discrete ejections lasting 1 to 4 minutes, occurring every 5 to 30 minutes, depending upon the stimulation received by the sow. More recently Castren *et al.* (1993a) demonstrated that discrete milk ejections during parturition and 4 hours post partum, frequently occurred in the absence of oxytocin peaks. However, it was pointed out that at this time basal oxytocin concentrations may be high enough for milk ejection to occur without further excretion of the hormone. During this time the sow emits rhythmical grunting sounds which increase in rate at intervals during the first 5 hours post partum (Castren, Algers, Jensen and Saloniemi 1989). An investigation conducted by Castren *et al.* (1993a) demonstrated that both oxytocin secretion and milk ejection must occur to induce an increased grunting rate by the sow.

The teat sampling phase of suckling is the first opportunity for piglets to obtain the colostrum, essential for their survival and fitness. As farrowing typically lasts for 3 to 4 hours, earlier born piglets have a greater opportunity to benefit from the energy and immunoglobulins contained in colostrum than their later born litter mates (Graves 1984). According to de Passillé *et al.* (1988) piglets which suckled earlier, suckled from several teats, won more teat disputes and had the highest within litter immunoglobulin levels, whereas later born piglets had much lower antibody protection.

Once a definite teat order for suckling has developed, piglets generally suckle from the same teat or pair of teats throughout lactation (McBride 1963; de Passillé and Rushen 1989b). According to McBride (1963), Fraser (1980) and Whittemore (1993), the formation of a teat order may promote orderly feeding and eliminate competition between piglets when feeding. It is also suggested that as sows in natural conditions farrow in isolation, the establishment of a teat order would ensure that milk is only produced in teats regularly used by that particular litter, so reduce opportunities for intruder piglets to suckle (Newberry and Wood-Gush 1984; Jensen 1986).

As teat ownership becomes established, a regular suckling pattern begins to develop (Hartstock and Graves 1976; Rosillon-Warnier and Paquay 1984; Lewis and Hurnik 1985; Castren *et al.* 1989). Once a pattern is established, nursings involving all or most of the litter occur at regular intervals throughout lactation (Table 1.4).

interval (minutes)	*day of lactation*	*reference*
48 to 52	10 to 24	(Auldist and King 1995)
76	3	(Spinka, Illmann, Algers and Stetkova 1997)
52 (42 to 68)	14 to 56	(Wechsler and Brodmann 1996)
44 (21 to 92)	7 to 28	(Ellendorf, Forsling and Poulain 1982)
51 and 63 (26 to 96)	6 and 51	(Barber, Braude and Mitchell 1955)
29 to 78	1 to 42	(Newberry and Wood-Gush 1984)
40 to 45	1 to 13	(Arey and Sancha 1996)
40 to 60*	-	(Meynhardt 1991)
51*	-	(Delcroix, Signoret and Mauget 1985)
36 to 40*	1 to 4	(Gundlach 1968)
47 to 52*	5 to 6	(Gundlach 1968)

* wild boar
range in parentheses

Table 1.4 Mean inter-suckling intervals reported for sows and piglets

1.7.2 Suckling frequency

The milk yield of the sow is influenced by litter size, piglet live weight and suckling demand (Auldist and King 1995; King, Mullan, Dunshea and Dove 1997). The more frequent the opportunities for piglets to suckle, the higher their milk intake and subsequent live weight gain over lactation (Barber *et al.* 1955; Newberry and Wood-Gush 1984; Spinka *et al.* 1997). The results of studies of the effect of nursing frequency on piglet weight gain and sow milk yield are summarised in Table 1.5.

Suckling frequency may be increased by exposure to an extended photoperiod (Mabry, Coffey and Seerley 1983) and by auditory stimuli (Auldist and King 1995).

nursing frequency per 24 hours	*sow milk yield*	*piglet weight*	*reference*
8	241g/24hrs	_	(Barber *et al.* 1955)
9.6	304g/24hrs	_	"
24	553g/24hrs	_	"
		21day litter weight	
25.25	5.07kg/21days	39 kg	(Mabry *et al.* 1983)
30.75	6.07kg/21days	44.8 kg	"
		piglet weight gain/24hrs	
20.2	595g/24hrs	135g	(Spinka *et al.* 1997)
33.9	755g/24hrs	198g	"

Table 1.5 The effect of nursing frequency on sow milk yield and piglet weight gain

Indeed, studies conducted by Wechsler and Brodmann (1996) revealed that nursing bouts could be stimulated by playback of sounds made by sows and piglets during suckling. Similarly, Newberry and Wood-Gush (1984) suggested that sows responded to the suckling vocalisations of each other, resulting in synchrony of sucklings within the sow group. An investigation conducted by Algers and Jensen (1985) indicated that high levels of continuous noise, such as that emanating from ventilation fans, affected communication between sow and piglets. As a result, suckling routines were disrupted, leading to lower milk yields and reduced piglet weight gains.

1.7.3 The sequence of behaviours during suckling

The nursing and suckling behaviour of the pig is complex and consists of several distinct phases (Whittemore and Fraser 1974; Fraser 1980; Algers and Jensen 1985) (Figure 1.2). Initial observations distinguished four distinct suckling phases of udder nosing, quiet interval, milk ejection phase and renewal of udder nosing in both domestic sows (Barber *et al.* 1955) and wild boar sows (Gundlach 1968). Following further studies, Whittemore and Fraser (1974) described five phases of suckling behaviour, beginning with a phase of jostling for teats, followed by a phase of nosing the udder, then a phase of quiet suckling with slow mouth movements of high amplitude, a phase of sucking with rapid mouth movements of smaller amplitude and finally a further phase of slow sucking and nosing of the udder.

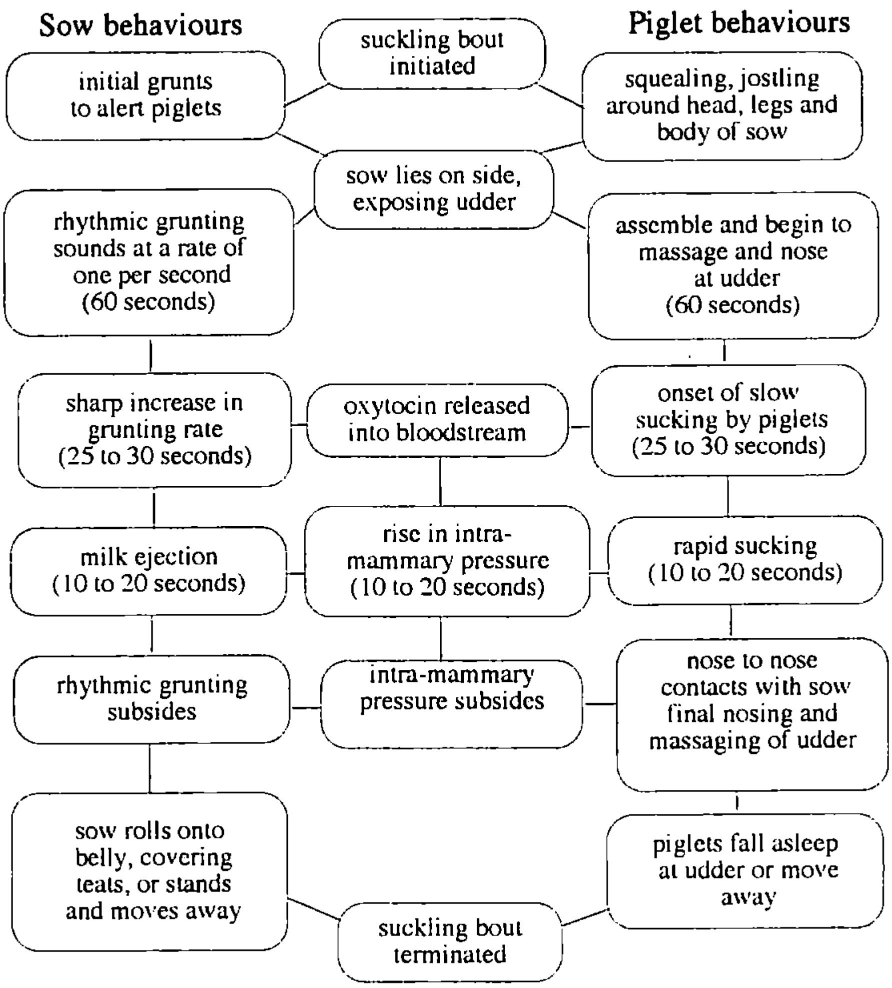


Figure 1.2 The sequence of behaviours of sow and piglet during nursing

Sucklings may be initiated by either the sow grunting to alert her litter and attract them to her udder or by the piglets congregating around the sow, squealing and massaging the udder

(Fraser 1980; Ellendorf *et al.* 1982; Lewis and Hurnik 1986; Castren *et al.* 1989). At this point the sow will generally lie on one side with both rows of teats exposed as the nursing bout begins (Fradrich 1965; Gundlach 1968; Fradrich 1974; Meynhardt 1991). Once piglets assemble at the udder and perform the udder nosing phase of suckling, the sow begins rhythmic grunting, at a rate of about 1 per second. The prolonged period of udder massage performed by piglets and the grunting sounds emitted by the sow at the start of a suckling bout give every member of the litter a chance to find a place at the udder before the short period of milk ejection occurs (Fraser 1980; Algers, Rojanasthien and Uvnas-Moberg 1990). However, this does not mean that all piglets need be assembled at the udder for milk ejection to occur, as if this was the case, all piglets would suffer if nursing did not proceed due to the absence of one litter member, which might have died (Newberry and Wood-Gush 1984).

After about one minute a sharp increase in sow grunting rate occurs, which coincides with the onset of slow sucking by the piglets and the release of the hormone, oxytocin into the blood stream (Fraser 1980; Algers *et al.* 1990). According to Ellendorf *et al.* (1982) a rise in intra-mammary pressure occurs approximately 23 seconds after the onset of fast grunting by the sow. The timing of this rise in intra-mammary pressure corresponds to the 25 second circulation time reported for oxytocin and results in milk ejection (Fraser 1980; Algers *et al.* 1990). The start of the rapid sucking phase of piglet suckling behaviour, occurring 25 to 30 seconds after the increase in sow grunting rate, also coincides with milk ejection (Whittemore and Fraser 1974; Fraser 1980). The slow sucking phase of nursing behaviour may serve to position piglets (Fraser 1980), following a change in sow grunting rate, in readiness for the short milk ejection which follows (Algers and Jensen 1985).

Milk is only available to piglets for between 10 and 20 seconds (Barber *et al.* 1955; Whittemore and Fraser 1974; Fraser 1980), corresponding to the duration in rise of intra-mammary pressure (Ellendorf *et al.* 1982). Once the pressure subsides, the milk supply ceases as the mammary glands of the sow have no teat cistern for storing milk (de Passillé and Rushen 1989b). Once milk flow ceases, the rapid sucking of piglets immediately stops, to be replaced by the final period of udder massage, whilst sow grunting gradually subsides (Fraser 1980). The whole sequence of suckling behaviours may last for no more than 2 to 3 minutes (Fraser 1980).

The 'restaurant hypothesis' was suggested by Algers and Jensen (1985) to explain the function of the final udder massage. This means that by spending more or less time massaging their particular teat, the blood flow through that teat and subsequent milk production are stimulated, so that in effect, piglets order the size of their next meal (Algers and Jensen 1985). This stimulation effect appeared to be greatest during the first few days of lactation, after which the teat order stabilised (Rosillon-Warnier and Paquay 1984) and milk production adjusted to individual piglet requirements (Jensen, Stangel and Algers 1991). More recently Spinka and Algers (1995) concluded that although nursings on day 3, which were preceded by sucklings with longer final massage times, produced more milk, there was still no firm evidence to support the 'restaurant hypothesis'.

1.7.4 Changes in nursing over time

In a study of the nursing behaviour of semi-naturally kept pigs Jensen *et al.* (1991) reported that sow initiated sucklings decreased from 85% to 55% of sucklings over the first 10 days postpartum, suggesting that the sows became less inclined to nurse. Bøe (1993) found that sows in group farrowing systems spent increasing amounts of time lying sternally, during weeks 2 and 3 of lactation. Sows in farrowing crates were also observed to increase sternal lying time over a 27 day lactation (de Passillé and Robert 1989a). In the confinement of a farrowing crate sows are the only object of interest in an otherwise barren environment, and are subjected to detailed investigation by exploring piglets for longer than sows in straw bedded pens (Schouten 1986; Arey and Sancha 1996). Observations of de Passillé and Robert (1989a) demonstrated that sows in farrowing crates use postural changes including increased sitting, standing and sternal lying to limit piglet access to the udder and other vulnerable body parts. Whatson and Bertram (1982) observed that the only recourse the confined sow had was to 'snap' at her 28 day old piglets as they chewed her ears, snout, tail, scabs and vulva. It was suggested that the well-being of confined sows may suffer as a result of a reduction in the quality and total duration of resting time (de Passillé and Robert 1989a; Arey and Sancha 1996) and that the amount of irritating interactions between sow and piglets might be reduced with the provision of alternative forms of stimulation for the piglets (Whatson and Bertram 1982).

At first, sucklings were initiated by the sow with the piglets taking a passive role, but as they grew older, more and more sucklings were begun by piglet stimulation (Jensen *et al.* 1991). During the first week of lactation the number of sucklings terminated by sows in a semi-natural environment gradually rose from less than 5% to 60% of sucklings (Jensen *et al.* 1991). According to Jensen (1988), the number of suckling terminations by free-ranging sows had increased to 90% by the fourth week of lactation. Suckling terminations by sows in indoor group farrowing systems followed a similar pattern (Bøe 1993). The time spent foraging by free-ranging sows increased between weeks 1 and 4, whilst the time spent lying decreased along with the frequency of sucklings (Jensen 1988). The same author noted that piglets reduced the time spent nosing and massaging the udder, following milk ejection, during weeks 1 to 4 of lactation. The percentage of sucklings with piglets missing increased over time, from 1.8% in week 1 to 7.8%in week 4 (Jensen 1988).

In the Edinburgh family pen system pigs are able to carry out more normal patterns of behaviour and form normal social groups (Arey and Sancha 1996). In this system, sows began to suckle their piglets outside the farrowing area, at between 10 and 14 days post partum. In contrast, sows in a fully integrated, group farrowing system, in which piglets were confined to the farrowing enclosure, reduced the time spent with their piglets from over 90% during the first week of lactation, to only 58% of each 24 hour period in week 2 (Bøe 1993). By week 3, this had reduced further to a mere 17.1% of the day. Houwers, Buré and Koomans (1992) also found that sows in a free access farrowing system gradually increased the amount of time away from their litters and reduced the number of sucklings, over lactation. In a natural situation the sow and piglets would leave the farrowing site approximately 10 days post-partum and join other sows and litters (Jensen and Redbo 1987). Sow behaviour in the Family Pen System was similar to that of free-ranging sows which abandon the farrowing nest when piglets were about 10 days of age. The reduction in time sows spent with their piglets which were confined to the farrowing enclosure, also coincided with the time when sows and litters would leave the farrowing nest and re-join the herd. As the confined piglets were unable to follow the sow, her interest in them declined, resulting in weaning before 3 weeks of age in some instances (Bøe 1994).

1.7.5 Suckling synchrony

Gundlach (1968) and Meynhardt (1991) noted that within a group of wild boar sows and litters, suckling was closely synchronised, due in part to a 'contagious' effect of the squealing by piglets which preceded each suckling bout. Synchrony of suckling bouts amongst groups of free-living domestic sows was also reported by Newberry and Wood-Gush (1984). This same phenomenon occurs in group housed lactating sows (Bryant, Rowlinson and van der Steen 1974; Wechsler and Brodmann 1996) and in sows housed individually in pens with farrowing crates within the same farrowing house (*personal observation*). It is possible that the synchrony of sucklings among groups of sows and litters, whether in free-ranging conditions or in a conventional farrowing house, might be an adaptation to minimise the incidence of cross suckling (Newberry and Wood-Gush 1984; Delcroix *et al.* 1995; Wechsler and Brodmann 1996).

However, Fradrich (1965) observed young boars changing over from one sow to another during suckling bouts. This is in accordance with findings of Delcroix *et al.* (1985) and Delcroix *et al.* (1995) who reported a high degree of tolerance by lactating wild boar sows towards alien piglets, indicating that it was up to the piglets to defend their teats against intruders. Meynhardt (1991) suggested that the fact that the number of functional teats matched the number of piglets showed that each individual was faithful to its teat for 3 or 4 weeks after birth. He also confirmed that although individuals attempted to suckle from other sows, the teats were defended by the resident piglets. Dellmeier and Friend (1986) and Newberry and Wood-Gush (1984) noted that domestic sows in semi-natural environments were tolerant of piglets from other litters and also suggest that the onus of defense of teats against intruder piglets was placed upon the resident piglets. Jensen (1986) observed very few cases of aggression by sows towards alien piglets and is in agreement that resident piglets prevent intruders from suckling. In contrast, Gundlach (1968) observed that although piglets moved and tried to suckle other sows during the final massage, they were fended off by the sow. Graves (1984) never saw any co-operative nursing within mother-offspring groups of wild boar. Gundlach (1968) suggested that these conflicting reports arose from a change in behaviour, brought about by confinement in small enclosures. As the studies of Delcroix *et al.* (1985), Delcroix *et al.* 1995), Dellmeier and Friend (1986) and Newberry and Wood-Gush (1984) were conducted in 1 and 2 hectare enclosures and that of Fradrich (1965), in zoological gardens, they provide further evidence of the effect of space limitations, even within relatively large areas, on social organisation and the maintenance of characteristic distances between individuals and groups.

Following the formation of multisuckling groups, the fighting which occurred amongst piglets severely disrupted suckling routines during the 24 hours following mixing (Bryant and Rowlinson 1984; Sinclair *et al.* 1993; Wattanakul *et al.* 1997). This resulted in more than 50% incidence of cross suckling throughout lactation and reduction in piglet growth rates compared with that of unmixed piglets in pens with farrowing crates (Wattanakul *et al.* 1997).

1.8 FEED AND WATER INTAKES OF THE FARROWING AND LACTATING SOW

1.8.1 Feed intakes

It is recognised that the higher the feed intake during gestation, the poorer the appetite of sows during lactation (Cole 1982; Yang, Eastham, Phillips and Whittemore 1989; Mullan, Close and Cole 1990; Dourmad 1991). A study conducted by Dourmad (1991) established that the level of feeding in gestation had the greatest effect on voluntary feed intakes of sows during the first week of lactation. In addition a negative relationship was established between backfat depth at farrowing and feed intakes in lactation (Yang *et al.* 1989; Dourmad 1991). Furthermore, losses in sow live weight during lactation, due to poor appetite, were dependent upon the rate of gain made during the preceding pregnancy (Elsley, Bannerman, Bathurst, Bracewell, Cunningham, Dodsworth, Dodds, Forbes and Laird 1969; O'Grady, Lynch and Kearney 1985; Dourmad 1991).

Elsley *et al.* (1969) found that higher feed intakes in pregnancy resulted in increased piglet birth weights. In contrast, Dourmad (1991) more recently reported no significant effect of gestation feeding on average weight of piglets at birth. In support of this finding, Yang *et al.* (1989) found that fatness at parturition had only a marginal influence on birth weight in parity 1, but no effect in subsequent parities.

Even with careful control of gestation feeding levels, feed intakes of sows in lactation are often insufficient to meet their nutrient requirements for maintenance and milk production (Lynch 1989; Mullan *et al.* 1990; Dourmad 1993). The voluntary feed intake of lactating sows in five commercial herds varied from 4.27 ± 0.20 to 6.31 ± 0.27kg per day and 5.53 ± 0.14 to 6.66 ± 0.10kg per day for primiparous and multiparous sows, respectively (Handley 1995). Feed intakes of sows fed *ad libitum* fell at parturition, before rising gradually during the first week of lactation (Friend 1969; Neil, Ogle and Anner 1996). Several authors report increased overall lactation feed intakes when sows are fed *ad libitum* compared with restricted feeding regimes (Stahly, Cromwell and Simpson 1979; Rudd and Simmins 1994; Neil 1996; Neil *et al.* 1996). The feeding of lactating sows *ad libitum* is also supported by Eastham, Smith and Whittemore (1988) and Yang *et al.* (1989), who pointed out that even on this regime, a degree of backfat loss was inevitable during lactation. Increased lactation intakes were reported in sows fed wet mash to appetite twice daily compared with those fed dry meal *ad libitum* (O'Grady *et al.* 1985; Genest and D'Allaire 1995) and in sows allowed to mix feed and water compared with those fed the same diet, dry (Pettigrew, Moser, Cornelious and Miller 1984). The feeding of high energy diets results in higher energy intake (Lynch 1989), particularly when the energy is provided by fats or oils, which create less metabolic heat during digestion (Seerley 1984; Whittemore 1993).

Increased metabolic heat production resulting from higher feed intake and the metabolic activity of milk production effectively reduces the lower critical temperature (LCT) of the sow. The zone of thermal comfort of the sow includes the range of temperatures between the LCT and the evaporative critical temperature (ECT), between which there are no extra demands for heat production and optimal feed intakes are achieved. The LCT varies widely according to sow body weight and condition and housing conditions and is considerably lower for lactating sows than for other classes of pigs. Lynch (1977) suggested that the LCT of sows in gestation ranged from 20^{0}C to below 10^{0}C depending on feeding levels. A more recent estimate of the lower limit to the zone of thermal comfort for the lactating sow was 12^{0}C (Black, Mullan, Lorschy and Giles 1993). A number of authors have reported studies in which the relationship between ambient temperature and voluntary feed intake have been investigated. For example, Lynch (1977) demonstrated that for each 1^{0}C increase in temperature between 21^{0}C and 27^{0}C, sows reduced feed intakes by 0.1kg per day. More recently, Stansbury, McGlone and Tribble (1987) reported reductions in lactation feed intake of 0.2 kg per day per 1^{0}C increase in environmental temperature from 18^{0}C to 30^{0}C. It is estimated that feed intake will be reduced by 1g for every 1^{0}C above the LCT for every 1kg of body weight (Whittemore 1993). Conversely, when ambient temperatures fall below the LCT homoeothermy is maintained by reducing heat loss to the environment and increasing heat production through a rise in feed intake (Sorensen 1961). Ambient temperatures above the evaporative critical temperature (ECT) lead to a reduction in food intake, milk yield, reproductive performance and growth rate of piglets (Black *et al.* 1993).

Nutrient intakes in lactation affect the overall productivity of the herd, not only by influencing piglet growth rates, but also the post weaning reproductive performance of the sow (Lynch 1989; Mullan *et al.* 1990; Koketsu, Dial, Pettigrew and King 1996a; Koketsu, Dial, Pettigrew, Marsh and King 1996c). Sows on higher feeding levels had shorter weaning to oestrus intervals and lost less body weight and backfat than sows on restricted feeding (Table 1.6).

feed intake (kg)	*wean to oestrus interval (days)*	*wt loss (kg)*	*fat loss (mm)*	*reference*
2.5 vs. 5.5	-	44 vs. 23	7.2 vs. 3.5	(Prunier, Dourmad and Etienne 1993)
3.0 vs. 6.0	7.3 vs. 5.9	-	-	(Baidoo, Aherne, Kirkwood and Foxcroft 1992)
3.0 vs. 6.0	8.9 vs. 6.0	26.6 vs. 13.8	6.5 vs. 3.6	(Kirkwood, Baidoo and Aherne 1990)
2.0 vs. 6.5	-	50 vs. 8	9.0 vs. 2.9	(Eastham *et al.* 1988)

Table 1.6 The influence of feeding level during lactation on reproductive performance of sows

1.8.2 Energy requirements in lactation

In lactation, energy is needed by the sow for both maintenance and milk production (Mullan *et al.* 1990; Noblet, Dourmad and Etienne 1990; Close 1992).

The energy requirement for maintenance varies according to the environmental factors such as floor type, number of animals in the group, humidity, air speed and ambient temperature, to which sows are exposed (Noblet *et al.* 1990). As ambient temperatures rise above the LCT there must either be a reduction in body heat production or dissipation of the excess heat produced by metabolic processes, including digestion. Ambient temperatures below the LCT induce cold thermogenesis in which the energy supplied by feed is redirected to produce more heat for the maintenance of body temperature (Sorensen 1961). The quality of the environment in terms of insulation and provision of bedding material alters the effective air temperature as experienced by the sow (Whittemore 1993)

The energy required for lactation is dependent on the litter size and piglet growth rate (Auldist and King 1995; King *et al.* 1997). When nutrient intakes are insufficient to meet energy requirements, body fat reserves are depleted in order to maintain milk yields as measured by piglet growth rates (Lynch 1977; Eastham *et al.* 1988; Yang *et al.* 1989; Genest and D'Allaire 1995). However, Eastham *et al.* (1988) found that although sows with lower feed intakes in lactation catabolised proportionately more body fat to maintain milk yield and piglet growth, they still had lighter litters at weaning than sows with higher feed intakes.

1.8.3 Feeding strategies

The information about the feeding strategies of pigs is sparse. Blackshaw *et al.* (1994) found that lactating sows in farrowing pens and crates fed twice daily spent 19.0 ± 4.6 minutes eating in the morning and 13.6 ± 1.1 minutes in the afternoon, whereas sows fed to appetite during lactation spent between 48 and 56 minutes feeding per day (Dourmad 1993). Outdoor gestating sows took 18.1 ± 0.68 minutes to consume their diet when it was spread on the ground (Martin and Edwards 1994).

Lactating sows fed 4 times daily to appetite (Dourmad 1993) and growing pigs (Schouten 1986; Nielsen 1995) fed *ad libitum*, exhibited a marked diurnal pattern of feeding, with most feeding occurring during the daytime, peaking in early morning and in mid afternoon.

The sows studied by Dourmad (1993) took their daily feed intake during a mean of 8.7 small meals each day. Sows with lower feed intakes reduced the duration of each meal and the amount eaten on each occasion, leaving the number of meals constant. Gestating sows, rationed by electronic sow feeders, usually consumed the whole of their daily feed allowance during a single feeder visit, however, all sows made more than one feeder visit per day on some occasions (Eddison and Roberts 1995). Nielsen (1995) and de Haer and Merks (1992) revealed that growing pigs fed *ad libitum* made several visits to the feeder and took their daily feed allowance in a series of meals. As the group size and competition for food increased pigs reduced the meal duration, increased the meal size and reduced the number of meals taken.

1.8.4 Water consumption

Water plays an essential role in most metabolic functions, including transportation, lubrication, maintenance of mineral homeostasis and adjustment of body temperature (Fraser, Patience, Phillips and McLeese 1990; Brooks, Carpenter and Barber 1992). Insufficient water consumption results in increased faecal dry matter which could predispose sows to mastitis, metritis, agalactia syndrome (Klopfenstein, D'Allaire and Martineau 1995). In the absence of symptoms of ill health, low water intake by sows is thought to contribute to reduced milk yields and inferior piglet weight gains in early lactation (Fraser and Phillips 1989).

Friend (1969) noted a gradual decline in water intake by sows towards the end of pregnancy and suggested this might be due to a reduction in uterine fluids in late gestation. In contrast, Gill (1989) found that water use increased over the week before farrowing and reached 12.2 litres per sow on the day before parturition. Since water constitutes around 80% by weight of milk, the increased metabolic activity of milk production may be expected to require an equivalent increase in demand for water. However, at farrowing, water consumption by sows fell sharply and remained lower than previous gestation levels for the first 3 to 4 days of lactation (Friend 1969; Fraser and Phillips 1989; Gill 1989; Klopfenstein *et al.* 1995). Thereafter, water intakes gradually rose to around 20 litres per day by mid lactation. Daily water intakes ranging from 8.1 to 25.1 litres per day have been reported for lactating sows (Fraser *et al.* 1990).

1.8.5 Factors affecting water intake by pigs

Water intake of sows is affected by both physiological and environmental factors including

* stage of gestation or lactation (Friend 1969; Fraser and Phillips 1989; Gill 1989; Fraser *et al.* 1990; Klopfenstein *et al.* 1995)

* feed intake and diet composition (Friend 1969; Gill 1989; Fraser *et al.* 1990)

* ambient temperature (Fraser *et al.* 1990; Brooks *et al.* 1992)

* water delivery system (Fraser and Phillips 1989; Gill 1989; Fraser *et al.* 1990; Brooks *et al.* 1992)

* water quality and temperature (Fraser *et al.* 1990; Brooks *et al.* 1992)

Friend (1969) demonstrated a close relationship between water and feed intakes of sows fed *ad libitum* in lactation. Water demand increases in proportion to the quantity of crude protein in the diet in order that the extra urea produced from the excess protein may be excreted from the body (Brooks and Carpenter 1990; Brooks *et al.* 1992). High mineral levels in the diet, particularly of sodium and potassium, increase the demand for water which is required for detoxification (Gill 1989).

At higher ambient temperatures the pig uses increased water consumption and urinary water loss to dissipate body heat (Brooks *et al.* 1990). Water consumption may also be improved in hot conditions if the water supply is cold, whereas at low ambient temperatures higher water temperatures result in improved water intakes (Varrabukka *et al.* 1981, cited in CSIRO (1987).

Water intakes suffer if water is difficult to access, either because drinkers are difficult to manipulate (Fraser and Phillips 1989) or because the delivery rate is too slow. Water intakes of weaned pigs rose from 0.78 to 1.63 litres per day as delivery rates increased from 175 to 700 cm^3 per minute (Barber, Brooks and Carpenter 1989). Furthermore, it was noted that pigs were only prepared to allocate a very short time per day to drinking. Interestingly, Blackshaw *et al.* (1994) found that lactating sows spent no more than 5.0 ± 0.7 minutes drinking during days 1 to 5 following parturition, after which the time spent drinking by sows increased until day 15 of lactation. Water delivery rates of from 1500ml per minute to at least 4000ml per minute have been recommended for lactating sows (Brooks *et al.* 1992; Anon. 1995a).

1.9 CONCLUSIONS

There are a number of interacting factors which influence the choice of farrowing site by sows. Their incorporation into the design of unrestricted farrowing accommodation would ensure that farrowings were more likely to occur in the designated areas within the system.

Given freedom of movement and suitable material, the modern domestic sow is just as capable as her wild boar ancestors of preparing a farrowing nest, appropriate to the environment, in which to give birth and rear her piglets.

In both wild and semi-natural environments, sows and piglets leave the farrowing nest from time to time in order to forage, exercise and eliminate before returning to the nest to rest and suckle. In order to ensure continuing maternal investment and maintain the sow piglet bond established in early lactation, similar behaviour should be encouraged by providing a means by which piglets may leave the farrowing enclosure, explore their surroundings and remain in contact with the sow.

Studies have established that the timing of trips out from the nest and the length of time spent outside it were determined by weather conditions in wild and semi-natural environments. By providing a wide contrast between farrowing enclosure and the outside pen area in terms of comfort, protection and warmth, this environmental effect could be simulated and used to advantage in an unrestricted farrowing system. Thus, the nest occupation time and use of the farrowing enclosures might be extended to last until weaning at 19 to 25 days of age as practiced in commercial production (MLC 1998).

The provision of an easily accessible food and water supply for each individual within a group farrowing environment is essential if sows are to achieve adequate feed and water intakes in lactation. *Ad libitum* feeding of sows in a group farrowing system might encourage the maintenance of feed intakes and water consumption in line with individual requirements during lactation. In addition the increased sow activity which is related to regular feeding times and the associated risk of injury to piglets would be avoided.

1.10 AIMS AND OBJECTIVES

The aim of this research programme was to investigate the behaviour of groups of sows in a novel design of free access farrowing system which allowed each sow farrowing site choice and the opportunity to feed, rest and socialise away from the farrowing site and litter.

The objectives were:

* to describe the activities and use of space by sows over parturition and during lactation

* to determine the extent to which space allowance influenced the sows' pattern of activity

* to identify factors which might aid management and contribute to the successful development of communal, non-confinement farrowing systems

2. EXPERIMENTAL DESIGN AND GENERAL METHODOLOGY

The methodology described in the following chapter is confined to that which applied to all sections of this research programme. The methods which applied specifically to each section of the study are described in the relevant chapters.

2.1 EXPERIMENTAL DESIGN

A series of four studies was conducted in which four groups of four multiparous sows were allocated to one of two pen areas in a loose house farrowing system from 5 days before the first expected farrowing date until the oldest litter was 21 days of age.

2.2 RATIONALE FOR THE FARROWING SYSTEM DESIGN

The farrowing system was designed to accommodate groups of four sows in keeping with the size of matriarchal groups of sows reported in the literature (see Table 1.1). The provision of individual farrowing enclosures allowed the sow a choice of farrowing site, designed to give protection and privacy for the sow and litter. The dimensions of the enclosures were intended to allow sows to lie and stand lengthwise, without touching the sides of the structure. The provision of two entrances to each farrowing compartment was intended to

* reflect the natural situation in which sows entered the nest at one end and left via the other and thus, reduce the need to turn within the enclosure

* facilitate the flow of sows around a system in which there were no culs-de-sac in which individuals could become trapped and threatened by their penmates

The entrances were designed to allow easy passage for a heavily pregnant or lactating sow, whilst the entrance thresholds were devised from examples reported in the literature (Algers 1991; Baxter 1991; van de Burgwal 1993; Rudd 1994) to reduce risk of injury to the udder of the sow and to prevent piglets from leaving the enclosures until they were at least 7 days of age. Deep straw bedding was restricted to the farrowing compartments in order to direct the farrowing site choice of the sow and to provide warmth and comfort for both sow and piglets.

The overall dimensions of the large pen configuration were the maximum possible within the space available. In contrast, the dimensions of the smaller pen configuration were the minimum in which the free flow of sows around the system could be preserved.

2.3 DESIGN AND CONSTRUCTION OF THE EXPERIMENTAL FARROWING ACCOMMODATION

The experimental system was accommodated within a naturally ventilated, brick built, slate roofed building. The flooring was of uninsulated concrete, which drained to a central point. Natural lighting from two small windows was supplemented by fluorescent strip lights which were on continuously to facilitate video recording.

2.3.1 Pilot study

An initial pilot study was conducted to facilitate the testing of the system, including the feeding and video recording equipment, and familiarise the researcher with specialist computer software and video recording equipment (Appendix 2.1).

The investigation established that the multiparous sow, previously confined in a farrowing crate during parturition and lactation, would use the facility as intended and farrow in the enclosure provided. The study provided the opportunity to adjust video recording equipment and improve the clarity of the information collected on the video tapes. The researcher gained valuable experience and training in behavioural observation techniques.

2.3.2 Layout and design of the group farrowing system

Following the pilot study modifications and refinements were made to the design of the farrowing enclosure and the system was expanded to accommodate a group of sows over parturition and lactation.

A row of four farrowing enclosures (Figure 2.1), each measuring 2.0m x 1.5m, was constructed using Sima Board (Sima Kunststoffen BV, Gramsbergen, NL). The corners of the enclosures were supported by angled steel and the whole structure bolted to the concrete floor. Temporary, slide-in doors, which doubled as sow boards, were constructed for the nest entrances, in order that sows could be retained in the enclosures for short periods of time, should the need arise.

Piglet creep areas (Figure 2.2), measuring 1.0m x 0.5m and incorporated adjacent to each farrowing enclosure, were fitted with 1.5 litre capacity piglet drinkers (Selvan B, Quality Equipment Ltd., Bury St. Edmunds, UK) and were heated by ceramic heaters (Department of Psychology, University of Exeter, Exeter, UK) positioned 0.8m above floor level. Creep box entrances were fitted with vertically sliding doors which could be lowered either fully to retain piglets within the creep area or partially to reduce the size of the opening into the piglet area and exclude the sow.

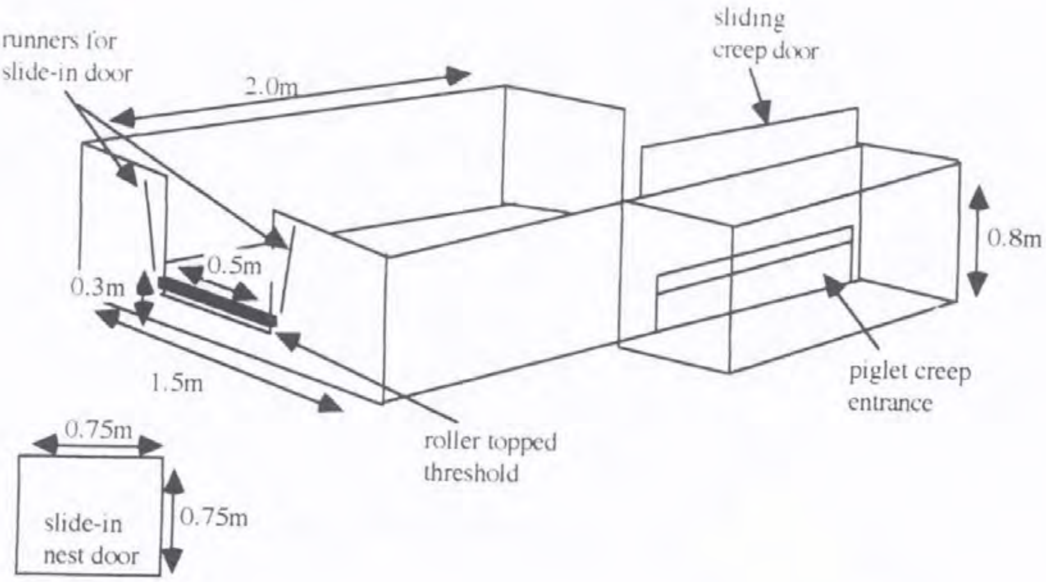


Figure 2.1 Design and layout of one of a row of four farrowing enclosures incorporating a heated piglet creep area, slide-in door and roller topped entrance threshold

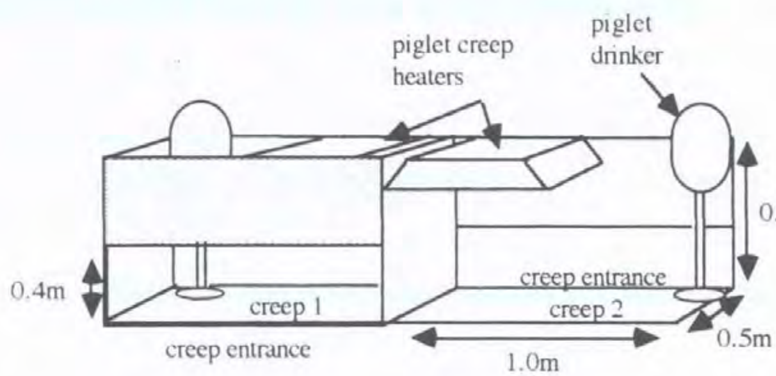


Figure 2.2 Piglet creep area fitted with heater and piglet drinker

The 0.3m high entrance thresholds (Plate 2.1) consisted of a 0.075m diameter roller fixed above a strip of Sima Board (Figure 2.3). A 0.1m high concrete step was placed outside each nest entrance to assist piglets' re-entry to the enclosure.

Plate 2.1 Roller topped threshold fixed at the farrowing enclosure entrances

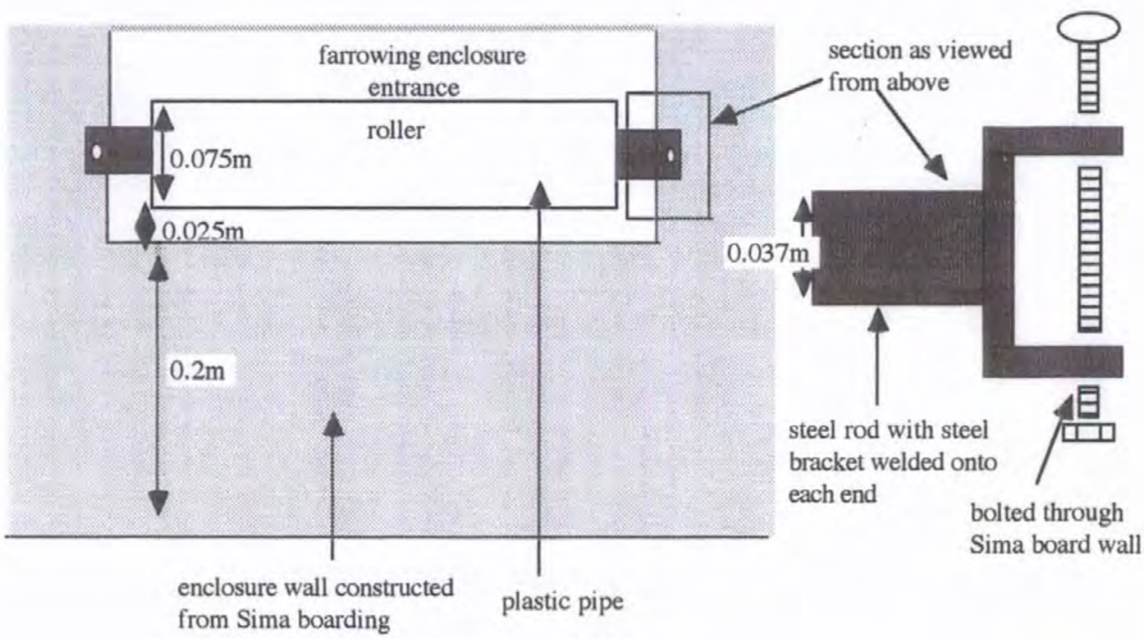


Figure 2.3 Design of the roller topped entrance threshold placed in each farrowing enclosure entrance

The row of farrowing enclosures was fixed in position within a rectangular pen, bounded on two sides by walls of brick construction and on the other two sides by barred gates. The large (L) and small (S) pen configurations provided overall space allowances of 13.4m^2 and 8.6m^2 per sow, respectively (Plate 2.2 and 2.3). The reduction in pen size was achieved by repositioning the boundary gates, whilst the dimensions and positioning of the farrowing enclosures remained the same (Figure 2.4 and 2.5).

To facilitate handling of sows within the large pen area, a collecting area at the end of the row of farrowing enclosures could be formed by closing a 3.7m gate hung on the long gated side of the pen boundary against the end enclosure. A second 1.5m gate hung on the long walled boundary, also closed against the the end nest enclosure to complete the handling pen. However, this proved to be inadequate for the control of sows which were overly protective of their piglets and aggressive towards the stockperson when piglets were handled and during daily cleaning routines.

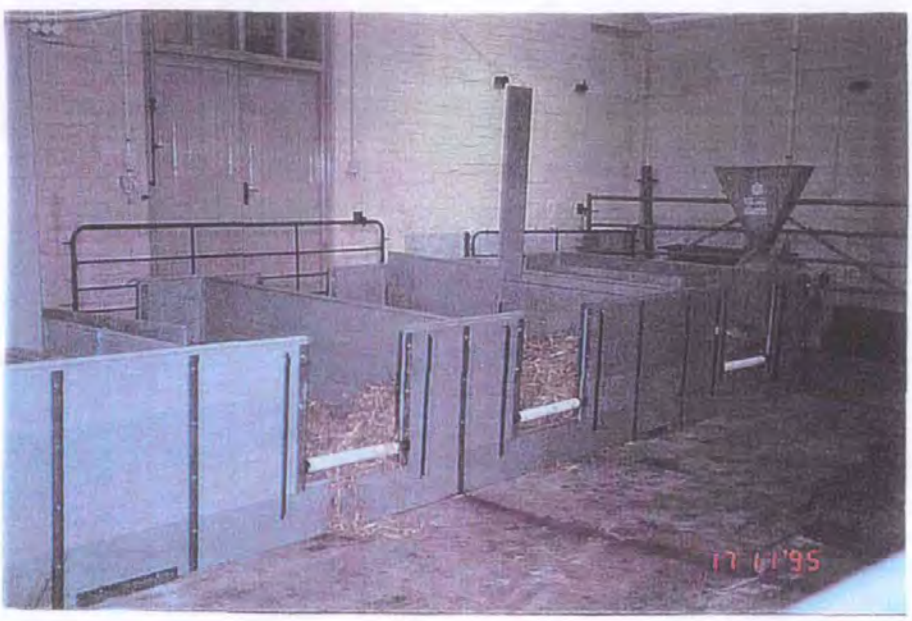


Plate 2.2 The layout of the farrowing accommodation in the large pen configuration

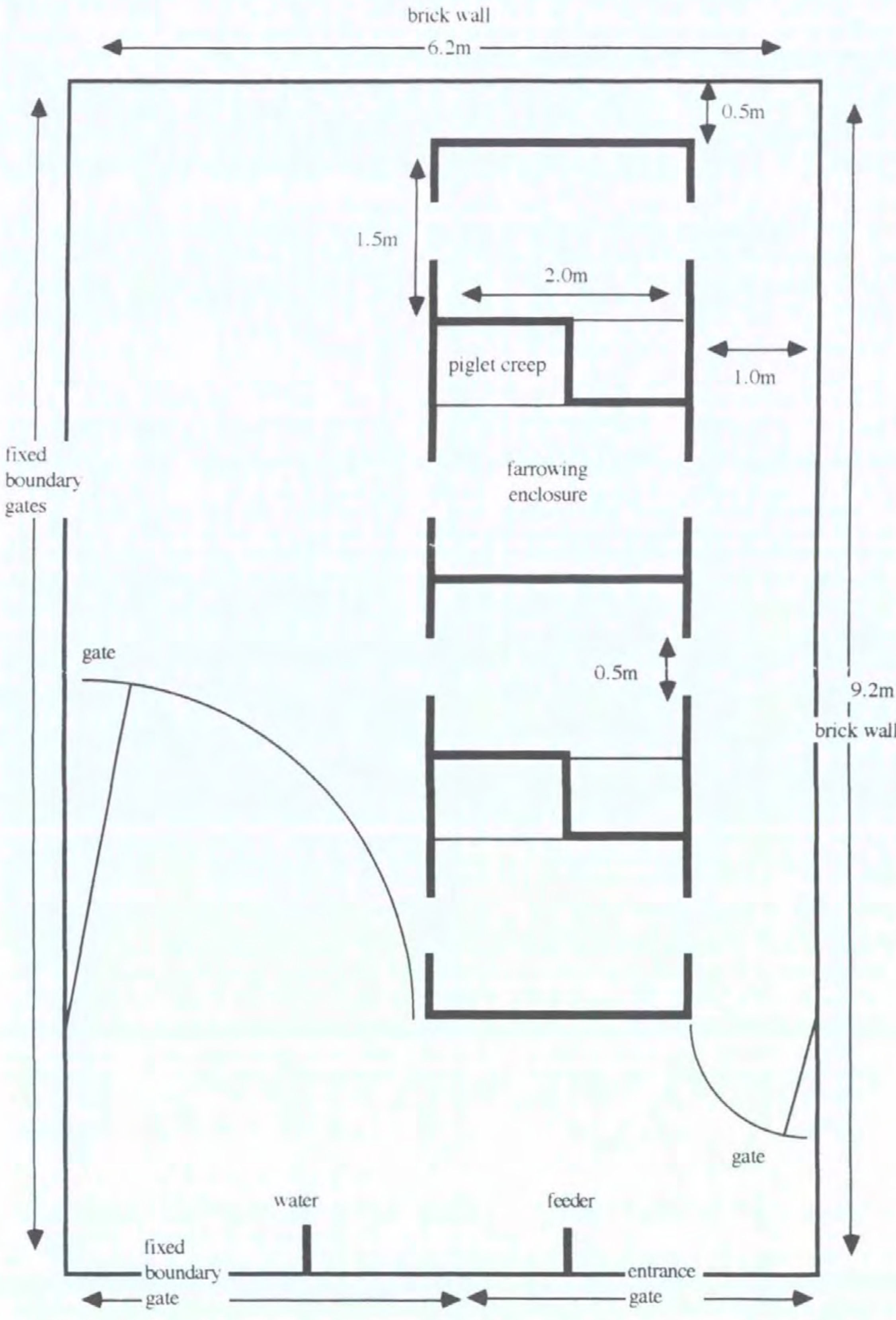


Figure 2.4 Diagrammatic representation of the farrowing accommodation in the large pen configuration, providing 13.4m2 per sow

Plate 2.3 The layout of the farrowing accommodation in the small pen configuration

The reduction in pen size provided the opportunity to improve the handling facilities within the pen and provide a safer working environment for the stockperson (Plate 2.4). A series of gates which could be closed at intervals across the passageways were fitted, enabling areas of the pen to be partitioned off in a number of different ways.

Plate 2.4 Gates and slide-in enclosure doors fitted in the small pen configuration

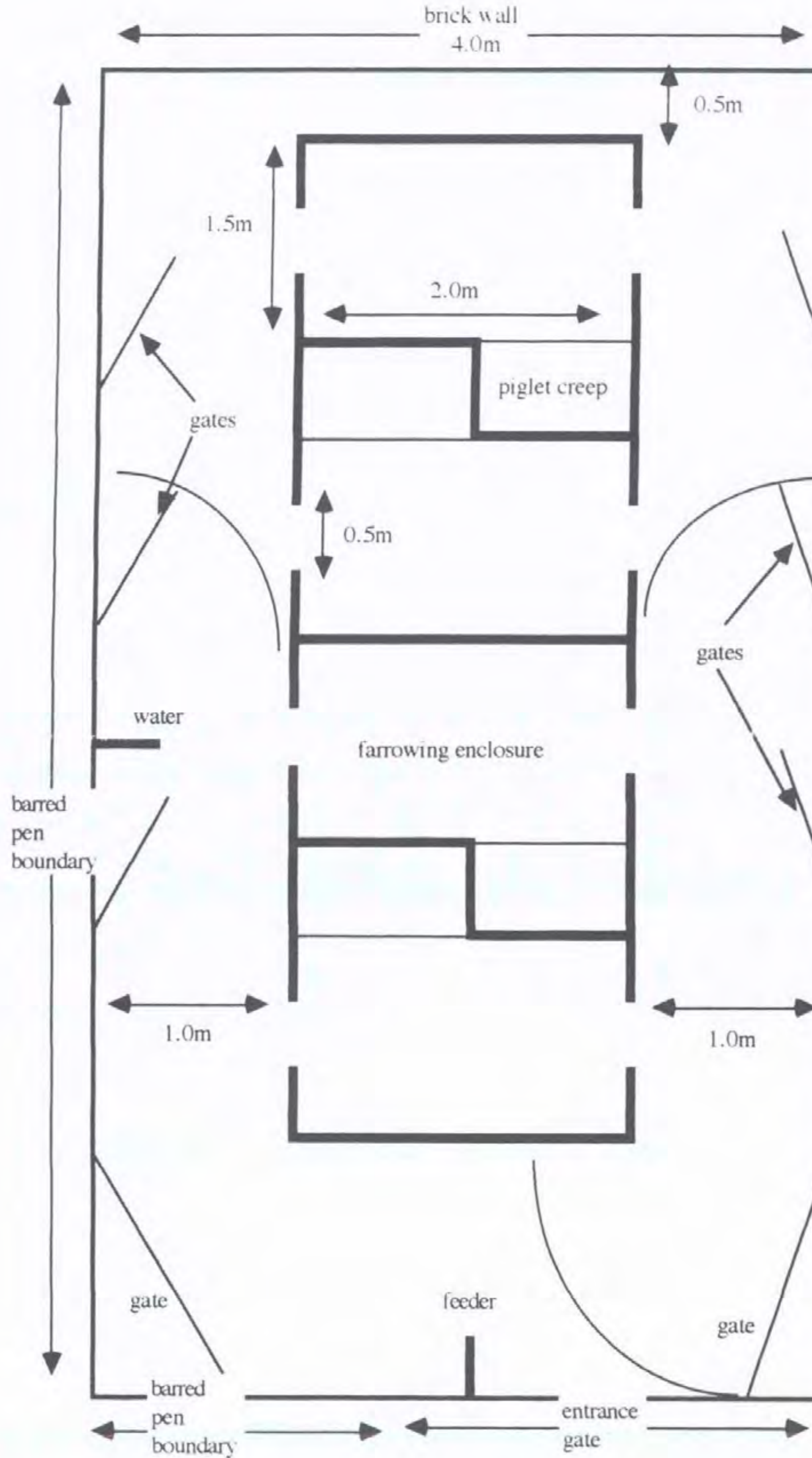


Figure 2.5 Diagrammatic representation of the farrowing accommodation in the small pen configuration, providing 8.6m^2 per sow

2.4 ANIMALS AND MANAGEMENT

2.4.1 Sow management

For each study, four pre-partal, multiparous Camborough sows (PIC, Fyfield Wick, Oxfordshire, UK) were selected from the Seale-Hayne Farm herd on the basis of expected farrowing dates. The sows used in the studies had been housed throughout gestation, as part of a dynamic group of between 70 and 80 individuals, in a straw based loose housing system and fed by two electronic sow feeders (Porcode, Nedap Poiesz, NL). The daily feeding cycle of the gestating sows began at 16.30 hours.

Selected sows were marked (Jensen, Algers and Ekesbo 1986) using a stock marker spray (Porcimark, Kruuse, Denmark) for individual identification (Figure 2.6). Each group of sows were introduced to the experimental system at an average of 107 (range 100 to 109) days of gestation, as calculated from date of service.

Studies terminated after 28 and 26 days in the large and small pen areas, respectively. Weaned sows were removed for service and those with under age piglets were transferred to individual loose pens on the farm for the remainder of lactation.

At the beginning of each study approximately half a small square bale of straw was spread in each farrowing enclosure then left for the sow to arrange. The remainder of the pen was left unbedded.

Cleaning and feeding routines were carried out between 09.00 and 10.00 hours, during which time the sows and litters were inspected. The sows and their litters were observed at regular intervals on the video monitor and inspected physically again at 16.00 hours. The bedding in the farrowing enclosures was disturbed as little as possible. Faeces on the surface of the straw were removed and fresh straw was added when the nest appeared flattened and thinned out.

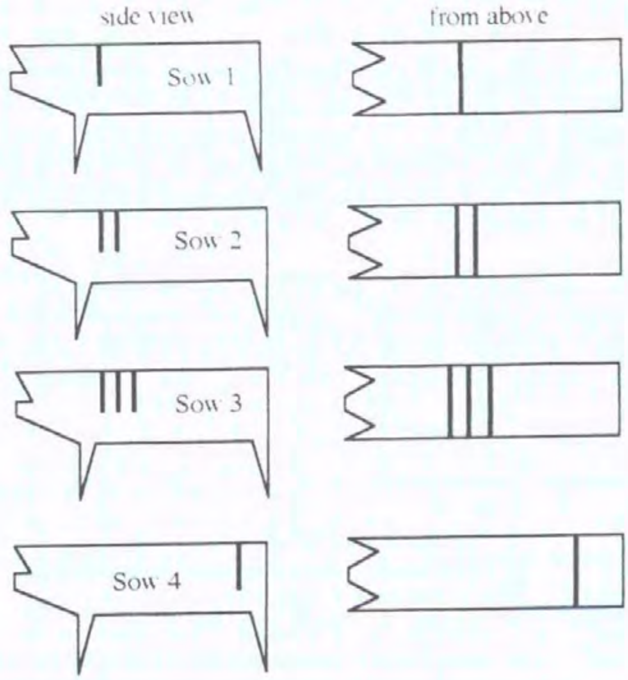


Figure 2.6 Marking system for individual sow identification on video recordings

If a farrowing enclosure became badly soiled and wet it was cleaned out completely and fresh bedding supplied. The concrete area outside the enclosures was cleaned out daily and kept free of straw.

2.4.2 Piglet management

On day one after birth, piglets were weighed, had their eye teeth clipped, tails docked and were given iron injections (Leo Laboratories Ltd., Princes Risborough, UK).

In the first replicate study conducted in the large pen area litters were identified from day 5 using different coloured stock marker sprays. The sprays quickly wore off so marking had to be repeated on a daily basis. This procedure proved to be very disruptive to the piglets and caused sows to become anxious and aggressive towards the stockperson, so was abandoned after the third day. As a result individual litters could not be identified and tracked through this trial. In the second replicate in L pen area, each litter was coded and individual piglet performance monitored using coloured, numbered ear tags. Tags were placed in both ears on day one after birth, to reduce the risk of total loss of identification. Coloured plastic tags (Temptags, Dalton Supplies Ltd., Henley-on-Thames, UK) were placed in the right ear and coloured aluminium chick wing tags (Pegrex Ltd, Birmingham, UK) were placed in the left ear of each individual piglet (Plate 2.5). The highest tag losses were of the chick wing tags, so for subsequent trials the coloured plastic tags were placed in both ears.

Plate 2.5 Two types of coloured, numbered ear tags were used to identify individual piglets and litters

The reservoirs on the piglet drinkers were refilled at intervals as necessary.

When each study terminated, the piglets were weighed and their ear tags removed. Those weighing more than 5kg and 21 or more days of age were weaned. Under weight piglets were fostered and transferred with under age piglets and their dams to the pig unit.

2.5 VIDEO EQUIPMENT AND DATA COLLECTION

2.5.1 Cameras and video recording equipment

In the first replicate study in the large pen configuration three colour cameras (DXC-107A/107AP; Sony Corporation, Japan) and one black and white camera (CTIC 4700 Type G; ITC Ikegami, Tsushinki Co. Ltd., Japan) were positioned to cover the whole pen area. Although some finer behavioural detail would be unavailable, positioning of the cameras in this way ensured there were no blind spots, in which sows would be out of view, over the pen area. In the three subsequent studies the black and white camera was replaced by a fourth colour camera. Sow activity was observed throughout the whole of each study period, using continuous time lapse video recording. Film was recorded in 72 hour time lapse mode (recording at 0.5 second intervals) which resulted in 72 hours of real time being recorded onto a 3 hour video tape. With the aid of a digital field switcher (Panasonic, WJ-FS20; Matsushita Electric Industrial Co. Ltd., Osaka, Japan) the output from four cameras was recorded onto a single video tape. This was accomplished by sampling the output from each camera in turn, one every 0.5 seconds, thus providing full coverage of the whole pen area every 2 seconds. During playback the film could be viewed either showing a different camera output in each quadrant of the screen, or by displaying the full screen output from one selected camera.

2.5.2 Data collection

Sow behaviours were entered directly into data files created in The Observer System for collection and analysis of observational data, version 3.0 for Windows (Noldus Information Technology, Wageningen, NL) during playback of the video tapes. Data were collected using the focal sampling method which enabled all of the behaviours of each individual sow to be recorded, throughout every study period. This was used in conjunction with continuous recording so that the frequencies, durations and the start and end times of behavioural states and the frequencies of events, were accurately recorded (Martin and Bateson 1994). The data for each individual sow, within each treatment group, was organised into three separate time blocks for comparative analysis;

* days -5 to onset of parturition (Time block 1)
* from onset of parturition to day 7 of lactation (Time block 2)
* days 8 to 17 of lactation (Time block 3)

As aggressive interactions between sows occurred infrequently, the social rank of sows was determined by recording the number of times an individual was displaced at the feeder by another sow. A sow was judged to have been displaced when it stopped feeding and moved away from the feeder upon the approach of the focal sow, allowing the focal animal access to the feeder. The data were recorded in a sociometric matrix (Appendix 2.2).

Ambient room temperatures were recorded every 24 minutes throughout each study using a Tinytalk data logger (Orion Components (Chichester) Ltd., UK) placed at floor level in a central position within the experimental building.

2.6 STATISTICAL ANALYSIS OF DATA

The data analysis module of 'Observer' was used for the calculation of the frequency and duration of behaviours. This information was exported to Microsoft Excel, version 5.0 spreadsheets (Microsoft Corporation, USA) for further organisation.

Behavioural data for each space allocation, for time blocks 1, 2 and 3 and for individual sows were analysed by oneway analysis of variance using Minitab Statistical Software, release 8 (Minitab Inc., USA), in order to identify differences and interactions between pen size (n = 2), day of gestation (n = 5, time block 1), day of lactation (n = 7 and 10, time blocks 2 and 3, respectively) and individual sows within each treatment group (n = 8). These analyses conformed to the model

$$Y_j = t_j + e_j \qquad \text{Equation 2.1}$$

where Y_j is the observed response value for treatment *j*, t_j is the treatment effect on the response variable for treatment *j* and e represents random error (Zar 1996). Where significant differences were indicated, Tukey's Wholly Significant Difference test (Zar 1996) was used to show differences between the means. Proportional data were subjected to arcsine transformation before statistical analysis. To aid interpretation, the untransformed data are presented in the tables.

Multiple regression analysis was used to identify factors exerting the greatest influence on the measures studied. These analyses were carried out using the best subset and stepwise regression functions of Minitab (release 8) that are based upon Hocking's algorithm (Hocking 1976). Tables of R^2 values are included in tables in the main text wherever appropriate. Full models (equations, coefficients, sample sizes and probabilities) for all regression analyses are detailed in Appendices 3.4, 4.9, 4.10, 5.4, 6.3 and 7.4.

Diurnal patterns were analysed using Oriana, version 1.0 (Kovach Computing Services, UK) and identified using the Rayleigh test of uniformity (Zar 1996). Circular means were compared with the Watson's F-test (Cabrera, Schmidt-Koenig and Watson 1991) to identify differences in patterns between treatments.

The results were presented as tables and graphs, using the graphics available in Microsoft Excel, version 5.0, spreadsheets.

3. REPRODUCTIVE OUTPUT

3.1 INTRODUCTION

Management of the farrowing and lactating sow focuses on maximising the number of live born piglets and the improvement of piglet viability in order to reduce pre-weaning mortality (English and Wilkinson 1982). The efficiency of parturition affects piglet viability, which may be reduced through anoxia, caused either by premature rupture of the umbilical cord, or decreased placental blood flow, associated with uterine contractions (Randall 1972a; English and Wilkinson 1982). Later born piglets and those from prolonged farrowings are most at risk (Randall 1972a; Randall 1972b).

According to English and Wilkinson (1982) and Randall, (1972a), older sows take longer to farrow. However, Castren *et al.* (1993a) demonstrated that although oxytocin levels in farrowing sows were highly variable, with low levels connected to prolonged parturition, parity was not correlated to oxytocin levels or duration of parturition. Randall (1972b) considered that as the length of parturition was unaffected by litter size, the intervals between births were a more useful measure of farrowing efficiency. The same author demonstrated that longer inter-birth intervals preceded the delivery of piglets dying intra-partum and suggested that delayed delivery might predispose to stillbirth.

The main causes of live-born piglet mortality were crushing by the sow and starvation leading to hypoglycaemia (English and Wilkinson 1982; Dyck and Swierstra 1987; de Passillé and Rushen 1989a; Edwards *et al.* 1994). Over 50% of post-partum piglet deaths occurred during the first 3 to 4 days of life (Hartstock, Graves and Baumgardt 1977; English and Wilkinson 1982; Dyck and Swierstra 1987). Piglet mortality tended to be higher in larger litters (Dyck and Swierstra 1987; de Passillé and Rushen 1989a; van der Lende and de Jager 1991; Edwards *et al.* 1994) and in those with high within litter weight variation (English and Wilkinson 1982; van der Lende and de Jager 1991). According to English and Wilkinson (1982), within litter weight variation increased with advancing parity. Piglets with the lowest within litter birth-weight had a higher death risk than their heavier litter mates, even at weights between 1 and 1.8 kg, particularly within larger litters (van der Lende and de Jager 1991). However, van der Lende and de Jager (1991) considered that piglets weighing less than 1 kg at birth had a high death risk regardless of their within litter status. In addition, English and Wilkinson (1982) reported that piglets of below 0.8 kg birth-weight had less than 50% chance of survival, due to their increased susceptibility to chilling, starvation and overlying by the sow.

The objective of this chapter is to present and discuss the reproductive output recorded for sows in the novel farrowing system.

3.2 METHOD

3.2.1 Productivity measures

A number of performance related and reproductive parameters were recorded for the four groups of four sows, allocated to one of two space allowances in a free access farrowing system (Table 3.1). General materials and methodology were as described in Chapter 2.

Sow	*Piglet*
parity	number born alive, dead, mummified
weight at entry	birth weight
farrowing date	number reared
parturition time	% mortality of pigs born alive
parturition length	day of death
inter-birth intervals	cause of death
	weight at end of study
	daily weight gain

Table 3.1 Productivity measures recorded for sows within the novel farrowing system

3.2.2 Assessment of cause of piglet deaths

The piglets classified as mummified were those of dark brownish black colouring, with an immature body form. Still born piglets were identified by the floating lung test (Dyck and Swierstra 1987; Carr and Walton 1995) and by the presence or absence of the cartilaginous covering on the feet which protects the uterus from damage (Carr and Walton 1995). The cause of death of live-born piglets was assessed visually (Table 3.2).

Cause	*Criteria*
deformity	malformation compromising health and welfare
crushed	video evidence and bruised, flattened body, frequently with protruding tongue
savaged	video evidence and lacerations, severed body parts, piglet disappeared and unaccounted for
other causes	no obvious injury

Table 3.2 Criteria used for assessing cause of live-born piglet deaths

3.2.3 Statistical analysis

Since the variances between inter-birth intervals of individual sows were significantly different, all inter-birth interval data were subjected to logten transformation before analysis. For clarity, the untransformed data are presented in Appendix 3.1.

3.3 RESULTS

3.3.1 Parity and weight

There were more higher parity sows and a greater spread of parities in the S (range 2 to 9) compared with the L (range 4 to 6) pen area, however, this difference was not statistically significant (Table 3.3). Sow weights at entry to the farrowing system ranged from 236kg to 285kg and 247kg to 273kg in the L and S pen configurations, respectively.

Pen area	*L*	*S*	SE_D
sow parity	4.8	5.6	1.7
sow weight	259	260	12.7

Table 3.3 Mean sow parity and mean weight (kg) at entry to the novel farrowing system of sows in the L and S pen configurations

3.3.2 Parturition

The majority of sows farrowed between 5 and 8 days after entry to the farrowing system. One sow in the S pen area farrowed on day 3 and two sows in the L pen area on day 11 following introduction to the novel system. The sow which replaced the individual removed from the S pen area for failing to manipulate the feeder, farrowed on day 14 of the study, 11 days after introduction to the system. Farrowings tended to occur during the afternoon, evening and night, with 15 of the 16 farrowings beginning between the hours of 13.50 and 06.30 hours (Table 3.4). Onset of the remaining farrowing was at 10.04 hours.

Pen area	*L*		*S*	
Replicate	*1*	*2*	*1*	*2*
Sow 1	04.47	19.51	01.23	04.05
2	19.58	13.52	16.28	10.04
3	22.45	04.31	16.55	06.24
4	23.44	14.23	15.54	02.52

Table 3.4 The time of day at which parturition commenced for sows in the L and S space allocations

The mean inter-birth intervals and the mean length of parturition for sows in each space allocation are presented in Table 3.5.

Pen area	*L*	*S*	SE_D
interval (minutes)	17.33	22.16	37.23
duration (hours)	3.28	4.00	1.96

Table 3.5 Mean inter-birth intervals and mean duration of parturition for sows in the L and S pen configurations

There was a significant difference between the inter-birth intervals of sows in the L pen configuration ($P<0.05$). This was a function of a wide range of mean inter-birth intervals of 7.65 (s.e. 3.0) minutes to 39.5 (s.e. 10.5) minutes for sows in this treatment group (Appendix 3.1).

3.3.3 Piglet survival

Mortality of piglets born alive was 19.6% and 24.6% in the L and S pen configurations, respectively. Mean production measures were similar for sows in each treatment group (Table 3.6).

Pen area	*L*	*S*	*SE_D*
piglets born			
alive	12.25	11.88	2.46
stillborn	1.00	1.50	1.25
mummified	0.50	0.25	0.63
birth weight(kg)	1.47	1.38	0.42
piglets weaned	9.75	7.88	2.34
weaning weight(kg)	5.93	6.44	1.69
daily weight gain(g)	219	240	0.032

Table 3.6 Mean production measures in the L and S pen configurations

The data revealed that some sows in the L pen configuration reared all of their live-born piglets successfully, whilst high numbers of other sows' offspring died (Appendix 3.2). In contrast, all sows in the S pen configuration lost some of their piglets. Nevertheless, there was still a tendency for more piglet deaths to occur with some sows than others. As a result the three high mortality litters (>20% mortality) in L accounted for 85% and the five high mortality litters in S, 79% of piglet losses.

The most common cause of death of piglets born alive was crushing by the sow (Table 3.7). The high percentage of deaths from savaging was due to the actions of one sow in each replicate study in the L pen area. On each occasion the sow was observed to attack piglets which were moving around in the straw close to the head and snout. Deformed piglets were euthanatized humanely as soon as possible after birth. All piglet deaths occurred within the farrowing enclosures.

Pen area	*L* *n = 20*	*S* *n = 27*
deformed	-	7
crushed	55	90
savaged	30	-
other causes	15	3

Table 3.7 The percentage of live-born piglet deaths arising from specified causes in the L and S pen configurations

Most of the piglet deaths occurred during the first week of lactation (Figure 3.1). Of these deaths, 65.0% and 67.9% occurred during the first three days following birth, in the L and S pen configurations, respectively.

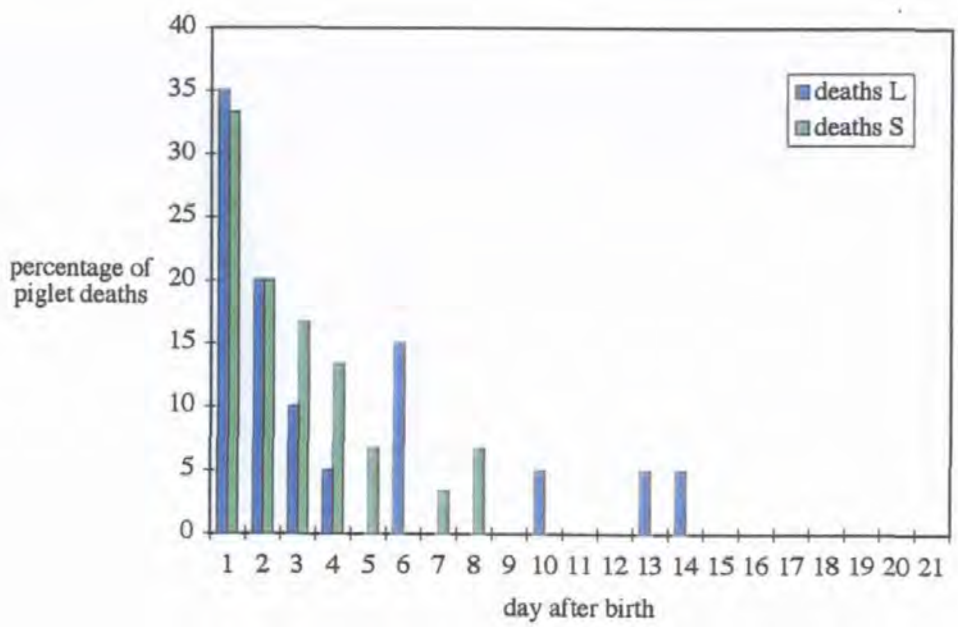


Figure 3.1 Days after birth upon which piglet deaths occurred for sows in the L and S pen configurations

3.3.4 Ambient temperatures

Mean ambient temperatures were significantly lower in the L than in S pen configuration, during all three time periods (Table 3.8). The mean ambient temperatures experienced by individual sows were similar within each replicate group of sows (Appendix 3.3). However, there was significant variation between replicates in the L and S pen areas (P<0.001) during time blocks 1 (8.2 (s.e. 0.18) vs. 2.3 (s.e. 0.15) ^{0}C and 17.5 (s.e. 0.08) vs. 8.3 (s.e. 0.40) ^{0}C) and 2 (8.3 (s.e. 0.49) vs. 3.5 (s.e. 0.09) ^{0}C and 18.0 (s.e. 0.10) vs. 6.2 (s.e. 0.23) ^{0}C). The variation between replicate groups continued to be of statistical significance in the S pen area (17.9 (s.e. 0.10) vs. 5.1 (s.e. 0.16) ^{0}C) during time block 3 (P<0.001).

Pen area	*L*	*S*	SE_D
Time block 1	5.2	12.5	3.95***
Time block 2	5.9	12.1	4.79***
Time block 3	3.4	12.0	4.63***

*** = P<0.001

Table 3.8 Mean daily ambient temperatures (^{0}C) in the L and S pen areas, during time blocks 1, 2 and 3

3.3.5 Factors influencing piglet survival

There were a number of measurable factors which may have influenced piglet survival within the novel farrowing system (Figure 3.2). The influence of space allocation, length of parturition, inter-birth intervals, parity, litter size, piglet birth weights, low birth weight piglets per litter, stillbirths and ambient temperature on

* stillbirths
* piglet mortality
* number reared

* weaning weight

was determined by multiple regression analysis.

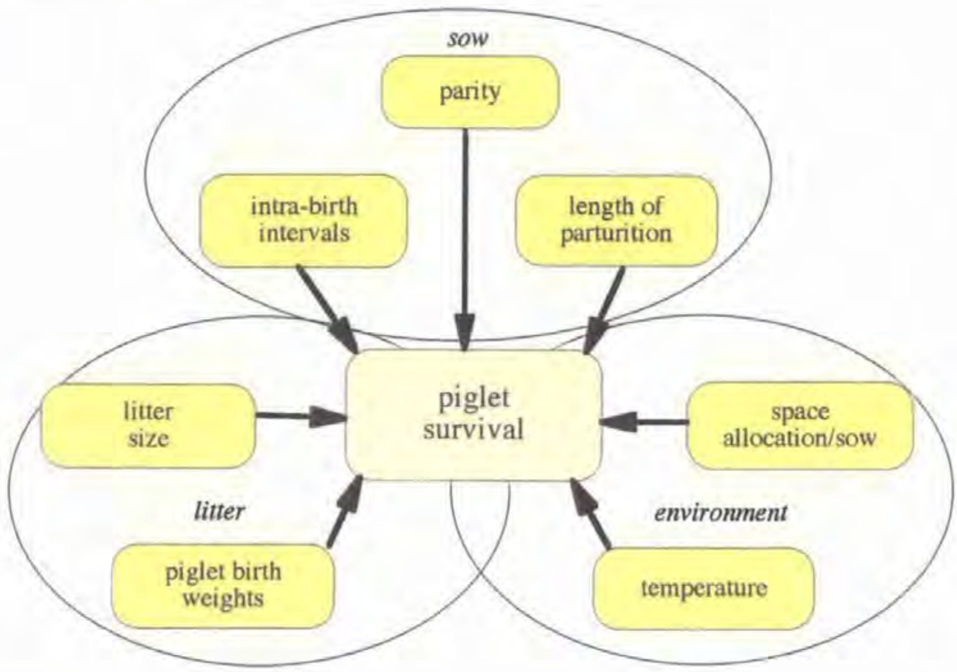


Figure 3.2 Schematic illustration of factors which may influence piglet survival in a group farrowing system

The percentage contributions made by the factors which significantly affected the variation in piglet mortality, the number of stillbirths, the number of piglets reared and weaning weights are presented in Table 3.9.

The factors which exerted a significant influence upon the variation in piglet mortality ($P<0.001$) were the number of stillbirths, litter size and space allocation (Appendix 3.4). The variation in the number of stillborn piglets was significantly influenced by the number of low birth weight piglets, litter size and length of parturition ($P<0.001$). The variation in the number of piglets reared was influenced significantly by litter size, the number of low birth weight piglets, the length of parturition and space allocation ($P<0.001$). Factors which had a significant effect on the variation in weaning weights were birth weight, litter size and space allocation ($P<0.001$).

% Contribution	*Parturition length*	*Inter-birth intervals*	*Parity*	*Litter size*	*Birth weight*	*Wean weight*	*LBW piglets*	*Stillbirths*	*Temperature*	*Space allocation*
Piglet mortality	-	-	-	+12.39	-	-	-	+44.96	-	+7.06
Stillbirths	- 5.94	-	-	-22.11	-	-	+8.54	-	-	-
Piglets reared	+12.53	-	-	+17.99	-	-	-14.41	-	-	-10.24
Weaning weight	-	-	-	+12.15	+19.25	-	-	-	-	+2.09

LBW = piglets weighing < 1kg at birth

Table 3.9 Percentage contributions as indicated by R-sq values from multiple regression analyses, made by the most influential factors to the variation in piglet mortality, the number of stillbirths, the number of piglets reared and weaning weights in a communal farrowing system

3.4 DISCUSSION

This study was not designed to measure productivity and was not large enough to do so, therefore the results presented must be interpreted with caution. However the high piglet mortality in the group farrowing system is a cause for concern.

3.4.1 Length of parturition

The efficiency with which parturition progresses, measured by the duration of parturition and the length of the intervals between births, has a direct effect on both intra and post-partum piglet mortality (Randall 1972a; English and Wilkinson 1982). The duration of farrowing has been reported as ranging from 1.3 to 11.5 hours and 1.6 to 11.4 hours for sows with and without straw bedding in farrowing crates (Edwards and Furniss 1988), 0.5 to 10.5 hours for sows in either farrowing crates or pens (Randall 1972b), a mean of 3 hours (s.d. 0.8) for short farrowings and 7.8 hours (s.d. 2.1) for long farrowings for sows in pens (Castren *et al.* 1993a) and 0.4 to 14.1 hours for sows in farrowing crates (Cronin, Schirmer, McCallum, Smith and Butler 1993). The duration of parturition was from 1.4 to 6.8 hours and 1.3 to 7.4 hours for the L and S space allocations, respectively.

Confinement in the farrowing crate was considered to cause a stress reaction in the sow as pre-farrowing nest building activities were frustrated (Baxter 1980). More recently, Lawrence, Petherick, McLean, Gilbert, Chapman and Russell (1992) demonstrated that oxytocin secretion and the progress of parturition in sows were inhibited by a stressful environmental disturbance. Thus, the reduced ranges and lower maximum farrowing times in the group system might, in part, reflect the fact that there was a choice of nest site and there were no restrictions imposed on the sow. However, evidence in support of this suggestion is sparse. Vestergaard, Hansen and Lydehoj-Hansen (1986) found that mean parturition times were 5.7 and 4.0 hours for tethered and loose housed sows respectively, but Olsson and Svendsen (1989) and McLean, Lawrence, Petherick and Gilbert (1994) found that farrowing times of sows in farrowing crates and pens were unaffected by housing system. There is no published information on parturition times for sows in group farrowing systems.

3.4.2 Still born piglets

Longer parturition times are associated with an increased number of stillborn piglets and reduced viability of live born piglets, largely due to foetal anoxia during birth (Randall 1972a; English and Wilkinson 1982; Dyck and Swierstra 1987). Anoxia may result from reduced placental blood flow following uterine contractions and damage to, or premature rupture of the umbilical cord (Randall 1972a; English and Wilkinson 1982). There is some evidence that the degree of anoxia, as measured by blood lactate levels at birth, influences the subsequent survival of live born piglets (English and Wilkinson 1982). Later born piglets, those from prolonged farrowings and from larger litters are most at risk (Randall 1972a; English and Wilkinson 1982; Dyck and Swierstra 1987; de Passillé and Rushen 1989a). Randall (1972a) demonstrated that 82.1% of intra-partum deaths occurred during the last third of parturition. Stillbirths accounted for 5.6 to 9.7% of piglets in litters from farrowings lasting from 2 to 5 hours, rising to 30% when the duration of parturition was over 6 hours (Randall 1972a). Other reports were that 5.3% (Dyck and Swierstra 1987) and 7.5% of piglets were stillborn (Cronin *et al.* 1993). In accordance with these findings, stillbirths accounted for 6.8% and 9.9% of all piglets born in the L and S pen configurations, respectively. Length of parturition, litter size, sow parity and piglet birth-weight had the greatest influence on the incidence of stillborn piglets. According to Cronin *et al.* (1993) and English and Wilkinson (1982), farrowing times are longer and the incidence of stillbirths higher for older sows. However, in agreement with the findings of Castren *et al.* (1993a), no relationship was demonstrated between the length of parturition, sow parity and the number of stillbirths in the present study.

3.4.3 Inter-birth intervals

According to Randall (1972a), stillbirths were delivered more slowly than live born piglets. The same author demonstrated that although mean inter-birth intervals preceding delivery of stillborn piglets were longer, many stillbirths were delivered after a relatively short time. Intervals between individual piglet births were reported as 0 to 220 minutes, with a mean of 16 minutes (Randall 1972b), a mean of 16.9 (s.d. 6.3) and 18.1 (s.d. 12.5) minutes for high mortality litters and those with no mortality, respectively (de Passillé and Rushen 1989a) and from 6 to 62 minutes and 8 to 47 minutes for sows with and without straw bedding (Edwards and Furniss 1988). The inter-birth intervals for the L and S sows ranged from 0.02 to 93.7 and 0.8 to 92.5 minutes for each group, respectively. However, in accordance with findings of Edwards and Furniss (1988) who found that the interval between births increased with later born piglets, the intervals between births lengthened as farrowing progressed, for all sows in both treatment groups. However, there was no relationship between inter-birth intervals and the incidence of stillborn piglets in the current study.

3.4.4 Piglet mortality

Recent surveys of housing systems for sows have omitted detail on the number of sows kept in the different types of farrowing accommodation used in the United Kingdom (Mercer, Kingstone and Ward 1995; Sheppard 1996). However, 87% of herds surveyed in Scotland used farrowing crates (Baxter 1971) and a survey of Meat and Livestock Commission (MLC) recorded herds indicated that 91% of indoor units in the UK used farrowing crates (Baldwin 1996). From this evidence it can be assumed that data from recorded herds will be based on farrowing crate systems.

The mortality of live-born piglets in MLC recorded herds in the UK averaged 11.3% and 10.8% for indoor and outdoor herds, respectively (MLC 1998). As the identification of stillbirths was often difficult, Edwards *et al.* (1994) considered that total mortality might be a more accurate measure of production in outdoor systems. The best commercially operated group farrowing systems in Norway and Sweden achieved 10% and 14 to 15% mortality, respectively (Marchant 1997). By comparison, mortality of piglets born alive in the L and S pen configurations was unacceptably high. Interestingly, the results suggest that the number of stillbirths may be a predictor of piglet mortality. This may be a reflection of reduced viability of piglets due to anoxia in litters with a higher incidence of stillbirths. This observation suggests that a longer, more detailed study would be justified. Litter size and birth-weight, recognised as predisposing factors of piglet deaths, (Hartstock and Graves 1976; English and Wilkinson 1982; Dyck and Swierstra 1987; de Passillé and Rushen 1989a; van der Lende and de Jager 1991) also had considerable influence on piglet mortality in the group farrowing system.

Estimates of the birth-weight below which there is a high risk of death include; below 1 kg (van der Lende and de Jager 1991), below 0.8 kg (English and Wilkinson 1982) and below 0.9 kg (Whittemore 1993). By definition, these piglets have the lowest within litter birth-weights, which further increases their risk of death (van der Lende and de Jager 1991). The number of low birth weight piglets present can therefore be expected affect overall mortality within a litter. The percentage of piglets born alive with birth-weights under 1kg was 7.8% and 19.8% in the L and S pen configurations, respectively. Of these, 43% in the L and 67% in the S space allowances died. Low birth weight piglets represented 20% and 33% of all piglet deaths in the L and S pen areas, respectively.

Of all piglet deaths in the novel farrowing system, 65.0% and 67.9% occurred during the first three days following birth, in the L and S pen configurations, respectively. In agreement with this finding, Holyoake *et al.* (1995) and Dyck and Swierstra (1987) reported that 62% and 61.5%, respectively, of live-born piglet deaths occurred during the first 4 days following parturition. Rudd (1994) also demonstrated that piglet mortality was highest during the first few days following parturition in three different indoor farrowing environments.

Of the four causes of death of live-born piglets recorded, the most important was crushing by the sow which accounted for 55% and 90% of all deaths in the L and S pen areas, respectively. These results are comparable with those of Edwards *et al.* (1994) who reported that crushing was the most common cause of death of piglets of all ages in an outdoor breeding herd. A combination of starvation and overlying accounted for 50.8% (Dyck and Swierstra 1987) and 50.1 to 79.0% (English and Wilkinson 1982) of deaths prior to weaning. In comparison, other causes of death were of relatively minor importance (English and Wilkinson 1982; Dyck and Swierstra 1987). Apart from savaging by the sow which caused 30% of mortality in the L pen area, results from this study were in agreement with these observations of crushing being the main cause of piglet mortality. Deformities accounted for 6.7% of piglet losses in the S pen area, and piglet mortalities due to other causes accounted for 15% and 3% of deaths in the L and S pen areas, respectively.

There was a tendency for more piglet deaths to occur with some sows than others, in common with others' findings (de Passillé and Rushen 1989a; Rudd and Marchant 1995). The recognition of sows possessing either good or bad mothering qualities lead to investigations focused on the identification of characteristics which could be used to indicate the future mothering success of gilts (Marchant 1997). A report on farrowing systems in use throughout Europe and Scandinavia concluded that the outcome for the piglets was dependent upon both the mothering qualities of the sow and the management approach of the stockperson (*personal observation*).

3.4.5 Improving piglet survival

The low intervention policy, adopted to provide an accurate record of sow behaviours in the novel system, undoubtedly contributed to piglet losses. In most indoor units, human assistance would be given to weaker piglets and those failing to suckle, so improving their chances of survival. Indeed, (Hartstock and Graves 1976) considered that nearly all live-born piglets could survive, given a suitable environment and appropriate nutrition.

Furthermore, through full supervision of sows from 3 hours before farrowing onset until 3 days post-partum, Holyoake *et al.* (1995) reduced the number of stillbirths and the number of pre-weaning piglet deaths, which increased the number of pigs weaned from 9.44 per litter when unsupervised to 10.17 per litter.

Farrowing occurred outside normal working hours in 63% of the sows in the present study. Similarly, many sows in commercial production units farrow outside working hours (*personal observation*). The supervision of parturition would therefore necessitate either additional staffing or the use of medication to induce and synchronise farrowing in groups of sows. The adoption of either method would improve piglet survival rates (Holyoake *et al.* 1995) and contribute to improved piglet welfare. Holyoake *et al.* (1995) demonstrated that additional labour for out-of-hours supervision was cost effective, as an extra 0.72 pigs per litter were reared. An additional benefit of this approach to reducing piglet mortality might be an improved public perception of this aspect of pig production systems. However, opposition from consumer and welfare lobbies to the induction method might arise on the grounds that it was an unnecessary use of drugs, unnatural and reduced sow welfare.

It is envisaged that the supervision of farrowing in the small pen configuration of the novel system would pose few problems. The pen area around the farrowing sow could be partitioned off so that new born piglets could be attended to without the risk of interference through the presence of other sows. Further investigation into the effectiveness of supervision at farrowing on piglet survival might lead to a reduction in the unacceptably high piglet mortality in the group farrowing system.

4. TIME ALLOCATION

4.1 INTRODUCTION

Monetary cost in consumer economics is analogous to time and energy in animal behaviour (Dawkins 1983b; McFarland 1985). In the same way that people with limited incomes allocate different amounts of money to different purposes, animals must partition the limited amount of time they have available in an optimal way, to different activities. Thus, activities are prioritised according to their importance to the animal in any particular situation and according to the amount of time available (Toates 1980). When increased amounts of time must be spent on certain activities, such as during nest building in preperation for the birth of offspring and whilst caring for and feeding offspring, other behaviours might cease to be performed or be performed less often (Dawkins 1983a; McFarland 1985).

The amount of time allocated to different behaviours may also be affected by the relative cost to the animal of carrying out that behaviour. The cost of movement around an area or accessing a particular resource might be an increased risk of attack from territorial rivals or reduced protection for offspring, in addition to energy and time expenditure (McFarland 1985). Sherwin and Nicol (1996) demonstrated that the number of visits made to a variety of resources by caged mice was reduced by the presence of obstacles which created difficulties and so imposed additional costs of access to resource areas.

Each individual animal has a physical space requirement based on body size and conformation, which alters according to the activity performed (Baxter and Schwaller 1983; Curtis, Hurst, Gonyou, Jensen and Muehling 1989). Individuals within a group of animals have an additional requirement for social space which also varies according to the situation and behaviours concerned (Baxter 1985).

According to Keeling (1994), groups of hens used space to position themselves appropriately in relation to each other within the space available. Following introduction into a dynamic group of 30, groups of sows maintained shorter inter-sow distances within their subgroup than within the main body of sows for a period of 21 days (Spoolder, Burbidge, Edwards, Lawrence and Simmins 1996). Groups of hens in a pen measuring 0.65m x 0.65m positioned themselves further apart than anticipated, whereas those in a 1.3m x 1.3m pen grouped closer together than expected (Keeling and Duncan 1989). Keeling (1994) suggested that as distances between hens varied according to the activity performed, the performance of certain activities was limited by the availability of sufficient space to maintain appropriate inter-bird distances.

Spitz (1986) reported that free living wild boar have one period of rest each day, which often lasted for more than 12 hours, whilst exploration and feeding activity occupied between 4 and 8 hours daily. Similarly, Mauget (1981) found that wild boar spent approximately 58.3% of their time resting, 25.2% of time feeding and the remaining 16.5% in travelling. The same author pointed out that where the food supply was plentiful, resting time may take up 80% of the time. Domestic pigs kept in semi-natural environments rested mainly at night, whilst 52% of observed time was spent foraging and 23% exploring and travelling (Stolba and Wood-Gush 1989).

A few days before farrowing, wild boar sows leave the matriarchal group to select a suitable site in which to build the farrowing nest (Stegeman 1938; Fradrich 1965; Gundlach 1968; Mauget 1981). The preparation of the nest is an elaborate process involving the hollowing out of a depression in the earth, which is then lined with vegetation collected from the surrounding area (Fradrich 1965; Gundlach 1968; Meynhardt 1991). Domestic sows in a semi-natural environment travelled between 2.5 and 6.5km searching for a suitable nest site, then spent 1.2 to 3.0 hours collecting material and nest building in the 15 to 24 hours leading up to farrowing (Jensen 1986). Baxter (1991) reported that sows housed in $5m^2$ pens, moved approximately 30km during the 20 hours prior to parturition. In a study conducted by (Haskell and Hutson 1993), sows housed in a $49m^2$ pen, walked a mean distance of 678 (s.e. 132) metres during the 15 hours prior to farrowing. Although estimates of distances travelled vary, it is clear that sows are strongly motivated to move around and investigate their surroundings prior to farrowing.

Spitz (1986) reported that sows remained in or close to the nest for between 2 and 4 days after birth, whereas Gundlach (1968) observed one sow and piglets move a short distance from the nest on the day following birth. Estimates of when the farrowing site is finally abandoned by the sow and litter range from between 3 and 4 days of age (Mauget *et al.* 1984), from 2 to 4 days (Spitz 1986) and between 7 and 14 days after birth (Gundlach 1968). Similarly, Jensen and Redbo (1987) revealed that the average time of nest leaving in domestic sows in semi-natural surroundings was 10.4 days (range 3 -16 days). In some commercial group farrowing systems piglets readily escaped their nest enclosures at between 7 and 10 days of age (Algers 1991; Marchant 1997). However, when the system prevented the piglets leaving the farrowing site, many sows abandoned their piglets (Bøe 1993; Bøe 1994).

The time spent foraging by free-ranging sows increased between weeks 1 and 4 of lactation, whilst the time spent lying decreased along with the frequency of sucklings (Jensen 1988). In both group farrowing and farrowing crate systems sows increased the amount of time lying sternally, protecting the udder from the attentions of the piglets, particularly during the daytime, as lactation progressed (Whatson and Bertram 1982; de Passillé and Robert 1989; Boe 1993). de Passillé and Robert (1989) noted that sows spent more time in lateral recumbency at night.

The objectives of this part of the study were

* to describe the way in which groups of sows, housed in a communal farrowing system, partition the time available between different activities over parturition and during lactation

* to investigate the effect of a reduced space allowance per sow on the time allocated to different activities over parturition and during lactation.

4.2 METHOD

The way in which four groups of four sows, allocated to one of two space allowances in a communal farrowing system, partitioned their time between their different activities was observed from 5 days before parturition until day 17 of lactation. General materials and methodology were as described in Chapter 2.

4.2.1 Behavioural definitions

Definitions of sow behaviours discussed in this section are presented in Table 4.1. The data for time spent lying is the sum of lying laterally and ventrally. Similarly, lying frequency is the sum of the occurrence of lateral and ventral lying and therefore includes the number of position changes made during any one lying bout.

Behaviour	Definition
lying	reclining in a lateral or ventral position, with the full body length in contact with the ground
lying sternally	reclining in a ventral position, with the full body length in contact with the ground and udder obscured from view
standing	all four feet on the ground, totally supporting the body weight of the sow
sitting	haunches on the ground whilst the chest is supported by the forelegs, dog style
walking	a sequence of steps whilst standing, resulting in locomotion from one location to another
in nest	full body length positioned within one of the four farrowing enclosures
turning	rotational movements carried out whilst standing within a farrowing enclosure
rooting	the use of the snout, mouth and accompanying head movements to manipulate the straw bedding

Table 4.1 Definitions of terminology related to sow time budgets

4.3 RESULTS

4.3.1 Time allocation

There was considerable variation in the mean daily time allocated to different activities between the L and S pen configurations during all three time blocks (Table 4.2). Lying occupied the greatest proportion of time, followed by time spent standing, whereas sitting and walking occupied comparatively short periods of time in both treatment groups throughout the study period.

Pen area	*L*	*S*	*SE_D*
Time block 1 (days -5 to onset of parturition)			
Lying	0.74	0.84	0.10***
Standing	0.20	0.12	0.14**
Sitting	0.008	0.015	0.060*
Walking	0.05	0.03	0.07***
Time block 2 (days 1 to 7 of lactation)			
Lying	0.85	0.87	0.07*
Standing	0.12	0.10	0.07***
Sitting	0.009	0.008	0.038
Walking	0.02	0.02	0.04
Time block 3 (days 8 to 17 of lactation)			
Lying	0.83	0.83	0.08
Standing	0.12	0.13	0.06*
Sitting	0.007	0.003	0.039***
Walking	0.04	0.04	0.06

* = P<0.05; ** = P<0.01; *** = P<0.001
SE_D calculated from data subjected to arcsine transformation

Table 4.2 Mean proportion of daily time spent lying, standing, sitting and walking by sows in the L and S pen configurations during time blocks 1, 2 and 3

Less time was spent lying ventrally in the S (P<0.05), compared with the L pen area, during time block 2 (Table 4.3). However, the amount of time in this position increased in both pen areas during days 8 to 17 of lactation. The straw bedded farrowing enclosures were the preferred resting place for sows during each time block, in both pen configurations. However, the S sows spent significantly less of their total daily lying time within the straw bedded areas compared with the L sows, during time blocks 1 and 3.

Pen area	*L*	*S*	SE_D
Time block 1 (days -5 to onset of parturition)			
Ventral recumbency	0.10	0.12	0.12
Lying in enclosures	0.82	0.53	0.43***
Rooting	0.038	0.013	0.081***
Time block 2 (days 1 to 7 of lactation)			
Ventral recumbency	0.12	0.09	0.09*
Lying in enclosures	0.99	0.98	0.09
Rooting	0.019	0.010	0.048
Time block 3 (days 8 to 17 of lactation)			
Ventral recumbency	0.18	0.16	0.10
Lying in enclosure	0.95	0.92	0.17*
Rooting	0.010	0.004	0.035***

* = $P<0.05$; *** = $P<0.001$
SE_D calculated from data subjected to arcsine transformation

Table 4.3 The mean proportion of daily time allocated to ventral recumbency, lying in the farrowing enclosures and rooting in the L and S pen configurations, during time blocks 1, 2 and 3

The mean daily time allocated to standing included time spent rooting within the farrowing enclosures and time spent feeding and drinking. The latter two are discussed in detail in later sections. The amount of daily time spent rooting was lower in the S than in the L pen configuration during all time blocks, although the difference between treatments was not statistically significant during time block 2. Interestingly, time allocated to this activity steadily decreased over the study period in both treatment groups.

There was a marked day effect on the way in which time was allocated to different activities leading up to parturition and during week 1 of lactation, which was not evident during days 8 to 17 of lactation, in both treatment groups (Figure 4.1). The time spent lying reduced significantly in the L ($P<0.001$) and the S ($P<0.01$) pen areas on day -1 prior to onset of parturition. At the same time there was a significant increase in time allocated to walking ($P<0.001$) in both treatments and to time spent sitting in the L pen area ($P<0.001$).

On day 1 of lactation a significantly higher proportion of time (0.91 (s.e.0.015) vs. 0.84 (s.e. 0.007)) was allocated to lying and less to standing (0.07 (s.e. 0.012) vs. 0.13 (s.e. 0.005)) and walking (0.01 (s.e. 0.002) vs. 0.02 (s.e. 0.002)) than on days 2 to 7 of lactation ($P<0.001$), by sows in the L pen area.

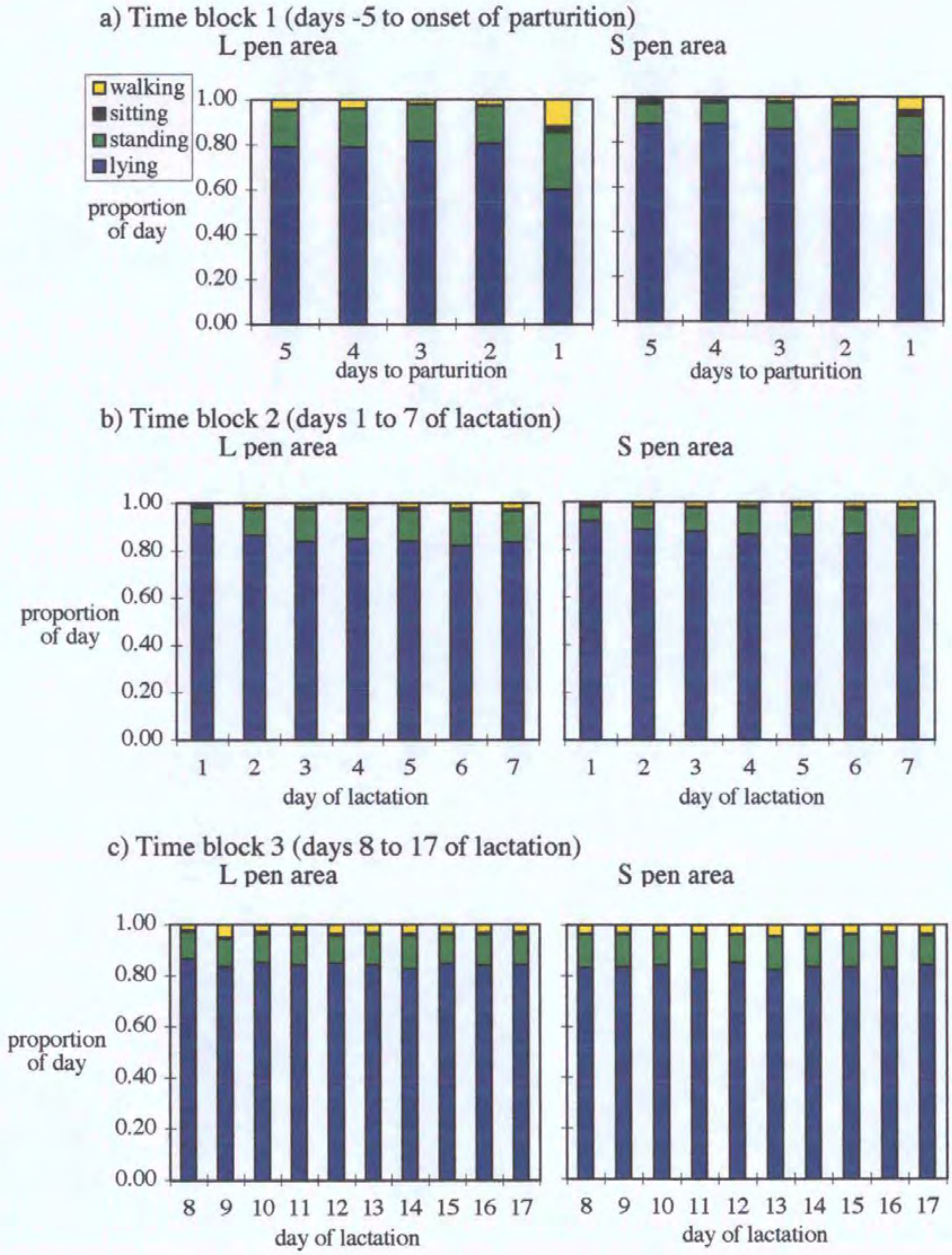


Figure 4.1 Mean proportion of time allocated to lying, standing, sitting and walking per day by sows in the L and S pen configurations, during time blocks 1, 2 and 3

The proportion of time sows spent rooting increased from 0.006 (s.e. 0.006) to 0.113 (s.e. 0.113) and from 0.002 (s.e. 0.002) to 0.055 (s.e. 0.055) between days -2 and -1 before parturition (P<0.001), in the L and S pen areas, respectively (Figure 4.2). No further significant effects of day on time allocated to rooting activity could be demonstrated during subsequent time blocks.

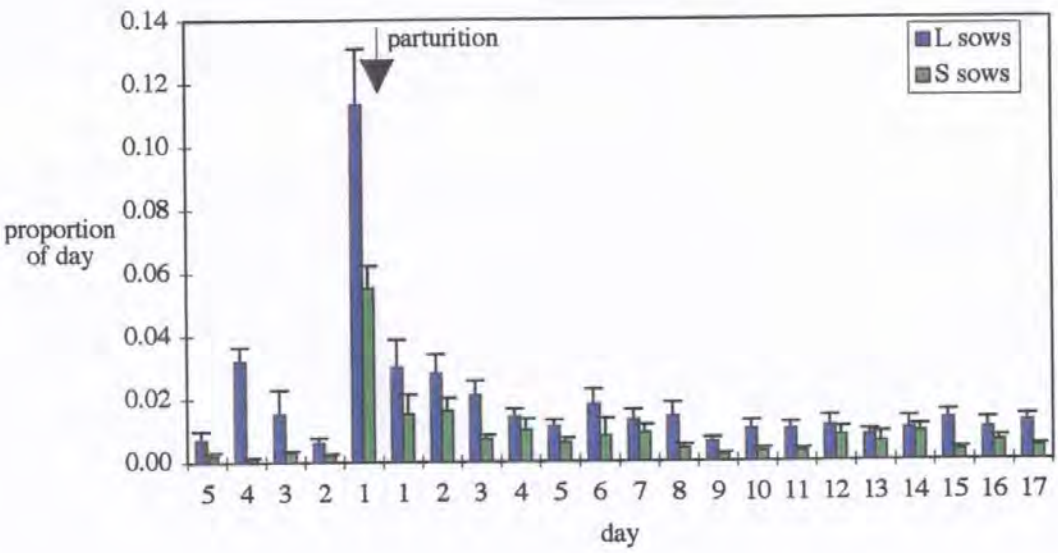


Figure 4.2 Mean proportion of time allocated per day ± s.e. to rooting activity by sows in the L and S pen configurations, from day 5 to 1 before parturition, then from days 1 to 17 of lactation

The way in which individual sows in each treatment group allocated their time between the different activities was remarkably similar, with no significant differences demonstrated between sows during the 5 days leading up to parturition onset and during days 8 to 17 of lactation (Appendices 4.1, 4.2 and 4.3). Statistically significant differences in time spent lying, standing, sitting and walking between sows in the S pen configuration, during week 1 of lactation were due, in each case, to a single outlier. However, there was wide individual variation in the amount of time spent sitting (P<0.001) by sows in the L pen configuration during this time period.

The amount of lying time spent within the farrowing enclosures by individual sows was significantly different in both the L and S pen areas, during time block 1 (Appendix 4.4). This was due to one individual in each pen area spending significantly less time ($P<0.001$) and one in the S pen area spending more time ($P<0.001$) within the enclosures compared with other sows in the respective treatment groups. During the first week of lactation, time spent lying in the enclosures was similar for sows within each treatment group, with the exception of one individual in the S pen area which spent significantly less time inside the farrowing nest ($P<0.05$). As lactation progressed the differences between sows became significantly more widespread ($P<0.001$) in both the L and S pen configurations.

Individual sows in both treatments spent similar amounts of time lying ventrally during time block 1. However, the amount of time spent resting in this position varied significantly between sows in the L ($P<0.001$) and S ($P<0.05$) treatment groups during week 1 of lactation. The difference between sows remained the same for the L ($P<0.001$), and became more widespread between the S sows ($P<0.001$) as the time spent in ventral recumbency continued to vary between sows in each treatment group, during time block 3.

The amount of rooting time was similar between sows in both treatments during time block 1, but varied significantly between the S sows ($P<0.05$) during time blocks 2 and 3. During time block 3 the variation in rooting time between the L sows also became significantly different ($P<0.001$).

4.3.2 Frequency of occurrence of activities

The mean daily frequency with which activities occurred varied between the L and S pen configurations during each of the three time blocks (Table 4.4). Lying was the most frequently occurring activity, followed by standing and walking, whilst sitting postures were adopted comparatively infrequently by both treatment groups throughout the study period.

Pen area	*L*	*S*	*SE_D*
Time block 1 (days -5 to onset of parturition)			
Lying	51	60	21
Standing	47	33	19**
Sitting	7	9	8
Walking	35	30	14
Time block 2 (days 1 to 7 of lactation)			
Lying	74	60	20***
Standing	42	36	16
Sitting	9	7	6
Walking	29	28	12
Time block 3 (days 8 to 17 of lactation)			
Lying	87	81	24
Standing	50	41	17**
Sitting	6	6	6
Walking	41	34	15**

** = P<0.01; *** = P<0.001

Table 4.4 The mean daily frequency of occurrence of lying, standing, sitting and walking in the L and S pen areas during time blocks 1, 2 and 3

The mean daily frequency with which a ventral lying position was adopted was lower in the L than in the S pen configuration during time block 1 (P<0.05). However, during time block 2 this posture was adopted significantly more frequently by sows in the L pen area (P<0.001); (Table 4.5). Although the overall occurrence of ventral recumbency was lower in the S pen area than in L, during time blocks 2 and 3, the posture was adopted more frequently in both pen areas during the third time block. The mean daily frequency with which rooting occurred was lower in the S than in the L pen configuration (P<0.001) during time block 1. Turning frequency was also lower in the S than in the L pen area (P<0.01) during time block 3, but was similar in both treatment groups during the first week of lactation.

Pen area	*L*	*S*	*SE_D*
Time block 1 (days -5 to onset of parturition)			
Ventral recumbency	18	25	14*
Rooting	24	8	13***
Turning	16	13	13
Time block 2 (days 1 to 7 of lactation)			
Ventral recumbency	29	22	11***
Rooting	15	13	12
Turning	16	16	13
Time block 3 (days 8 to 17 of lactation)			
Ventral recumbency	40	37	15
Rooting	10	9	7
Turning	11	9	6**

* = P<0.05; ** = P<0.01; *** = P<0.001

Table 4.5 Mean daily frequency of ventral recumbency, rooting and turning activity in the L and S pen areas during time blocks 1, 2 and 3

There was a strong influence of day on the frequency of occurrence of lying, standing, sitting and walking during time block 1 and on lying, standing and walking frequency during time block 2 which was not evident in time block 3, in both the L and S pen configurations (Table 4.6). There was a significant increase in frequency of all these activities on the day prior to parturition onset (P<0.001) in both treatment groups. This was followed by a reduction in standing and walking frequency, in both the L and S pen areas and a reduction in lying frequency in the S pen area on day 1 of lactation. From then on, the daily frequency of occurrence of the activities steadily increased during the first week of lactation (P<0.001) in the L and S pen areas, after which the frequency of activities remained stable in both treatment groups throughout the remainder of lactation.

Pen area	L				S			
Activity	*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Time block 1 (days -5 to onset of parturition)								
Day 1	47^{d}	38^{d}	2^{a}	31^{d}	48^{a}	13^{a}	6^{a}	12^{a}
2	42^{b}	32^{b}	2^{b}	26^{b}	54	19^{b}	7	22^{b}
3	41^{a}	31^{a}	3^{c}	23^{a}	59	31^{c}	7	28^{d}
4	46^{c}	35^{c}	5^{d}	29^{c}	60	32^{d}	7	26^{c}
5	80^{abcd}	97^{abcd}	23^{abcd}	68^{abcd}	81^{a}	72^{abcd}	17^{a}	61^{abcd}
SE_D	13***	12***	5***	9***	13***	12***	5***	9***
Time block 2 (days 1 to 7 of lactation)								
Day 1	83	24^{ab}	12	10^{abcde}	54	22	7	14^{abc}
2	56^{a}	39	7	28^{e}	48^{ab}	34	6	25
3	61	40	9	27	50	36	6	29
4	67	40	8	29^{d}	56	39	7	32^{c}
5	86^{a}	47	10	33^{c}	63	41	8	33^{b}
6	80	55^{a}	8	37^{a}	75^{a}	38	9	30
7	82	50^{b}	9	37^{b}	73^{b}	45	6	34^{a}
SE_D	11***	8***	3	6***	11***	8***	3	6***
Time block 3 (days 8 to 17 of lactation)								
Day 8	87	44	8	36	78	40	6	31
9	84	51	5	41	80	38	6	30
10	80	52	7	43	81	39	7	32
11	76	51	6	43	81	43	7	34
12	83	45	7	40	86	37	5	33
13	97	53	5	43	67	38	6	29
14	83	50	6	39	81	42	5	37
15	91	53	6	44	85	43	7	37
16	97	52	5	42	83	46	5	38
17	90	47	5	38	83	45	6	39
SE_D	11	8	2	7	11	8	2	7

Means in the same column with the same superscript differ at $P \leq 0.05$
*** = $P<0.001$

Table 4.6 Mean frequency of occurrence of lying, standing, sitting and walking per day in the L and S pen areas during time blocks 1, 2 and 3

There was an influence of day on the frequency of rooting (RT) and turning (TU) during the first time block and in lying ventrally (LV) in time blocks 1 and 2, in both treatment groups (Table 4.7). However, there were no further effects of day on these behaviours during the remaining time periods.

Pen area	*L*			*S*		
Activity	*LV*	*RT*	*TU*	*LV*	*RT*	*TU*
Time block 1 (days -5 to onset of parturition)						
Day 1	18	6^{a}	5^{a}	18^{a}	2^{b}	4^{b}
2	15	10^{d}	6^{d}	19^{b}	1^{a}	4^{c}
3	10^{a}	8^{b}	5^{b}	22^{c}	3^{c}	6^{d}
4	13^{b}	8^{c}	5^{c}	23	3^{d}	3^{a}
5	33^{ab}	85^{abcd}	59^{abcd}	41^{abc}	32^{abcd}	49^{abcd}
SE_D	9***	8***	9***	9***	8***	9***
Time block 2 (days 1 to 7 of lactation)						
Day 1	28	15	14	16^{b}	12	18
2	17^{a}	15	16	15^{a}	11	14
3	24	14	19	15	18	17
4	27	17	16	23	13	16
5	40^{a}	14	17	23	15	14
6	33	13	13	32^{ab}	17	21
7	36	14	15	30	18	19
SE_D	21***	7	7	21***	7	7
Time block 3 (days 8 to 17 of lactation)						
Day 1	40	15	15	35	6	7
2	35	8	9	33	7	7
3	36	7	11	38	13	12
4	35	8	7	35	7	9
5	36	14	16	41	8	10
6	44	9	9	33	8	7
7	40	7	11	38	17	15
8	44	7	7	41	8	9
9	46	15	15	37	6	7
10	47	14	14	40	10	7
SE_D	7	3	3	7	3	3

Means in the same column followed by the same superscript differ at $P \leq 0.05$
*** = $P<0.001$

Table 4.7 Mean frequency of occurrence of lying ventrally (LV), rooting (RT) and turning (TU) per day in the L and S pen areas during time blocks 1, 2 and 3

The frequency with which individual sows in each treatment group engaged in lying, standing, sitting and walking activity was very similar during time block 1 (Appendix 4.5). The one exception was one individual sow in the S pen area which adopted a lying posture significantly more often ($P<0.05$) than the other sows in this treatment group. However, there was considerable variation in the frequency with which activities were performed between sows in both the L and S pen configurations, during subsequent time blocks (Appendices 4.6 and 4.7).

The frequency with which ventral recumbency occurred was significantly different between sows in the S pen area ($P<0.01$) during time block 1 (Appendix 4.8). The variation in frequency with which this position was assumed increased significantly between sows in both the L ($P<0.001$) and the S ($P<0.001$) pen configurations, during time blocks 2 and 3.

4.3.3 Diurnal patterns of time allocation

As the frequency with which standing, sitting, walking and lying ventrally occurred per hour were known, it was possible to determine diurnal activity patterns in each treatment group, during the three time blocks studied (Figure 4.3). The data collection method employed resulted in the frequency of lying becoming a measure of the number of position changes whilst lying per hour. It was therefore, not possible to distinguish between separate lying bouts, so these data were omitted from this part of the analysis.

The frequency of occurrence of activities increased over time and was higher in the L than in the S pen configuration in all three time blocks ($P<0.001$).

Time block 1

During time block 1, three peaks of standing and walking activity could be identified at 03.00, 08.00 and 16.00 hours in the L ($P<0.001$) and at 09.00, 16.00 and 19.00 hours in the S ($P<0.001$) pen configurations. Sitting and lying ventrally occurred at low levels which increased slightly in line with the peaks of standing and walking activity in both treatment groups.

Time block 2

A more clearly defined pattern of standing, walking and lying ventrally began to emerge in the L pen area, during time block 2 ($P<0.001$). In this treatment group there were now two main peaks of activity from 06.00 to 12.00 hours and from 14.00 to 21.00 hours.

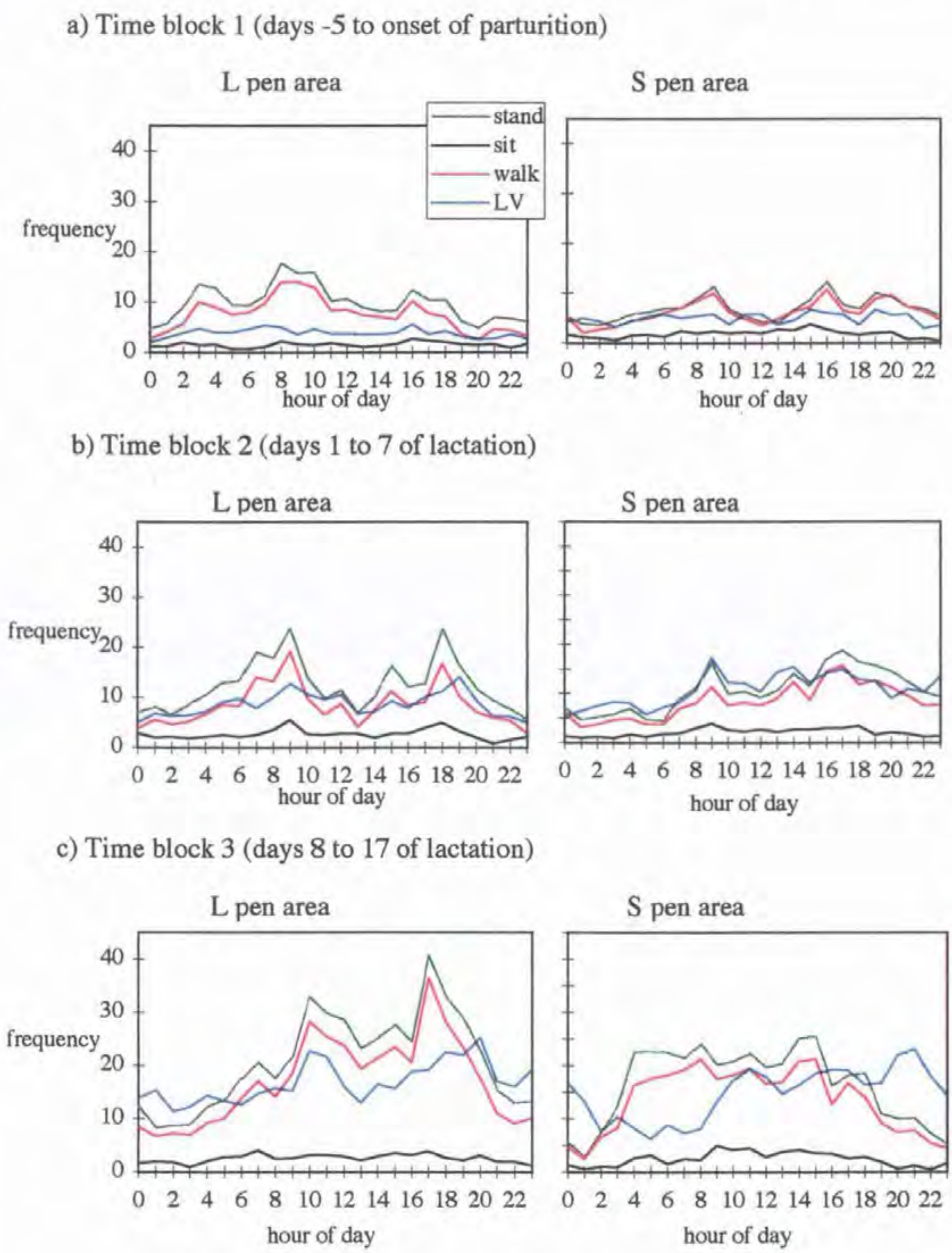


Figure 4.3 Frequency of occurrence per hour of standing, sitting, walking and ventral recumbency (LV) in the L and S pen configurations, during time blocks 1, 2 and 3

In contrast, a somewhat lower peak of activity began at 08.00 hours and continued, with only minor fluctuations until 22.00 hours in the S pen area ($P<0.001$). Sitting activity again occurred at low levels and peaked only slightly in line with the other activities in both treatment groups.

Time block 3

Later in lactation, two quite distinct peaks of standing, walking and lying ventrally occurred in the L pen configuration ($P<0.001$). The first peak began at 09.00 hours, corresponding to morning cleaning routines, and continued until 12.00 hours. A short decline in activity preceeded the second and highest peak which lasted from 14.00 unitl 20.00 hours.

In the S pen area, the activities of standing and walking were contained within one long peak period which lasted from 03.00 until 19.00 hours, whilst the peak of ventral lying occurred from 09.00 to 23.00 hours, very similar to its position in time block 2 ($P<0.001$). Sitting continued at low levels, with only a slight increase in frequency during peak periods of the other activities, in both treatments.

4.3.4 Factors influencing time allocation

A number of measurable physical, environmental, management and production factors which may have influenced the way in which time was allocated by individual sows to different activities during each of the time periods studied were identified (Figure 4.4). It was possible to examine the influence of day, sow parity, social rank, the number of piglets reared, the final litter weight, distance from the feeder, distance from the water, ambient temperature and space allocation on

* the time spent lying, lying ventrally, standing, sitting, walking and rooting

* the frequency of occurrence of ventral recumbency, standing, sitting, walking, rooting and turning

during time blocks 1, 2 and 3, within the dataset available, by multiple regression analysis. The factors within the shaded boxes were constants, so were not included in the analysis.

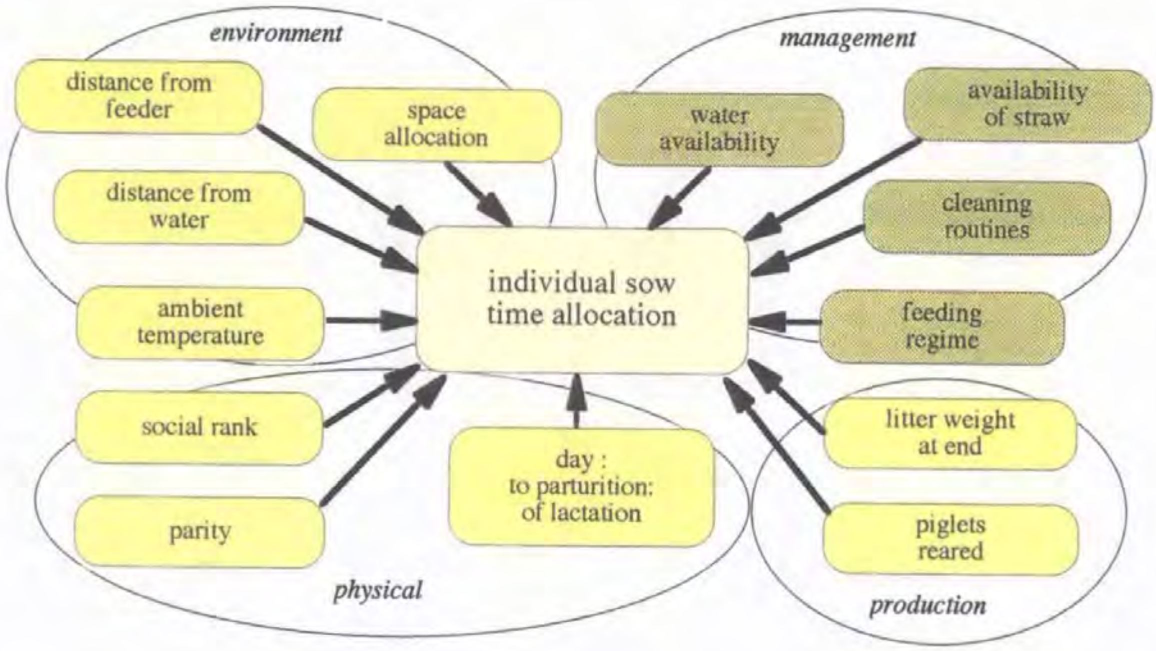


Figure 4.4 Schematic illustration of the factors which may influence time allocation to different activities by group housed sows over parturition and during lactation

4.3.5 Factors influencing the time spent engaged in activities

The percentage contributions made by the factors which had the greatest effect on the variation in time allocated to lying, lying ventrally, standing, sitting, walking and rooting during time blocks 1, 2 and 3 are presented in Table 4.8.

Day and space allocation exerted a significant influence ($P<0.001$) upon the variation in the time spent lying, standing, sitting, walking and rooting, during time block 1 (Appendix 4.9). In time block 2, day of lactation, space allocation and sow parity were the most influential factors affecting the variation in sow activities ($P<0.001$). In the latter part of lactation, during time block 3, the factors tested had a significant influence upon the time spent in ventral recumbency ($P<0.001$). No further influence of the factors tested on the time invested in activities was demonstrated.

4.3.6 Factors influencing the frequency of occurrence of activities

The percentage contributions made by the factors which had the greatest influence on the frequency of occurrence of lying ventrally, standing, sitting, walking, rooting and turning during time block 2 are presented in Table 4.9.

During time block 1, day was the most significant factor ($P<0.001$) affecting the variation in frequency of occurrence of lying ventrally, standing, sitting, walking, rooting and turning (Appendix 4.10). Day of lactation, space allocation and distance to the feeder had a significant influence on the frequency of occurrence of activities during time block 2 ($P<0.001$). In the later stages of lactation, distance from the feeder and sow parity significantly influenced the frequency of lying ventrally, sitting and rooting ($P<0.001$). No other effects of the factors tested upon the frequency of occurrence of activities.

	Activity	*Contribution %*								
		D	*P*	*SR*	*NR*	*W*	*DF*	*DW*	*T*	*S*
Time block 1	Lying	- 20.75	-	-	-	-	-	-	-	- 20.38
	LVentrally	-	-	-	-	-	-	-	-	-
	Stand	+ 6.98	-	-	-	-	-	-	-	+ 9.79
	Sit	+ 5.41	-	-	-	-	-	-	-	-13.51
	Walk	+ 17.04	-	-	-	-	-	-	-	+ 8.94
	Root	+ 23.55	-	-	-	-	-	-	-	+ 8.11
Time block 2	Lying	- 17.40	- 6.18	-	-	-	-	+3.20	-	- 8.23
	LVentrally	+ 12.66	-	-	-	- 3.72	-	-	-	+ 3.85
	Stand	+ 16.16	+ 9.22	-	-	-	-	-	-	+7.74
	Sit	-	-	-	-	-	-	-	-	-
	Walk	+ 19.73	+ 6.20	-	+ 2.70	-	-	-	-	-
	Root	- 22.73	-	-	-	-	-	-	-	-
Time block 3	Lying	-	-	-	-	-	-	-	-	-
	LVentrally	+ 5.47	+ 6.67	-	+ 9.99	- 4.87	- 3.36	+ 2.61	-	- 9.89
	Stand	-	-	-	-	-	-	-	-	-
	Sit	-	-	-	-	-	-	-	-	-
	Walk	-	-	-	-	-	-	-	-	-
	Root	-	-	-	-	-	-	-	-	-

Key: D = day; P = sow parity; SR = social rank; NR = number of piglets reared; W = weaning weight; DF = distance from the feeder; DW = distance from the water; T = ambient temperature; S = space allocation

Table 4.8 Percentage contributions as indicated by R-sq values from multiple regression analyses, made by the most influential factors to the variation in time allocated to different activities by group housed sows over parturition and during lactation

	Activity	*Contribution %* *D*	*P*	*SR*	*NR*	*W*	*DF*	*DW*	*T*	*S*
Time block 1	LVentrally	+ 15.03	-	-	-	-	- 14.37	+ 5.22	-	- 4.63
	Stand	+ 35.34	-	-	-	-	-	+ 6.98	-	-
	Sit	+ 25.71	-	-	-	-	-	-	-	-
	Walk	+ 31.82	-	-	-	-	-	-	-	-
	Root	+ 31.07	-	-	-	-	-	-	-	+ 8.58
	Turn	+ 35.30	-	-	-	-	-	-	-	-
Time block 2	LVentrally	+ 18.24	-	-	-	-	- 17.61	-	-	+ 7.77
	Stand	+ 18.14	+ 3.13	- 4.25	-	-	- 3.40	-	-	+ 2.78
	Sit	-	-	-	-	+ 4.22	-	-	-	+ 2.09
	Walk	+ 23.86	+ 3.33	-	-	-	-	-	-	-
	Root	-	-	-	-	-	-	- 3.81	-	+ 34.83
	Turn	-	-	-	+ 6.61	-	- 12.02	-	-	-
Time block 3	LVentrally	-	- 7.31	- 10.24	+ 5.19	- 14.42	- 4.79	+ 4.22	+ 5.77	-
	Stand	-	-	-	-	-	-	-	-	-
	Sit	-	- 2.16	-	-	-	+ 17.87	-	-	-
	Walk	-	-	-	-	-	-	-	-	-
	Root	-	- 3.10	-	-	-	-	- 1.38	-	+ 32.20
	Turn	-	-	-	-	-	-	-	-	-

Key: D = day; P = sow parity; SR = social rank; NR = number of piglets reared; W = weaning weight; DF = distance from the feeder; DW = distance from the water; T = ambient temperature; S = space allocation

Table 4.9 Percentage contributions as indicated by R-sq values from multiple regression analyses, made by the most influential factors to the variation in the frequency of occurrence of activities of group housed sows over parturition and during lactation

4.4 DISCUSSION

Animals adapt to environmental conditions and to changes in their physical state by altering both the amount of time spent in different activities and the frequency with which the activities are performed (Toates 1980; Dawkins 1983a; McFarland 1985; Mason, Cooper and Garner 1997).

4.4.1 Adaptation to environmental conditions

Sows in the novel farrowing system spent 81% and 85% of the total time available lying down in the L and S pen configurations, respectively. This is consistant with Mauget's (1981) observation that free-living wild boar increased the time spent resting from 58% to 80% of the time when food was plentiful.

From introduction to the system until onset of parturition, sows in the larger space allowance spent less time resting in lying and sitting postures and more time in standing, walking and rooting activities than sows in the reduced pen area.

Even though the L sows continued to spend less time lying down than the S sows during the first week of lactation, they spent 12% of this time relatively alert, in ventral recumbency. Standing also continued to occupy more time in the L than in the S pen area during this time period. These differences in time allocation between treatment groups were no longer evident later in lactation. However, the L sows continued to sit for longer and spent more time rooting than the S sows during this final time period.

These results suggest that exploration and movement by the S sows around their new surroundings might have been constrained, perhaps due to an increased cost imposed by the lack of space (Sherwin and Nicol 1996; Mason *et al.* 1997). In a study on hens, walking was the first activity to be reduced as pen size decreased (Keeling 1994). Keeling (1994) concluded that whilst pen size decreased and the inter-bird distances required for activities such as walking could not be maintained, other activities requiring less social space continued to be performed. This implies that the space allowance in the S pen configuration may also have been insufficient to provide the social space required by the sows in which to investigate their surroundings. Alternatively, the increased standing, walking and rooting by sows in the L pen area, following introduction to their new surroundings, could be interpreted as lack of security in an area which offered less protection and was difficult to police. As a result, time spent lying down was reduced in favour of increased vigilance and exploration. This suggestion is supported by the fact that sows in the L pen configuration stood and rooted more frequently than the S sows, during the 5 days before to parturition. Although lying down was the most frequently occurring activity in both treatment groups, the activity occurred more often in the L pen area, during the first week of lactation. The incidence of ventral lying was also higher for the L sows, accounting for 39% of their mean daily lying frequency during this time block. Sows in the L pen area continued to stand and also turned within the farrowing enclosure and walked more often than the S sows, during time block 3.

Interestingly, the straw bedded farrowing enclosures were the preferred resting place of sows during all three time blocks. However, sows in the S pen area spent more of their total lying time in the passageways outside the enclosures during the days before parturition and in the latter part of lactation than sows in the L pen configuration. A recumbent sow would block the 1 metre wide passageway and as the action of stepping over a resting penmate frequently caused aggression (Baxter 1985), movement of other sows around the system would be restricted. This behaviour may, therefore, be partially responsible for the reduced amount of standing and walking activity in S pen area during time block 1.

Sows spent 84% and 85% of the day lying within the farrowing enclosures, during the first week of lactation, in L and S pen areas, respectively. This reduced to 79% in L and 76% in S pen areas, during days 8 to 17 of lactation. In contrast Bøe (1993) reported that sows spent only 53.8% of time daily with their piglets in week 2 of lactation and a mere 1.9% of each 24 hour period by week 4 of lactation. In this study, the piglets were confined to the farrowing enclosure throughout lactation, whereas in the present study, they were free to leave the enclosures and follow the sow around the system as would occur in a natural situation (Jensen and Redbo 1987; Stangel and Jensen 1991). This might have been an important factor in maintaining the bond between sow and offspring and ensuring continued maternal investment in the novel farrowing system.

4.4.2 Adaptation to changes in physical state

There was a strong effect of day on the way in which sows allocated available time to different activities prior to farrowing and during the first week of lactation in both treatment groups. This served to illustrate how changes in the physical state, in this case the changing hormonal balance (Castren *et al.* 1993a; Castren *et al.* 1993b) of the peri-parturient and newly lactating sow affect the way in which time was allocated to different activities. A reduction in the time spent lying and an increase in time spent walking and rooting was accompanied by a sharp rise in frequency of all activities in both treatment groups during the 24 hours leading up to parturition as sows prepared a farrowing site. Similar changes in behaviour during the 24 hours before parturition have been reported for domestic sows kept in semi-natural conditions (Jensen 1986) and sows housed in pens (Arey *et al.* 1991; Baxter 1991; Haskell and Hutson 1993; Haskell *et al.* 1997). The first day of lactation saw an increase in lying time and a reduction in time spent standing, walking and rooting, whilst with the exception of lying in the L pen area, there was a sharp fall in frequency of all activities in both the L and the S pen areas as sows recovered from farrowing and allowed their piglets to suckle. In agreement with these findings, Jensen (1986) observed that free-ranging domestic sows remained inside their farrowing nests during the first day after farrowing. Sows housed in pens and in farrowing crates were also less active for a period of time following parturition (Lammers and de Lange 1986; Cronin and Smith 1992b).

The time spent in ventral recumbency by sows during lactation was affected by the litter weight and the number of piglets reared, which might simply be a way of protecting the udder from the attentions of the piglets (Whatson and Bertram 1982; de Passillé and Robert 1989). However, ventral lying behaviour was also influenced by the distance from the feed and water. It is suggested, therefore, that the ventral lying postion was also adopted to permit observation of the pen area and reduce risk of conflict with penmates when accessing the feed and water points.

4.4.3 Diurnal pattern of activities

The diurnal pattern of activity was more clearly defined for sows in the L than for those in the S pen area. Two quite distinct peaks of standing, walking and ventral lying activity developed, from 09.00 to 12.00 hours and from 14.00 until 20.00 hours, as lactation progressed. Domestic sows kept in a semi-natural environment were active during the morning and afternoon, with a short rest period at midday (Stolba and Wood-Gush 1989). Similarly, sows in farrowing crates were more active during the daytime, with a slight lull around midday (de Passillé and Robert 1989). In contrast, a single, protracted peak of standing and walking activity, occurred between the hours of 03.00 and 19.00 in the S pen area. The wider spread of standing and walking activity over time might have reflected the reduced opportunities for sows to move around the system and may have served to minimise the occurrence of potentially aggressive encounters in the reduced space allocation.

Although the space allowance influenced activity patterns, sows in both treatment groups were able to perform the activities associated with parturition and settle into the farrowing enclosures to rear their offspring. The combination of less time spent in activities and the more frequent occurrence of activities in the L pen configuration suggests that sows in this treatment group were less settled and made more transitions between activities than sows in the S pen area during all three time blocks studied. The reduced amount of activity in the S pen configuration might be expected to contribute to piglet survival in the system. However, there was no evidence to support this suggestion in this study (see Appendix 3.2).

5. SUCKLING BEHAVIOUR OF SOWS AND PIGLETS

5.1 INTRODUCTION

A suckling pattern develops during the first hours following the birth of the piglets (Hartstock and Graves 1976; Rosillon-Warnier and Paquay 1984; Lewis and Hurnik 1985; Castren *et al.* 1989b; de Passillé and Rushen 1989a). Once the pattern has been established, nursings involving all or most of the litter occur at regular intervals throughout lactation (Barber *et al.* 1955; Ellendorf *et al.* 1982; Auldist and King 1995; Wechsler and Brodmann 1996; Spinka *et al.* 1997). According to Schouten (1986), piglets spent approximately 30% of their time engaged in nursing behaviour during the first two weeks of lactation. Thereafter, nursing activity decreased over time, occupying only 15% of time when piglets were six weeks of age. As time goes on sows become less inclined to nurse their piglets. Bøe (1993) found that loose housed sows spent increasing amounts of time lying sternally, during weeks 2 and 3 of lactation. Sows in farrowing crates were also observed to increase sternal lying time over a 27 day lactation (de Passillé and Robert 1989). Jensen *et al.* (1991) reported that early suckling bouts were initiated by the sow with the piglets taking a passive role, but as they grew older, more and more nursings were begun by piglet stimulation. During the first week of lactation the number of sucklings terminated by sows in a semi-natural environment gradually rose from less than 5% to 60% of sucklings (Jensen *et al.* 1991).

The more frequent the opportunities for piglets to suckle, the higher their milk intake and subsequent live weight gain over lactation (Barber *et al.* 1955; Newberry and Wood-Gush 1984; Spinka *et al.* 1997). It has been shown that maternal behaviour and the responsiveness of sows to their piglets is improved with the provision of a degree of comfort and environmental stimuli for the sow (Cronin and van Amerongen 1991; Herskin *et al.* 1997). However, other aspects of the environment have been shown to have a marked effect on parental investment in their young. Domestic sows in group farrowing accommodation were reported to encourage their piglets to climb out of the nest enclosures at around 7 days of age

(Marchant 1997), coinciding with the time when sows and litters in a natural situation would leave the farrowing site and rejoin the herd (Jensen and Redbo 1987). Sows in fully integrated, group farrowing systems, in which piglets were confined to the farrowing enclosure, gradually increased the amount of time away from their litters and reduced the number of sucklings, over lactation (Houwers *et al.* 1992; Bøe 1993). Bøe (1994) suggested that as the confined piglets were unable to follow the sow away from the farrowing site, her interest in them declined, and resulted in weaning before 3 weeks of age in some instances.

The re-integration of groups of free-living sows and litters following nest leaving is simulated in some commercial production systems by the formation of multisuckling groups when litters are approximately two weeks of age. Although most piglet deaths occurred in the first few days following birth, the disruption that the formation of multisuckling groups caused to suckling patterns and the aggression displayed amongst piglets is reported to cause another peak of deaths at the start of this phase (Sinclair *et al.* 1993; Marchant 1997; Wattanakul *et al.* 1997).

Gundlach (1968) and Meynhardt (1991) noted that within a group of wild boar sows and litters, suckling was closely synchronised, due in part to a 'contagious' effect of the squealing by piglets which preceded each suckling bout. Synchrony of suckling bouts amongst groups of free living domestic sows was reported by Newberry and Wood-Gush (1984). This same phenomenon occurs in group housed lactating sows (Bryant *et al.* 1974) and in sows housed individually in pens within the same farrowing house (Wechsler and Brodmann 1996). Newberry and Wood-Gush (1984), Wechsler and Brodmann (1996) and Delcroix *et al.* (1995) suggested that synchronisation of suckling amongst litters of similar age and size might be an adaptation to minimise the incidence of cross suckling. However, Fradrich (1965) observed young wild boar changing over from one sow to another during suckling bouts. More recently Wattanakul *et al.* (1997) reported that, despite synchronised suckling, a high incidence of cross suckling occurred throughout lactation in a multisuckling system.

The objective of this part of the study was to describe the suckling behaviour of group housed sows and their litters in a novel loose housed farrowing system, providing two different space allowances, in which piglets could leave the farrowing site and socialise with other litters.

5.2 METHOD

The suckling behaviour of four groups of four sows, allocated to one of two space allocations in a free access farrowing system, was observed from day 1 to day 17 of lactation. Pen layouts, observation procedures and statistical analyses were as described in Chapter 2.

5.2.1 Behavioural definitions

Definitions of sow and piglet activities discussed in this section are presented in Table 5.1.

5.2.2 Data collection by direct observation

Cross suckling data were collected by direct observation of sows and piglets in the second replicate in the L pen configuration (L2) and replicates 1 and 2 in the S pen area (S1 and S2). Litters within each replicate were identified by coloured ear tags. Data could not be collected from replicate 1 in the L pen area as individual litters in this group were not marked for identification. Observations were conducted between 10.00 and 12.00 hours and 14.00 and 16.00 hours each Monday, Wednesday and Friday from the day upon which one or more piglets were first observed outside the farrowing enclosures.

The following information was recorded:

* the number of suckling bouts observed

* the number of cross suckling events observed

* the number of piglets involved in each cross suckling event

* litter identity of cross suckling piglets and of the target litter, in order to identify both cross suckling and cross suckled litter

Behaviour	Definition
suckling bout	started when the sow lay laterally with the udder exposed and the piglets assembled along the udder, actively seeking a teat
inter-suckling interval	the time from the start of one suckling bout to the start of the next
synchronised suckling	an event when all sows present within the farrowing enclosures suckling their litters at the same time, even if the last sow began as others were ending the nursing bout
sow suckling termination	an event when the sow moved to lie ventrally and concealed the udder, or stood to walk away whilst the litter was still assembled and nosing the udder
piglet suckling termination	an event when piglet activity at the udder ceased as they moved away and slept, whilst the sow continued to lie laterally with the udder exposed
cross suckling	occurred when a piglet or piglets from one litter suckled from the dam of another litter

Table 5.1 Definitions of terminology related to suckling behaviour

5.2.3Statistical analysis

Information on suckling behaviour from days 1 to 7 (time block 2) and from days 8 to 17 (time block 3) of lactation, for each space allocation and for individual sows, was analysed as described in Chapter 2. In addition, the incidence of cross suckling was analysed by analysis of covariance with litter birth order as a factor and days between farrowings as a covariate.

5.3 RESULTS

5.3.1Establishment of suckling routines

The establishment of regular suckling bouts occurred at a mean of 5.5 (s.e. 0.76) hours and 7.1 (s.e. 0.72) hours after the birth of the first piglet, in the L and S pen configurations, respectively. This difference between treatments was not statistically significant.

5.3.2 Location of suckling bouts

The majority of suckling bouts took place within the farrowing enclosures in both treatment groups. Sucklings outside the farrowing enclosures only occurred during time block 3 and accounted for 1.3% (n = 3065) and 1.1% (n = 3951) of all sucklings during this time period, in the L and S pen areas, respectively.

5.3.3Suckling frequency

Sows in the S pen area suckled their piglets significantly more frequently each day compared with the L sows ($P<0.001$), during time periods 2 and 3 (Table 5.2).

Pen size	*L*	*S*	*SE_D*
Time block 1 (days 1 to 7)	39	50	7.1***
Time block 2 (days 8 - 17)	38	52	6.2***

*** = P<0.001

Table 5.2 Mean daily number of suckling bouts for sows in the L and S pen configurations during time blocks 2 and 3

Day of lactation had a significant effect on suckling frequency (P<0.05) of sows in the S pen configuration during time block 2 (Figure 5.1). This was a function of a reduced level of suckling activity by these sows during day 1 of lactation, followed by a steady increase in suckling frequency. Although numerical data suggest further variation in daily suckling frequency, there was no significant effect of day of lactation for the L sows during time block 2, or for either treatment group in time block 3.

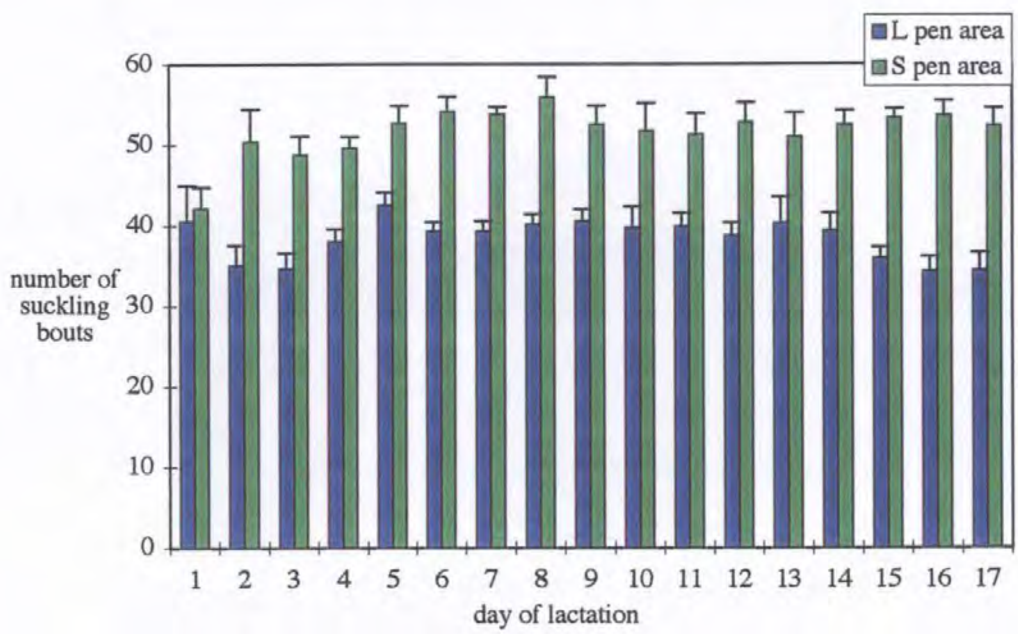


Figure 5.1 The mean daily suckling frequency ± s.e. from day 1 to day 17 of lactation of sows in the L and S pen configurations

The variation in frequency of suckling between individual sows was statistically significant during the first week of lactation (P<0.001) in the S pen area and during days 8 to 17 of lactation (P<0.001) in sows in the L pen area (Appendix 5.1). However, these differences were due, in each case, to a single outlier. The significant difference in variation between the the S sows during time block 3 (P<0.001) was again due to the reduced suckling frequency of two individual sows.

5.3.4 Inter-suckling intervals

The mean inter-suckling intervals were similar for sows in the L and S pen configurations, during time blocks 2 and 3 (Table 5.3).

Pen area	*L*	*S*	SE_D
Time block 2 (days 1 to 7)	40.6	41.0	20.6
Time block 3 (days 8 to 17)	40.1	40.1	19.4

Table 5.3 The mean inter-suckling intervals (minutes) during days 1 to 7 and 8 to 17 of lactation for sows in the L and S pen configurations

The mean interval between sucklings was significantly different between individual sows in the L pen configuration (P<0.001), during both time blocks (Appendix 5.2). This was due to the longer inter-suckling intervals of sow 7 in time block 2 and of sow 4 in time block 3, reflected in the reduced suckling frequency of these particular sows (see Appendix 5.1).

The variation in the length of inter-suckling intervals between sows in the S pen area was more widespread, with a range of mean interval durations of 34.8 (s.e. 0.89) to 52.5 (s.e. 2.69) minutes and 34.6 (s.e. 0.67) to 48.6 (s.e. 1.14) minutes, during time blocks 2 and 3 respectively. These differences between sows were statistically significant (P<0.001) during both time blocks.

5.3.5 Termination of suckling bouts

Piglets terminated significantly more sucklings than sows in both treatment groups, during both time blocks (Table 5.4). The reduced number of sucklings terminated by piglets in the L pen area, during time block 2 (P<0.001) and by both piglets and sows in this pen configuration during time block 3 (P<0.001), was a function of the lower overall suckling frequency throughout lactation, of this treatment group (see Figure 5.1).

Pen area	*L*	*S*	SE_D
Time block 2 (days 1 to 7 of lactation)			
sow	12.9	13.1	8.21
piglet	20.3	37.0	7.63***
SE_D	6.54***	9.10***	
Time block 3 (days 8 to 17 of lactation)			
sow	19.1	24.5	7.55***
piglet	15.0	27.9	7.69***
SE_D	6.33***	8.79*	

* = P<0.05; *** = P<0.001

Table 5.4 Mean number of suckling terminations by sows and piglets in the L and S pen configurations during time blocks 2 and 3

Interestingly, the effect of reduced suckling frequency (SF) in the L sows compared with the S sows, during time block 2, was to reduce the number of piglet terminated sucklings (PT) (Equation 5.1), whereas sucklings terminated by the sow (ST) were similar in both treatments (Equation 5.2).

$$PT = -5.18 + 0.763SF \qquad \text{Equation 5.1}$$

(RSD = 8.98; R-sq(adj) = 37.4%; P<0.001)

$$ST = 0.65 + 0.279SF \qquad \text{Equation 5.2}$$

(RSD = 7.80; R-sq(adj) = 9.0%; P<0.001)

There was variation in the number of sow and piglet suckling terminations between individual sows and litters in each treatment group, during time blocks 2 and 3 (Appendix 5.3). There was a significant difference between S litters during the first week of lactation ($P<0.001$) which was due to the lower number of suckling terminations of litters 5 and 8 in the second replicate group. The reduced activity of litter 5 was again a reflection of their lower overall suckling frequency. Opportunities for litter 8 to terminate sucklings were curtailed by the increased number of terminations performed by their dam even though differences between sows in this treatment group were not statistically significant.

The variation between individual sows and litters increased and became significantly more widespread during time block 3 in both treatment groups ($P<0.001$). No relationship between sow terminated sucklings and piglet mortality could be identified.

Day of lactation had a strong influence on the number of sucklings terminated by both sows and piglets during time block 2 ($P<0.001$), reflecting a gradual increase in sow terminations, accompanied by a gradual decrease in piglet terminations in both treatment groups (Figure 5.2). The number of daily sow and piglet terminations stabilised by day 5 in the L pen area and by day 7 in the S pen area. No further influence of day of lactation was demonstrated in time block 3 during which a mean of 19.1 (s.e. 0.72) and 24.4 (s.e. 0.99) sow terminated sucklings and 15.1 (s.e. 0.70) and 28.0 (s.e. 1.04) piglet terminated sucklings occurred daily in the L and S pen configurations, respectively.

a) L pen area

b) S pen area

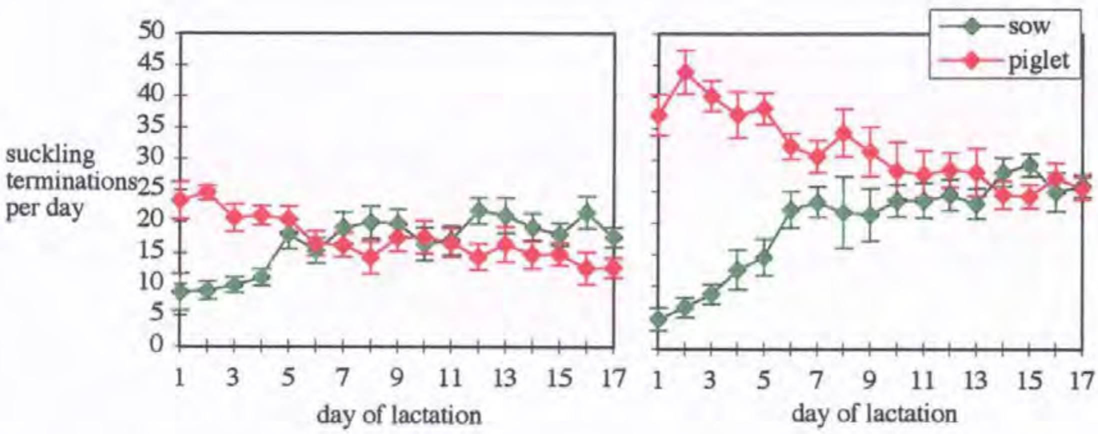


Figure 5.2 Mean daily number of terminations of suckling bouts performed by sows and piglets in the L and S pen areas from day 1 to day 17 of lactation

As the time of day of sucklings was known, it was possible to determine diurnal suckling termination patterns of sows and piglets in each treatment group, during time blocks 2 and 3 (Figure 5.3). The diurnal rhythm of sucklings terminated by sows and piglets followed a similar pattern in both treatment groups, although this was more clearly defined in the S pen configuration. A pattern of sow terminations began to develop in the L ($P<0.05$) and the S ($P<0.001$) pen areas during time block 2. The number of sow terminated sucklings exceeded those of piglets at 09.00 and 18.00 hours in the L pen area whereas terminations by sows in the S pen area were less frequent than those of the piglets throughout this time period. During time block 3, sucklings terminated by sows were concentrated into two main peaks falling approximately between the hours of 06.00 to 11.00 and 15.00 to 22.00 hours in both treatment groups ($P<0.001$).

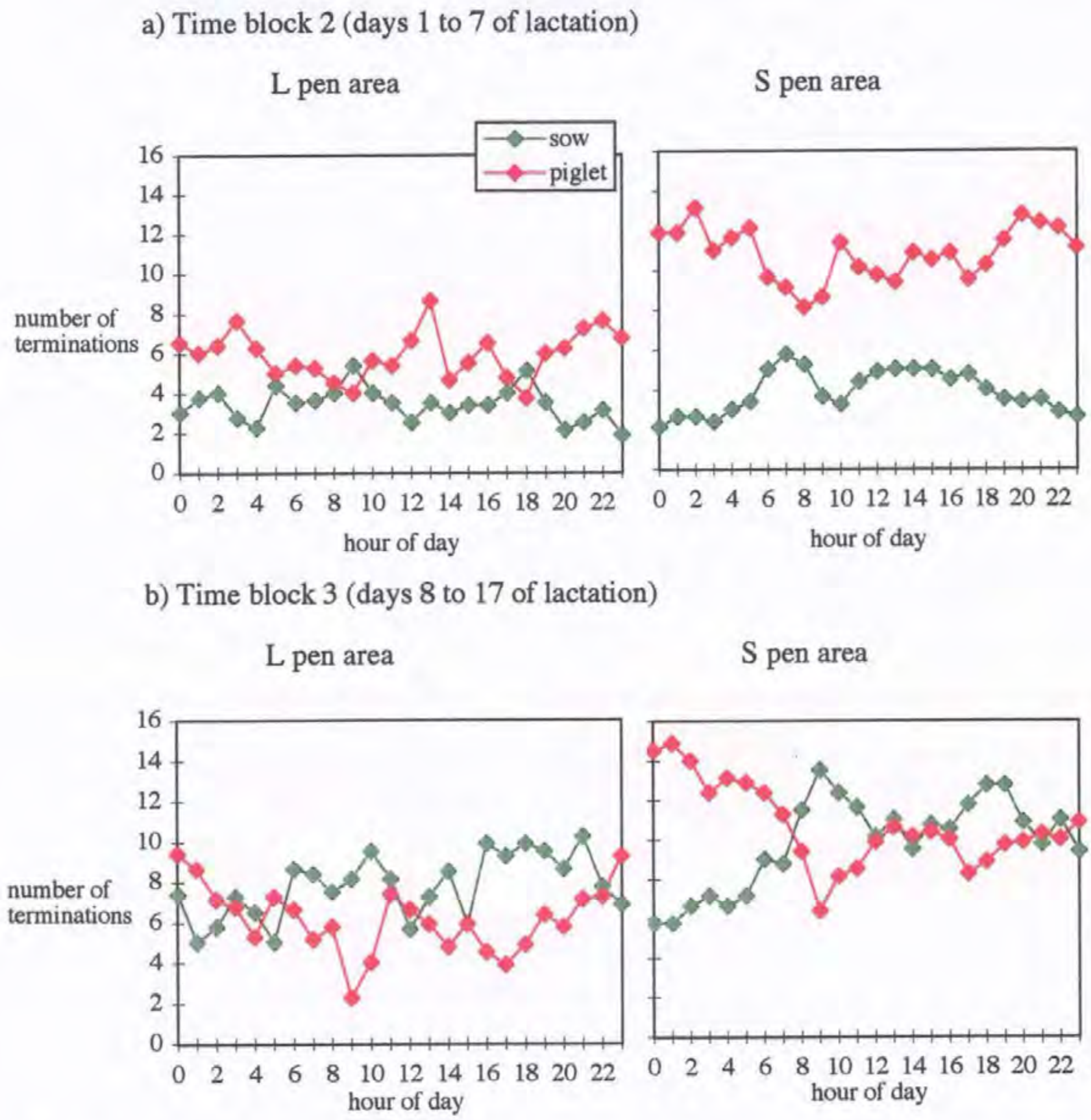


Figure 5.3 Time of day of sow and piglet suckling terminations in the L and S pen configurations, during time blocks 2 and 3

There was a tendency for more sucklings to be terminated by piglets between the hours of 10.00 and 16.00 and again between 18.00 and 07.00 during time block 2. This trend was statistically significant for S piglets ($P<0.001$), but failed to reach significance in the L pen area. In time block 3, piglet suckling terminations peaked between 22.00 and 03.00 hours and between 22.00 and 08.00 hours in the L and S pen configurations, respectively. During these times, piglet terminations exceeded those of the sows. The lowest frequency of terminations by piglets coincided with morning cleaning routines at 09.00 hours and periods of increased feeding activity of the sows. These trends in piglet terminated sucklings in the L and the S pen areas, during time block 3 were statistically significant ($P<0.001$).

Video evidence suggested that sow suckling terminations increased during the daytime and those of the piglets during the night time. This impression was supported by the times of the mean vectors (μ) for sow and piglet suckling terminations in the L and S pen configurations, during time blocks 2 and 3 (Table 5.5). With the exception of piglet terminations during time block 2, differences between patterns of sow and piglet terminations in the L and S pen areas, during each time block, were statistically significant (P<0.001).

Pen area	*L*		*S*	
Terminations	*sow*	*piglet*	*sow*	*piglet*
Time block 2 (days 1 to 7)	10.37	23.15	12.52	23.28
Time block 3 (days 8 to 17)	16.59	00.58	15.01	02.29

Table 5.5 Hour of day of mean vectors (μ) for sow and piglet suckling terminations in the L and S pen configurations during time blocks 2 and 3

5.3.6 Synchronisation of suckling bouts

There was considerable variation in the time between the first and last sows to join a synchronised nursing (Table 5.6). Thus, the first sow to begin frequently finished nursing some time before the last sow started to participate in the synchronised suckling bout. Of the synchronised nursings, 5.3% (n = 2051) and 2.3% (n = 3798) occurred whilst 1 or sometimes 2 sows were engaged in feeding, drinking or resting away from the farrowing enclosure in L and S pen areas, respectively.

Pen area	*L*	*S*	SE_D
synchronised sucklings	0.39	0.56	0.16
time between sows	3.29	2.49	4.00**

** = P<0.01

SE_D of synchronised sucklings was calculated from data subjected to arcsine transformation

Table 5.6 The proportion of sucklings which were synchronised and the mean time (minutes) between the first and last sow to suckle in synchrony, in the L and S pen areas

5.3.7 Cross suckling

Farrowings were spread over 5, 4 and 10 days in the L2, S1 and S2 sow groups, respectively. However, these differences had no significant influence on the incidence of cross suckling in the system. Although piglets began to leave the farrowing enclosures at between 8 and 10 days of age, cross suckling did not occur until some days later (Table 5.7).

Pen area	*L*	*S*		SE_D
Replicate	*2*	*1*	*2*	
litter 1	14	nil	16	
2	14	14	19	
3	15	13	18	
4	15	12	12	
mean	15	13	16	1.63

Table 5.7 Age (days) of litters at which cross suckling behaviour was first recorded

Suckling bouts during which cross suckling occurred accounted for 48% (n = 54), 83% (n = 40) and 38% (n = 40) of all sucklings observed in replicate L2 and replicates S1 and S2, respectively. The higher figure for replicate S1 may have resulted from the noise caused by the activities of workmen carrying out repairs in a neighbouring building, to which sows and litters in this replicate were subjected, during 4 of the observation periods. The noise was observed to unsettle the sows and disrupt suckling routines within the group.

The birth order of litters actively involved in cross suckling and of litters which were the target for cross suckling varied between the groups of sows (Table 5.8). This was due to a tendency for the earlier born litters to cross suckle with those born later in replicates L2 and S2, whereas later born litters cross suckled with earlier born litters in replicate S1. There was no significant effect of the birth order on the frequency of either the initiation or receipt of cross suckling events.

Pen area	*L*		*S*			
Replicate	*2*		*1*		*2*	
birth order	participation	receipt	participation	receipt	participation	receipt
1	12	9	0	2	10	5
2	15	4	4	33	4	2
3	8	12	28	7	1	1
4	2	12	13	3	4	11

Table 5.8 Frequency of participation in and receipt of cross suckling episodes by litters according to birth order within each sow group

Cross sucklings involving a single intruder piglet accounted for 81%, 89% and 58% of all cross suckling events in L2, S1 and S2 sow groups, respectively (Table 5.9). The significantly lower figure for S2 ($P<0.01$) may have been an effect of the spread of farrowings over 10 days for this group, in which cross sucklings targeting the youngest litter involved 7, 5, 2 and 7 piglets from the oldest litter on each of four separate occasions, respectively. This resulted in reciprocal cross suckling targeted at the oldest litter by 3, 3 and 8 of the youngest piglets, on each of three separate occasions.

Pen area	*L*	*S*	
Replicate	*2*	*1*	*2*
Number of piglets		*frequency*	
1	30	40	11
2	3	3	2
3	0	1	2
4	0	1	0
5	1	0	1
6	1	0	0
7	1	0	2
8	1	0	1

Table 5.9 Frequency of involvement of different numbers of piglets in cross suckling events in replicates L2, S1 and S2

5.3.8 Factors influencing suckling behaviour

These results suggest that both space allocation and day of lactation influenced suckling behaviour in the novel farrowing system. A number of other measurable physical and environmental factors including ambient temperature, sow parity, litter size, the number of daily feeding visits, daily feed intake, noise level and sow nursing motivation may also have contributed to the variation in suckling behaviour of sows during lactation (Figure 5.4).

It was possible to examine the influence of a number of these factors on

* suckling frequency
* sow suckling terminations
* piglet suckling terminations

during time blocks 2 and 3 by multiple regression analysis. As measures of sow nursing motivation and noise level were unavailable, these factors were omitted from the analysis.

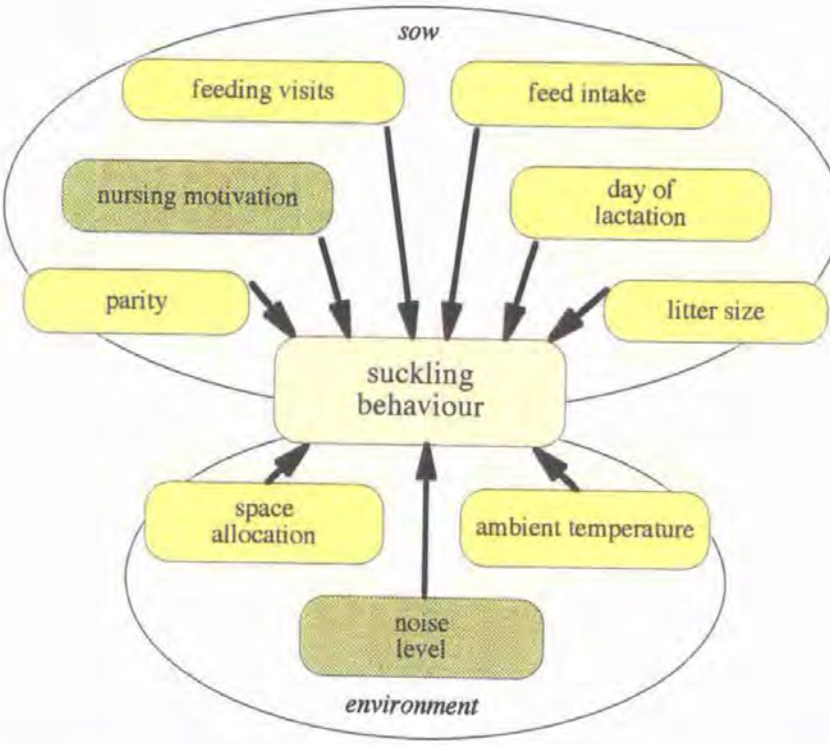


Figure 5.4 Schematic illustration of the factors which may influence suckling behaviour of group housed sows during lactation

5.3.9 Factors exerting greatest influence on suckling frequency and sow and piglet suckling terminations

The percentage contributions made by factors which had a significant effect on variation in the frequency of suckling bouts and of sow and piglet terminated sucklings, are presented in Table 5.10.

Space allocation, day of lactation and ambient temperature exerted a significant influence upon the variation in suckling frequency ($P<0.001$), during time block 2 (Appendix 5.4). In time block 3, ambient temperature, sow parity, the number of visits to the feeder, sow feed

		Contribution %							
	Activity	*D*	*P*	*L*	*F*	*V*	*SF*	*T*	*S*
Time block 2	Suckling frequency	+5.47	-	-	-	-	-	+6.11	-40.92
	Sow terminations	+40.16	-	+3.09	-	+2.97	+4.01	-	-
	Piglet terminations	-7.11	-	-	-	-	+7.54	-	-55.19
Time block 3	Suckling frequency	-	-6.41	-3.28	-4.20	-4.20	-	-5.89	-
	Sow terminations	-	-12.78	+3.02	-	+3.59	-	-	-10.99
	Piglet terminations	-3.05	-	-	-6.22	-	-	-	-43.00

Key: D = Day of lactation; P = Sow parity; L = Litter size; F = Sow feed intake; V = Number of feeding visits; SF = Suckling frequency; T = Ambient temperature; S = Space allocation

Table 5.10 Percentage contributions as indicated by R-sq values from multiple regression analyses, made by the most influential factors to the variation in the frequency of sucklings and of sow and piglet terminated sucklings in a communal farrowing system, during time blocks 2 and 3 intake and litter size were the most influential factors affecting the variation in suckling frequency (P<0.001).

Day of lactation, suckling frequency, litter size and the number of feeding visits had a significant influence upon the number of sow terminated sucklings during time block 2 (P<0.001). During time block 3, litter size and the number of feeding visits continued to affect the variation in sow terminations along with space allocation and sow parity (P<0.001).

The variation in frequency of piglet terminated sucklings was influenced by day of lactation, space allowance and suckling frequency, during time block 2 (P<0.001). In time block 3, day of lactation, space allowance and sow feed intake exerted the greatest influence upon sucklings terminated by the piglets (P<0.001).

5.4 DISCUSSION

5.4.1 Suckling frequency

Piglet survival and live weight gain during lactation depend upon the maternal behaviour and responsiveness of the sow to the piglets (Dyck and Swierstra 1987; de Passillé and Rushen 1989a; van der Lende and de Jager 1991), which may be encouraged by the provision of certain environmental stimuli (Cronin and van Amerongen 1991; Herskin *et al.* 1997). It has been demonstrated that higher milk intakes are achieved by piglets when suckling bouts occur more frequently (Barber *et al.* 1955; Spinka *et al.* 1997). However, sows in communal farrowing systems were reported to reduce the average number of sucklings from 26 to 20.4 per day (Bøe 1993) and from 30 to 26 per day (Houwers *et al.* 1992) in weeks 1 and 3 of lactation. In contrast, mean suckling frequencies of 39 to 36 per day and 50 to 53 per day were achieved during week 1 and days 1 to 3 of the third week of lactation, by sows in the L and S pen areas, respectively. The suckling frequencies of sows in the larger pen configuration were similar to those of 37 to 41 per day over weeks 1 to 3 of lactation, recorded for sows in farrowing crates (Gotz 1991). Gotz (1991) suggested that the maintenance of high suckling frequency might result from the continued closeness of piglets and sow and the low degree of complexity of the farrowing crate environment. The maintenance of suckling frequency might well be a function of the housing design and the management system employed, since in the studies conducted by Bøe (1993; 1994) and Houwers *et al.* (1992)

* sows had to operate complicated entrance barriers to enter and exit the farrowing enclosures

* litters were confined to the farrowing enclosures throughout lactation

* litters were obscured from view by the entrance barriers once sows were outside the farrowing enclosures

* lactating sows could feed and associate with gestating sows out of sight and contact with their litters

whereas in the present study

* sows could enter and exit the farrowing enclosures freely

* piglets were able to leave the farrowing enclosure and follow the sow at all times

* the overall pen design ensured that sows remained in sight and contact with their litters

* sows did not associate with gestating sows during lactation

As the sows did not have to work to obtain access to the farrowing enclosure and distractions were limited, their interest could remain focused on their offspring so there was no significant reduction in suckling frequency over lactation. In support of this argument, sucklings occurred significantly more frequently in the reduced space allowance compared with the larger pen configuration, in which the social space outside the farrowing enclosures was increased.

Whilst space allocation had a strong influence on the variation in suckling frequency between treatments during week 1 of lactation, its effect subsequently reduced and although unidentified factors then carried most weight, an interaction between sow feeding activity and suckling frequency began to emerge in time block 3. Interestingly, at this time, sucklings occasionally occurred outside the farrowing enclosures. In accordance, Jensen (1988) noted that free-ranging sows foraged more frequently and locomotion increased as lactation progressed signalling the start of a prolonged, natural weaning process (Jensen and Recen 1989; Jensen *et al.* 1991; Jensen and Stangel 1992).

5.4.2 Inter-suckling intervals

The range of mean inter-suckling intervals for sows from day 1 to day 17 of lactation of 37.5 (s.e. 1.04) to 48.8 (s.e. 1.78) minutes and 34.6 (s.e. 0.67) to 52.8 (s.e. 2.69) minutes in the L and S pen configurations, respectively, compared well with results of other workers (Table 5.11). Interestingly, the lowest mean intervals in the novel farrowing system were below those recorded for indoor systems and closer to the mean interval of 29 minutes in free-ranging domestic sows (Newberry and Wood-Gush 1984).

According to Newberry and Wood-Gush (1984), even shorter intervals occurred between sucklings without milk ejection, which accounted for 20 to 37% of all sucklings in both conventional farrowing accommodation (Whittemore and Fraser 1974; Whatson and Bertram 1980; Ellendorf *et al.* 1982) and semi-naturai conditions (Newberry and Wood-Gush 1984;

Castren *et al.* 1989a; Jensen *et al.* 1991). Whatson and Bertram (1980) demonstrated that a similar number occurred in grouped and isolated sows. Unsuccessful sucklings are therefore, considered to be part of the natural behavioural repertoire of pigs and not caused specifically by intensive housing systems (Castren *et al.* 1989a). As the mean interval between two successful sucklings was shorter than that between two successful sucklings separated by one or more unsuccessful suckling, frequent unsuccessful nursings might reduce overall milk intake and decrease piglet growth rates (Newberry and Wood-Gush 1984; Castren *et al.* 1989a).

interval (minutes)	*day of lactation*	*reference*
48 to 52	10 to 24	(Auldist and King 1995)
76	3	(Spinka *et al.* 1997)
52	14 to 56	(Wechsler and Brodmann 1996)
44	7 to 28	(Ellendorf *et al.* 1982)
51 to 63	6 to 51	(Barber *et al.* 1955)
29 to 78	1 to 42	(Newberry and Wood-Gush 1984)
40 to 45	1 to 13	(Arey and Sancha 1996)

Table 5.11 Mean inter-suckling intervals reported for sows and piglets

In the present study, incomplete nursings could not be identified due to lack of fine detail of piglet mouth movements on video recordings. However, in the light of only slightly improved piglet weight gains in the S pen area, even though sucklings were more frequent, it is speculated that a higher number of incomplete nursings might have occurred in sows in the reduced space allocation.

5.4.3 Suckling synchrony

The higher proportion of sucklings which were synchronised in the S, compared with the L pen area, support the suggestion that more incomplete nursings occurred in the S pen area as, according to Newberry and Wood-Gush (1984), some incomplete nursings resulted from sows joining a synchronised suckling bout shortly after having suckled, when milk ejection was unlikely to occur. Furthermore, the same author reported that most synchronised nursings occurred when sows were within 10m of one another. The percentage of nursings which were synchronised in the present study was considerably lower than the 82.3% reported for sows in the Family Pen System (Wechsler and Brodmann 1996), but comparable to the 51.5% of sucklings which occurred within 5 minutes of the end of a suckling bout by another sow, in the Edinburgh Pig Park (Newberry and Wood-Gush 1984).

In agreement with Wechsler and Brodmann (1996) and Newberry and Wood-Gush (1984), social facilitation appeared to be important in the organisation of synchronised suckling bouts in the novel farrowing system, as when one sow started to suckle, the others responded to her vocalisations and even sows and piglets engaged in activities outside their own farrowing enclosures, returned to their 'home' enclosure and began suckling within 2.2 and 4.5 minutes after the start of the first sow. The main exception was that sows which were out feeding whilst their litter slept, at the start of a synchronised nursing, would often remain at the feeder and miss the suckling bout. On these occasions, the litter stayed huddled and undisturbed by the suckling sounds around them, only becoming active when the sow returned. However, 95% and 98% of synchronised nursings in the L and S pen areas, respectively, involved all four sows in the group. Similarly, Wechsler and Brodmann (1996) reported that synchronised nursings involving all four sows present were more frequent than those with only two or three sows joining in.

The evidence suggests that incomplete nursings might be a product of synchronised sucklings, which, according to Wechsler and Brodmann (1996), Delcroix *et al.* (1995) and Newberry and Wood-Gush (1984), might be a behavioural adaptation to minimise the incidence of cross suckling in groups of sows living in close proximity with each other. The social facilitation of suckling amongst groups of sows and their litters, and the resulting synchronisation of both complete and incomplete nursings might be a mechanism to ensure that piglets stay with their dam, whether or not they receive nourishment. Unable to predict the outcome, piglets remain assembled at the udder over the period when milk ejection would occur, making any attempts to cross suckle unrewarding. In this way the mother-offspring bond is continually reinforced and the chance of piglet survival improved as competition from intruders at the udder is minimised.

5.4.4 Cross suckling

Cross suckling data were limited to only three of the four groups of sows studied. Added to this, data collected from the S1 sows was confounded by high noise levels caused by repair work being carried out in an adjoining building. These results must therefore be interpreted with caution.

It was interesting to note that, in this study, cross suckling did not begin until piglets were 14 to 19 days of age, some time after they were able to leave the farrowing enclosures, whereas Jensen (1986) and Gotz (1991) reported that it began in the second week following parturition in free-ranging and group housed sows, respectively. This suggests that factors other than age are important. The most likely would be the adequacy of milk supply from their natural mother. Piglets probably only cross-suckle if the milk supply from their dam is inadequate to meet their needs. Cross suckling occurred in less than 50% of sucklings, in the L2 and S2 sow groups, but rose to 83% in the group subjected to high noise levels. This may have resulted from the masking of sounds made by the sow leading to a breakdown in communication between sow and piglets. Algers and Jensen (1985) suggested that as a result of continuous noise, piglets could not follow the grunting phases of the sow during suckling, so were poorly prepared for milk ejection. As a result piglets in a noisy environment may receive less milk from the sow (Algers 1984), so perhaps be more inclined to suckle from other sows.

Disruption of suckling routines, fighting amongst piglets and high levels of cross suckling were reported to follow the formation of multisuckling groups, some two weeks after parturition (Sinclair *et al.* 1993; Hatet, Edwards, Gall and Arey 1994; Wattanakul *et al.* 1997). In contrast, low levels of aggression and few attempts to cross suckle occurred in semi-natural conditions (Newberry and Wood-Gush 1984; Jensen 1986). In group farrowing systems where litters mixed naturally, only 11.2% (Wechsler and Brodmann 1996) were involved in cross sucklings. Similarly, litters mixed gradually with a minimum of aggression and no disruption of suckling routines, in the novel farrowing system, with the effect that the incidence of cross suckling was kept to a comparatively low level. It appears that when integration of sows and litters is allowed to proceed at a natural pace, suckling routines remain undisturbed allowing individual piglets to defend their teat against opportunistic intruder piglets.

The majority of the observed cross suckling incidents, involved only one piglet. However, as reported by Delcroix *et al.* (1995), when farrowings within a group of wild boar sows were more widely spread, as in replicate S2, groups of older piglets cross suckled from the last sow to farrow, forcing the youngest piglets to find sustenance elsewhere. The tendency for sows to provide easier access to the udder by lying for longer periods with the udder exposed, during early lactation (de Passillé and Robert 1989; Jensen *et al.* 1991; Bøe 1993) might be why older piglets were attracted to the more recently farrowed sow.

5.4.5 Sow and piglet terminations of suckling

In both semi-natural conditions (Jensen *et al.* 1991) and indoor group farrowing systems (Bøe 1993), the number of sow terminated sucklings rose gradually during the first week of lactation. Sows were more passive and allowed more continued access to the udder during the first week of lactation, when piglets were more vulnerable. There was a marked influence of day of lactation on sow suckling terminations which rose from 21% to 48% and 11% to 43% of sucklings, from day 1 to day 7 of lactation, in the L and S pen configurations, respectively. Thereafter, space allocation and sow parity exerted some influence on the number of sucklings terminated by sows, which accounted for 51% and

50% of sucklings in the L and S pen areas by day 17 of lactation. This was considerably lower than the 90% reported for free-ranging sows by the fourth week of lactation (Jensen 1988) and might be interpreted as a reflection of the reduced level of environmental stimulation in the indoor system. However, as an interaction between the requirement of the sow to obtain feed and suckling routines has already been noted, it is suggested that the maintenance of sow nursing motivation in the novel system might have resulted from the security of an *ad libitum* supply of food, whereas in the semi-natural condition, a rationed feed provided once daily at specific sites within enclosures of 7 and 13 hectares (Jensen *et al.* 1991) required that sows travelled some distance to the site. In addition, a rationed food supply might have required supplementation through foraging activity, thus promoting a conflict of interests for the sow. Further evidence of an interaction between suckling and feeding activities was the fact that both sow terminated sucklings and sow feeding activity increased during the daytime with similar morning and afternoon to evening peaks. The effects of different feeding regimes on the suckling behaviour of groups of sows in communal farrowing systems warrants further investigation.

The frequency of piglet suckling terminations increased over night, during which time, sows in group farrowing accommodation were observed to remain with their piglets (Bøe 1993). This may well be a behavioural adaptation to provide warmth and protection from predators for piglets during the hours of darkness. Nevertheless, piglet terminated sucklings were largely influenced by space allocation throughout the 17 days of lactation studied. This demonstrated a dependence upon the overall suckling frequency which reflected sow behaviour and willingness to suckle.

6. FEED INTAKES AND FEEDING STRATEGIES

6.1 INTRODUCTION

The feed intake of the lactating sow is often insufficient to meet nutrient requirements for maintenance and milk production (Lynch 1989; Mullan *et al.* 1990; Dourmad 1993). Nutrient intakes in lactation affect the overall productivity of the herd by influencing piglet growth rates and the post weaning reproductive performance of the sow (Lynch 1989; Mullan *et al.* 1990; Prunier *et al.* 1993; Koketsu *et al.* 1996a; Koketsu *et al.* 1996c).

Voluntary feed intake in lactation is affected by

* previous nutritional history and body condition (Cole 1982; Eastham *et al.* 1988; Yang *et al.* 1989; Mullan *et al.* 1990; Dourmad 1991)

* feeding regime (Stahly, Cromwell and Simpson 1979; Rudd and Simmins 1994; Neil 1996; Neil *et al.* 1996)

* composition and form of diet (Pettigrew *et al.* 1984; O'Grady *et al.* 1985; Lynch 1989; Genest and D'Allaire 1995)

* metabolic heat production (Seerley 1984; Whittemore 1993)

* ambient temperature (Sorensen 1961; Lynch 1977; Stansbury *et al.* 1987; Black *et al.* 1993; Whittemore 1993)

Whittemore (1993) considered that the maximum intake of a sow, when fed pelleted food, at a single feed, is between 3 and 4kg, suggesting that feeding sows more frequently might increase overall daily intakes.

The information about feeding strategies adopted by pigs is sparse and focuses mainly on growing pigs. A strong diurnal effect on feeding patterns, with most feeding occurring during daytime, peaking in early morning and mid afternoon has been demonstrated in growing pigs (Schouten 1986; de Haer and Merks 1992; Nielsen 1995) and in lactating sows (Dourmad 1993) under temporate conditions.

Nielsen (1995) and de Haer and Merks (1992) revealed that growing pigs fed *ad libitum* made several visits to the feeder and took their daily feed allowance in a series of meals. Gestating sows, rationed by electronic sow feeders, usually consumed the whole of their daily feed allowance during a single feeder visit, however, all sows made more than one feeder visit per day on some occasions (Eddison and Roberts 1995). Dourmad (1993) demonstrated that lactating sows confined in farrowing crates and fed four times per day to appetite, took a mean of 8.7 meals each day. Groups of lactating wild boar sows in a 1 hectare enclosure, spent between 24.8% and 59.1% of their time searching for food and feeding (Teilland 1986). Similarly, Mauget (1981) reported that wild boar spent 25.2% of their time feeding, although this may reduce considerably when food is plentiful. There is no published information about the feeding strategies of group housed lactating domestic sows.

The aim of this section is to describe the feeding behaviour of group housed sows fed *ad libitum* during lactation, in order to discover which factors exert the greatest influence on feed intakes and feeding strategies.

6.2 METHOD

The feeding behaviour of four groups of four sows allocated to one of two space allowances in a free access farrowing system, was observed from 5 days before parturition, until day 17 of lactation. Pen layouts, observation procedures and statistical analyses were as described in Chapter 2.

6.2.1 Measurement of feed intakes

The feeding point for sows in both pen areas was positioned on the shorter, gated pen boundary (see Figures 2.6 and 2.7). In L the water point was also placed on this boundary, but lack of space in S, meant it had to be relocated in the centre of the long gated boundary.

A lactation diet in 3mm pellet form (J. Bibby Agriculture Ltd., Peterborough, UK), providing 14 MJ/kg digestible energy and 18% crude protein, was supplied *ad libitum* via a sow operated star-wheel feeder (Quality Equipment Ltd., Bury St Edmunds, Suffolk, UK); (Plate 6.1). The quantity of feed delivered from the 30kg capacity hopper was checked every third day by collecting and weighing the feed delivered by ten turns of the auger. The procedure was repeated ten times on each occasion and the mean delivery calculated. As the variation in weight of feed delivered was never more than 0.001kg, the mean amont of feed delivered per ten turns of the wheel was used to calculate daily feed intakes.

Feed was delivered as the star wheel, attached to an auger in the base of the feed hopper, was turned by the sow (Plate 6.2). After a brief settling-in period, sows were trained to use the feeder. The majority of sows took only a few minutes to become proficient at manipulating the star wheel and obtaining food. However, one individual failed to master the technique so was removed and a replacement sow introduced on day 3 of the first replicate study in the smaller pen configuration. Data for the animal taken out of the study was omitted from the analysis.

Plate 6.1 Sow operated star wheel feeder attached to gated pen boundary in a communal farrowing system

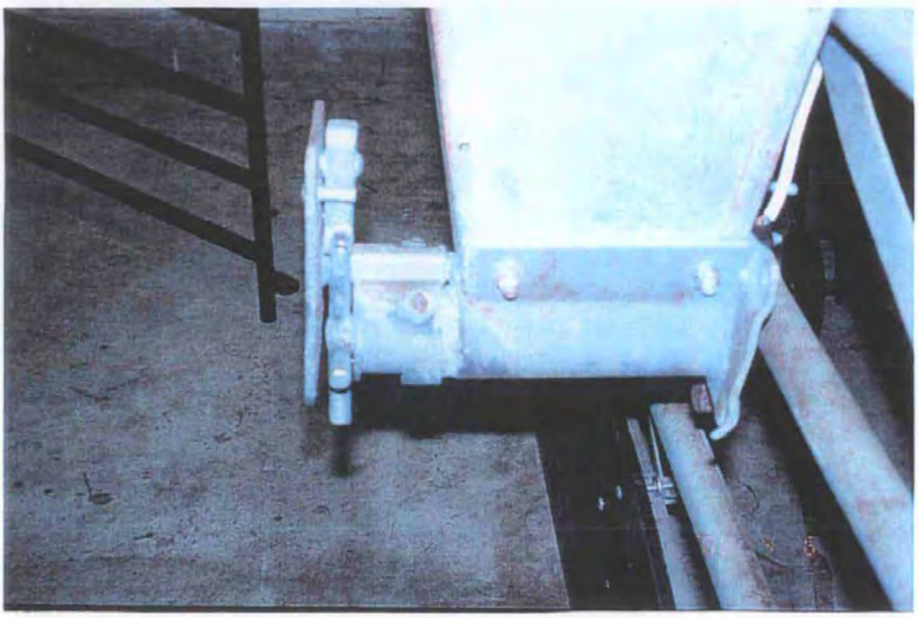


Plate 6.2 Close-up of the star wheel, feed outlet and casing covering the auger in the base of the feeder

The feeder was modified to enable the measurement of individual sow feed intakes. This was accomplished by fitting a wheel, slightly off centre to the rear of the auger spindle and attaching a micro-switch onto the rear of the hopper, above the wheel (Plate 6.3).

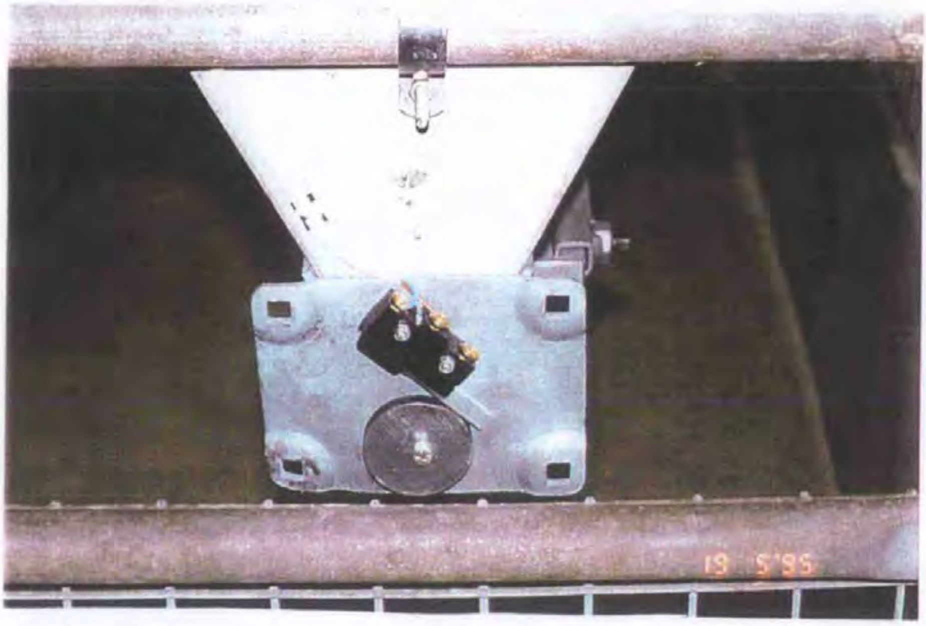


Plate 6.3 Wheel and micro-switch fitted to the rear of the feeder to facilitate the calculation of sow feed intakes

Upon each full 360^{0} turn of the wheel, the micro-switch closed and transmitted a signal to a digital display, positioned in view of the video camera covering the pen area around the feeder, which registered the total number of revolutions of the auger made each day by sows whilst feeding (Plate 6.4). As sows were marked for identification, and the quantity of feed delivered by each revolution of the auger was known, it was possible to calculate feed intakes from the number of times the wheel was turned by each individual sow during each visit to the feeder.

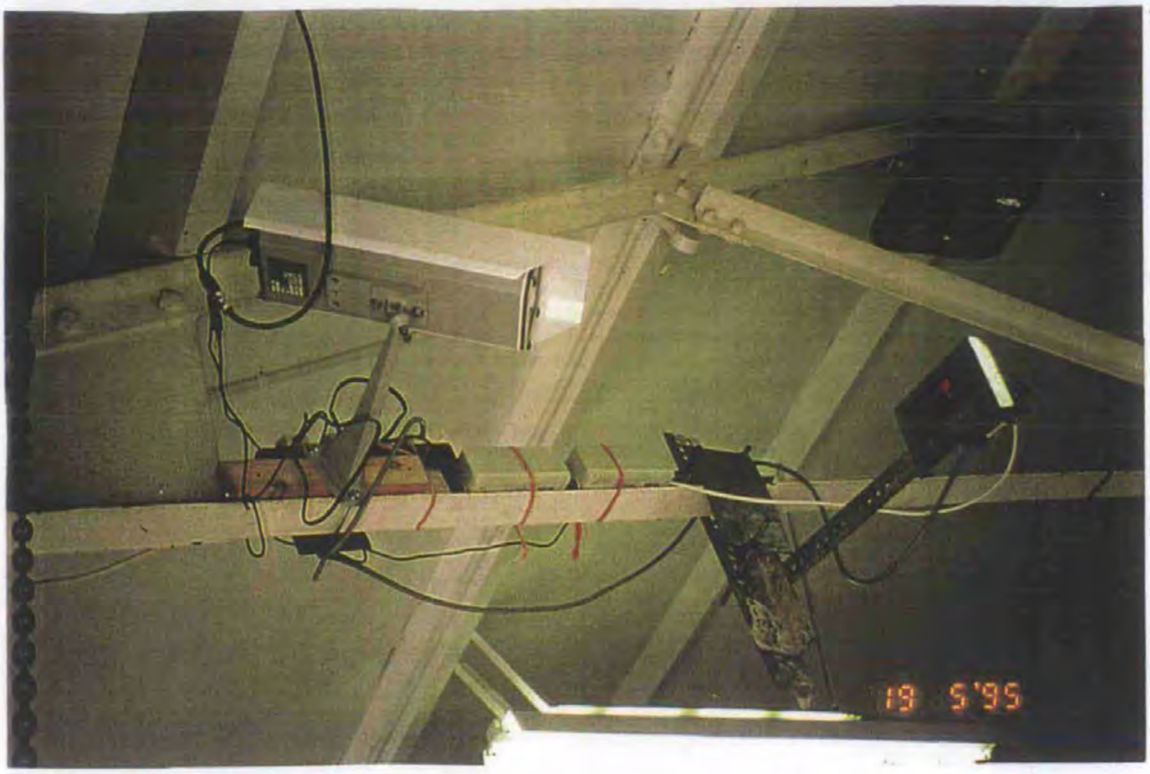


Plate 6.4 Digital display which registered each 360^0 turn of the star-wheel, positioned in view of one of the video cameras

The marker facility in the 'Observer' programme was used to record the readings from the digital display at the beginning and end of each visit to the feeder, for each sow, in preparation for the calculation of individual feed intakes.

6.2.2 Calculation of predicted energy requirements

The equations used for the calculation of predicted energy requirements of individual sows during lactation were as follows:

* the maintenance energy requirement of the lactating sow

E_m (MJ ME) = $0.471W^{0.75}$/day Equation 6.1

(Mullan *et al.* 1990)

* adjustment for ambient temperatures above the LCT

Feed intake reduction (g/day) = W(T - Tc) Equation 6.2

where W is the live weight (kg), T is the ambient temperature and Tc is the LCT

(Whittemore 1993)

* adjustment for ambient temperatures below the LCT

$E_h = 0.018W^{0.75}(Tc - Te)$ Equation 6.3

where W is the live weight (kg), Tc is the LCT and Te is the effective ambient temperature

(Whittemore 1993)

* adjustments linked with the environment

Te = T(Ve)(Vl) Equation 6.4

(Whittemore 1993)

where Ve is a measure of insulation effects and Vl of flooring effects (Table 6.1).

rate of air movement and degree of insulation	Ve
not draughty, not insulated	0.9
floor type in farrowing enclosures	Vl
deep straw bed	1.4

after Whittemore (1993)

Table 6.1 Scores for Ve and Vl which apply to the housing conditions within the experimental farrowing system

* the energy requirement for lactation

$$E_l = 7.7(DWG \times n \times 4) \quad \text{Equation 6.5}$$

where DWG is the piglet daily weight gain and n is the number of piglets in the litter (Whittemore 1993).

For the purposes of the calculations

* sow body weight immediately post farrowing was determined by subtracting the total weight of live births, plus 5.0kg to account for placental membranes and fluid loss (Eastham *et al.* 1988)

* DWG in replicate 1 in the L pen area was taken to be

$$\frac{(\text{av. weaning wt. x no. reared/sow}) - (\text{no. reared/sow x av. birth wt of litter})}{\text{number of days of lactation}} \quad \text{Equation 6.6}$$

* DWG in all other replicate studies was determined by subtracting total live birth weight from total weaning weight of surviving piglets

* the LCT of all sows was assumed to be 12^{0}C (Lynch 1977; Black *et al.* 1993)

6.2.3 Definitions of terminology

* *distance from the feeder*

This was defined as the distance in metres from the centre of the farrowing enclosure entrance occupied by each individual sow for farrowing, to the gated barrier upon which the feeder was attached.

* *sow body weight*

This was defined as the weight of the sow immediately post farrowing, calculated as described in section 6.2.2.

* *number of piglets reared*

This was defined as the number of piglets present for each sow at the end of each study period. As individual litters were not identified in replicate 1 in the L pen area, numbers reared per sow in this instance, were calculated from numbers born live to each sow, minus piglets losses for each sow.

* *litter weight at the end of each trial*

This was the total weight of piglets reared by each sow. These data were not available for replicate L1, so in this case, the total weight of piglets reared per sow was apportioned according to the number of piglets reared per sow, using the formula

(total weight of piglets/total number of piglets) x number of piglets reared per sow

Equation 6.7

6.3 RESULTS

6.3.1 Feed intakes

Mean daily feed intakes were 6.7kg (s.e. 0.42), 5.8kg (s.e. 0.46), 9.0kg (s.e. 0.35) and 6.8kg (s.e. 0.54), 6.8kg (s.e. 0.58), 8.4kg (s.e. 0.40) during time blocks 1, 2 and 3, in the L and S pen configurations, respectively (Figure 6.1).

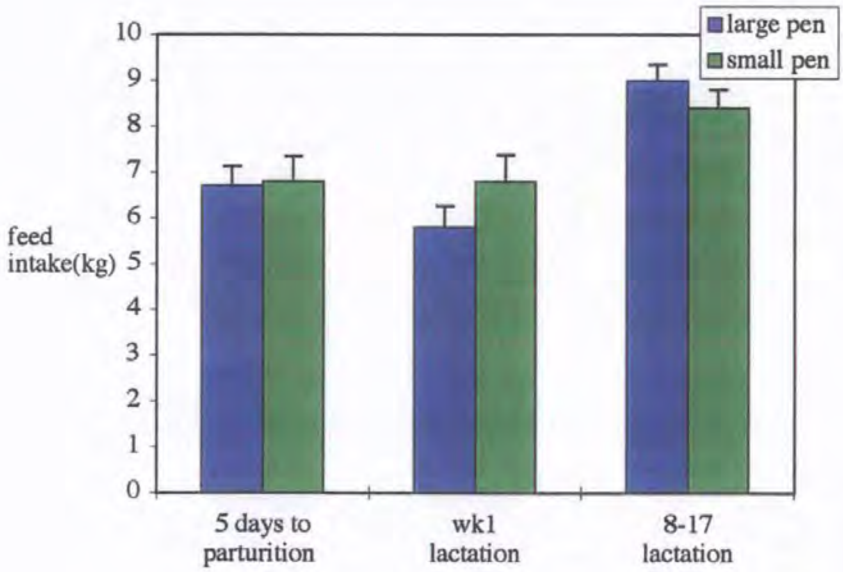


Figure 6.1 Mean daily feed intakes ± s.e. of group housed sows in the L and S pen configurations, during time blocks 1, 2 and 3

The mean daily feed intakes of individual sows were similar in each pen area, during time block 1 (Table 6.2). The difference in mean daily feed intakes between individual sows in the S pen area was statistically significant (P<0.001), due to a low mean daily feed intake of sow 2 (1.97 (s.e. 0.86) kg) and high intakes of sows 5 and 6 (10.19 (s.e. 1.13) kg and 10.18 (s.e. 1.70) kg), during the first week of lactation. In time block 3, there was significantly wider variation in mean daily feed intakes between sows (P<0.001) in both treatment groups. This was reflected in a range of mean daily intakes from 5.37kg (s.e.

0.59) to 13.55kg (s.e. 1.01) and 2.82kg (s.e. 0.56) to 12.33kg (s.e. 0.91) in the L and S pen areas, respectively, during this time block.

Pen area	L			S		
Time block	*-5 to -1*	*1 to 7*	*8 to 17*	*5 to -1*	*1 to 7*	*8 to 17*
Sow 1	7.65	7.65	11.27^{abc}	5.37	4.12^{ab}	5.51^{adgjl}
2	6.79	3.70	5.37^{adefgh}	4.04	1.97^{cde}	9.07^{ab}
3	6.61	6.92	13.55^{dijklm}	5.86	4.06^{fg}	7.97^{cehm}
4	6.72	7.56	9.30^{ein}	6.34	7.46	2.82^{bcfink}
5	4.89	5.15	5.94^{bjnop}	10.04	10.19^{acf}	12.33^{def}
6	7.45	3.75	8.02^{cfk}	7.93	10.18^{bdg}	11.27^{ghi}
7	6.69	6.10	9.56^{glo}	6.25	7.70	9.55^{jk}
8	6.72	5.89	8.97^{hmp}	6.67	8.90^{e}	11.06^{lmn}
SE_D	1.39	1.69	0.92***	1.45	1.72***	0.97***

Means in the same column, followed by the same superscript differ at $P \leq 0.05$
*** = $P<0.001$

Table 6.2 Mean daily feed intakes(kg) of individual sows in the L and S pen configurations, during time block 1, 2 and 3

There was a marked effect of day of lactation on mean daily feed intakes in both treatment groups ($P<0.001$) during time block 2 (Table 6.3). During the first 24 hours following parturition feed intakes fell dramatically with sows 1, 2, 3, 6 and 7 in the L pen area and sows 1, 2, 3 and 7 in the S pen area eating nothing at all. Sow 6 in the L and sow 1 in the S pen areas fasted for two full days and sow 2 in the S space allocation, for three days, following parturition. One sow in the L pen area ate only 0.16kg and two sows in the S pen area consumed no more than 0.55kg and 1.6kg on the first day of lactation. Thereafter, feed intakes rose gradually until peak daily feed intakes were reached, on average, by day 10 (range day 5 to day 15) of lactation in the L and by day 6 of lactation (range day 3 to day 10) in the S pen configuration.

Pen area		*L*	*S*
Time block 1 (day -5 to onset of parturition)			
Day	1	5.29	5.87
	2	7.43	6.36
	3	7.09	7.94
	4	6.64	6.83
	5	6.99	6.45
	SE_D	1.69	2.05
Time block 2 (days 1 to 7 of lactation)			
Day	1	0.71^{abcde}	1.70^{abcd}
	2	3.88	4.71
	3	6.12^{a}	6.60
	4	6.34^{b}	8.49^{a}
	5	7.52^{c}	9.17^{b}
	6	9.32^{d}	7.94^{c}
	7	6.99^{e}	9.16^{d}
	SE_D	1.30***	1.98***
Time block 3 (days 8 to 17 of lactation)			
Day	8	8.67	9.33
	9	9.29	7.64
	10	8.08	9.09
	11	8.39	8.87
	12	9.38	8.86
	13	8.60	7.12
	14	9.45	9.16
	15	8.75	8.23
	16	10.00	7.27
	17	9.57	8.31
	SE_D	1.44	1.61

Means in the same column followed by the same superscript differ at $P \leq 0.05$
*** = $P < 0.001$

Table 6.3 Mean feed intakes (kg) per day of sows in the L and S pen areas during time blocks 1, 2 and 3

6.3.2 Energy requirements and actual energy intakes in lactation

Using Equations 6.1 to 6.6 in Section 6.2, the production figures for individual sows (Appendix 3.2) and the mean daily ambient temperatures (Appendix 3.3), the predicted total energy requirements for sows in the L and S pen areas, during lactation were calculated (Table 6.4). The actual daily energy intakes were then calculated from the mean daily feed intakes of individual sows (see Table 6.2) during lactation, for comparison.

6.3.3 Daily visits to the feeder

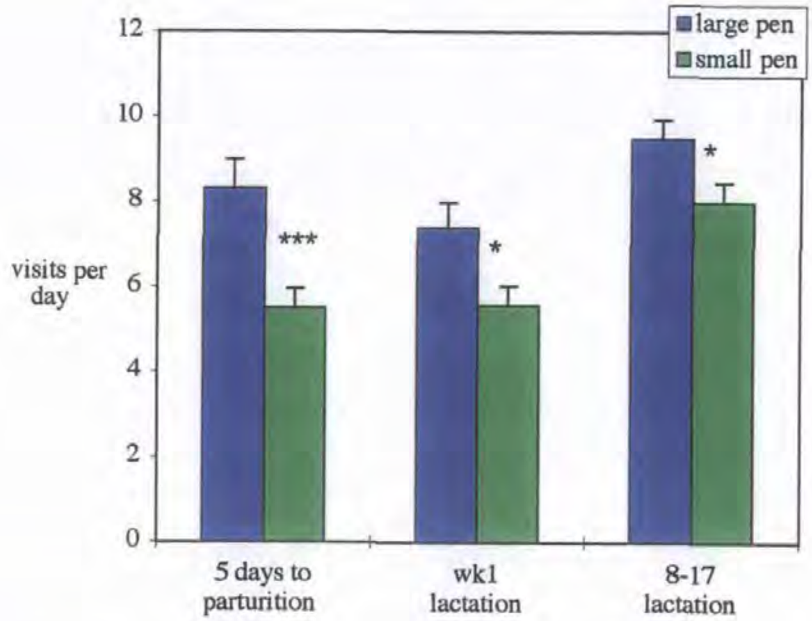
Sows obtained their daily feed intake during a series of visits to the feeder (Figure 6.2). Significantly fewer feeding visits per day were made in the S than in the L pen area (8.3 (s.e. 0.68) vs. 5.5 (s.e. 0.45)) during days -5 to -1 before parturition ($P<0.001$), (7.4 (s.e. 0.60) vs. 5.6 (s.e. 0.45)) during days 1 to 7 of lactation ($P<0.05$) and (9.5 (s.e. 0.45) vs. 8.0 (s.e. 0.46)) during days 8 to 17 of lactation ($P<0.05$).

The mean number of daily feeding visits varied between individuals sows (Appendix 6.1). This variation between individual sows was statistically significant in both the L and S treatment groups ($P<0.001$) during time block 3, due to a range of 4.5 (s.e. 0.52) to 14.6 (s.e. 0.99) and 4.1 (s.e. 0.41) to 13.3 (s.e. 0.73) feeding visits being made per day in the L and S pen areas, respectively.

	pen area L						pen area S					
sow	E_m	E_l	E_h	*predicted energy requirement*	*actual energy intake*	*energy intake difference*	E_m	E_l	E_h	*predicted energy requirement*	*actual energy intake*	*energy intake difference*
1	29.5	79.1	5.0	113.6	136.9	+23.3	28.9	43.8	-19.6	53.1	69.1	+16.0
2	30.4	71.9	8.0	110.3	65.6	-44.7	29.4	54.7	-19.7	64.4	86.1	+21.7
3	29.6	86.2	5.3	121.1	151.5	+30.4	30.8	75.9	-20.5	86.2	89.0	+2.8
4	27.7	71.9	4.7	104.3	120.2	+15.9	29.6	45.2	-19.9	54.9	66.2	+11.3
5	28.5	66.9	8.5	103.9	78.6	-25.3	31.4	17.6	6.9	55.9	153.5	+97.6
6	27.6	50.4	7.9	85.9	86.1	+0.2	29.5	66.4	5.5	101.4	151.5	+50.1
7	31.0	58.6	9.2	98.8	113.9	+15.1	29.7	92.1	4.7	126.5	123.1	-3.4
8	32.2	46.6	9.6	88.4	107.9	+19.5	29.1	86.6	5.5	121.2	142.4	+21.2

E_m = energy for maintenance; E_l = energy for lactation; E_h = energy for thermogenisis

Table 6.4 Predicted daily energy requirements and mean daily energy intakes achieved for the L and S sows during lactation (MJ DE/day)



* = P<0.05; *** = P<0.001

Figure 6.2 Mean daily number of feeding visits made by sows in the L and S pen areas, during time blocks 1, 2 and 3

There was a marked effect of day on the number of feeding visits made in the L and S pen configurations, during time blocks 1 and 2 (Table 6.5). The mean number of feeder visits increased from 7.5 (s.e. 0.73) and 5.4 (s.e. 0.46) to 13.8 (s.e. 1.91) and 8.3 (s.e. 0.80) between days -2 and -1 prior to onset of parturition in the L ($P<0.001$) and S ($P<0.001$) pen areas, respectively. This was followed by a sharp reduction in the number of feeding visits to 1.1 (s.e. 0.48) in the L pen area ($P<0.001$) and 1.6 (s.e. 0.96) in the S pen area ($P<0.01$) during day 1 of lactation. Four sows in the L and one sow in the S pen area made no feeding visits at all on day 1 of lactation. One individual in each treatment group made no feeding visits for two full days and a second sow in the S pen area, for three full days following parturition. There then followed a steady increase in the number of feeding visits which peaked at 10.1 (s.e. 1.38) on day 7 of lactation in the L and at 7.8 (s.e. 1.46) by day 8 of lactation in the S pen configuration.

Pen area		L	S
Time block 1 (day -5 to onset of parturition)			
Day	1	7.6[a]	2.8[a]
	2	6.1[b]	3.8[b]
	3	6.5[c]	5.4
	4	7.5[d]	5.3[c]
	5	13.8[abcd]	8.3[abc]
	SE_D	2.14***	1.21***
Time block 2 (days 1 to 7 of lactation)			
Day	1	1.1	1.6
	2	6.6	4.6
	3	7.3	5.0
	4	8.4	6.5
	5	8.3	7.1
	6	9.9	6.6
	7	10.1	7.5
	SE_D	1.96***	1.58**
Time block 3 (days 8 to 17 of lactation)			
Day	8	9.8	7.8
	9	11.3	6.6
	10	9.9	7.0
	11	9.6	7.3
	12	9.5	8.6
	13	9.9	7.1
	14	8.3	9.0
	15	9.6	8.7
	16	8.4	8.4
	17	8.6	9.9
	SE_D	1.89	1.84

Means in the same column followed by the same superscript differ at $P \leq 0.05$
** = $P<0.01$; *** = $P<0.001$

Table 6.5 Mean number of feeding visits made per day by sows in the L and S pen areas, during time blocks 1, 2 and 3

Non-feeding visits to the feeder occurred during all time blocks in both treatment groups (Table 6.6). During time block 1, the number of non-feeding visits, expressed as a percentage of the total number of visits to the feeder, was higher in the S than in the L pen area. However, in subsequent time blocks more non-feeding visits were made by sows in the L than in the S pen configuration.

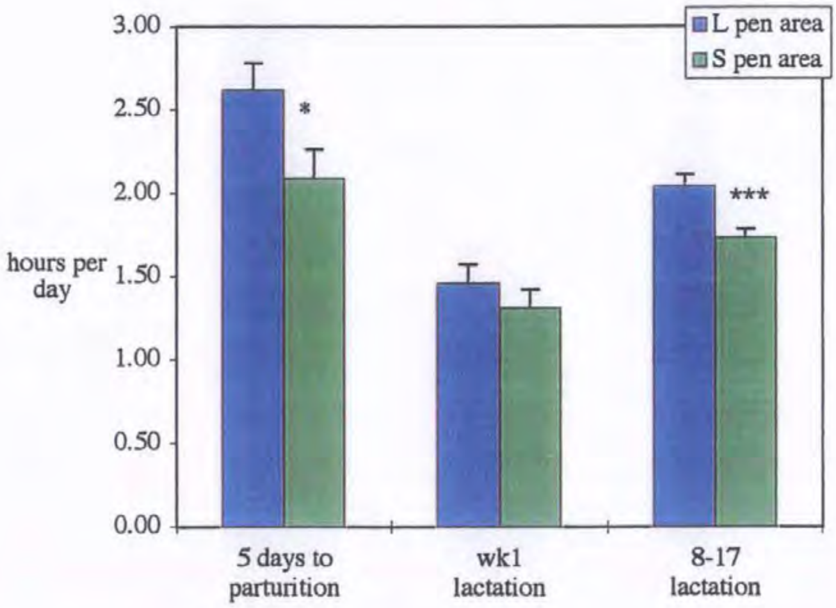
Pen area	*L*	*S*
Time block 1 (-5 to onset of parturition)	2.3	3.7
Time block 2 (days 1 to 7 of lactation)	7.7	1.9
Time block 3 (days 8 to 17 of lactation)	2.1	0.8

Table 6.6 The number of non-feeding visits to the feeder, expressed as the percentage of the total number of feeding visits made in the L and S pen areas, during time blocks 1, 2 and 3

6.3.4 Time allocated to daily feeding activity

Sows in the S pen configuration allocated significantly less time to daily feeding activity compared with sows in the L pen area, (2.6 (s.e. 0.16) vs. 2.0 (s.e. 0.17) hours) during days -5 to -1 before parturition ($P<0.05$) and (2.0 (s.e. 0.07) vs. 1.7 (s.e. 0.05) hours) during days 8 to 17 of lactation ($P<0.001$) (Figure 6.3).

The time allocated to daily feeding activity was significantly different between individual sows in the S pen area ($P<0.01$) during time block 1 (Appendix 6.2). In time block 2, there was significant variation in time spent feeding by individual sows in both the L ($P<0.05$) and S pen areas ($P<0.001$). Although the variation between the time spent feeding by sows in the L pen area during time block 3 was statistically significant ($P<0.001$), it was due entirely to a single outlier. In contrast, there was significantly wider variation in daily time spent feeding by all sows in the S pen area ($P<0.001$), during this time period.



* = P<0.05; *** = P<0.001

Figure 6.3 Mean daily amount of time (hours) spent feeding by sows in the L and S pen areas, during time blocks 1, 2 and 3

Day of lactation influenced the amount of time invested in feeding behaviour in both treatment groups (P<0.001), during time block 2 (Table 6.7). Sows allocated a mean of only 0.19 (s.e. 0.12) and 0.36 (s.e. 0.22) hours to feeding in the L and S pen areas, respectively, on day 1 of lactation. Thereafter, the time invested in feeding increased steadily during early lactation and peaked at 2.0 (s.e. 0.20) hours on day 6 of lactation, in the L pen configuration and at 1.8 (s.e. 0.17) hours by day 8 of lactation in the S pen configuration.

The mean length of visits to the feeder were significantly longer for the S sows than for the L sows (P<0.05), during time block 1 (Table 6.8). However, for subsequent time periods this difference was not apparent. Even so, the amount of food consumed during each feeder visit was significantly greater for the S than for the L sows during each of the three time blocks studied (P<0.001). This suggested that sows in the S pen area were consuming feed at a faster rate than the L sows.

Pen area		*L*	*S*
Time block 1 (day -5 to onset of parturition)			
Day	1	2.32	1.92
	2	2.74	1.90
	3	2.79	2.38
	4	2.61	2.28
	5	2.63	1.84
	SE_D	0.64	0.63
Time block 2 (days 1 to 7 of lactation)			
Day	1	0.19^{abcde}	0.36^{abcd}
	2	1.02	0.88
	3	1.63^{a}	1.37
	4	1.71^{b}	1.63^{a}
	5	1.83^{c}	1.68^{b}
	6	2.02^{d}	1.52^{c}
	7	1.79^{e}	1.71^{d}
	SE_D	0.32***	0.36***
Time block 3 (days 8 to 17 of lactation)			
Day	8	2.06	1.84
	9	2.01	1.60
	10	2.20	1.80
	11	1.91	1.73
	12	1.95	1.89
	13	2.00	1.46
	14	2.08	1.90
	15	1.84	1.76
	16	2.18	1.59
	17	2.09	1.66
	SE_D	0.30	0.19

Means in the same column followed by the same superscript differ at $P \leq 0.05$
*** = $P<0.001$

Table 6.7 Mean amount of time invested per day in feeding activity by sows in the L and S pen areas, during time blocks 1, 2 and 3

Feeding rate was calculated on a daily basis using the equation

Feeding rate (kg/hour) = intake per day(kg)/time feeding per day(hours)

Equation 6.8

The feeding rate of the S sows was significantly greater than that of the L sows, during time block 1 ($P<0.001$) and time block 2 ($P<0.01$).

Pen area	*L*	*S*	SE_D
Time block 1 (day -5 to onset of parturition)			
Intake per visit	0.87	1.39	1.22***
Length of visit	0.32	0.38	0.38*
Feeding rate	2.65	3.53	0.95***
Time block 2 (days 1 to 7 of lactation)			
Intake per visit	0.77	1.22	1.10***
Length of visit	0.20	0.22	0.22
Feeding rate	4.23	5.25	1.67**
Time block 3 (days 8 to 17 of lactation)			
Intake per visit	0.94	1.16	1.10***
Length of visit	0.21	0.22	0.22
Feeding rate	4.63	4.84	1.63

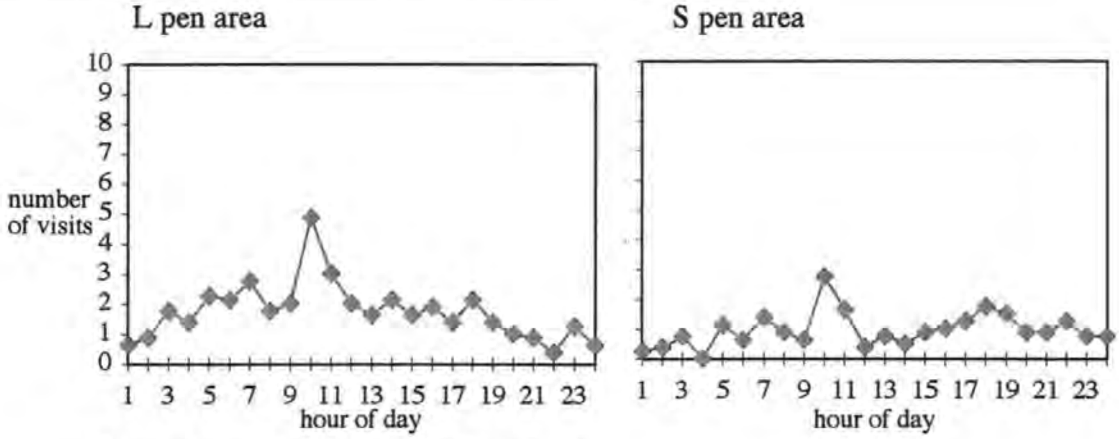
* = P<0.05; ** = P<0.01; *** = P<0.001

Table 6.8 Mean feed intake per visit (kg), mean length of feeder visits (hours) and mean daily feeding rate (kg per hour) for sows in the L and S pen areas, during time blocks 1, 2 and 3

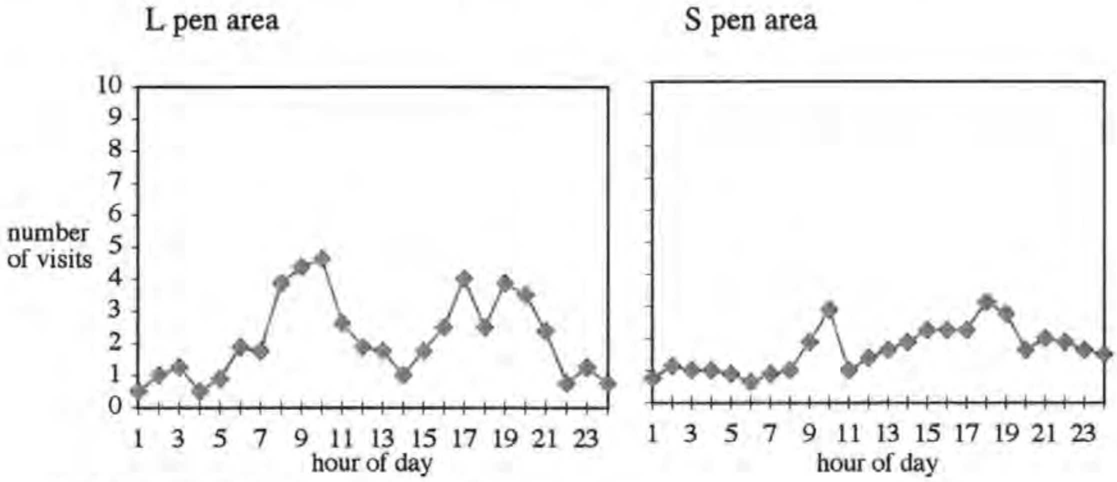
6.3.5 Diurnal feed intake patterns

As the time of day of visits to the feeder were known, it was possible to determine diurnal feeding patterns of sows in each treatment group, during the three time blocks studied (Figure 6.4).

a) Time block 1 (day -5 to onset of parturition)



b) Time block 2 (days 1 to 7 of lactation)



c) Time block 3 (days 8 to 17 of lactation)

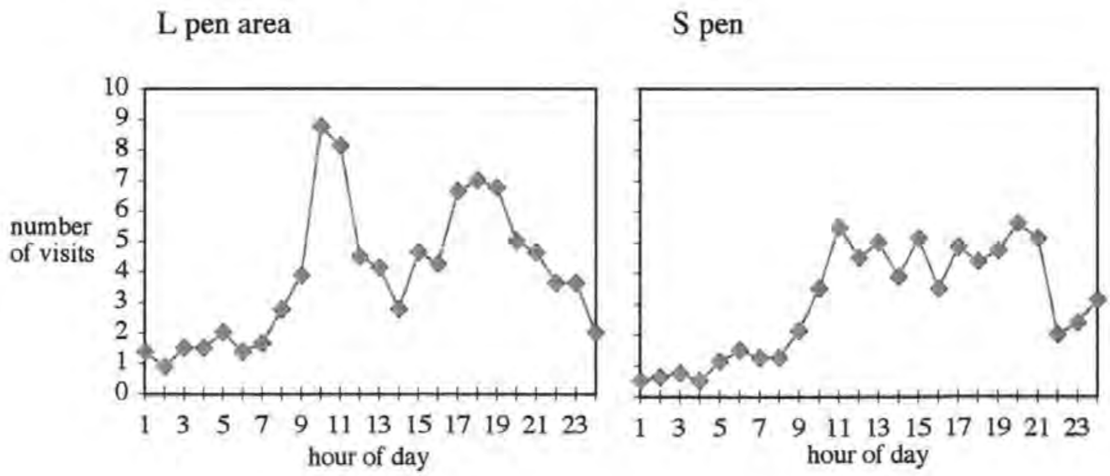


Figure 6.4 Time of day of feeding visits made by sows in the L and S pen configurations during time blocks 1, 2 and 3

Time block 1

Feeding occurred throughout the 24 hour period, however, a single peak of feeding activity occurred at 10.00 hours. The peak, which coincided with morning cleaning routines, was more prominent in the L compared with the S pen area (P<0.001). The pattern in the L pen configuration was statistically significant (P<0.001), with the mean vector positioned at 9.24 hours, demonstrating that the data was not uniformly distributed throughout the 24 hours.

Time block 2

A more clearly defined feeding pattern with two main peaks of activity, began to develop during early lactation, although this was again, more marked in the L pen configuration. In this treatment group, the morning activity peak was of longer duration, lasting from 06.00 to 13.00 hours, compared with 09.00 to 11.00 hours in the S sows. The second peak of feeding activity which emerged in the afternoon and evening, was of lower amplitude in the S sows, reflecting the reduced number of feeding visits made by these sows and lasted from 15.00 until 21.00 hours in both treatment groups. An interval of reduced activity followed, which lasted from 22.00 until 05.00 hours and 22.00 until 08.00 hours in the L and S sows, respectively. These differences between treatments were statistically significant (P<0.001). The two main periods of feeding represented 81% (L) and 54% (S) of total daily feeding activity during this time block. Statistical analysis indicated that the data were not in a uniform circular distribution, but showed evidence of concentration for both the L (P<0.001) and the S (P<0.001) sows.

Time block 3

Later in lactation two distinct peaks of activity occurred in the L sows (P<0.001). The first and highest, began at 09.00 hours, corresponding to the morning cleaning time, and continued until 13.00 hours. This was followed by a short decline in activity, before the onset of the second, longer lasting peak, from 15.00 to 23.00 hours. In contrast, the feeding activity of the S sows was contained within one long peak period, which began as morning cleaning routines commenced at 09.00 and continued throughout the day and into late evening, finishing at 22.00 hours (P<0.001). The differences in the feeding patterns between treatment groups were of statistical significance (P<0.05). From this point, feeding activity in both the L and S sows continued at a low level until 09.00 hours. These main periods of feeding activity accounted for 77% and 88% of total daily feeding activity in the L and the S sows, respectively.

6.3.6 Factors influencing individual feed intakes and feeding strategies

These results demonstrate that feed intakes and feeding strategies were influenced by day of gestation and lactation and that feeding strategies were affected by space allocation. However it was possible to identify a number of other measurable physical, environmental, management and production factors which may have influenced individual sow feed intakes and feeding strategies (Figure 6.5).

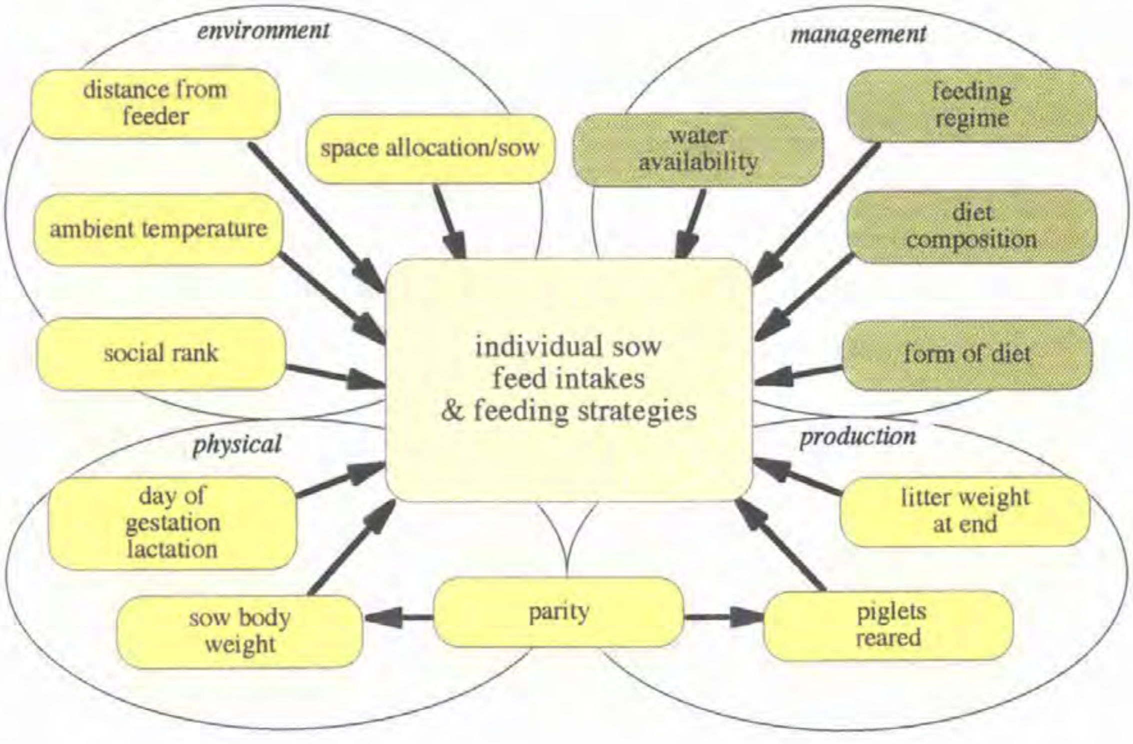


Figure 6.5 Schematic illustration of the factors which may influence individual feed intakes and feeding strategies of group housed sows, fed *ad libitum*, during time blocks 1, 2 and 3

The influence of space allocation, day of lactation, sow parity, sow weight, the number of piglets reared, the final litter weight, distance from the feeder, social rank and ambient temperature on

* individual sow feed intakes

* the daily number of feeding visits made by individual sows

* the total time spent feeding per day by each individual sow

during time blocks 1, 2 and 3 was examined by multiple regression analysis. The factors within the shaded boxes were constants in the studies so were not included in the data analysis.

6.3.7 Factors influencing daily feed intakes, the daily number of feeding visits and the time invested in feeding activity

The percentage contributions made by factors exerting a significant influence on the variation in feed intakes, the number of visits made daily to the feeder and the time spent feeding by sows, during each of the three time blocks, are presented in Table 6.9.

The factors which exerted a significant influence upon the variation in sow feed intakes during time block 2 ($P<0.001$) were day of lactation, the ambient temperature and space allowance (Appendix 6.3). In time block 3, the most significant factors affecting sow feed intakes were the ambient temperature, space allocation, the number of piglets reared, sow weight and parity ($P<0.001$).

The factors which exerted a significant influence upon the variation in the number of visits to the feeder, during time block 1 were day of gestation, space allowance and sow weight

(P<0.001). During time block 2, the factors exerting a significant effect upon the variation in the daily number of visits made to the feeder were day of lactation and ambient temperature (P<0.001). No further influence of the factors tested upon the number of feeding visits was demonstrated.

During time block 1, the distance from the feeder and the ambient temperature had a significant effect on the variation in time spent feeding (P<0.001). The factors which had a significant influence upon the amount of time allocated daily to feeding activity, during time block 2 were day of lactation, ambient temperature, sow parity and social rank (P<0.001). In the later stages of lactation, ambient temperature, the distance from the feeder, social rank and the number of piglets reared exerted a significant influence (P<0.001) upon the time spent feeding.

		Contribution %								
	Activity	*D*	*P*	*SR*	*W*	*L*	*LW*	*DF*	*T*	*S*
Time block 1	Feed intake	-	-	-	-	-	-	-	-	-
	Number of visits	+19.03	-	-	-6.58	-	-	-	-	+17.37
	Time feeding	-	-	-	-	-	-	+12.74	-9.81	-
Time block 2	Feed intake	+32.34	-	-	-	-	-	-	-3.71	-7.70
	Number of visits	+26.58	-	-	-	-	-	-	-7.11	-
	Time feeding	+30.89	+4.24	+5.09	-	-	-	-	-9.88	-
Time block 3	Feed intake	-	-6.62	-	+4.74	+5.24	-	-	-15.14	-5.59
	Number of visits	-	-	-	-	-	-	-	-	-
	Time feeding	-	-	+9.16	-	+4.13	-	+11.46	-11.45	-

Key: D = Day of lactation; P = Sow parity; SR = Social rank; W = Sow weight; L = Litter size; LW = Litter weight; DF = Distance from feeder; T = Ambient temperature; S = Space allocation

Table 6.9 Percentage contributions as indicated by R-sq values from multiple regression analyses, made by the most influential factors affecting the variation in daily feed intakes, the number of visits made daily to the feeder and the time allocated to feeding per day by group housed sows during time blocks 1, 2 and 3

6.4 DISCUSSION

6.4.1 Feed intakes

The feed intake of the modern, highly prolific, lactating sow is often insufficient to meet the nutrient requirements for maintenance and milk yield (Cole 1982; Lynch 1989; Mullan *et al.* 1990). The energy deficit is met by mobilisation of maternal fat and protein reserves, resulting in body weight loss of around 10kg over a 25 day lactation (Close 1992). The average feed intakes of sows during lactation reported in the literature are presented in Table 6.10. Few of these studies reported feed intakes for sows fed on a true *ad libitum* basis, defined as 'where the animal has continuous access to a supply of fresh food and water' (Cole 1984).

In contrast to these reports, mean daily feed intakes of 7.69 (s.e. 0.31) kg and 7.72 (s.e. 0.35) kg were achieved by sows in the L and S treatment groups, respectively, during lactation. There was a depression in lactation feed intakes of the sows housed at the higher mean ambient temperature of 17.5^{0}C (see Section 3.3.4), compared with the other groups. Interestingly this temperature is considerably lower than that found on most commercial production units where ambient temperatures of 17 - 39^{0}C (Black *et al.* 1993); 19.3 to 28.8^{0}C (Koketsu *et al.* 1996c); 22 - 27^{0}C (Lynch 1977); 20 - 24^{0}C (le Dividich, Noblet, Herpin, van Milgen and Quinou 1997); 18 - 25^{0}C (Dourmad 1993) have been reported.

The day of lactation had a strong influence on sow feed intake during the week following farrowing. In accordance with findings of Neil (1996), there was a sharp decline in food consumption at farrowing. Nevertheless, when *ad libitum* feeding was introduced at or shortly after farrowing this reduction in feed intake did not occur (Stahly *et al.* 1976; Genest and D'Allaire 1995; Neil 1996; Neil *et al.* 1996).

Daily feed intake(kg)	*Diet form*	*Feeding regime*	*Reference*
7.02	dry pellets	*ad libitum*	(Neil *et al.* 1996)
5.86	"	twice daily increasing scale	"
5.2	not clear	not clear	(Koketsu, Dial, Pettigrew, Marsh and King 1996b)
6.19	dry mash	at least twice daily to appetite	(Handley 1995)
4.73†	dry pellets	four times daily to appetite	(Dourmad 1991)
4.53	feed/water mix	not clear	(Pettigrew *et al.* 1984)
4.04	dry	not clear	"
4.72	dry	*ad libitum*	(O'Grady and Lynch 1978)
5.27	wet	twice daily	"
5.8	corn based + sugar beet	*ad libitum*	(Stahly *et al.* 1976)
5.2	"	increasing scale	"

† = gilts

Table 6.10 Summary of data from various studies on the feed intakes of sows during lactation

The results of these studies suggest that a better strategy for increasing lactation feed intakes would be to restrict feeding until parturition onset and thereafter introduce *ad libitum* feeding. However, sows would have to be familiarised with the feeding system before farrowing in order to prevent feed intake depression through problems in accessing the nutrient supply.

After farrowing, daily feed intakes rose gradually, peaking on days 10 and 6 for the L and S sows, respectively. Thereafter, the day of lactation ceased to influence feed intakes, perhaps as litter sizes stabilised and sow milk yields were reaching a peak (Dourmad 1988).

A comparison of actual energy intakes of individual sows with predicted values, which allowed for the effect of ambient temperature and litter size, revealed a certain amount of individual variation. The majority of sows (68.8%) consumed energy well in excess of their predicted requirements, whilst 18.7% of sows had intakes within ±3.4MJ DE of predictions. Only 12.5% of sows had intakes which produced an energy deficit in lactation.

Part of the extra energy intake could be that required for the increased activity of sows in a non-confinement farrowing system. Noblet, Shi and Dubois (1993) calculated that the energy cost of standing activity was 0.26kJ/minute/kg$W^{0.75}$ for sows housed in metabolism crates and concluded that the activity level of sows should be considered in the determination of their energy requirements. This is an important consideration, not only for alternative systems to the confinement of the farrowing crate, but also for outdoor production systems, which allow more freedom of movement for lactating sows.

Any feed intake above that which accounts for the total energy requirements discussed might be to produce a sensation of gut fill or satiety in the sow. Sows in late pregnancy, fed diets containing a range of fibrous raw materials *ad libitum* consumed up to 7.7kg per day (Brouns, Edwards and English 1991). Gestating sows fed *ad libitum* on a diet containing sugar beet pulp consumed over 8kg per day (Hodgkiss, unpublished data). If satiety is the aim, this level of intake might be expected to increase once the pressure from the contents of a gravid uterus on the gut had been relieved following parturition.

6.4.2 Feeding strategy

During each of the three time blocks, sows obtained their food from 8.3, 7.4, 9.5 and 5.5, 5.6, 7.9 feeding visits, for the L and S treatment groups, respectively. The results for the L sows, during time blocks 2 and 3, are similar to those of Dourmad (1993) who reported that *ad libitum* fed, tethered sows took 7.3 and 9.4 meals per day in week 1 and weeks 2 to 3 of lactation, respectively. Sows in the smaller pen configuration made significantly fewer visits to the feeder than sows in the larger space allowance. In addition, the mean number of hours allocated to daily feeding activity was significantly lower for the S sows than the L sows prior to parturition and also during the final period of lactation. During each feeding visit, more feed was consumed by the S sows, compared with the L sows, achieved by an increase in feeding rate, resulting in similar overall daily feed intakes in both treatment groups. This strategy is similar to that noted by Nielsen (1995) who found that growing pigs in groups of 20, reduced the number of feeding visits and the time spent feeding, so increased the rate of feeding, compared with smaller groups in identical pen size and layout. As a result, feed intakes in both group sizes were similar. The results of the current study indicate that in order to maintain feed intakes, sows in the reduced pen configuration adapted their feeding behaviour by reducing their movements around the system. This suggestion is further supported by the fact that the S sows made fewer non-feeding visits than the L sows during lactation. The spread of daily feed intakes over a number of small meals may assist sows to achieve higher total daily intakes spreading the thermal loading from digestion and creating a more even use of energy throughout the day (Genest and D'Allaire 1995).

6.4.3 Diurnal feeding pattern

The diurnal pattern of feeding activity differed between treatment groups in that the formation was more clearly defined for the L sows than for those in the S pen area. As lactation progressed, two distinct peaks of feeding activity occurred from 09.00 to 13.00 hours and from 15.00 to 23.00 hours for the L sows, accounting for between 77% and 81% of total daily feeding activity. In confined lactating sows (de Passillé and Robert 1989; Dourmad 1993) and in growing pigs (Montgomery, Flux and Carr 1978; Schouten 1986; de Haer and Merks 1992; Nielsen 1995) feeding activity was also found to occur mainly during the daytime with similar morning and afternoon peaks. The feeding activity of sows in the S pen area also commenced at 09.00 hours but continued until 22.00 hours, with no evidence of the peaks of activity seen in the L sows. The way in which feeding activity was widely spread over time is further evidence of alterations to feeding strategies by sows which may have minimised the occurrence of potentially aggressive encounters in the smaller pen configuration.

The start of the main period of feeding in both the L and S sows may have been influenced by daily cleaning and inspection routines, a point noted by other authors (de Haer and Merks 1992; Dourmad 1993; Nielsen 1995).

During lactation energy needs of the sow vary according to sow maintenance requirements, the milk yield necessary to support growth of the suckling piglets and housing conditions and frequently cannot be met by voluntary food intake. The majority of sows in this study sustained feed intakes in excess of predicted energy requirements during lactation. This was accomplished by sows adopting individual feeding strategies involving taking small amounts of food in a series of small meals throughout the day. Sows in the smaller pen configuration adapted their feeding strategy and maintained similar feed intakes to sows in the larger pen area. The effect of changes in ambient temperature, even at comparatively low levels, on the voluntary feed intake of sows was clearly shown. These results demonstrate that *ad libitum* feeding in conjunction with low ambient temperatures, provides the necessary flexibility to allow optimum feed intakes to be achieved by group housed sows in a communal farrowing system.

7. WATER INTAKES AND DRINKING STRATEGIES

7.1 INTRODUCTION

Water intake is essential for the maintenance of feed intake and milk production in lactation. Insufficient water intake may affect the health and productivity of the sow. Reduced water consumption results in increased faecal dry matter and constipation which may predispose sows to mastitis, metritis, agalactia syndrome (Klopfenstein *et al.* 1995). Reduced piglet weight gains and increased piglet mortality have been associated with low water intake by sows (Fraser and Phillips 1989).

Water requirements vary according to physiological and environmental factors including stage of gestation or lactation (Friend 1969; Gill 1989; Fraser *et al.* 1990), ambient temperature (Fraser *et al.* 1990; Brooks *et al.* 1992) and water availability (Barber *et al.* 1989). As pigs were reported to allocate a limited amount of time to drinking behaviour each day (Barber *et al.* 1989; Blackshaw *et al.* 1994), any failings in drinker operation or water flow rate might be expected to reduce consumption (Barber, Brooks and Carpenter 1988; Fraser and Phillips 1989).

There is little information about the daily water use and drinking behaviour of the lactating sow. That which is available, is confined to water intakes and drinking behaviour of individually housed sows in farrowing crates (Fraser and Phillips 1989; Gill 1989; Blackshaw *et al.* 1994; Klopfenstein *et al.* 1995).

The objective of this part of the study was to describe the drinking behaviour of group housed sows in a novel farrowing system, which provided two different space allowances, over parturition and during lactation.

7.2 METHOD

The drinking behaviour of four groups of four sows allocated to one of two space allowances in a free access farrowing system, was observed from 5 days before parturition until day 17 of lactation. Pen layouts, observation procedures and statistical analyses were as described in Chapter 2.

7.2.1 Water supply

Water for the sows was supplied via a bite drinker (Arato 80, Bernard Partridge, Clacton-on-Sea, UK) at a delivery rate of 1.5 litres per minute (Brooks 1992). The daily water use by each group of sows was recorded by a turbine flow water meter (PSM-L, Kent Meters, Luton, Bedfordshire, UK). The drinker was checked daily to ensure that it was in working order and that water was freely available. The water flow rate and the accuracy of the water meter were checked every third day during the study by timing the delivery of 1 litre of water, collected in a measuring jug. This procedure was carried out ten times on each occasion.

7.2.2 Behavioural definitions

Definitions of drinking activity terminology discussed in this section were as follows:

* *visit to the drinker*

  This was defined as beginning when the sow stood at the water point and made contact with the drinker by mouth. The bout was considered to be terminated when the sow walked away from the water point.

* *distance from the water*

  This was the distance measured from the centre of the front entrance of each farrowing enclosure to the water point in each pen configuration.

7.3 RESULTS

7.3.1 Water intakes

It was expected that the time spent drinking could be used in conjunction with the water flow rate to calculate the daily water intakes of sows. In practice, water intake took place intermittently during each visit to the drinking station. Thus, calculations of water intakes, based on time spent drinking as defined in this study, were unreliable. Regrettably therefore, water intakes of individual sows could not be reported. It was possible to calculate the mean daily water use by sows in the L and S pen areas over the study period from the water meter readings (Figure 7.1). Water use was similar in both treatment groups and mean intakes ranged from 11.69 litres on day 1 and 11.65 litres on day 2 to 30.88 litres on day 20 and 36.25 litres on day 17 in the L and S pen areas, respectively.

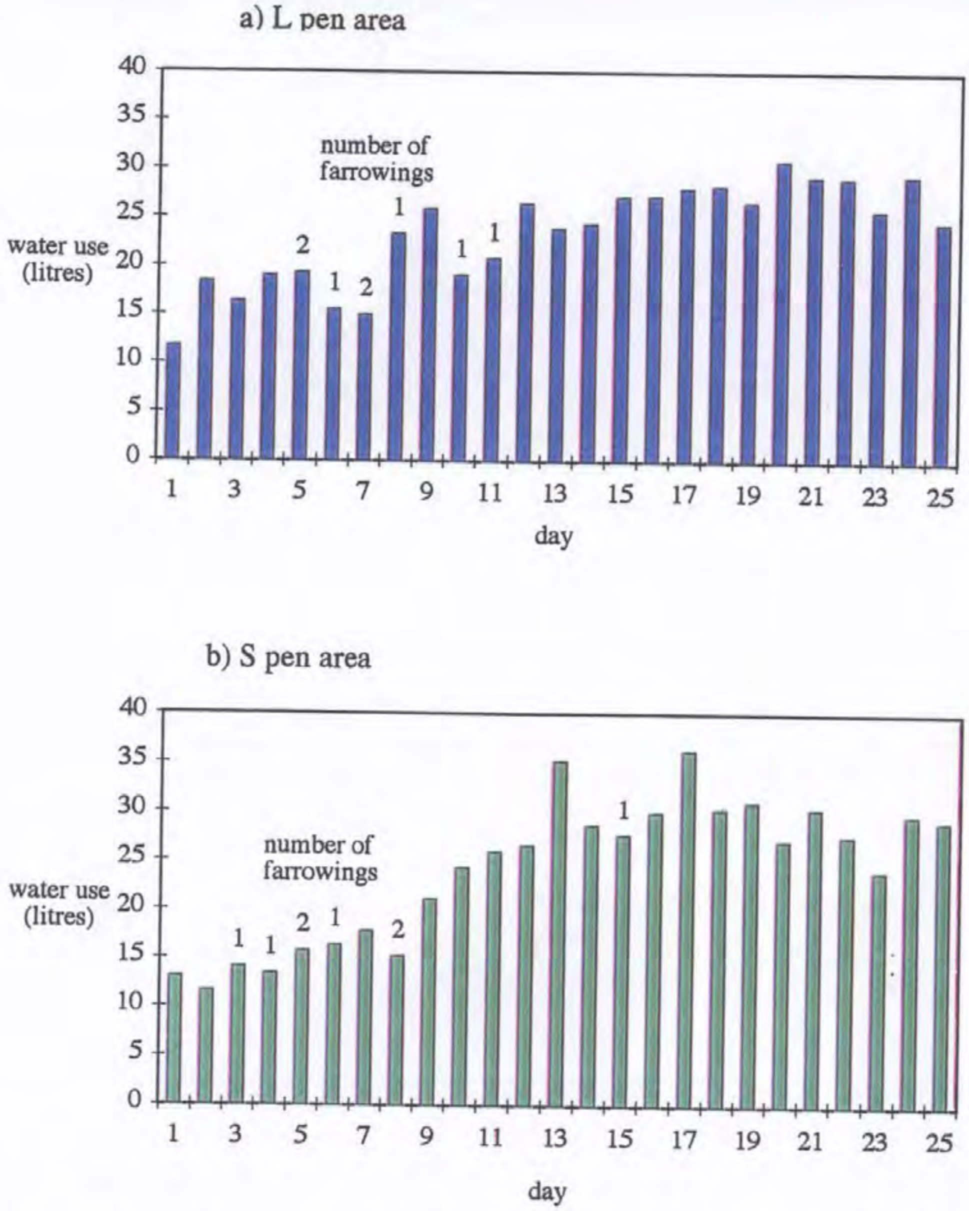
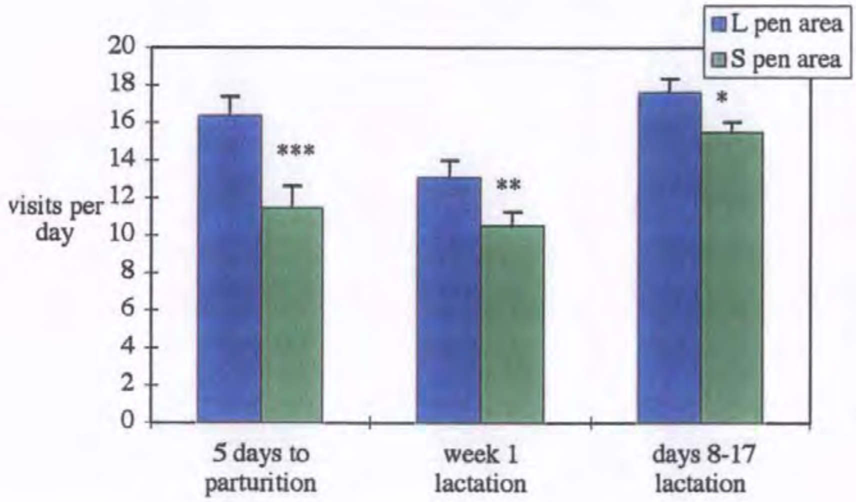


Figure 7.1 Mean daily water use by group housed sows fed *ad libitum* over parturition and during lactation in the L and S pen configurations

7.3.2 Drinking strategies

All sows obtained their daily water intake during a series of visits to the drinker. Sows in the S pen configuration made significantly fewer drinking visits per day than those in the L pen area during all three time blocks studied (Figure 7.2). The pattern of drinking frequency per day over parturition and during lactation was similar in both treatment groups (Table 7.1). Following a gradual increase over the first 4 days after introduction to the novel farrowing system, there was a sharp increase in the number of drinking visits on the day immediately before farrowing ($P<0.001$). A marked reduction on the first day of lactation ($P<0.001$) was followed by a gradual but insignificant rise in the frequency of visits to the drinker over the remainder of lactation. The mean number of visits made daily to the drinker, excluding the day before farrowing and the first day of lactation, ranged from 13 (s.e. 2.84) to 22 (s.e. 2.11) and from 7 (s.e. 1.74) to 19 (s.e. 2.15) in the L and S pen areas, respectively.



* = P<0.05; ** = P<0.01; *** = P<0.001

Figure 7.2 Mean daily number of drinking visits ± s.e. in the L and S pen areas during time blocks 1, 2 and 3.

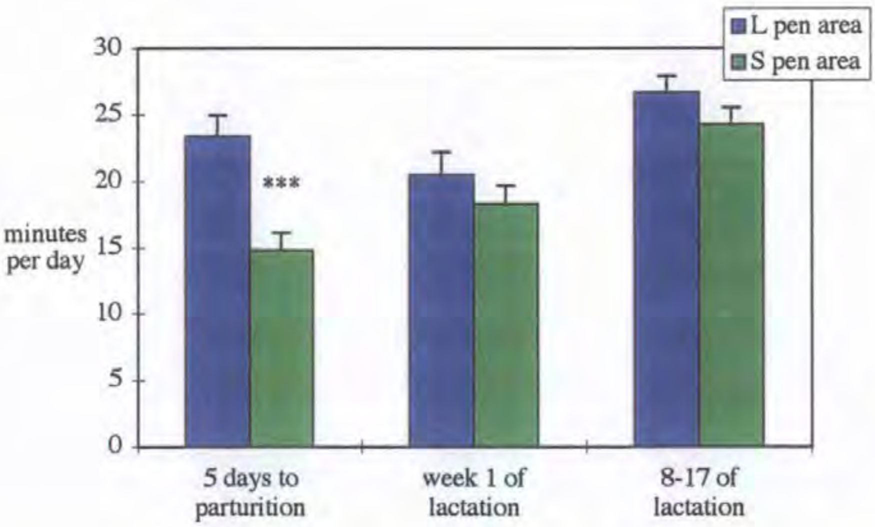
The daily number of visits to the drinker by individual sows was similar during time blocks 1 and 2 in both pen configurations (Appendix 7.1). During time block 3 the mean daily number of visits to the drinker made by individual sows in both the L and S pen areas became significantly different (P<0.001). However, the difference was due to one and two outliers in each case, which made more drinking visits than other sows in the treatment group.

Pen area		*L*	*S*
Time block 1 (day -5 to onset of parturition)			
Day	1	13[a]	7[a]
	2	14[b]	7[b]
	3	14[c]	9[c]
	4	16[d]	12[d]
	5	25[abcd]	20[abcd]
	SE_D	19.3***	19.1***
Time block 2 (days 1 to 7 of lactation)			
Day	1	3[abcdef]	2[abcdef]
	2	13[a]	9[a]
	3	15[b]	12[b]
	4	15[c]	13[c]
	5	15[d]	13[d]
	6	14[e]	13[e]
	7	17[f]	14[f]
	SE_D	19.3***	14.7***
Time block 3 (days 8 to 17 of lactation)			
Day	8	15	14
	9	18	13
	10	17	13
	11	17	16
	12	16	14
	13	17	16
	14	19	17
	15	22	19
	16	20	17
	17	16	18
	SE_D	24.2	17.3

Means in the same column followed by the same superscripts differ at $P \leq 0.05$
*** = $P<0.001$

Table 7.1 Mean frequency of visits to the drinker per day in the L and S pen areas during time blocks 1, 2 and 3

Sows in the S pen configuration spent significantly more time drinking (P<0.001) than sows in the L pen area (23.4 (s.e. 1.6) vs. (14.8 (s.e. 1.31) minutes), during time block 1 (Figure 7.3). No further differences between pen areas were demonstrated during subsequent time blocks. The mean daily time allocated to drinking activity, excluding the day before parturition and day 1 of lactation, ranged from 18 minutes (s.e. 3.31) to 31.31 minutes (s.e. 6.72) and from 10 minutes (s.e. 2.32) to 33.45 minutes (s.e. 9.23) in the L and S pen areas, respectively.



*** = P<0.001

Figure 7.3 Mean amount of time (minutes) ± s.e. allocated daily to drinking activity in the L and S pen areas during time blocks 1, 2 and 3

The time allocated by sows to drinking behaviour increased gradually during the five days before parturition in both the L and S pen areas (Table 7.2). The difference between days was statistically significant in the S pen area (P<0.01). The reduction in the number of drinking visits made by sows on day 1 of lactation was reflected in the sharp fall in the time invested in drinking by sows in L (P<0.01) and S (P<0.001) treatment groups at this time. The time spent drinking per day rose from 4.46 (s.e. 2.09) and 2.29 (s.e. 1.44) minutes on day 1 to 27.70 (s.e. 5.97) and 22.08 (s.e. 3.51) minutes on day 3 of lactation in the L and S pen areas, respectively. Thereafter time spent drinking remained at a relatively constant level.

No further differences in time allocated to drinking activity per day could be demonstrated in time block 3.

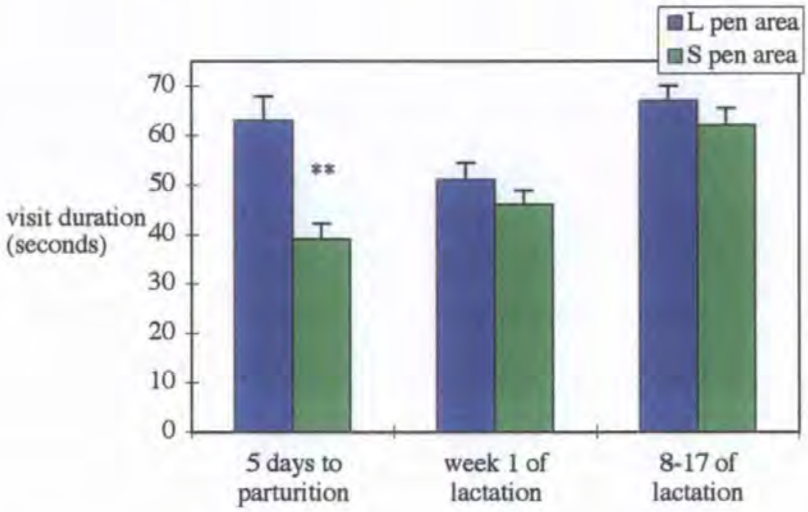
Pen area		*L*	*S*
Time block 1 (day -5 to onset of parturition)			
Day	1	18.06	11.53[a]
	2	21.57	10.14[b]
	3	20.67	12.04[c]
	4	28.35	15.73
	5	28.40	23.16[abc]
	SE_D	6.07	4.23**
Time block 2 (days 1 to 7 of lactation)			
Day	1	4.46[abc]	2.29[abcdef]
	2	19.69	14.86[a]
	3	27.70[a]	22.08[b]
	4	26.19[b]	19.43[c]
	5	19.43	22.23[d]
	6	24.61[c]	23.08[e]
	7	21.16	23.78[f]
	SE_D	5.86**	4.16***
Time block 3 (days 8 to 17 of lactation)			
Day	8	21.18	23.32
	9	25.50	25.58
	10	24.60	23.52
	11	25.86	33.45
	12	31.31	19.96
	13	26.90	21.89
	14	30.18	25.74
	15	29.17	23.30
	16	28.36	27.05
	17	23.82	18.92
	SE_D	4.90	4.88

Means in the same column followed by the same superscript differ at $P \leq 0.05$
** = $P<0.01$; *** = $P<0.001$

Table 7.2 Mean time (minutes) invested in drinking activity per day by sows in the L and S pen configurations during time blocks 1, 2 and 3

Individual sows in each treatment group spent similar amounts of time drinking during time block 1 (Appendix 7.2). During time block 2, differences between sows were statistically significant in the L ($P<0.05$) and the S ($P<0.01$) pen areas, due in each case to a single outlier. There was wide variation in the way in which individuals allocated time to drinking activity in the L pen area during time block 3 ($P<0.001$).

The duration of each visit to the drinker was significantly shorter for sows in the S than in the L pen area ($P<0.01$) from day -5 to parturition onset (Figure 7.4). This was reflected in the reduced amount of time these sows allocated daily to drinking activity compared with the L sows. No further differences between treatment groups was demonstrated during subsequent time blocks.



** = $P<0.01$

Figure 7.4 Mean duration of drinking visits (seconds) ± s.e. in the L and S pen areas during time blocks 1, 2 and 3

There was a gradual increase in the length of drinking visits during the 5 days before farrowing in both pen configurations (Table 7.3). The difference between days was statistically significant in the S pen area ($P<0.05$). Day of lactation had a significant effect on

Pen area		*L*	*S*
Time block 1 (day -5 to onset of parturition)			
Day	1	55	34
	2	54	28[a]
	3	52	33[b]
	4	71	39
	5	84	58[ab]
	SE_D	96	57*
Time block 2 (days 1 to 7 of lactation)			
Day	1	11[abcd]	6[abcdef]
	2	49	37[a]
	3	69[a]	55[b]
	4	66[b]	49[c]
	5	49	56[d]
	6	62[c]	58[e]
	7	53[d]	59[f]
	SE_D	68***	55***
Time block 3 (days 8 to 17 of lactation)			
Day	1	53	58
	2	64	64
	3	62	59
	4	65	84
	5	78	50
	6	67	62
	7	75	64
	8	73	60
	9	71	68
	10	66	55
	SE_D	59	66

Means in the same column followed by the same superscript differ at $P \leq 0.05$
* = $P<0.05$; *** = $P<0.001$

Table 7.3 Mean duration (seconds) of drinking visits made per day by sows in the L and S pen areas during time blocks 1, 2 and 3 the duration of drinking visits in both treatment groups (P<0.001) during time block 2, due to a mean visit length of only 11 (s.e. 3.85) and 6 (s.e. 2.18) seconds on day 1 of lactation, after which visit duration rose to 69 (s.e. 11.9) and 55 (s.e. 8.28) seconds on day 3 of lactation in the L and S pen areas, respectively. Thereafter, the length of visits to the drinker gradually stabilised over the remainder of the first week of lactation. There was no further effect of day of lactation on the length of drinking visits, in either treatment group, during time block 3.

There was a significant difference in the mean duration of visits to the drinker by individual sows in the L pen area (P<0.01), during time block 1 and in both the L (P<0.01) and S (P<0.001) pen configurations during time block 2 (Appendix 7.3). This was due in each case to a single outlier which had considerably longer visits to the drinker than other sows in the group. The difference between sows became more widely distributed in the L pen area (P<0.001), whereas there was no significant difference in the length of drinking visits made by individual sows in the S pen area, during time block 3.

7.3.3 Diurnal water intake patterns

Since the time of day of visits to the drinker were known, it was possible to determine diurnal water intake patterns for each treatment group of sows, during each of the three time blocks studied (Figure 7.5).

Time block 1

During the 5 days from introduction to the novel farrowing system until onset of parturition the number of daily drinking visits began to increase from 06.00 hours and peaked at 09.00 hours, coinciding with morning cleaning routines, in both the L and S pen areas. A second increase in the number of visits to the drinker occurred between 16.00 and 18.00 hours in the L and at 17.00 hours in the S pen areas, coinciding with afternoon inspection times.

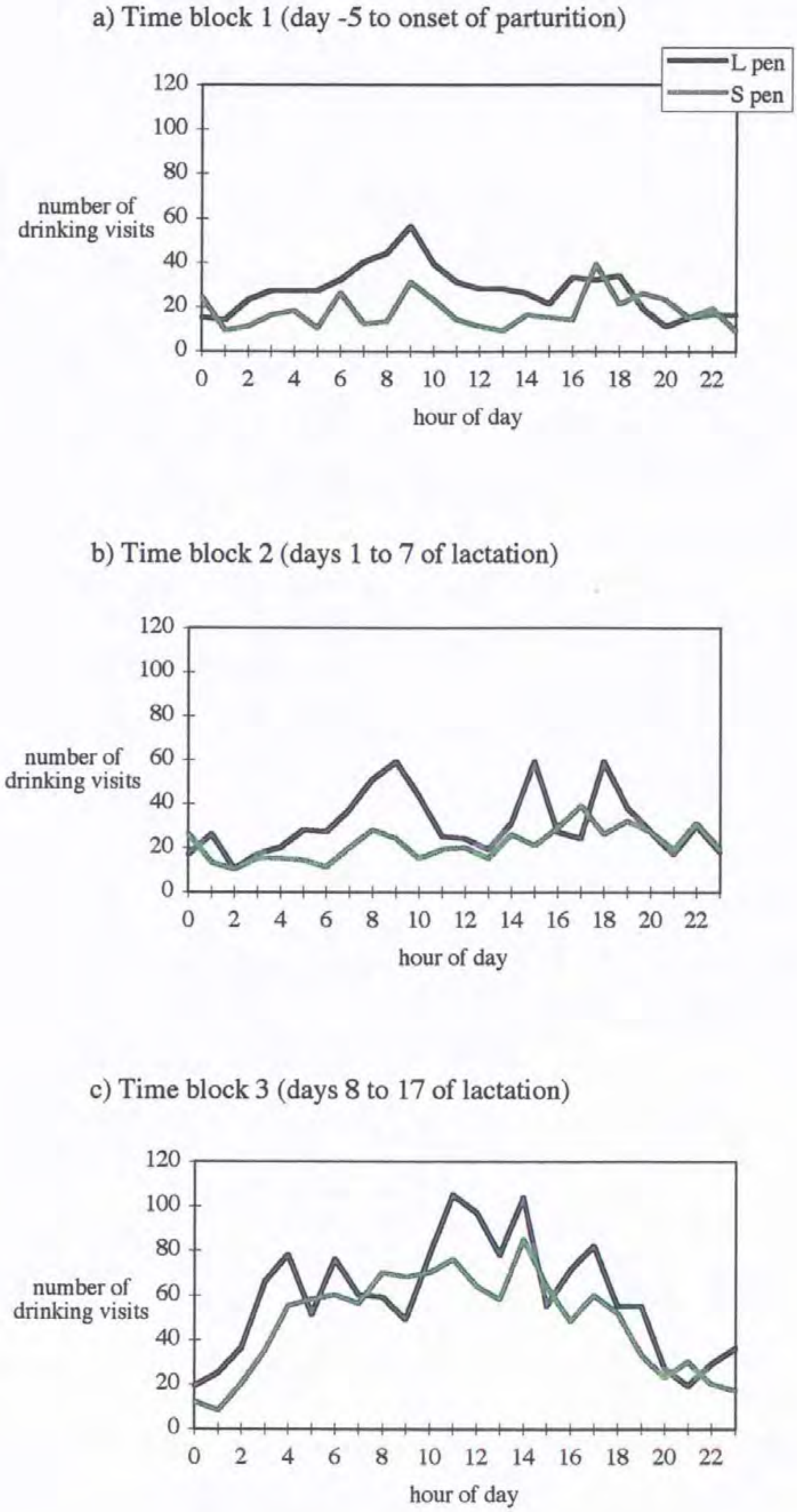


Figure 7.5 The time of day of visits to the drinker made by sows in the L and S pen areas during time blocks 1, 2 and 3

for 52% and 42% of total drinking time in the L and S pen areas, respectively. The mean vector (μ) in the L pen area was at 09.39 hours, indicating that data were not uniformly distributed around the circle (P<0.001) in this treatment group.

Time block 2

During the first week of lactation, the morning activity peak between 06.00 and 11.00 hours remained in the L pen area, but was less clearly defined and occurred between 07.00 and 10.00 hours in the S pen area. Two quite distinct afternoon peaks, equal in amplitude to the morning peak, developed from 14.00 to 16.00 hours and from 17.00 to 19.00 hours in the L pen area, whereas a single peak between 16.00 and 18.00 hours was the most marked feature in the S pen area. These main periods of drinking activity accounted for 65% and 35% of total daily drinking activity in the L and S pen areas, respectively. These differences between treatment groups were statistically significant (P<0.001). Nevertheless, there was evidence of concentration of data in both the L (P<0.001) and the S (P<0.001) pen areas, with mean vectors at 12.30 and 17.18 hours in the L and S pen configurations, respectively.

Time block 3

As lactation progressed and the frequency of visits to the drinker increased, the daily drinking activity pattern became more disorganised in both treatment groups. Drinking visits were contained within one long peak period which lasted from 03.00 until 19.00 hours in the L pen area (P<0.001) and from 04.00 until 18.00 hours in the S pen area (P<0.001). The mean vectors occurred at 11.23 hours in the L and 11.08 hours in the S pen areas. Slightly elevated levels of drinking activity which were more prominent in the L pen area and superimposed on this protracted peak drinking period, occurred at 11.00, 14.00 and 17.00 hours in both pen configurations. During this long peak 86% and 83% of total daily drinking activity took place in the L and S pen configurations, respectively, whilst a period of reduced drinking activity occurred in both pen areas between the hours of 20.00 and 03.00 hours.

7.3.4 Factors affecting drinking strategies

These results have demonstrated that pen size and day pre or post farrowing influenced both daily time spent drinking and the number of visits made daily to the drinker by group housed sows, over parturition and during lactation. In addition, a number of other physical, environmental, management and production factors may have influenced individual sow drinking strategies (Figure 7.6).

The influence of space allocation, distance of the chosen farrowing enclosure from the drinker, ambient temperature, day of gestation or lactation, social rank, parity, sow feed intake, litter weight and the number of piglets reared on

* the number of visits made to the drinker
* the time spent drinking
* the duration of visits to the drinker

during time blocks 1, 2 and 3, was determined by multiple regression analysis. The factors with shaded boxes were constants in the studies, so were not included in the analysis.

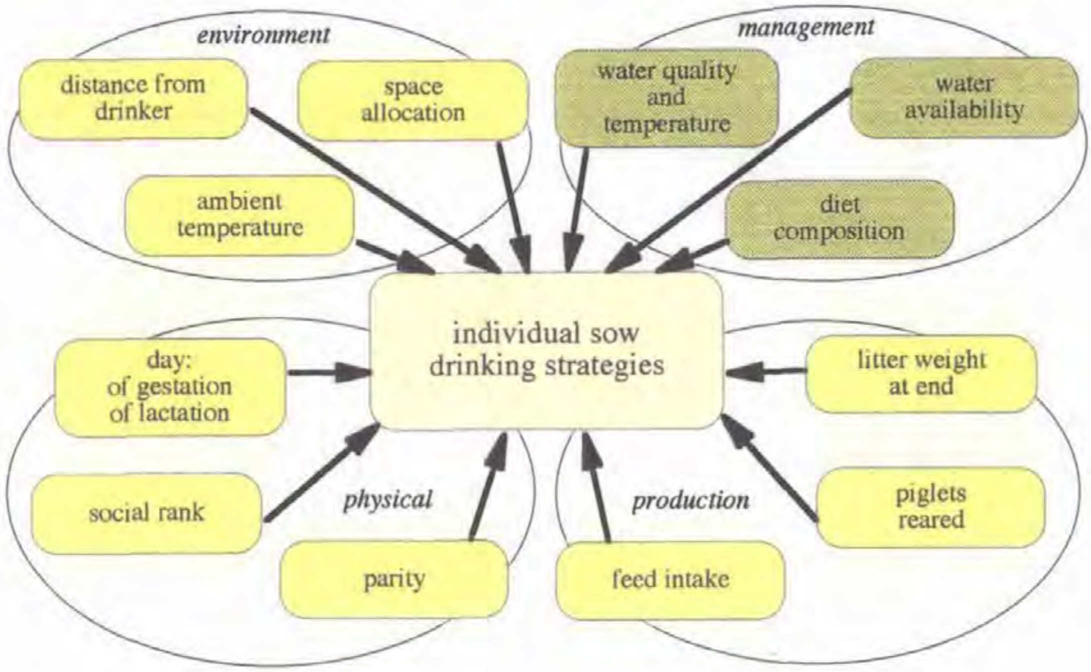


Figure 7.6 Schematic illustration of the factors which may influence individual drinking strategies of group housed sows over parturition and during lactation

7.3.5 Factors influencing the number of visits to the drinker, time spent drinking and the length of drinking visits

The percentage contributions made by factors exerting a significant influence on the variation in the number of visits made daily to the drinker, the time spent drinking and the length of drinking visits made by sows, during each of the three time blocks, are presented in Table 7.4.

The day of gestation and space allocation exerted a significant influence (P<0.001) on the number of visits made daily to the drinker by sows during time block 1 (Appendix 7.4). In time block 2, the most influential factors affecting the number of drinking visits were day of lactation, social rank, feed intake and space allocation (P<0.001). No further influence of the factors tested on daily visits to the drinker were demonstrated.

The time spent drinking was significantly influenced by day of gestation, sow feed intake and space allocation during time block 1 (P<0.001). In time block 2, sow feed intake, day of lactation, space allocation and sow parity had a significant effect on the time spent drinking by sows (P<0.001). In the later stages of lactation, the time allocated by sows to drinking was significantly influenced by the distance from the water, sow feed intake, social rank, space allowance and litter weight (P<0.001).

The distance from the water and day of gestation had a significant influence upon the length of drinking visits during time block 1 (P<0.001). Sow feed intake, space allocation and sow parity exerted a significant influence upon the duration of drinking visits (P<0.001) in time block 2. No further influence of the factors tested upon the length of visits made by sows to the drinker was demonstrated.

	Activity	Contribution % D	SR	P	F	L	W	T	DW	S
Time block 1	Number of visits	+27.45	-	-	-	-	-	-	-	+13.66
	Time drinking	+15.27	-	-	+8.78	-	-	-		+15.13
	Visit length	+8.23	-	-	-	-	-	-	+20.45	-
Time block 2	Number of visits	+27.98	-6.09	-	+6.64	-	-	-	-	+6.33
	Time drinking	+3.90	-	+3.06	+39.92	-	-	-	-	+2.80
	Visit length	-	-	+2.56	+29.19	-	-	-	-	+2.73
Time block 3	Number of visits	-	-	-	-	-	-	-	-	-
	Time drinking	-	+3.35	-	+8.43	-	+2.72	-	+10.58	-2.70
	Visit length	-	-	-	-	-	-	-	-	-

Key: D = Day of lactation; SR = Social rank; P = Sow parity; F = Feed intake; L = Litter size; W = Litter weight; T = Ambient temperature; DW = Distance from drinker; S = Space allocation

Table 7.4 Percentage contributions as indicated by R-sq values from multiple regression analyses, made by the most influential factors affecting the variation in the number of drinking visits, the time spent drinking and the length of drinking visits made by group housed sows, during time blocks 1, 2 and 3

7.4 DISCUSSION

7.4.1 Time allocation

Water is a vital component of virtually all metabolic functions of the body and is the single nutrient required in the greatest quantity by animals (Brooks and Carpenter 1990). Nevertheless, sows spent no more than 1.6%, 1.4%, 1.9% and 1.0%, 1.3%, 1.7% of each 24 hour period, during each of the three time blocks, engaged in drinking activity, in the L and S pen configurations, respectively. Since these figures were obtained during lactation, when increased heat production results from higher feed intakes and the metabolic activity of milk production, the time allocated to drinking activity might be expected to be at a maximum level. However, as lactating sows must also allocate time to activities associated with rearing their piglets, this may not be the case. For example, the distance of the chosen farrowing enclosure from the water supply had a positive effect on the total daily time allocated to drinking before parturition and during days 8 to 17 of lactation, but no influence during week 1 of lactation. Furthermore, sow feed intake had a positive influence upon the time spent drinking, particularly during the first week of lactation. Interestingly, Fraser and Phillips (1989) found a positive relationship between water intake and the amount of time that sows in farrowing crates spent active during lactation. The effect of providing a drinking point for each sow, in or close to each farrowing enclosure, on time allocation and water intakes by sows and on measures of production, is worthy of investigation.

7.4.2 Visits to the drinker

Sows obtained their daily water intake from a mean of 16 (s.e. 1.0), 13 (s.e. 0.9), 18 (s.e. 0.7) and 12 (s.e. 1.2), 11 (s.e. 0.7), 16 (s.e. 0.6) visits to the drinker in the L and S pen configurations, respectively, during each of the three time blocks. In comparison, group housed gestating sows of the lowest, middle and highest social rank made 7, 10 and 13 visits to the drinker per day, respectively (Vermeer, Peet-Schwering and van der Wilt 1996).

The mean duration of visits to the drinker was 63 (s.e. 4.9), 51 (s.e. 3.5), 67 (s.e. 3.0) and 39 (s.e. 3.1), 46 (s.e. 2.8), 62 (s.e. 3.5) seconds in the L and S pen configurations, respectively, during time blocks 1, 2 and 3. The lower visit duration in the S pen area reflected the reduced amount of time invested in water consumption by this treatment group of sows. These results implied that, upon each visit to the drinker, sows consumed only relatively small quantities of water. It is suggested that the frequent consumption of small amounts of water might be the mechanism by which high intakes are achieved by sows. Furthermore it is speculated that it might be a strategy to control excess thermogenesis, particularly when associated with feeding (Friend 1969) and also a way in which the milk ejections which take place at regular intervals in the lactating sow (Barber *et al.* 1955; Whittemore and Fraser 1974; Fraser 1980; Ellendorf *et al.* 1982; Castren *et al.* 1993a) are maintained.

7.4.3 Diurnal drinking patterns

Vermeer *et al.* (1996) demonstrated that although group housed gestating sows fed by electronic sow feeder consumed water throughout the day, intake was highest during the first 8 hours after the start of the feeding cycle. In the present study, the majority of drinking activity occurred during the day time in both treatment groups of sows. Both before parturition and during week 1 of lactation, activity was associated with morning cleaning routines and afternoon inspection times. As lactation progressed this relationship was less evident, although a period of reduced drinking activity persisted between the hours of 20.00 and 03.00 hours.

7.4.4 Water consumption

It was found that when the water flow rate from the drinker and the time spent drinking were used to calculate water use by individual sows, the cumulative figures obtained from the calculation were greater than the readings of daily water use on the water meter attached to the drinker. As the meter readings were known to be accurate, the discrepancy could only be due to the way in which sows obtained water during their drinking visits. It is reasonable to suppose that there would be pauses in actual water consumption during a drinking visit which lasted for one full minute, which would account for differences between the two methods of monitoring water intake. Therefore, based upon the water meter readings, mean daily water intakes of 23.4 (s.e. 1.06) litres and 24.1 (s.e. 1.47) litres per sow were achieved during the short time periods allocated to drinking, in the L and S pen areas, respectively. In agreement with these findings, mean daily water intakes of up to 25.1 litres per day have been reported for sows housed in farrowing crates over farrowing and during lactation (Fraser *et al.* 1990).

The water intake of pigs is affected by their physiological state, feed intake and diet composition, the ambient temperature and the quality, temperature and accessibility of the water (Brooks and Carpenter 1990). However, as individual sow water consumption was unknown the relationships between these factors and water intakes could not be investigated. Nevertheless, the greatest physiological change occurs in the sow at parturition and the onset of lactation, when corresponding changes in water intake might be expected. Sow water intakes have been reported to increase gradually up to farrowing, fall sharply at parturition, then rise to a maximum at 4 (Fraser and Phillips 1989), 11 (Klopfenstein *et al.* 1995) and 18 (Gill 1989) days post partum. Mean water use in both the L and S pen areas followed a similar pattern, in that intake rose gradually following parturition, to a level exceeding pre-farrowing intakes during week 1 post partum, which was then maintained throughout the remainder of lactation.

Sows in the reduced space allocation made fewer visits to the drinker than those in the larger pen configuration, during all three time blocks. Even so, water consumption was similar in both treatment groups. It is speculated that the differences between space allocations might have been influenced by the positioning of the drinker near to the feeder in the L pen area. The proximity of the water supply to the feeder may have stimulated the L sows to visit the drinker intermittently during feeding, whereas visits to the drinker by the S sows were made more specifically to obtain water.

Although drinking activity takes only a small part of the overall time budget of the lactating sow, the acquisition of water is complicated by the requirement for sows to perform rearing duties, obtain food and to find time to rest.

8. GENERAL DISCUSSION

The preceding chapters have described the activities of four groups of four sows which were assigned to one of two space allocations, in a novel loose house farrowing system from 5 days before the first expected farrowing date, until the oldest litter was 21 days of age. As expected, the way in which time was allocated to different activities by the sows and the feeding and drinking strategies of the sows were influenced by the environment provided and by the physiological state of the sow.

8.1 ENVIRONMENTAL EFFECTS ON BEHAVIOUR

8.1.1 Aggressive interactions

Contrary to expectations, the reduced space allocation did not result in an increase of aggressive encounters between sows. Overt aggression between sows occurred so infrequently in both treatment groups that there was insufficient data for analysis. It is considered that the low levels of aggression were a consequence of the pen layout, which allowed a circular flow of movement around the novel farrowing system. The provision of two entrances to each farrowing enclosure and passageways around the block of enclosures afforded sows a number of choices of direction and the formation of culs-de-sac in which a sow could become trapped and attacked by pen mates was circumvented. Jensen *et al.* (1986) speculated that avoidance behaviour may serve to inhibit aggression, since it was often performed by free-ranging sows, without any previous threat of attack. Furthermore, the dominance order amongst sows kept in semi-natural conditions was found to be largely maintained through the submissive behaviour of the subordinate animals (Jensen and Wood-Gush 1984).

It would not be unreasonable to conclude therefore, that the number of options available to sows when moving around the system, provided the opportunity to avoid direct confrontations with others.

8.1.2 General activity

There was less exploration and movement by sows around the reduced space allocation compared with those in the larger pen configuration during time block 1. Most importantly, the S sows spent significantly more time lying down, less time standing and less time in ventral recumbency than the L sows, during the first week of lactation. In addition, the S sows made fewer transitions between postures than the L sows during early lactation, when piglets are most vulnerable to injury and death (Dyck and Swierstra 1987; de Passillé and Rushen 1989a).

8.1.3 Suckling behaviour

The increased amount of time spent lying down was reflected in the significantly higher frequency with which the S sows were prepared to suckle their piglets compared with sows in the larger pen configuration. It is suggested that the increased number of sucklings which occurred in the S pen area, were the direct result of sows being less restless and lying with the udder exposed over longer periods of time in this pen configuration. A number of studies have demonstrated that the more frequent the opportunities for piglets to suckle, the higher their milk intake and subsequent live weight gain over lactation (Barber *et al.* 1955; Newberry and Wood-Gush 1984; Spinka *et al.* 1997). However, as similar daily piglet weight gains were achieved in both the L and S pen configurations, it is speculated that an increased number of nursings without milk ejection might have occurred in the reduced space allocation, compared with the larger pen area. Incomplete sucklings accounted for between 23% and 31% of sucklings at different stages of lactation, in free-ranging domestic sows (Newberry and Wood-Gush 1984; Castren *et al.* 1989a; Jensen *et al.* 1991) and 27% of sucklings by sows in conventional farrowing accommodation (Whatson and Bertram 1980). Sucklings without milk ejection were considered to be part of the natural behavioural repertoire of the pig (Castren *et al.* 1989a) and to be a mechanism to reduce the incidence of cross suckling in groups of sows (Newberry and Wood-Gush 1984; Delcroix *et al.* 1995; Wechsler and Brodmann 1996). The combination of a reduced amount of activity by sows and increased opportunities for piglets to suckle suggests that the smaller space allocation provided a better environment for the piglets. However, the impact of these differences in sows behaviour on piglet survival and growth rates requires further investigation, as there was insufficient production data in the present study, for reliable conclusions to be drawn.

8.1.4 Maternal investment

Sows in fully integrated group farrowing systems, in which piglets were confined to the farrowing site, reduced the time spent with their piglets from week 2 of lactation onwards (Houwers *et al.* 1992; Bøe 1993). Bøe (1994) concluded that as the piglets could not follow the sow, her interest in them declined, resulting in weaning before 3 weeks of age in some instances. Consequently, the entrance thresholds of the farrowing enclosures in the novel farrowing system were designed to allow piglets to climb over and leave the farrowing site to explore their surroundings, as would occur in nature (Gundlach 1968; Spitz 1986; Stangel and Jensen 1991). As anticipated, piglets in the novel farrowing system began to venture out of the enclosures when they were between 8 and 10 days of age (Plate 1). This was consistent with observations that wild boar sows and litters abandoned the farrowing nest from between 3 and 4 days (Mauget *et al.* 1984), 2 to 4 days (Spitz 1986), 2 to 18 days (Delcroix *et al.* 1995) and 7 and 14 days after birth (Gundlach 1968). Similarly, Jensen and Redbo (1987) found that nest leaving occurred in domestic sows in semi-natural surroundings when piglets were 3 to 16 days of age.

During early lactation, sows returned rapidly to their litters following short trips outside the enclosures to feed, drink, eliminate and exercise. Contrary to expectations, sows continued to return to their 'home' farrowing enclosures for suckling bouts and rest periods even after piglets were able to follow them around the pen area, with the result that very few sucklings occurred outside the farrowing enclosures during the study period. Surprisingly, piglets also tended to go back to their 'home' enclosure to suckle, even when initially in a different enclosure with another sow and litter, when a suckling bout began.

Plate 8.1 Piglets negotiating the entrance thresholds and leaving the farrowing enclosures to explore their surroundings at between 8 and 10 days of age

The continued allegiance of sows and litters to their particular place of farrowing during the study, is difficult to explain. Jensen and Redbo (1987) considered that the quality of the nest, the degree of protection provided by the nest site in relation to weather conditions and the amount of food available in the nest area influenced the time of nest leaving by free-ranging domestic sows and their litters. It is speculated therefore, that 'nest leaving' was effectively delayed by the low ambient temperatures and the close proximity of an *ad libitum* supply of feed and water in the system.

8.1.5 Ingestive behaviour

The feed intake of the lactating sow is often insufficient to meet nutrient requirements for maintenance and milk production (Cole 1982; Lynch 1989; Mullan *et al.* 1990; Dourmad 1993). Daily feed intakes of no more than 5 to 6 kg have been reported for lactating sows (NRC 1987; Mullan *et al.* 1990). In contrast, sows in this study achieved considerably higher feed intakes during lactation of 7.69 kg (s.e. 0.31) and 7.72 kg (s.e. 0.35) in the L and S pen configurations, respectively. This was accomplished by sows taking a series of small feeds throughout the day. Tethered sows housed in conventional farrowing pens also spread their daily feed intake over a number of smaller meals (Dourmad 1993). Sows in the reduced space allowance made fewer visits to the feeder per day and spent less time per day engaged in feeding, compared with sows in the larger pen configuration. By increasing their feeding rate, the S sows consumed more feed during each visit. As a result similar daily feed intakes were achieved by both treatment groups.

The most striking point about water consumption by sows was that no more than 31.3 minutes (s.e. 6.7) and 33.5 minutes (s.e. 9.2) was allocated to drinking per day in the L and S pen areas, respectively. Similarly, weaned pigs limited the amount of time invested in drinking activity to 4.5 minutes per day (Barber *et al.* 1989). As with feed intakes, sows obtained their daily water intakes during a series of short visits to the drinker. Even though sows in the reduced space allocation made fewer drinking visits than those in the L pen configuration, water intakes were similar in both treatment groups. The S sows also spent less time drinking and made shorter visits to the drinker, although the difference between treatments was only of significance in time block 1. These results imply that sows in the reduced space allocation drank more efficiently and continuously, possibly taking fewer pauses whilst consuming water during each visit to the drinker, in order to maintain comparable intake levels to sows in the larger pen area. The frequency of visits to the drinker was higher in both the L and S pen areas than that reported for gestating sows (Vermeer *et al.* 1996), perhaps reflecting the increased demand for water in lactation. Published information about the drinking behaviour of pigs is very sparse and no work has been found to date which describes the drinking strategies of lactating sows.

The way in which sows consumed a number of small meals and small quantities of water during visits spread over each 24 hour period, may be a mechanism to assist sows to achieve higher total daily intakes of feed and water. The same strategy might also help to spread the thermal loading of digestion and aid the control of excess thermogenesis created by the metabolic activity of milk production. Improved access to drinking water for sows in the novel farrowing system, through the provision of a number of drinking points either within or close to each farrowing enclosure, so that sows were not required to leave the farrowing site to obtain water, might contribute to improved sow water and feed intakes and higher piglet weight gains, particularly during early lactation.

These results demonstrate that the acquisition of food and water was complicated by the requirement for sows to prepare for parturition, perform rearing duties and find time to rest. It is therefore concluded that an *ad libitum* supply of feed and water is an essential requirement for group housed farrowing and lactating sows, in order that sows can meet their individual nutrient requirements.

8.1.6 Space allocation

The alterations in feeding strategies of sows in the reduced space allowance resembled findings in a number of other studies. For example, Nielsen (1995) found that pigs kept in groups of 20 made fewer, longer visits, during which they ate more, at a faster rate, than pigs kept in smaller groups, resulting in comparable daily feed intakes in each group size. de Haer and Merks (1992) reported similar differences in feeding strategies between growing pigs housed in groups and pigs housed individually. However, the daily feed intake of the group housed animals was lower than that achieved by the individually housed pigs. Rats decreased the number of meals taken and increased the size of each meal as the number of bar presses required to obtain food increased, resulting in a constant daily feed intake (Johnson and Collier 1994). Mice which had to negotiate either a narrow gap, shallow or deep water to access the feed cage, reduced the number of feeding visits but their daily feed intake was unaffected (Sherwin and Nicol 1995). The response to increased difficulty in obtaining food was the same in every case. Sherwin and Nicol (1995) concluded that the three obstacles imposed perceived costs on the mice and thereby influenced their motivation to feed. Nielsen (1995) suggested that animals used changes in feeding rate to increase food intake when under some form of environmental constraint.

If these arguments are applied to the novel farrowing system, the changes in feeding strategy and in time allocation between different activities may well have been a consequence of constraints imposed upon the sows by the reduction in space allowance per sow in the S pen configuration. It is possible that sow movement around the reduced pen area was constrained due to the perceived threat of potentially aggressive encounters in the narrow passageways surrounding the farrowing enclosures and at the feeder. Baxter (1985) suggested that groups of pigs had a requirement for social space which was greater than the sum of their individual space requirements. The amount of space required by individuals within a group of animals was dependent upon the activity in which they were engaged and increased if it involved the defense of a resource. If overall space was limited so that appropriate distances between animals could not always be maintained, the performance of activities requiring the greatest amount of social space, such as walking, were reduced or ceased to occur (Keeling 1994). Thus the opportunities for sows to walk and stand to feed and drink might have been limited by the lack of social space within the smaller pen configuration. Although the narrow passageways may have contributed to the constraints imposed on the S sows, they were not necessarily the primary cause. It is reasonable to presume that the farrowing enclosure of choice, in which the litter were born and reared, was an important resource to the sow. The reduced movement around the smaller pen configuration might therefore, have resulted from the need for sows to avoid passing close to the openings of enclosures occupied by other sows and litters.

8.1.7 Management of sows and litters

Difficulties were encountered in controlling sows whilst attending to their litters and during routine cleaning operations in the large pen configuration. On a number of occasions, individual sows were particularly aggressive towards the stockperson, even to the point of charging to attack from the far side of the pen. These aggressive acts inevitably disturbed the other sows in the group, increasing the danger of injury to their piglets and arousing their interest in the perceived threat of the human intruder. Consequently, the opportunity was taken during the construction of the smaller pen configuration, to incorporate a series of gates which could be closed at intervals across the passageways, to aid handling and control of sows in the system (see Plate 2.4). Curiously, closing the gates, thus sectioning off different parts of the pen area, whilst handling piglets, appeared to have calming effect upon sows not directly involved, as they largely ignored activities going on in another part of the pen. Similarly, sows which otherwise objected to cleaning of the passageways immediately outside their farrowing enclosure, remained relaxed and undisturbed if the slide-in doors were positioned in the farrowing enclosure entrances.

This reaction was interesting, not least because the barriers could have easily been demolished by a moderately determined sow. A number of studies have demonstrated that earlier experiences affect the later behaviour of pigs (Hemsworth 1982; Schouten 1986; Beattie, Walker and Sneddon 1993). Sows housed in farrowing crates are unable to affect events occurring around them, which they perceive as a threat to their piglets. This previous experience might explain the disinterest shown by sows in the presence of the stockperson when separated merely by the presence of a plywood partition. Alternatively, the effect may have been attributable to the more confident, relaxed manner of the stockperson when working in the security of a more manageable environment. In support of this hypothesis, Hemsworth *et al.* (1993) described the mutual reinforcement of attitudes and behaviour between animal and stockperson in which negative or aversive behaviour by the stockperson might cause fear and lead to avoidance or defensive behaviour by the sow. Furthermore, the nature and operation of production systems might significantly affect the behaviour and attitude of the stockperson towards the animals (Seabrook and Mount 1993) and hence the way in which the animals react to human presence. Perhaps it is more likely that the observed effects of the system design resulted from a combination of the previous experience of the sow and the change in the attitude and behaviour of the stockperson within the new pen layout.

8.2 PHYSIOLOGICAL EFFECTS ON BEHAVIOUR

8.2.1 Parturition and early lactation

As parturition approaches wild boar and free-ranging domestic sows search for a suitable nest site and construct an elaborate nest in which they farrow (Gundlach 1968; Jensen 1989; Stolba and Wood-Gush 1989; Meynhardt 1991). Similar pre-farrowing nest building activity was described for sows in communal farrowing systems (Algers 1991), for sows housed individually in straw bedded pens (Widowski and Curtis 1990; Arey *et al.* 1991; Cronin *et al.* 1994) and for sows confined in farrowing crates (Baxter 1980; Lammers and de Lange 1986). Typically, nest building began with an initial increase in activity, rooting and pawing, which was followed by the carrying and arranging of nest material (Jensen 1993). As expected, the sows in the novel farrowing system were no exception and all sows in each treatment group became increasingly active during the 24 hours prior to parturition as they selected and prepared a farrowing site. Castren *et al.* (1993b) demonstrated that the nest building process commenced as pre-parturient blood plasma levels of prolactin began to rise and ended when oxytocin concentrations began to rise.

There was a sharp reduction in the activity of all sows in both treatment groups during the 24 hours following onset of parturition, to the extent that one sow in each pen area remained inside the farrowing enclosure for the whole of this time. Activity rose steadily during the first week of lactation to levels which were then maintained for the remainder of the study period. This is consistent with the observation that free-ranging sows and piglets remained within or close by the farrowing nest during the first day post-partum, after which activity outside the nest gradually increased (Jensen 1986; Jensen *et al.* 1991). Lammers and de Lange (1986) also reported that parturition strongly reduced the activity levels of sows housed in pens and in farrowing crates, after which activity was restored sooner in the free sows than in the confined ones.

The physiology of the sow ensures that colostrum, which provides the energy and antibody protection necessary for piglet survival (de Passillé *et al.* 1988) is freely available from before farrowing onset until several hours afterwards (Fraser 1984; Castren *et al.* 1993a). It is considered that the reduction in sow activity at this time is an important behavioural adaptation to assist new born piglets to find their way to the udder and acquire colostrum, thus improving their chances of survival.

8.2.2 Ingestive behaviour

The feed intakes and the activity associated with water consumption of sows in the novel farrowing system followed a similar pattern to the other activity levels. In accordance with the findings of Neil (1996) and Friend (1969), feed intakes fell sharply on day 1 of lactation, then rose again over the first week of lactation to a peak on day 10 and day 6 of lactation in the L and S pen configurations, respectively. The frequency of visits made to the drinker and the time spent drinking daily also decreased abruptly on the first day of lactation, before rising to a level which was subsequently maintained throughout lactation, in both pen areas. A number of studies have demonstrated that water consumption of sows also fell markedly at parturition then rose steadily during the first week of lactation (Friend 1969; Fraser and Phillips 1989; Gill 1989; Klopfenstein *et al.* 1995). The milk yield of the sow is influenced by litter size, piglet live weight and suckling demand (Auldist and King 1995; King *et al.* 1997) so rises gradually to peak at between 3 and 4 weeks post partum (Barber *et al.* 1955; Elsley 1970; Whittemore 1993).

The results obtained indicate that feed intakes and the activity associated with water consumption were influenced by the physiological changes around parturition and the increasing demands for milk production during lactation. This reinforces the conclusion made earlier that in order that individual nutrient requirements are met, an *ad libitum* system for the separate provision of feed and water is essential for group housed farrowing and lactating sows.

8.3 ASSESSMENT OF WELFARE

It is generally acknowledged that the measurement of welfare is complex (Broom 1986; Broom 1989; Mendl 1992; Broom and Johnson 1993; Mason and Mendl 1993; Webster 1994). Broom (1986) stated that 'the welfare of an individual is its state as regards its attempts to cope with its environment'. Attempts to cope include both physiological and behavioural responses to environmental conditions (Broom and Johnson 1993). This definition implies that welfare can be measured scientifically, using a variety of measures including growth and production, disease and injury, activity and responsiveness, aggressive behaviour and physiology. Thus, the welfare of an animal can vary on a sliding scale, from very good to very bad (Broom 1992).

The results of the present study demonstrated that the reduction in space allowance in the novel farrowing system imposed a degree of constraint on some of the activities of the sows. Nevertheless, within this pen configuration, sows were able to adapt and express a wide range of natural behaviours, including the selection and preparation of a farrowing site by sows during the 24 hours prior to parturition, without any increased incidence of

* aggressive encounters between sows

* injury or disease

or reduction in

* daily feed intakes
* daily water intakes
* care of young

In addition, the smaller pen configuration turned out to be a better organised system in which the control of sows was easier and less stressful for both the sow and the stockperson.

A full assessment of the relative welfare status of sows in the two treatment groups is beyond the scope of this investigation. However, it is speculated that the costs imposed in the form of constraints on the behaviour of the sows were outweighed by the benefits so that the welfare of the sows in the reduced space allocation was as least as good, if not better than that of the sows in the larger pen configuration.

As there were only limited data on measures of productivity available from the present study, any results must be interpreted with caution. Nevertheless, the high piglet losses in the novel farrowing system are a cause for concern as they indicate that the welfare of the piglets was compromised. The greater proportion of piglet deaths were due to crushing by the sow, which was found to be the most common cause of death of piglets in both outdoor (Edwards *et al.* 1994) and indoor pig production systems (English and Wilkinson 1982; Dyck and Swierstra 1987). The majority of piglets deaths occurred during the first three days following birth. This was also the case in studies conducted by Holyoake *et al.* (1995), Dyck and Swierstra (1987) and Rudd (1994). It is suggested that the supervision of farrowings and a proactive approach towards assisting piglets, particularly the smaller, weaker ones and those failing to suckle during their first days of life would improve piglet survival in the novel farrowing system. In addition, adjustments to the quantity and type of bedding material used in the system might improve the mobility of new born piglets and contribute to their chances of survival. The effect of these measures on sow behaviour and piglet mortality in the communal farrowing system require investigation.

8.4 THE APPLICATION OF STUDIES OF SOW BEHAVIOUR IN WILD AND SEMI-NATURAL ENVIRONMENTS

The study of the behaviour of wild boar sows and domestic sows in natural conditions provides invaluable information about the habitat use and social interactions of breeding sows and litters in wild and semi-natural environments. Frequently, changes in habitat use are related to the seasonal variability of food supplies and are particularly associated with the choice and the degree of preparation of the farrowing site. With the aid of this knowledge of sow behaviour in the wild, the incorporation of certain housing design features might be usefully employed to encourage sows to use the system as intended. Examples include

* the provision of protection and privacy and a supply of manipulatable substrate within the farrowing enclosures, to direct the choice of farrowing site of the sows

* the manipulation of the ambient temperature within the system, to encourage continued use of the farrowing enclosures and to maintain feed intakes in lactation.

Sows in wild and semi-natural situations readily adapt their behaviour according to the feed supply, weather conditions, environmental features and vegetation within their particular habitat. The results of this research project have demonstrated that sows housed in a communal farrowing system were equally able to adapt and carry out a range of appropriate behaviours, when given a degree of control and choices within their environment.

LIST OF APPENDICES

Appendix No. Page

Appendix 2.1 Experimental procedure and pen layout for the Pilot Study

A farrowing enclosure (Figure 2.1.1).was constructed of Sima Board (Sima Kunststoffen BV. Gramsbergen. NL) and Stockboard (Plastic Recycling Ltd., Worchester, UK). Entrances in the centre of each of the shorter sides, incorporated 0.3m high piglet barriers.

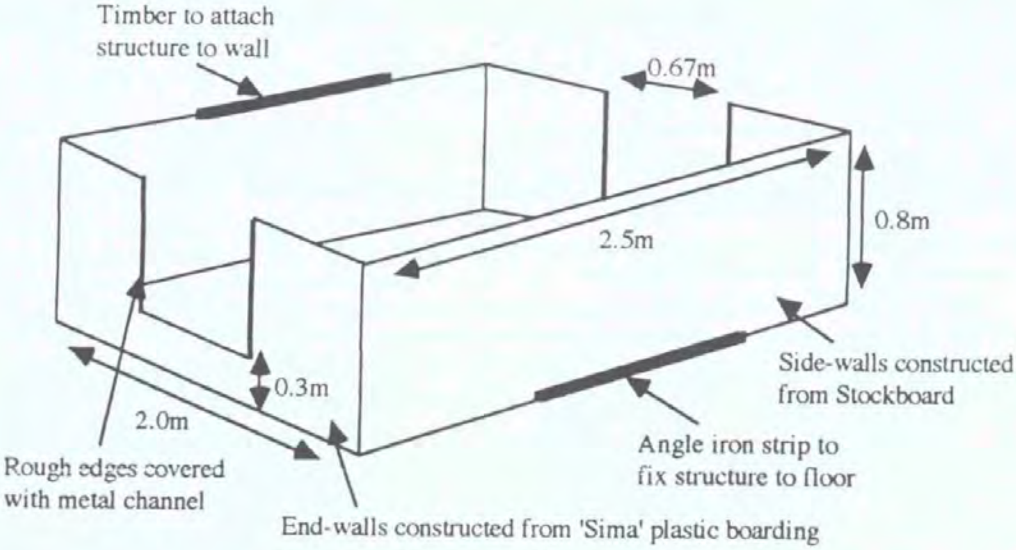


Figure 2.1.1 Farrowing enclosure layout used in the Pilot study

The straw filled farrowing enclosure was placed within a large pen, at the furthest point from food and water supply (Figure 2.1.2). Single sows were introduced into the experimental pen one week before their expected farrowing date and observed using continuous time lapse video recordings (Panasonic, AG-6730; Matsushita Electric Industrial Co. Ltd., Osaka, Japan). A companion sow, at approximately 93 days gestation, was placed in the adjacent pen, in sight and contact with the trial sow. Both sows were removed one week after farrowing of the trial sow.

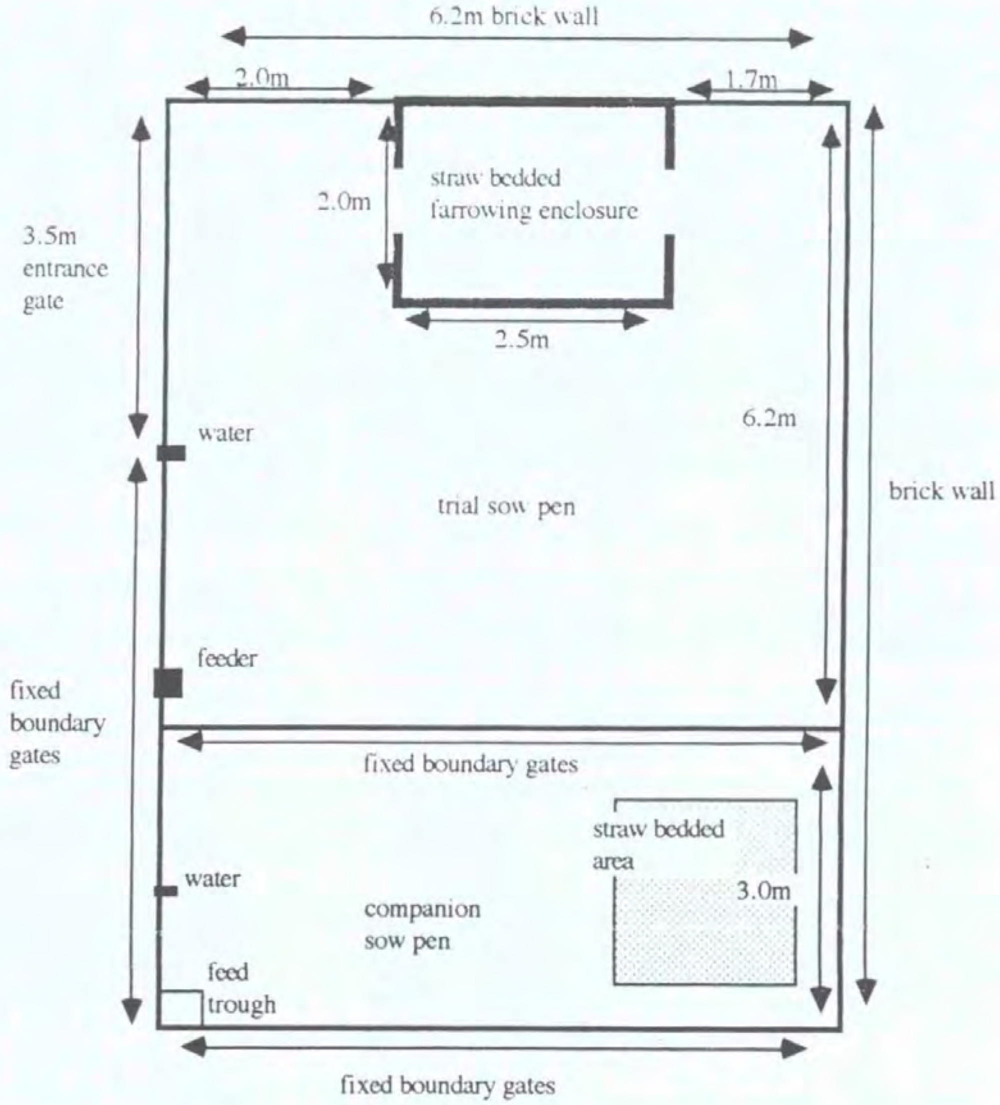


Figure 2.1.2 Pen layout used in the Pilot study

2.1.1 Intervention procedure to protect sow and piglet welfare in the experimental farrowing system

As the welfare of the sows and piglets took precedence over experimental considerations, potential problem areas were identified and an intervention procedure was compiled.

* any individual failing to obtain feed from the star wheel feeder, following a series of training sessions will be removed from the study and replaced by the sow with the closest expected farrowing date

* if a serious problem with aggression between sows arises which remains unresolved the victim or the main culprit will be removed from the trial as appropriate

* should a sow choose to farrow outside the nest enclosures, the piglets will be moved into the closest nest and the sow persuaded to follow and closed in temporarily if necessary

* any sow present in a nest when another is farrowing,will be removed and the nest door closed temporarily if necessary, for protection of the sow and litter during parturition

* any farrowing difficulties will be reported to the farm staff immediately, their advice followed and any assistance to sows carried out by them as required

* the presence of deformed or low birth weight piglets will be reported to farm staff then treated or euthanaised as necessary

* any ill health or injury of sows or piglets will be reported to farm staff and the required treatment provided. If the condition dictates, the animal will be removed from the trial for more intensive treatment

Appendix 2.2 The construction of a sociometric matrix for the determination of social rank among sows

The first step in this procedure was to arrange the data in a contingency table with the emitters of the behaviour specified by row and the recipients by column (Figure 2.3.1).

Large pen configuration

Replicate 1

arbitrary arrangement

	sow	recipient 1	2	3	4
emitter	1	x	0	0	21
	2	21	x	19	10
	3	12	0	x	[illegible]
	4	0	0	0	x

hierarchical arrangement

	sow	recipient 2	3	1	4
emitter	2	x	19	21	10
	3	0	x	12	11
	1	0	0	x	21
	4	0	0	0	x

Replicate 2

	sow	recipient 1	2	3	4
emitter	1	x	6	0	55
	2	64	x	0	6
	3	55	34	x	35
	4	4	38	0	x

	sow	recipient 3	2	1	4
emitter	3	x	34	55	35
	2	0	x	64	6
	1	0	6	x	55
	4	0	38	4	x

Small pen configuration

Replicate 1

	sow	recipient 1	2	3	4
emitter	1	x	15	8	1
	2	1	x	0	1
	3	6	7	x	13
	4	7	5	4	x

	sow	recipient 3	4	1	2
emitter	3	x	13	6	7
	4	4	x	7	15
	1	8	1	x	5
	2	0	1	1	x

Replicate 2

	sow	recipient 1	2	3	4
emitter	1	x	6	4	3
	2	0	x	0	0
	3	0	11	x	7
	4	0	6	0	x

	sow	recipient 1	3	4	2
emitter	1	x	4	3	6
	3	0	x	7	11
	4	0	0	x	6
	2	0	0	0	x

Figure 2.2.1 Sociometric matrix of displacement behaviour at the feeder by sows, arranged for the best representation of the dominance hierarchy within each sow group

Initially the order in which the sows are entered was arbitrary eg 1, 2, 3, 4 and the observations entered as in the left hand boxes of Figure 2.3.1. The data was then rearranged so that as far as possible only reversals ie. instances where an individual displaces a sow, which in turn displaces the previously successful sow at the feeder, are found below the diagonal of the matrix. The new order is entered as in the right hand boxes of Figure 2.3.1, representing the best representation of the hierarchy within each sow group (Jensen and Ekesbo 1986).

Appendix 3.1 Mean inter-birth intervals (minutes) of individual sows in the L and S pen configurations

Pen area		*L*	*S*
Sow	1	24.92	23.54
	2	11.58	16.63
	3	33.76	28.21
	4	7.65[a]	23.17
	5	8.35	20.04
	6	39.54[a]	15.97
	7	23.26	34.34
	8	14.19	49.47
	SE_D	0.24*	0.20

Means followed by the same superscript differ at P≤0.05
SE_D calculated from data subjected to logten transformation
* = P<0.05

Pen area	*L*				*S*			
Piglets	*born alive*	*stillbirths*	*mummified*	*weaned*	*born alive*	*stillbirths*	*mummified*	*weaned*
Sow 1	13	0	0	11	11	3	1	7
2	10	0	0	10	10	2	0	8
3	12	1	0	12	13	1	0	11
4	16	1	0	10	8	1	0	5
5	10	0	1	10	11	4	0	3
6	11	1	2	10	12	1	0	9
7	15	2	1	9	13	0	1	11
8	11	3	0	6	13	0	0	9

Appendix 3.2 The number of piglets born alive, stillborn and mummified and the number weaned for individual sows in L and S pen areas

Appendix 3.3 Mean daily ambient temperatures (^0C) experienced by individual sows in the L and S pen areas, during time blocks 1, 2 and 3

Pen area	*L*			*S*		
Time block	*1*	*2*	*3*	*1*	*2*	*3*
Sow						
1	8.39[abcd]	8.95[abcde]	3.91	17.28[abcd]	17.76[abcd]	18.17[abcd]
2	8.06	5.98[a]	2.71	17.39[efgh]	18.04[efgh]	17.99[efgh]
3	7.99	9.15	3.50	17.67[ijkl]	18.31[ijkl]	17.56[ijkl]
4	8.34	9.00	3.84	17.39[mnop]	18.04[mnop]	17.99[mnop]
5	2.27[a]	3.53[b]	3.23	5.97[aeim]	4.98[aeimqrs]	4.88[aeim]
6	2.29[b]	3.25[c]	3.81	8.88[bfjn]	6.28[bfjnq]	4.93[bfjn]
7	2.24[c]	3.51[d]	3.31	9.95[cgko]	7.36[egkor]	3.31[egko]
8	2.29[d]	3.52[e]	3.19	9.14[dhlp]	6.28[dhlps]	4.96[dhlp]
SE_D	0.39***	0.86***	0.77	0.32***	0.36***	0.38***

Means in the same column followed by the same superscript differ at $P \leq 0.05$
*** = P<0.001

Appendix 3.4 Factors which exerted a significant influence on the variation in the piglet mortality, the number of stillbirths, the number of piglets weaned and weaning weights in a communal farrowing system, during time blocks 2 and 3

Piglet mortality = - 0.455 + 0.168Stillbirths + 0.0404Litter size + 0.145Space Equation 3.2.1

(RSD = 0.162; R-sq(adj) = 63.8%; n = 177; P<0.001)

Stillbirths = 4.44 + 0.274Low birth weight piglets - 0.256Litter size - 0.152Parturition length Equation 3.2.2

(RSD = 0.937; R-sq(adj) = 35.5%; n = 177; P<0.001)

Number weaned = 2.49 + 0.580Litter size - 0.337Low birth weight piglets + 0.523Parturition length - 1.31Space Equation 3.2.3

(RSD = 1.409; R-sq(adj) = 60.3%; n = 177; P<0.001)

Weaning weight = - 1.55 + 2.51Birth weight + 0.265Litter size + 0.493Space Equation 3.2.4

(RSD = 1.391; R-sq(adj) = 32.0%; n = 177; P<0.001)

Pen area									
		L				*S*			
Activity		*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Sow	1	0.75	0.18	0.007	0.05	0.74	0.19	0.009	0.06
	2	0.81	0.15	0.002	0.05	0.89	0.08	0.007	0.02
	3	0.88	0.13	0.014	0.03	0.83	0.08	0.049	0.03
	4	0.61	0.26	0.008	0.05	0.84	0.10	0.025	0.02
	5	0.84	0.16	0.003	0.05	0.80	0.17	0.012	0.02
	6	0.76	0.18	0.006	0.03	0.86	0.10	0.004	0.03
	7	0.82	0.15	0.017	0.09	0.84	0.13	0.008	0.02
	8	0.74	0.20	0.003	0.04	0.80	0.15	0.006	0.04
	SE_D	0.06	0.05	0.03	0.06	0.06	0.09	0.04	0.04

SE_D calculated from data subjected to arcsine transformation

Appendix 4.1 Mean proportion of time per day allocated to lying, standing, sitting and walking by individual sows in the L and S pen configurations, during time block 1

Pen area		*L*				*S*			
Activity		*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Sow	1	0.81	0.16	0.013^{aeh}	0.02	0.89	0.07^{b}	0.006^{a}	0.02
	2	0.87	0.11	0.003^{abcdf}	0.01	0.93^{abcde}	0.04^{acefg}	0.005^{b}	0.01^{a}
	3	0.87	0.11	0.009^{bi}	0.02	0.85^{a}	0.10^{a}	0.007^{c}	0.03^{a}
	4	0.84	0.13	0.012^{cj}	0.02	0.89	0.07^{d}	$0.023^{abcdefg}$	0.01
	5	0.84	0.12	0.010^{dk}	0.03	0.82^{b}	0.14^{bcd}	0.010^{d}	0.02
	6	0.88	0.09	0.005^{eg}	0.02	0.86^{c}	0.12^{e}	0.004^{e}	0.02
	7	0.84	0.12	0.014^{fgl}	0.03	0.86^{d}	0.11^{f}	0.006^{f}	0.02
	8	0.85	0.13	0.002^{hijkl}	0.02	0.86^{e}	0.11^{g}	0.004^{g}	0.02
	SE_D	0.04	0.03	0.012***	0.02	0.03***	0.03***	0.014***	0.01**

Mean in the same column followed by the same superscripts differ at $P \leq 0.05$
SE_D calculated from data subjected to arcsine transformation
** = $P<0.01$; *** = $P<0.001$

Appendix 4.2 Mean proportion of time per day allocated to lying, standing, sitting and walking by individual sows in the L and S pen configurations, during time block 2

Pen area		*L*				*S*			
Activity		*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Sow	1	0.77	0.16	0.004	0.05	0.84	0.11	0.007	0.04
	2	0.91	0.08	0.001	0.01	0.88	0.09	0.003	0.02
	3	0.81	0.10	0.008	0.02	0.84	0.13	0.001	0.02
	4	0.70	0.17	0.010	0.06	0.89	0.07	0.022	0.01
	5	0.83	0.12	0.002	0.05	0.82	0.14	0.003	0.03
	6	0.84	0.11	0.004	0.04	0.83	0.13	0.003	0.03
	7	0.83	0.12	0.004	0.04	0.81	0.14	0.008	0.04
	8	0.79	0.16	0.002	0.04	0.88	0.10	0.001	0.01
	SE_D	0.05	0.03	0.022	0.04	0.03	0.02	0.016	0.02

SE_D calculated from data subjected to arcsine transformation

Appendix 4.3 Mean proportion of daily time allocated to lying, standing, sitting and walking by individual sows in the L and S pen configurations, during time block 3

Appendix 4.4 Mean proportion of daily lying time spent within the farrowing enclosures (LE), time spent in ventral recumbency (LV) and in rooting activity (RT) by individual sows in the L and S pen configurations during time block 1, 2 and 3

Pen area	L			S		
Activity	*LE*	*LV*	*RT*	*LE*	*LV*	*RT*
Time block 1 (day -5 to onset of parturition)						
Sow 1	0.92^{f}	0.09	0.040	0.91^{abc}	0.08	0.031
2	$0.09^{abcdefg}$	0.12	0.022	0.63^{g}	0.18	0.004
3	0.88^{e}	0.18	0.031	0.10^{adefg}	0.14	0.012
4	0.90^{d}	0.05	0.035	0.73^{d}	0.08	0.011
5	0.90^{c}	0.14	0.017	0.35^{c}	0.17	0.011
6	0.96^{b}	0.10	0.024	0.64^{f}	0.11	0.011
7	0.90^{g}	0.09	0.048	0.31^{b}	0.13	0.016
8	0.96^{a}	0.08	0.088	0.67^{e}	0.13	0.015
SE_D	0.11***	0.07	0.077	0.14***	0.06	0.046
Time block 2 (days 1 to 7 of lactation)						
Sow 1	0.98	0.11	0.029	0.99^{a}	0.12	0.006
2	0.97	0.14	0.023	0.99^{b}	0.09	0.004
3	0.98	0.07^{ab}	0.016	0.99^{c}	0.12	0.016
4	0.98	0.11	0.015	0.95^{abcd}	0.09	0.003^{a}
5	0.99	0.18^{ac}	0.010	0.98	0.13^{a}	0.008
6	0.99	0.18^{bd}	0.017	0.98	0.04^{a}	0.018^{a}
7	0.99	0.08^{cd}	0.022	0.99^{d}	0.06	0.010
8	0.99	0.10	0.019	0.97	0.12	0.013
SE_D	0.04	0.04***	0.024	0.05*	0.05*	0.022*
Time block 3 (days 8 to 17 of lactation)						
Sow 1	0.95	0.11^{ag}	0.021^{abcdef}	0.96^{d}	0.12^{bfj}	0.006
2	0.96^{g}	0.19^{f}	0.006^{bh}	0.94^{g}	0.21^{abcd}	0.006
3	0.93^{c}	0.11^{bh}	0.002^{agklmn}	0.93^{f}	0.18^{m}	0.007^{a}
4	0.87^{adeg}	0.24^{gh}	0.010^{fk}	0.87^{b}	0.13^{cgk}	0.001^{a}
5	0.99^{abc}	0.16^{e}	0.013^{el}	0.72^{adefgh}	0.26^{efgh}	0.007
6	0.88^{bf}	0.35^{abcdef}	0.015^{ghij}	0.89^{ch}	0.10^{aeim}	0.003
7	0.98^{ef}	0.16^{d}	0.006^{cin}	0.93^{e}	0.13^{dhl}	0.003
8	0.98^{d}	0.16^{c}	0.007^{djm}	0.98^{abc}	0.20^{ijkl}	0.003
SE_D	0.067***	0.045***	0.012***	0.071***	0.033***	0.014*

Means in the same column followed by the same superscript differ at $P \leq 0.05$
SE_D calculated from data subjected to arcsine transformation
* = $P<0.05$; *** = $P<0.001$

Pen area		*L*				*S*			
Activity		*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Sow	1	72	66	15	46	49^{a}	70	7	54
	2	35	33	1	26	$102^{abcdefg}$	34	9	28
	3	51	37	10	31	59^{f}	16	15	30
	4	42	61	10	48	57^{e}	42	14	35
	5	62	44	3	39	51^{c}	29	6	26
	6	68	49	6	33	50^{b}	22	3	20
	7	50	47	12	32	53^{d}	32	9	26
	8	38	48	3	37	60^{g}	43	6	35
	SE_D	11	16	5	11	11*	14	4	12

Means in the same column followed by the same superscript differ significantly ($P<0.05$)
* = $P<0.05$

Appendix 4.5 Mean daily frequency of occurrence of lying, standing, sitting and walking by individual sows in the L and S pen configurations, during time block 1

Pen area		L				S			
Activity		*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Sow	1	100^{abcde}	66^{abcd}	14^{acdj}	31	49^{ab}	38	6^{b}	29
	2	82	37^{a}	3^{abf}	20^{a}	55^{c}	27^{a}	3^{acg}	24
	3	60^{af}	29^{b}	10^{gk}	43^{ab}	76^{adef}	55^{abc}	9^{ad}	24
	4	56^{bg}	31^{c}	13^{bcl}	26	70^{g}	28^{b}	$15^{bcdefhi}$	23
	5	97^{fg}	42	8^{ch}	29	44^{dgh}	39	5^{e}	34
	6	69^{c}	44	5^{dei}	20^{b}	47^{ei}	26^{c}	5^{f}	32
	7	67^{d}	47	17^{fghim}	28	51^{fj}	37	9^{gh}	34
	8	58^{e}	39^{d}	3^{jklm}	29	84^{bchij}	42	5^{i}	29
	SE_D	9^{***}	8^{**}	2^{***}	6^{*}	7^{***}	7^{**}	2^{***}	7

Means in the same column followed by the same superscript differ at $P \leq 0.05$
* = $P<0.05$; ** = $P<0.001$; *** = $P<0.001$

Appendix 4.6 Mean daily frequency of occurrence of lying, standing, sitting and walking by individual sows in the L and S pen configurations, during time block 2

Pen area		L				S			
Activity		*lie*	*stand*	*sit*	*walk*	*lie*	*stand*	*sit*	*walk*
Sow	1	81^{b}	69^{ghijkl}	6^{bm}	53^{ghij}	92^{i}	59^{abcdef}	8^{blmno}	47^{ghijk}
	2	97^{ij}	24^{fhnort}	2^{gjklm}	15^{fjlnpq}	103^{abcde}	48^{almno}	4^{chl}	40^{almno}
	3	72^{cf}	29^{eimpqs}	6^{cl}	27^{eikmo}	80^{a}	39^{bgp}	2^{dim}	28^{bjl}
	4	65^{dgi}	48^{djqr}	$15^{abcdefg}$	46^{akl}	73^{b}	23^{chopqr}	$16^{abcdefg}$	24^{cim}
	5	86^{a}	55^{agmn}	3^{ei}	43^{bmn}	67^{cf}	33^{din}	2^{ejn}	27^{dhn}
	6	119^{abcde}	72^{abcdef}	6^{dk}	61^{abcdef}	59^{dgi}	33^{ejlq}	5^{f}	30^{eg}
	7	106^{fgh}	46^{ckst}	8^{ahij}	36^{dhq}	67^{eh}	56^{ghijk}	9^{ahijk}	51^{abcdef}
	8	64^{ehj}	52^{blop}	3^{fh}	41^{cgop}	97^{fgh}	33^{fkmr}	1^{gko}	23^{fko}
	SE_D	10^{***}	5^{***}	2^{***}	5^{***}	6^{***}	4^{***}	2^{***}	3^{***}

Means in the same column followed by the same superscrip differ at $P \leq 0.05$
*** = $P<0.001$

Appendix 4.7 Mean daily frequency of occurrence of lying, standing, sitting and walking by individual sows in the L and S pen configurations, during time block 3

Appendix 4.8 Mean daily frequency of occurrence of ventral recumbency (LV), rooting (RT) and turning (TU) for individual sows in the L and S pen configurations, during time blocks 1, 2 and 3

Pen area		*L*			*S*	
Activity	*LV*	*RT*	*TU*	*LV*	*RT*	*TU*
Time block 1 (day -5 to onset of parturition)						
Sow 1	29	41	32	23^{a}	23	29
2	12	21	16	51^{abcdef}	5	11
3	18	15	7	22^{b}	6	21
4	8	27	16	21^{c}	13	12
5	25	22	15	21^{d}	8	7
6	31	29	23	16^{e}	2	5
7	16	32	23	20^{f}	6	13
8	9	17	9	26	11	18
SE_D	7	19	14	7**	8	12
Time block 2 (days 1 to 7 of lactation)						
Sow 1	37^{a}	24	18	18^{a}	6	10
2	34	23	21	20^{b}	11	18
3	20^{b}	23	19	28	9	13
4	19^{ac}	19	14	27	8	14
5	45^{bcde}	21	20	17^{c}	9	14
6	31	18	23	13^{d}	6	8
7	24^{d}	18	18	16^{e}	5	12
8	23^{e}	18	14	36^{abcde}	6	12
SE_D	5***	6	7	5***	2	5
Time block 3 (days 8 to 17 of lactation)						
Sow 1	30^{cj}	13	11	40^{fij}	5	14
2	46^{flm}	13	9	54^{abcdef}	5	8
3	32^{dk}	15	10	38^{ekl}	5	9
4	29^{bim}	11	6	37^{dmn}	5	8
5	39^{e}	17	13	35^{c}	6	11
6	$66^{abcdefg}$	14	8	20^{ahikm}	4	12
7	50^{ghijk}	16	10	25^{bgjln}	5	12
8	29^{ahl}	11	7	46^{gh}	4	13
SE_D	6***	4	3	4***	2	3

Means in the same column followed by the same superscripts differ at $P \leq 0.05$
** = $P<0.01$; *** = $P<0.001$

Appendix 4.9 Factors which exerted a significant influence on the variation in time spent engaged in activities by group housed sows, during time blocks 1, 2 and 3

Time block 1 (day -5 to onset of parturition)

Lying = 1.55 - 0.0461Day - 0.0276Space Equation 4.9.1

(RSD = 0.111; R-sq(adj) = 39.6%; n = 80; P<0.001)

Stand = 0.0947 + 0.0197Space + 0.0277Day Equation 4.9.2

(RSD = 0.137; R-sq(adj) = 14.6%; n = 80; P<0.001)

Sit = 0.0996 + 0.0179Day - 0.00678Space Equation 4.9.3

(RSD = 0.064; R-sq(adj) = 16.8%; n = 80; P<0.001)

Walk = - 0.0378 +0.0276Day + 0.0115Space Equation 4.9.4

(RSD = 0.080; R-sq(adj) = 24.0%; n = 80; P<0.001)

Root = - 0.182 + 0.0437Day + 0.0146Space Equation 4.9.5

(RSD = 0.103; R-sq(adj) = 29.8%; n = 80; P<0.001)

Time block 2 (days 1 to 7 of lactation)

Lying = 1.49 - 0.0169Day - 0.0172Parity - 0.0154Space Equation 4.9.6

(RSD = 0.066; R-sq(adj) = 32.6%; n = 112; P<0.001)

Lying Ventrally = 0.205 + 0.0186Day + 0.0106Space

- 0.00134Weight Equation 4.9.7

(RSD = 0.094; R-sq(adj) = 18.0%; n = 112; P<0.001)

Stand = 0.0425 + 0.0164Day + + 0.0124Space + 0.0158Parity Equation 4.9.8

(RSD = 0.068; R-sq(adj) = 31.3%; n = 112; P<0.001)

Walk = 0.0128 + 0.00999Day + 0.00912Parity

+ 0.00347Number Reared Equation 4.9.9

(RSD = 0.038; R-sq(adj) = 26.7%; n = 112; P<0.001)

Root = 0.161 - 0.0128Day Equation 4.9.10

(RSD = 0.048; R-sq(adj) = 22.0%; n = 112; P<0.001)

Time block 3 (days 8 to 17 of lactation)

Lying Ventrally = 0.719 - 0.0107Weight + 0.0666NReared

+ 0.00935Day + 0.0737Distance from Water - 0.0465Space

- 0.0628Distance from Feeder + 0.0294Parity Equation 4.9.11

(RSD = 0.083; R-sq(adj) = 40.2%; n = 160; P<0.001)

Appendix 4.10 Factors which exerted a significant influence on the variation in frequency of occurrence of activities of group housed sows, during time blocks 1, 2 and 3

Time block 1 (day -5 to onset of parturition)

Lying Ventrally = 62.3 + 4.50Day - 5.48Distance from Feed
- 3.66Space + 3.60Distance from Water — Equation 4.10.1
(RSD = 12.37; R-sq(adj) = 35.9%; n = 80; P<0.001)

Stand = - 8.91 + 12.4Day + 3.36Distance from Water — Equation 4.10.2
(RSD = 22.74; R-sq(adj) = 40.8%; n = 80; P<0.001)

Sit = - 2.26 + 3.35Day — Equation 4.10.3
(RSD = 8.32; R-sq(adj) = 23.8%; n = 80; P<0.001)

Walk = 6.06 + 8.87Day — Equation 4.10.4
(RSD = 17.44; R-sq(adj) = 33.7%; n = 80; P<0.001)

Root = - 55.9 + 11.3Day + 3.39Space — Equation 4.10.5
(RSD = 21.83; R-sq(adj) = 38.0%; n = 80; P<0.001)

Turn = - 16.0 + 10.1Day — Equation 4.10.6
(RSD = 19.33; R-sq(adj) = 34.4%; n = 80; P<0.001)

Time block 2 (days 1 to 7 of lactation)

Lying Ventrally = 11.5 + 2.74Day - 2.67Distance from Feeder
+ 1.49Space — Equation 4.10.7
(RSD = 9.73; R-sq(adj) = 42.0%; n = 112; P<0.001)

Stand = 14.8 + 3.61Day - 2.46Distance from Feeder

- 2.58Social Rank + 1.58Space + 2.18Parity   Equation 4.10.8

(RSD = 14.15; R-sq(adj) = 28.5%; n = 112; P<0.001)

Walk = 8.08 + 3.21Day + 1.47Parity   Equation 4.10.9

(RSD = 11.32; R-sq(adj) = 25.9%; n = 112; P<0.001)

Root = - 20.6 + 3.53Space - 1.25Distance from Water   Equation 4.10.10

(RSD = 8.64; R-sq(adj) = 37.5%; n = 112; P<0.001)

Turn = 12.2 - 1.73Distance from Feeder + 1.35Number Reared   Equation 4.10.11

(RSD = 11.09; R-sq(adj) = 17.1%; n = 112; P<0.001)

Time block 3 (days 8 to 17 of lactation)

Lying Ventrally = 94.6 - 2.547Parity - 6.21Social Rank

- 0.506Weight - 3.77Distance from Feeder + 2.03Distance from Water

+ 0.960Day   Equation 4.10.12

(RSD = 11.19; R-sq(adj) = 42.1%; n = 160; P<0.001)

Sit = 2.57 + 1.26Distance from Feeder - 0.554Parity   Equation 4.10.13

(RSD = 4.67; R-sq(adj) = 19.0%; n = 160; P<0.001)

Root = - 3.99 + 1.59Space - 0.858Parity   Equation 4.10.14

(RSD = 5.87; R-sq(adj) = 34.5%; n = 160; P<0.001)

Appendix 5.1 The mean daily frequency of suckling bouts for individual sows in the L and S pen areas, during days 1 to 7 and 8 to 17 of lactation

Pen area		L		S	
time block		*1 to 7*	*8 to 17*	*1 to 7*	*8 to 17*
Sow	1	37.1	42.0^{c}	52.1^{c}	56.2^{di}
	2	40.3	37.3^{a}	56.4^{e}	57.7^{ej}
	3	39.1	39.6^{b}	52.6^{d}	53.1^{f}
	4	39.0	29.6^{abcdefg}	53.4^{f}	54.8^{g}
	5	41.0	41.1^{e}	39.1^{abcdef}	38.6^{abcdefg}
	6	37.9	39.6^{f}	47.6	46.8^{ahij}
	7	31.7	38.0^{d}	50.0^{a}	55.6^{bh}
	8	42.0	39.3^{g}	50.3^{b}	51.6^{c}
	SE_D	3.21	2.44***	2.99***	2.14***

means followed by the same superscript in the same column differ at $P \leq 0.05$
*** = $P<0.001$

Appendix 5.2 Mean inter-suckling intervals (minutes) for sows in the L and S pen configurations during time blocks 2 and 3

Pen area	*L*		*S*	
Time block	*1 to 7*	*8 to 17*	*1 to 7*	*8 to 17*
Sow 1	40.5^{f}	37.5^{a}	38.9^{ci}	34.6^{ablnoq}
2	39.5^{c}	41.3^{g}	34.8^{agkmn}	36.6^{cdpr}
3	39.7^{d}	39.9^{d}	36.5^{bhl}	40.2^{gio}
4	40.1^{e}	$50.1^{abcdefg}$	40.7^{djn}	40.7^{hjnr}
5	38.0^{a}	38.2^{c}	52.5^{abcdef}	47.7^{bdfijm}
6	41.1^{g}	37.9^{b}	46.5^{ghij}	48.6^{aceghk}
7	$48.8^{abcdefg}$	40.5^{f}	42.5^{fkl}	39.0^{efq}
8	38.8^{b}	40.3^{e}	41.6^{em}	41.5^{klmp}
SE_D	10.7***	11.4***	9.4***	8.3***

means with the same superscript in the same column differ at $P \leq 0.05$
*** = $P<0.001$

Appendix 5.3 Mean number of individual sow and litter suckling terminations in the L and S pen areas, during time blocks 2 and 3

Pen area		*L*		*S*	
		Sow	*Litter*	*Sow*	*Litter*
Time block 2 (days 1 to 7 of lactation)					
Sow	1	18	17	11	41[a]
	2	15	19	15	42[b]
	3	8	22	15	37
	4	12	18	10	43[cd]
	5	15	19	9	30[c]
	6	14	23	10	38
	7	12	18	12	38
	8	9	26	24	27[abd]
	SE_D	3.24	2.97	4.38	3.71***
Time block 3 (days 8 to 17 of lactation)					
Sow	1	20[ab]	17[abc]	24[a]	32[abc]
	2	24[cdef]	10[adef]	33[abcd]	23[ad]
	3	17[cg]	16[dghi]	22[be]	31[ef]
	4	17[dhi]	10[bgjkl]	16[cfg]	39[dghij]
	5	16[ej]	20[ejm]	23	16[begkl]
	6	29[aghjkl]	9[chmno]	18[dhi]	29[hk]
	7	19[km]	16[knp]	27[fh]	28[il]
	8	11[bfilm]	23[filop]	32[egi]	20[cfj]
	SE_D	2.06***	2.19***	3.27***	3.23***

Means in the same column followed by the same superscript differ at $P \leq 0.05$
*** = $P < 0.001$

Appendix 5.4 Factors which exerted a significant influence on the variation in frequency of suckling and of sow and piglet terminated sucklings by group housed sows, during time blocks 1, 2 and 3

Time block 2 (days 1 to 7 of lactation)

Suckling frequency = 55.4 - 1.79Space + 0.490Temperature + 1.07Day — Equation 5.4.1

(RSD = 6.35; R-sq(adj) = 51.2%; n = 112; P<0.001)

Sow terminations = - 14.6 + 1.88Day + 0.242Suckling frequency + 0.750Litter size + 0.431Feeding visits — Equation 5.4.2

(RSD = 5.79; R-sq(adj) = 48.4%; n = 112; P<0.001)

Piglet terminations = 42.2 - 2.37Space - 1.98Day + 0.462Suckling frequency — Equation 5.4.3

(RSD = 6.26; R-sq(adj) = 69.0%; n = 112; P<0.001)

Time block 3 (days 8 to 17 of lactation)

Suckling frequency = 81.8 - 2.48Parity - 0.529Temperature - 0.548Feeding visits - 0.665Feed intake - 1.02Litter size — Equation 5.4.4

(RSD = 8.39; R-sq(adj) = 21.3%; n = 160; P<0.001)

Sow terminations = 37.0 - 1.62Space - 1.44Parity + 0.398Feeding visits + 0.714Litter size — Equation 5.4.5

(RSD = 6.70; R-sq(adj) = 28.5%; n = 160; P<0.001)

$$\text{Piglet terminations} = 64.9 - 2.64\text{Space} - 0.768\text{Feed intake} - 0.612\text{Day} \quad \text{Equation 5.4.6}$$

(RSD = 6.99; R-sq(adj) = 51.3%; n = 160; P<0.001)

Appendix 6.1 The mean number of daily feeding visits made by individual sows in the L and S pen configurations during time blocks 1, 2 and 3

Pen area		L			S	
Time block	*-5 to -1*	*1 to 7*	*8 to 17*	*5 to -1*	*1 to 7*	*8 to 17*
Sow 1	6.6	8.9	10.5^{abg}	7.0	6.7	9.9^{abdfhn}
2	8.8	7.0	4.5^{acdhkn}	6.8	4.3	13.3^{acegio}
3	6.0	4.3	5.3^{beilo}	4.6	3.0	5.4^{bcj}
4	9.2	5.4	8.6^{cfj}	6.8	5.1	4.1^{dek}
5	11.2	9.4	13.0^{def}	4.6	7.1	5.5^{fgl}
6	10.4	7.3	14.6^{ghijmp}	4.4	5.7	6.4^{him}
7	7.8	8.9	10.2^{klm}	5.7	7.4	12.4^{jklmp}
8	6.4	7.9	9.7^{nop}	5.6	5.1	5.4^{nop}
SE_D	2.13	2.23	1.27***	1.34	1.64	1.08***

Means in the same column followed by the same superscript differ at $P \leq 0.05$
*** = $P<0.001$

Appendix 6.2 The mean amount of time invested daily in feeding activity (hours) by individual sows in the L and S pen areas, during time blocks 1, 2 and 3

Pen area		L			S	
Time block	*-5 to -1*	*1 to 7*	*8 to 17*	*5 to -1*	*1 to 7*	*8 to 17*
Sow 1	1.8	1.1	1.9[a]	2.9	1.0	1.5[cfi]
2	2.3	1.0	1.3[bfh]	1.0[a]	0.4[abc]	1.4[adgj]
3	2.2	1.4	1.9[c]	2.3	1.0	1.9[ab]
4	3.4	2.2[a]	3.0[abcdegi]	1.3	1.1	1.3[behk]
5	3.1	2.0	2.0[d]	2.9[a]	2.0[a]	2.2[cdel]
6	2.7	0.8[a]	1.8[e]	2.1	2.0[b]	2.0[fghm]
7	2.6	1.5	2.1[fg]	2.8	1.7[c]	2.2[ijkn]
8	2.9	1.7	2.3[hi]	1.6	1.3	1.5[lmn]
SE_D	0.47	0.37*	0.24***	0.39**	0.33***	0.16***

Means with the same following letter in the same column differ significantly (P<0.05)
* = P<0.05; ** = P<0.01; *** = P<0.001

Appendix 6.3 Factors which exerted a significant influence on the variation in the daily feed intakes, the number of visits to the feeder and the time spent feeding by group housed sows, during time blocks 2 and 3

Time block 2 (days 1 to 7 of lactation)

Feed intake = 10.3 + 1.10Day + 0.260Temperature
- 0.544Space Equation 6.4.1
(RSD = 2.97; R-sq(adj) = 42.2%; n = 112; P<0.001)

Visit number = 4.07 + 1.03Day - 0.189Temperature Equation 6.4.2
(RSD = 3.32; R-sq(adj) = 32.5%; n = 112; P<0.001)

Time feeding = - 688 + 802Day - 161Temperature
+ 463Parity + 607Rank Equation 6.4.3
(RSD = 2086; R-sq(adj) = 48.2%; n = 112; P<0.001)

Time block 3 (days 8 to 17 of lactation)

Feed intake = - 6.87 - 0.289Temperature - 0.601Space
+ 0.396Number Reared + 0.0932Sow weight - 0.651Parity Equation 6.4.4
(RSD = 2.60; R-sq(adj) = 35.2%; n = 160; P<0.001)

Time feeding = 1452 - 87.8Temperature
+ 440Distance from feeder + 693Rank - 233Number Reared Equation 6.4.5
(RSD = 1670; R-sq(adj) = 34.5%; n = 160; P<0.001)

Appendix 7.1 Mean daily frequency of visits to the drinker by individual sows in the L and S pen areas during time blocks 1, 2 and 3

Pen area		L			S	
Time block	*1*	*2*	*3*	*1*	*2*	*3*
Sow 1	16	16	28[abcdefg]	15	11	20[a]
2	19	18	13[a]	9	6	15
3	13	14	17[b]	10	10	14
4	19	10	17[c]	15	12	16
5	14	12	17[d]	14	14	14
6	19	14	20[e]	7	9	14
7	17	11	14[f]	12	11	19[b]
8	14	10	15[g]	12	10	12[ab]
SE_D	19	22	21***	20	18	17***

Means in the same column followed by the same superscript differ at $P \leq 0.05$

*** = $P<0.001$

Appendix 7.2 Mean daily amounts of time (minutes) spent drinking by individual sows in the L and S pen configurations during time blocks 1, 2 and 3

Pen area	L			S		
Time block	*1*	*2*	*3*	*1*	*2*	*3*
Sow 1	23.19	18.45	31.23[abc]	15.33	9.44[a]	27.61
2	22.84	35.33[ab]	18.18[adef]	9.38	9.95[b]	23.73
3	14.33	19.49	33.54[dghi]	12.28	15.54	23.21
4	29.97	22.32	38.46[ejkl]	12.56	21.50	24.73
5	16.92	12.62[a]	16.43[bgjm]	20.60	27.53[ab]	15.60
6	31.03	14.01[b]	17.13[chkn]	12.94	20.59	23.71
7	28.17	17.28	23.40[ilo]	15.37	21.44	26.73
8	20.85	24.23	35.13[fmno]	20.25	20.02	25.62
SE_D	4.56	5.72*	3.49***	3.87	4.50**	5.52

Means in the same column followed by the same superscripts differ at P≤0.05
*** = P<0.001

Appendix 7.3 Mean duration (seconds) of visits to the drinker made by individual sows in the L and S pen areas, during time blocks 1, 2 and 3

Pen area		*L*			*S*	
Time block	*1*	*2*	*3*	*1*	*2*	*3*
Sow 1	58	46	78[a]	48	24[a]	69
2	57	88[abc]	48[bc]	23	25[b]	59
3	36[a]	49	84[de]	31	39	59
4	111[ab]	59	96[bfgh]	39	54	67
5	42[b]	32[a]	41[adfi]	52	69[ab]	46
6	78	35[b]	44[egj]	32	52	59
7	70	43[c]	59[h]	46	54	69
8	52	61	89[cij]	51	50	64
SE_D	76**	64**	65***	45	52***	74

Means in the same column followed by the same superscript differ at P≤0.05
** = P<0.01; *** = P<0.001

Appendix 7.4 Factors which exerted a significant influence on the variation in the number of drinking visits, the time spent drinking and the length of drinking visits of group housed sows, during time blocks 1, 2 and 3

Time block 1 (days -5 to onset of parturition)

Number of visits = - 6.60 + 2.75Day + 1.10Space   Equation 7.4.1

(RSD = 5.53; R-sq(adj) = 39.5%; n = 80; P<0.001)

Time drinking = 0.0062 + 0.00797Day + 0.00319Feed intake + 0.00548Space   Equation 7.4.2

(RSD = 0.024; R-sq(adj) = 36.5%; n = 80; P<0.001)

Visit length = 9.83 + 5.99Distance from water + 6.69Day   Equation 7.4.3

(RSD = 26.59; R-sq(adj) = 27.5%; n = 80; P<0.001)

Time block 2 (days 1 to 7 of lactation)

Number of visits = 0.21 + 0.906Day - 1.37Social rank + 0.642Feed intake + 0.667Space   Equation 7.4.4

(RSD = 4.51; R-sq(adj) = 45.1%; n = 112; P<0.001)

Time drinking = - 0.0112 + 0.00509Feed intake + 0.0053Day + 0.00374Space + 0.00483Parity   Equation 7.4.5

(RSD = 0.030; R-sq(adj) = 47.8%; n = 112; P<0.001)

Visit length = - 18.9 + 3.86Feed intake + 2.49Space + 2.98Parity   Equation 7.4.6

(RSD = 23.39; R-sq(adj) = 32.7%; n = 112; P<0.001)

Time block 3 (days 8 to 17 of lactation)

Time drinking = 0.0983 + 0.00529Distance from water

+ 0.00168Feed intake + 0.00524Social rank - 0.0028Space

+ 0.000337Litter weight   Equation 7.4.7

(RSD = 0.021; R-sq(adj) = 25.3%; n = 160; P<0.001)

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PUBLICATIONS

The Lactating Sow

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Wageningen Pers

17 Behaviour of sows and piglets during lactation

P.H. Brooks and J. Burke

17.1 Introduction

Domestic sows have one function, namely to give birth to piglets and rear them until they have achieved sufficient physiological maturity that they can function successfully, as individuals, independent of their mothers. During the period from late pregnancy through to weaning, the sow exhibits a rich and varied repertoire of behaviours. The way in which the sow interacts with her piglets and responds to her environment has a significant influence on her success in rearing her piglets and on their subsequent growth and development. Lactation behaviour is multidimensional, comprising a complex series of interactions between component behaviours which cumulatively determine the sow's success in nurturing her piglets. The component behaviours and their interactions (summarized in Figure 17.1) are considered in this chapter.

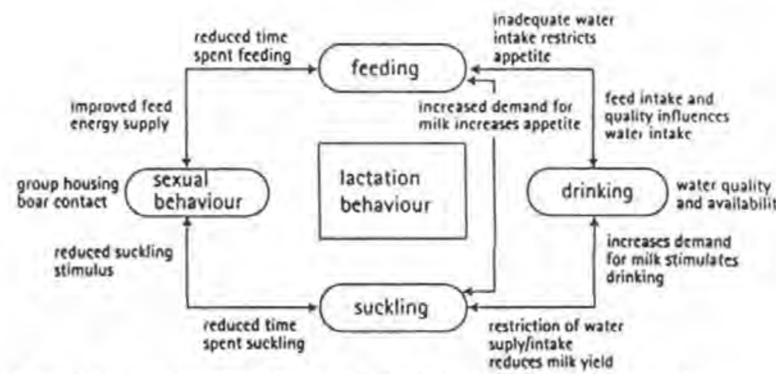

Figure 17.1. The interrelationship of different behaviours during lactation

17.2 Suckling behaviour of sow and piglets

17.2.1 Birth of the piglets

During the 24 hours prior to farrowing sows become increasingly restless. Wild boar sows and domestic sows in semi-natural environments spend much of this time seeking a suitable nest site, collecting vegetation and building an elaborate farrowing nest. In the confinement of a farrowing crate this activity is largely prevented and sows may become increasingly agitated. Attempts to perform nest building movements even when no nesting substrate is provided, frequently result in stereotyped behaviours such as bar biting and pawing (Baxter, 1980; Hansen and Curtis, 1981; Lammers and De Lange, 1986).

As a rule, piglets are born while the sow is in lateral recumbency. This is true of wild boar (Gundlach, 1968), domestic sows in semi-natural conditions (Jensen, 1986a) and sows farrowing in conventional farrowing crate systems (Fraser, 1984). Unlike other ungulates, the sow does not lick the newly born piglets and offers them no assistance in finding the udder (Petersen, Recen and Vestergaard, 1990; Rohde Parfet and Gonyou, 1991). However, wild boar sows and domestic sows in semi-natural conditions are reported to stand and sniff their piglets during farrowing, before turning to lie on the other side (Gundlach, 1968; Jensen, 1986a; Petersen *et al.*, 1990). Randall (1972) noted that sows in farrowing crates and pens got up on several occasions during farrowing.

17.2.2 Suckling development of the neonatal piglet

Location of udder
The development of a regular suckling routine by a litter of piglets follows a distinct pattern (Figure 17.2). Immediately following birth piglets struggle to free their head from birth membranes and upper respiratory tract of fluids (Randall, 1972; Welch and Baxter, 1986). Within minutes of birth young piglets are mobile and begin to make their way towards the udder of the sow. If not already severed during birth, the umbilical cord is broken at this stage, easing progress as piglets nose and nuzzle along the body of the sow. Occasionally piglets travel around the back of the sow, but more usually climb over or push between the hind legs to reach the udder (Welch *et al.*, 1986; Petersen *et al.*, 1990).

Teat seeking
Having reached the vicinity of the udder, the teat seeking phase of suckling development begins (Hartstock *et al.*, 1976). It appears that although piglets are born with their eyes open, they do not search visually for a teat. They will often pass very close to a teat without appreciating its presence (Randall, 1972; Hartstock *et al.*, 1976). Nosing and nuzzling intensify as developing suckling movements are directed towards the surface of the udder. Barber (1955) noted that during this exploratory phase piglets had some nose contacts with the sow. In the majority of cases, the first nose to nose contact between piglet and sow occurred before any suckling began (Petersen *et al.*, 1990).

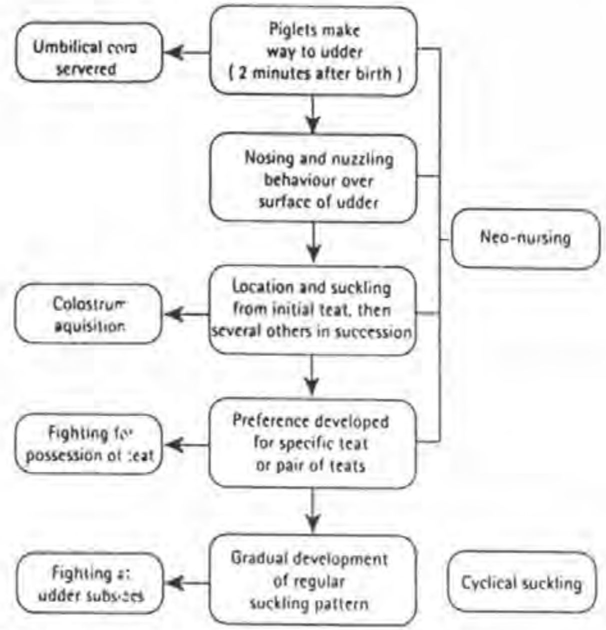

Figure 17.2. The development of nursing behaviour in piglets

Teat sampling
Once piglets establish contact and suckle from a teat they move along the udder, suckling from several teats in succession (Randall, 1972; Petersen *et al.*, 1990). Hartstock (1976) classified this behaviour, occurring at between 2 and 6 hours after parturition, as the teat sampling phase of suckling development. It is suggested that during this phase, the first fights at the udder occur as piglets compete with their littermates for possession of teats (Hartstock *et al.*, 1976; Petersen *et al.*, 1990). More recently De Passille (1989b) reported that piglets suckled from 2 to 13 teats during the first 8 hours after birth and that those suckling high numbers of teats had more agonistic interactions with litter mates. In sharp contrast, Rosillon-Warnier (1984) reported that no agonistic behaviour between piglets occurred during teat-order establishment.

Colostrum aquisition
The energy reserves of newborn piglets, in the form of liver glycogen, are rapidly depleted after birth, leaving piglets highly susceptible to chilling, hypoglycaemia, weakness and death from crushing by the sow (Dividich and Noblet, 1981; Moser, 1983). In addition, the neonatal piglet has only low levels of immunoglobulins

for protection from disease (De Passille, Rushen & Pellether, 1988). Colostrum is the source of dietary energy which also contains immunoglobulins which can be absorbed intestinally by piglets for up to 36 hours after birth, prior to 'gut closure' (Hartstock & Graves, 1976; De Passille et al., 1988). The speedy acquisition of colostrum by the piglet soon after birth is therefore essential to provide the energy and antibody protection necessary for survival. During farrowing and in the first few hours of lactation colostrum may be expressed relatively easily from the sow's teats. However, Fraser (1984) demonstrated that after 15 minutes yield declined sharply, after which colostrum could be collected during discrete ejections lasting 1 to 4 minutes, occurring every 5 to 30 minutes, depending upon the stimulation received by the sow. More recently Castren (1993) demonstrated that discrete milk ejections during parturition and 4 hours post partum, frequently occurred in the absence of oxytocin peaks. However, it was pointed out that at this time basal oxytocin concentrations may be high enough for milk ejection to occur without further secretion of the hormone.

During this time the sow emits rhythmical grunting sounds which increase in rate at intervals during the first 5 hours post partum (Castren *et al.*, 1989b). An investigation conducted by Castren (1993) demonstrated that both oxytocin secretion and milk ejection must occur to induce an increased grunting rate by the sow.

The teat sampling phase of suckling is the first opportunity for piglets to obtain the colostrum, essential for their survival and fitness. As farrowing typically lasts for 3 to 4 hours, earlier born piglets have a greater opportunity to benefit from the energy and immunoglobulins contained in colostrum than their later born littermates (Graves, 1984). According to De Passille et al. (1988) piglets which suckled earlier, suckled from several teats, won more teat disputes and had the highest within litter immunoglobulin levels, whereas later born piglets had much lower antibody protection.

Teat order establishment

According to Lewis (1985) this early period is a distinct phase of 'neo-nursing', during which individual piglet activity gradually polarises towards specific areas of the udder as their teat preferences become better established. Once a definite teat order for suckling has developed, piglets generally suckle from the same teat or pair of teats throughout lactation (McBride, 1963; De Passille *et al.*, 1989b). During this teat defence phase, aggressive encounters become limited to piglets occupying neighbouring teats (Hartstock *et al.*, 1976). It is generally presumed that the anterior teats are claimed by the stronger more vigorous piglets, however there is little evidence to support this. Barber (1955) suggested that the heavier, earlier born piglets fight for possession of the anterior teats. Hartstock (1977) claimed that as these teats are more productive, they were defended by the more successful, heavier fighters which achieved greater early weight gains. However, De Passille *et al.* (1989b) considered there was little evidence that piglets fought specifically for anterior teats or that heavier piglets had greater access to them. In addition, Rosillon-Warnier (1984) found that although there was a tendency for piglets suckling the first four teats to have slightly higher weight gains, birth weight and birth order had no effect on teat-order. Studies conducted by Fraser (1979b) demonstrated that piglet growth was influenced by the relative weight of littermates and not by the position of the teat suckled. There is evidence which suggests that piglet weight gain, dependent on milk intake, is influenced by the power of the piglet to suckle (Fraser & Thompson, 1979a; King *et al.*, 1997).

Transition from neo-nursing to cyclical nursing

As teat ownership becomes established, the incidence of fighting reduces and a regular suckling pattern develops, which Hartstock (1976) classified as the teat maintenance phase. This change in suckling behaviour signals the transition from 'neo-nursing' to more regular, synchronised or 'cyclical' bouts of nursing (Lewis *et al.*, 1985). The same author claims this transition occurs 10.7 ± 4.5 hours after parturition, whilst Castren *et al.* (1989b) and Rosillon-Warnier *et al.* (1984) state that the change begins to occur from 5 and 3 hours after birth, respectively. More recently De Passille *et al.* (1989b) concluded that although the estimate of Lewis *et al.* (1985) might be the more realistic, the change was a gradual one so that no definite point in time when continuous suckling gave way to regular, synchronised bouts of suckling could be identified.

17.2.3 Suckling frequency

Once cyclical suckling has been established, nursings involving all or most of the litter occur at regular intervals throughout lactation (Table 17.1). According to Schouten (1986), piglets spent approximately 30% of their time engaged in suckling behaviour during the first two weeks of lactation. Thereafter suckling activity decreased over time, occupying only 15% of time when piglets were six weeks of age.

Table 17.1. Mean intra-suckling intervals reported in the literature

Interval (minutes)	Day of lactation	Reference
48 to 52	10 to 24	(Auldist & King, 1995)
76	3	(Spinka *et al.*, 1997)
52 (range 42 to 68)	14 to 5	(Wechsler & Brodmann, 1996)
44 (range 21 to 92)	7 to 28	(Ellendorf *et al.*, 1982)
51 and 63 (range 26 to 96)	6 and 51	(Barber *et al.*, 1955)
29 to 78	1 to 42	(Newberry & Wood-Gush ,1984)
40 to 45	1 to 13	(Arey & Sancha 1996)

The milk yield of the sow is influenced by litter size, piglet liveweight and suckling demand (Auldist *et al.*, 1995; King *et al.*, 1997). The more frequent the opportunities for piglets to suckle, the higher their milk intake and subsequent liveweight gain over lactation (Barber *et al.*, 1955; Newberry *et al.*, 1984; Spinka *et al.*, 1997). The results of studies of the effect of nursing frequency on piglet weight gain and sow milk yield are summarised in Table 17.2.

Table 17.2. The effect of nursing frequency on sow milk yield and piglet weight gain

Nursing frequency per 24 hours	Sow milk yield	Piglet weight	Reference
8	241g/24hrs	–	(Barber *et al.*, 1955)
9.6	304g/24hrs	–	"
24	553g/24hrs	–	"
25.25	5.07kg/21days	39 (21 days)	(Mabry *et al.*, 1983)
30.75	6.07kg/21days	44.8 (21 days)	"
20.2	595g/24hrs	135g/24hrs	(Spinka *et al.*, 1997)
33.9	755g/24hrs	198g/24hrs	"

Suckling frequency may be increased by exposure to an extended photoperiod (Mabry *et al.*, 1983) and by auditory stimuli (Auldist *et al.*, 1995). Indeed, studies conducted by Wechsler (1996) revealed that nursing bouts could be stimulated by playback of sounds made by sows and piglets during suckling. Similarly, Newberry (1984) suggested that sows responded to the suckling vocalisations of each other, resulting in synchrony of sucklings within the sow group. An investigation conducted by Algers (1985) indicated that high levels of continuous noise, such as that emanating from ventilation fans, affected communication between sow and piglets. As a result, suckling routines were disrupted, leading to lower milk yields and reduced piglet weight gains.

17.2.4 Sow and piglet behaviour during suckling

The nursing and suckling behaviour of the pig is complex and consists of several distinct phases (Whittemore & Fraser, 1974; Fraser, 1980; Algers *et al.*, 1985) (Figure 17.3). Initial observations distinguished four distinct suckling phases of udder nosing, quiet interval, milk ejection phase and renewal of udder nosing (Barber *et al.*, 1955). Following further studies, Whittemore (1974) described five phases of suckling behaviour, beginning with a phase of jostling for teats,

followed by a phase of nosing the udder, then a phase of quiet suckling with slow mouth movements of high amplitude, a phase of sucking with rapid mouth movements of lower amplitude and finally a further phase of slow sucking and nosing of the udder.

Piglet vocalisations and repeated gruntings from the sow accompany these phases of suckling and play an important role in the interaction between sow and litter (Algers *et al.*, 1985). The grunting of the sow follows a distinct pattern related to the suckling behaviour of the piglets, oxytocin release and milk letdown (Whittemore *et al.*, 1974; Fraser, 1980; Ellendorf *et al.*, 1982; Algers *et al.*, 1990b).

Figure 17.3. The sequence of behaviours of sow and piglet during nursing

Sucklings may be initiated by either the sow grunting to alert her litter and attract them to her udder or by the piglets congregating around the sow, squealing and massaging the udder (Fraser, 1980; Ellendorf *et al.*, 1982; Lewis and Hurnik, 1986; Castren *et al.*, 1989b). At this point the sow will generally lie on one side with both rows of teats exposed as the nursing bout begins. Once piglets assemble at the udder and perform the udder nosing phase of suckling, the sow begins rhythmic grunting, at a rate of about 1 grunt per second. After about one minute a sharp increase in sow grunting rate occurs, which coincides with the onset of slow sucking by the piglets and the release of the hormone, oxytocin into the blood stream (Fraser, 1980; Algers *et al.*, 1990b). According to Ellendorf (1982) a rise in intra-mammary pressure occurs approximately 23 seconds after the onset of fast grunting by the sow. The timing of this rise in intra-mammary pressure corresponds to the 25 second circulation time reported for oxytocin and results in milk ejection (Fraser, 1980; Algers *et al.*, 1990b).

The start of the rapid sucking phase of piglet suckling behaviour, occurring 25 to 30 seconds after the increase in sow grunting rate, also coincides with milk ejection (Whittemore *et al.*, 1974; Fraser, 1980).

Milk is only available to piglets for between 10 and 20 seconds (Barber *et al.*, 1955; Whittemore *et al.*, 1974; Fraser, 1980), corresponding to the duration of the rise in intra-mammary pressure (Ellendorf *et al.*, 1982). Once the pressure subsides, the milk supply ceases as the mammary glands of the sow have no teat cistern for storing milk (De Passille *et al.*, 1989b). Once milk flow ceases, the rapid sucking of piglets immediately stops, to be replaced by the final period of udder massage, whilst sow grunting gradually subsides (Fraser, 1980). The whole sequence of suckling behaviours may last for no more than 2 to 3 minutes (Fraser, 1980).

The nose to nose contacts made between sow and piglet prior to initial sucklings immediately after birth continue during later more established sucklings. However, the number of pre-suckling contacts reduces during days 1 and 2 after birth, to be largely replaced by contacts which increasingly occur after the cessation of milk flow (Whatson and Bertram, 1982; Jensen, Stangel and Algers, 1991). This mainly piglet initiated behaviour is the only reciprocal interaction which occurs between sow and piglets and is considered to play an important part in the establishment and maintenance of close social bonds between sow and piglets (Whatson *et al.*, 1982; Petersen *et al.*, 1990).

17.2.5 Incomplete nursings

Studies conducted by Whittemore (1974) revealed that when the sow grunt rate did not increase, the rapid sucking phase of suckling did not follow and milk ejection did not occur. These incomplete nursings are a relatively common occurrence (Whittemore *et al.*, 1974) and have been reported for domestic sows in

semi-natural surroundings (Newberry *et al.*, 1984; Castren, Algers and Jensen, 1989a; Jensen *et al.*, 1991) and in sows in conventional farrowing accommodation (Whatson and Bertram 1980). There was concern that, as the mean interval between two successful sucklings was shorter than that between two successful sucklings separated by one or more unsuccessful suckling, frequent unsuccessful nursings might reduce overall milk intake and decrease piglet growth rates (Newberry *et al.*, 1984; Castren *et al.*, 1989a).

It was postulated that sounds of nursing by other sows might cause premature nursing in others, housed in the same room. However, Whatson (1980) found no difference in frequency of incomplete nursings in groups of sows housed in individual pens with farrowing crates and single sows housed in isolation in individual loose pens. In contrast, Arey *et al.* (1996) reported that sows in the family pen system had fewer false nursings than sows in farrowing crates. Incomplete nursings were most common during week 2 of lactation and accounted for 27% of all suckling bouts (Whatson *et al.*, 1980). Unsuccessful sucklings in sows kept in semi-natural conditions were most frequent during days 1 to 5 post partum, accounting for 30.5% of all sucklings, before decreasing to 23.4% during days 6 to 10 of lactation (Jensen *et al.*, 1991). This is in accordance with findings of Newberry (1984) who reported a mean of 22.6% unsuccessful sucklings over a 10 week period and results of Castren (1989a) who found that milk ejection failed in 31% of sucklings during the first 3 days post partum in sows kept in a semi-natural enclosure.

It was noted that sows which had recently suckled would start a subsequent suckling bout in synchrony with another sow, even though she was unlikely to let down milk (Newberry *et al.*, 1984). The same author suggests that, notwithstanding the number of unsuccessful sucklings and their effect of increasing the interval between successful sucklings, social stimulation in farrowing houses promotes increased milk production and piglet weight gain, by initiating an overall increase in the frequency of suckling bouts. Unsuccessful sucklings are considered to be part of the natural behaviour of pigs and not caused specifically by intensive housing systems (Castren *et al.*, 1989a).

17.2.6 Changes in nursing behaviour over time

Sows in group farrowing systems tended to stay inside the farrowing enclosure with their piglets during the night and spent time away from their litters during the day (Boe ,1993). The same author found that sows spent increasing amounts of time lying sternally, during weeks 2 and 3 of lactation. Sows in farrowing crates were also observed to increase sternal lying time over a 27 day lactation (De Passille and Robert, 1989a). The frequency of sternal lying was greater during the day time than at night, when more time was spent in lateral recumbency (De Passille *et al.*, 1989a).

At first, sucklings were initiated by the sow with the piglets taking a passive role, but as they grew older, more and more sucklings were begun by piglet stimulation (Jensen *et al.*, 1991). During the first week of lactation the number of sucklings terminated by sows in a semi-natural environment gradually rose from less than 5% to 60% of sucklings (Jensen *et al.*, 1991). According to Jensen (1988), the number of suckling terminations by free-ranging sows had increased to 90% by the fourth week of lactation. Suckling terminations by sows in indoor group farrowing systems followed a similar pattern (Boe, 1993; Burke, J. unpublished data). The number of sow and piglet suckling terminations which occurred daily, from day 1 to day 17 of lactation in a group farrowing system are presented in Figure 17.4. The time spent foraging by free-ranging sows increased between weeks 1 and 4, whilst the time spent lying decreased along with the frequency of sucklings (Jensen, 1988). The same author noted that piglets reduced the time spent nosing and massaging the udder, following milk ejection, during weeks 1 to 4 of lactation. The percentage of sucklings with piglets missing increased over time, from 1.8% in week 1 to 7.8% in week 4 (Jensen, 1988).

In the Edinburgh family pen system, pigs are able to carry out more normal patterns of behaviour and form normal social groups (Arey *et al*, 1996). In this system, sows began to suckle their piglets outside the farrowing area, at between 10 and 14 days postpartum.

In contrast, sows in a fully integrated, group farrowing system, in which piglets were confined to the farrowing enclosure, reduced the time spent with their piglets from over 90% during the first week of lactation, to only 58% of each 24 hour period in week 2 (Boe, 1993). By week 3, this had reduced further to a mere 17.1% of the day. Houwers (1992) also found that sows in a free access farrowing

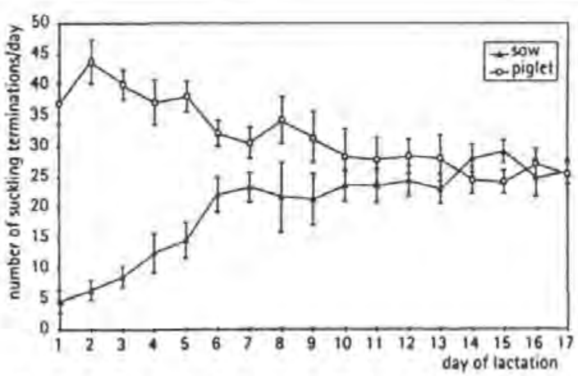

Figure 17.4. Sow and piglet nursing terminations from day 1 to day 17 of lactation in a group farrowing system (error bars denote SEM) (Burke, J. unpublished

system gradually increased the amount of time away from their litters and reduced the number of sucklings, over lactation. In a natural situation the sow and piglets would leave the farrowing site approximately 10 days post-partum and join other sows and litters (Jensen and Redbo, 1987). Sow behaviour in the family system was similar to that of free-ranging sows which abandon the farrowing nest when piglets were about 10 days of age. The reduction in time sows spent with their piglets which were confined to the farrowing enclosure, also coincided with the time when sows and litters would leave the farrowing nest and re-join the herd. As the confined piglets were unable to follow the sow, her interest in them declined, resulting in weaning before 3 weeks of age in some instances (Boe, 1994).

17.2.7 Reasons for suckling behaviour development

Parturition in the sow may take between 1 and 5 hours (Whittemore, 1993). The physiology of the sow ensures that colostrum is freely available from before farrowing onset and for several hours afterwards. All newborn piglets have an opportunity to find their way to the udder and acquire energy and disease protection so essential for survival (Fraser, 1980). It is hypothesised that the period of neo-nursing may allow learned responses to develop in the piglets, preparing them for the more advanced cyclical nursing which follows (Lewis *et al.*, 1985). According to McBride (1963), Fraser (1980) and Whittemore (1993), the formation of a teat order may promote orderly feeding and eliminate competition between piglets when feeding. It is also suggested that as sows in natural conditions farrow in isolation, the establishment of a teat order would ensure that milk is only produced in teats regularly used by that particular litter, thus reducing opportunities for intruder piglets to suckle (Newberry *et al.*, 1984; Jensen, 1986a).

Piglets of up to 14 days of age were found to move towards the sound of sow nursing vocalisations, which are an important cue for milk release, regardless of their level of hunger (Lewis *et al.*, 1986). It was hypothesised that this response maintained contiguity of the litter and was the method by which sucklings were initiated by the sow (Lewis *et al.*, 1986) and piglet behaviour during suckling was synchronised (Castren *et al.*, 1989b).

The prolonged period of udder massage performed by piglets and the grunting sounds emitted by the sow at the start of a suckling bout give every member of the litter a chance to find a place at the udder before the short period of milk ejection occurs (Fraser ,1980; Algers *et al.*, 1990b). However, this does not mean that all piglets need be assembled at the udder for milk ejection to occur, as if this was the case, all piglets would suffer if nursing did not proceed due to the absence of one litter member, which might have died (Newberry *et al.*, 1984).

The slow sucking phase of nursing behaviour may serve to position piglets (Fraser, 1980), following a change in sow grunting rate, in readiness for the short milk ejection which follows (Algers *et al.*, 1985).

The 'restaurant hypothesis' was suggested by Algers (1985) to explain the function of the final udder massage. This means that by spending more or less time massaging their particular teat, the blood flow through that teat and subsequent milk production are stimulated, so that in effect, piglets order the size of their next meal (Algers *et al.*, 1985). This stimulation effect appeared to be greatest during the first few days of lactation, after which the teat order stabilised (Rosillon-Warnier *et al.*, 1984) and milk production adjusted to individual piglet requirements (Jensen *et al.*, 1991). More recently Spinka (1995) concluded that although nursings on day 3, which were preceded by sucklings with longer final massage times, produced more milk, there was still no firm evidence to support the 'restaurant hypothesis'.

It is possible that the synchrony of sucklings among groups of sows and litters, whether in free-ranging conditions or in a conventional farrowing house, might be an adaptation to minimise the incidence of cross suckling (Newberry *et al.*, 1984; Wechsler *et al.*, 1996).

The changes in nursing behaviour of sows and piglets during lactation are linked to a gradual process of weaning which begins around 10 days post partum (Jensen and Recen, 1989). This timing coincides with when sows and piglets in a natural environment vacate the farrowing nest (Jensen, 1988). According to Jensen (1987), the piglets change from being hiders -remaining in the place where they were born, to become followers - keeping in close contact with the mother when she moves. The 'fast food hypothesis' was proposed by Jensen (1989) to explain the process of weaning. They suggest that by terminating more sucklings and shortening the time for final udder massage, which may decrease the amount of milk produced over time, the sow reduces the benefit of suckling. In addition, the cost of obtaining milk was gradually increased by the sow as she initiated fewer sucklings, increased the pre-massage time and made final massage difficult to perform.

As this process continues, piglets' dependence on milk reduces and they increase their intake of solid food until weaning in a natural environment is completed by around 17 weeks of age (Jensen *et al.*, 1989; Petersen, 1994).

17.3 Sow and piglet activities not directly associated with suckling

17.3.1 Exploratory behaviour of piglets

Over the first 8 weeks of piglet life the amount of time spent suckling decreases to be replaced by a rapid increase in exploratory behaviour, including sniffing of objects and substrate, chewing, biting, rooting, walking and standing (Schouten, 1986; Petersen, 1994). Piglets in a semi-natural environment were engaged in these activities for 40% of the time during the nest occupation phase, after which activity increased (Petersen, 1994). The amount of exploration carried out may be influenced by the quality of the environment in which pigs are kept. Pigs in straw bedded pens spent 44% of time exploring compared with only 24.9% of time for pigs reared in a farrowing crate pen with no bedding substrate (Schouten, 1986).

Walking and standing occurred during week 1 and increased from nest leaving time to week 8 in free-ranging piglets (Petersen, 1994), whereas in piglets in straw-bedded pens and crates, locomotion gradually decreased over this time (Schouten, 1986). This difference may have been an effect of reduced interest in surroundings as the novelty value diminished over time in housed pigs, whilst free-ranging animals continued to receive stimulation from a changing environment.

Rooting behaviour began in the first week of life, and increased in frequency over subsequent weeks (Schouten, 1986; Petersen, 1994). Chewing, present from the first week of life, was considered to be an important behaviour, as piglets in straw bedded pens spent up to 20% of their time in the activity by week 4 (Schouten, 1986). Piglets in natural conditions chewed earth and other objects from the first week of life, and gradually increased time spent chewing to week 4, after which grazing behaviour began (Petersen, 1994). According to Petersen (1994), piglets learn to identify food sources, whilst involved in these investigative behaviours, so that they are prepared for the time when nutritional requirements must come from the wider environment.

17.3.2 Social interactions between littermates and sow

Physical interactions

Social behaviour amongst piglets, which included nosing between piglets, considered to be important for individual recognition, decreased with age (Schouten, 1986). Nibbling and massaging of littermates was higher in crate piglets than those in straw bedded pens (Schouten, 1986). These behaviours did not occur in free-ranging piglets (Petersen, 1994). After suckling, the sow in a semi-natural environment, would move off to resume foraging while the piglets foraged, rested or played close by (Newberry *et al.*, 1984; Stangel and Jensen, 1991). Sows housed in farrowing crates and straw bedded pens were the focus of attention by piglets, whose nosing and nibbling resulted in sows standing for many hours (Whatson *et al.*, 1982). According to Schouten (1986) and Arey (1996), nibbling and massaging of the sow continued for longer in farrowing crates than in straw bedded pens, whereas Whatson (1982) concluded that there was no difference in this behaviour between the two types of environment. Observations of De Passille (1989a) demonstrated that sows in farrowing crates use postural changes including increased sitting, standing and sternal lying to limit piglet access to the udder and other vulnerable body parts. It is suggested that the well-being of confined sows may suffer as a result of a reduction in the quality and total duration of resting time (De Passille *et al.*, 1989a; Arey *et al.*, 1996) and that the amount of irritating interactions between sow and piglets might be reduced with the provision of alternative forms of stimulation for the piglets (Whatson *et al.*, 1982).

Piglet vocalisations

Piglets have a well developed auditory discrimination and a substantial repertoire of vocal communication (Rohde Parfet *et al.*, 1991; Horrell and Hodgson, 1992). Jensen (1983/84) identified five different classes of piglet vocalisations related to suckling behaviour. According to Jensen (1983/84), piglets make croaking sounds most frequently at the beginning of nursing. Other vocalisations include the scream and the squeak, both associated with aggressive interactions, and deep and high grunts which were uttered throughout nursing (Jensen *et al.*, 1983/84).

Suckling piglets vocalise a great deal when isolated from the sow and their littermates and the sow vocalises when separated from her litter (Weary *et al.*, 1997). Weary (1995) demonstrated that the extent of calling made by isolated piglets varied according to their level of need as small, slow growing piglets and those which missed a suckling bout called more, using longer, higher pitched sounds than large, faster growing piglets and those which had just suckled. There were similar differences in vocal behaviour between piglets isolated in an enclosure at 14°C and piglets isolated at 30°C (Weary *et al.*, 1997). Sows responded to piglet calls by vocalising and approaching the source of the sounds (Weary *et al.*,1995), showing a stronger response to playback sounds from more needy piglets than from less needy piglets by vocalising more, moving more and spending more time near the playback speaker (Weary, Lawson and Thompson, 1996). As piglet isolation calls provide reliable information about the young animal's needs, they might be used as an indicator of welfare (Weary *et al.*, 1995; Weary *et al.*, 1997). However, Horrell (1992) found no evidence to suggest that sows could discriminate between vocalisations of their own piglets and those of others. In support of these findings, Gundlach (1968) reported that if a wild boar piglet was threatened, its squeals brought other sows with young in the vicinity, to its defence.

There is evidence to suggest an effect of the farrowing environment on maternal behaviour of the sow (Cronin and van Amerongen, 1991; Arey *et al.*, 1996;

Herskin, Jensen and Thodberg, 1997). Sows confined in a farrowing crate covered with hessian cloth and bedded with chopped straw prior to parturition, were more responsive to piglet vocalisations than sows in unmodified crates without bedding (Cronin *et al.*, 1991). Herskin *et al.*, (1997) demonstrated that sows in 'get away' farrowing pens, provided with sand substrate for bedding, were more responsive to piglet distress calls and spent more time in the farrowing enclosure during days 1 to 12 post partum than sows on bare concrete. A greater proportion of sows provided with both straw and sand bedding responded to playback of piglet distress calls by standing, compared with those without environmental stimuli (Herskin *et al.*, 1997). Similarly, Arey (1996) reported that sows in the family pen system stood more frequently in response to the playback of piglet squeals than sows in farrowing crates.

17.3.3 Behaviours affected by the environment

Excretory behaviour

Free-ranging sows leave the farrowing nest to eliminate, whereas sows in farrowing pens are forced to soil the area in which they farrow (Stangel *et al.*, 1991). Stangel (1991) suggested this restriction may be stressful for sows in intensive units. Free-ranging sows have been observed to clean the nest of piglet faeces and afterbirth during the first days after farrowing (Stangel *et al.*, 1991). It was suggested that this behaviour decreased the risk of infections, improved insulation properties of the nest (Stangel *et al.*, 1991) and reduced the chance of attracting predators to the area (Graves, 1984). Sows housed in straw bedded pens were observed to lick up piglet faeces from the floor of the pen, during the first 7 days post partum, whereas sows in farrowing crates were unable to perform these cleaning operations (Whatson *et al.*, 1982).

From about 4 days of age free-ranging domestic piglets and wild boar piglets left the birth place to eliminate, moving further away as they grew older (Buchenauer, Luft and Grauvogl, 1982, 1983; Stangel *et al.*, 1991). Buchenauer (1982, 1983) observed that piglets in farrowing pens began to eliminate in a more specific part of the pen from day 4 onwards, preferring to do so on straw bedding than on bare concrete and frequently close to the walls. Piglets born in farrowing crates, only soiled the creep area during the first 2 days of life, after which they excreted mainly in corners and close to the wall (Petherick, 1982).

Thermo-regulatory behaviour

Domestic breeds of neonatal piglets chill rapidly as they have low energy reserves, sparse pelage and a poorly developed subcutaneous adipose layer which provides only minimal insulation (Dividich *et al.*, 1981). The lower critical temperature of the neo-natal piglet is around 32°C (Whittemore, 1993). Hypothermic piglets become lethargic and may not suckle successfully (Edwards *et al.*, 1994). These piglets are more susceptible to disease and to crushing by the sow. Up to

30% of all piglets alive at parturition do not survive until weaning (Edwards and Furniss, 1988). The majority of these perish within the first three days after birth (Dividich *et al.*, 1981).

Neonatal wild piglets and domestic piglets in semi-natural environments have been observed to huddle together, close to the sow, for warmth, during the initial days of life (Gundlach, 1968; Algers and Jensen, 1990a; Stangel *et al.*, 1991). Whilst huddled together, piglets moved from time to time, so that no individual stayed on the top or outside of the heap for more than a few minutes (Algers *et al.*, 1990a). Welch (1986) demonstrated that newborn piglets were attracted by a combination of warmth and softness, characteristics possessed by the udder of the sow. The same author described how the surface of the udder rose in temperature by 3°C around parturition, resulting in a skin temperature of 36-37°C in the region of the teats. It is believed that as piglets lie close to the sow during the first days post partum, the risk of death by crushing is increased. In most commercial farrowing systems newborn piglet survival is aided by the provision of a protected, heated creep area for the piglets, which often incorporates some form of insulated flooring material. However, attempts to induce piglets to lie in heated creep areas were unsuccessful in attracting the newborn away from the sow before 3 days of age (Rohde Parfet *et al.*, 1991). Arey (1996) suggests that the lower ambient temperature in the family pen system resulted in increased use of the creep area by piglets in the family system, compared with piglets in a farrowing crate system.

In cold conditions newborn piglets were less active than piglets in warm housing and huddled together, shivering and altering posture to reduce the amount of body contact with the floor (Dividich *et al.*, 1981). The intake of colostrum by neonatal piglets exposed to cold, for short periods of time, was markedly reduced (Dividich *et al.*, 1981). As a result these piglets were more susceptible to disease, hypothermia and death. The provision of straw will reduce conductive heat loss to the floor. Using the relationship between O_2 consumption of new born piglets and the ambient temperature, Stephens (1971) demonstrated that a straw covered floor at 10°C was equivalent to a concrete floor at 18°C in terms of thermal demand upon the piglet. This benefit was revealed by placing piglets on top of the straw and could reasonably be expected to be greater if piglets were covered by straw as would occur in a nest constructed by a sow.

Algers (1990a) investigated the thermal microclimate within the nests of free ranging domestic pigs during a Scandinavian winter. The nest structures and lining materials afforded considerable protection for the young piglets against the outside climate. The results of the study revealed that when outside temperatures averaged -1.5°C, temperatures inside the nests, 5 cm from the piglets, averaged 20.3°C. It is suggested that the nest material acts as insulation against the outside cold, retaining the heat generated by the sow and piglets, enabling them to maintain a suitable microclimate within the nest.

17.4 Feeding Behaviour

Although the nutritional requirements of the lactating sow have been extensively researched, feeding and drinking behaviour have received much less attention. As a consequence, at farm level, there are often failures to translate nutritional recommendations into satisfactory production practices.

The voluntary feed intake of the animal is the cumulative expression of the sow's physiological and biochemical requirements, moderated by feeding and drinking behaviour. Subtle changes in the feeding and drinking behaviour of the sow can significantly modify nutrient intake and thus negate advances that have been made in our understanding of the sows nutrient requirements. A number of factors interact to influence individual sow feed intakes and feeding strategies (Figure 17.5).

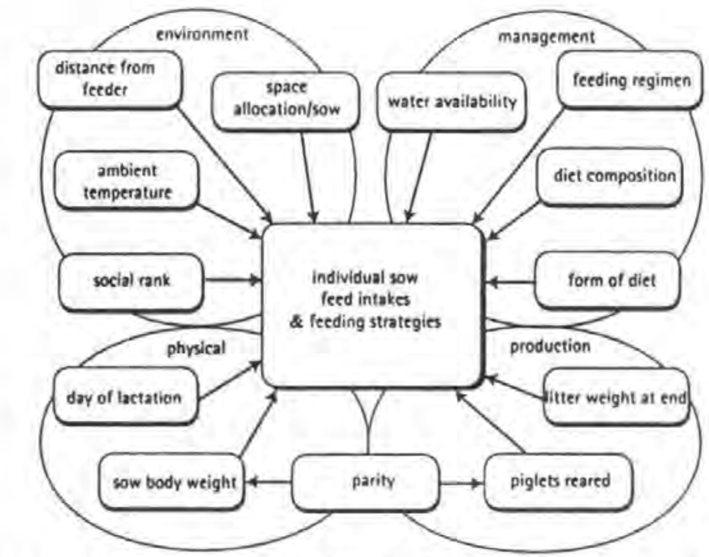

Figure 17.5. Factors influencing individual sow feed intakes and feeding strategies

In this section we consider how the major influences affect voluntary feed intake and where there is information indicate how these operate through the modification of feeding behaviour and feeding strategies.

17.4.1 Feeding strategies

In considering feeding strategies it is necessary to make a distinction between the foraging behaviour (activities associated with finding food) and feeding behaviour (the consumption of readily available food). A study of groups of lactating wild boar sows in a 1 hectare enclosure indicated that they spent between 24.8% and 59.1% of their time foraging and feeding, respectively (Teilland, 1986). Similarly, Mauget (1981) reported that wild boar spend 25.2% of their time foraging and feeding, although the proportion may reduce considerably when food is plentiful. De Passille *et al.* (19[illegible]) found that sows spent 5.5% of their time feeding on Day 17 (1.32h) of lactation and 4.0% (0.96h) on Day 27. They spent respectively 8.2% of the light period (15h) and 1.3% of the dark period feeding. In recent studies of group housed lactating sows, fed using a sow operated feed dispenser, sows spent 1.3 to 2.0 hours per day feeding (Burke *et al.*, 1997) (Table 17.3).

Table 17.3. The mean ±SEM daily feed intake, number of visits to the feeder per day and time spent feeding per day by farrowing and lactating sows in two different pen areas (Burke et al., 1997)

Area/sow	13.4m²/sow			8.6m²/sow		
Time period(days)	-5 to -1	1 to 7	8 to 17	5 to -1	1 to 7	8 to 17
intake/day(kg)	6.9 ± 0.42	5.8 ±0.46	9.0 ±0.35	6.8 ±0.54	6.8 ±0.58	8.4 ±0.40
visits/day	8.3[1] ±0.68	7.4[2] ±0.60	9.5[3] ±0.45	5.5[1] ±0.45	5.6[2] ±0.45	8.0[3] ±0.46
time/day(hrs)	2.6[4] ±0.16	1.5 ±0.11	2.0[5] ±0.07	2.1[4] ±0.17	1.3 ±0.11	1.7[5] ±0.05

pairs of means with the same following letter in the same row differ at [1]=$P<0.001$; [2]=$P<0.05$; [3]=$P<0.05$; [4]=$P<0.05$; [5]=$P<0.001$

When feed is presented in discrete meals the time spent consuming feed may be quite low. Blackshaw *et al.*, (1994) found that sows given two feeds per day spent 19.0±4.6 minutes eating in the morning and 13.6±1.1 minutes in the afternoon. Martin *et al.* (1994) found that gestating domestic sows fed outdoors took an average of 18.1 minutes to consume their diet when it was spread on the ground. In outdoor sow systems social rank may be important in determining the sow's

success in obtaining an adequate feed supply. High ranking sows appropriate areas of high food density and defend the area aggressively against lower ranking individuals (Csermely *et al.*,1990). However, Martin *et al.* (1994) concluded from their studies that when feed distribution is adequate, outdoor feeding of sows imposes relatively little disadvantage on low ranking animals.

Information about feeding strategies adopted by lactating sows is relatively sparse. Nutritional studies generally concentrate on total feed intake and pay little attention to the pattern and temporal variation in feed consumption of individual sows. In many studies, and in much of commercial practice, the sow's preferred pattern of consumption is subjugated to the needs of management with sows being fed in discrete meals rather than being given access to feed *ad libitum*. Lactating sows, fed *ad libitum*, exhibit a marked diurnal pattern of feeding (Dourmad, 1993; J. Burke *unpublished data*, 1997) with most feeding occurring during daytime, peaking in early morning and mid afternoon (Figure 17.6).

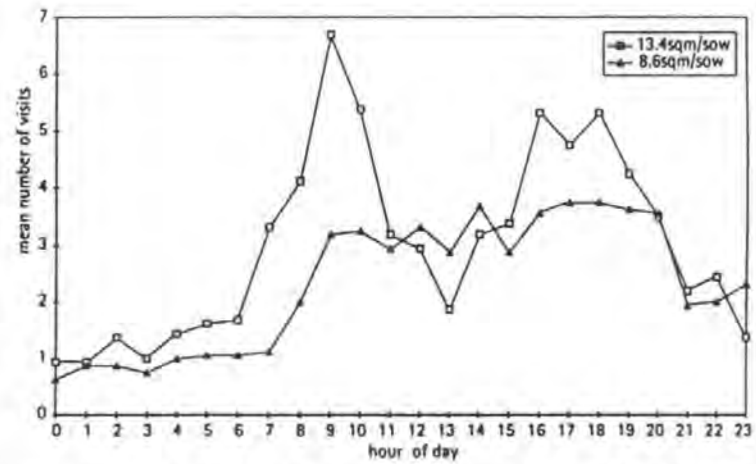

Figure 17.6. Time of day of feeding visits made by group housed sows in two different space allocations, providing 13.4m² and 8.6m² per sow, from day 1 to day 17 of lactation. (Burke et al., 1997)

The pattern of consumption and the number of meals taken is conditioned by the extent to which the dietary regimen creates a feeling of satiety. Thus growing pigs fed *ad libitum* made several visits to the feeder and took their daily feed allowance in a series of meals (de Haer *et al.*,1992; Nielsen, 1995). As the group size and competition for food increased, pigs reduced the meal duration, increased the meal size and reduced the number of meals taken. In contrast gestating sows, ration fed using electronic sow feeders, usually consumed the whole of their daily feed allowance during a single feeder visit. However, all sows made more than one feeder visit per day on some occasions (Eddison *et al.*, 1995).

Lactating sows confined in farrowing crates and fed four times per day to appetite, took a mean of 8.7 meals each day (Dourmad, 1993). Sows that had lower feed intakes took a similar number of meals but reduced the duration of each meal and the amount eaten on each occasion. Burke *et al.*, (1997) found that group housed lactating sows also took a number of meals each day (Table 17.3) and that the number of meals was influenced by the floor area provided per sow in the farrowing enclosure. Sows provided with 8.6 m^2 took fewer meals and spent less time feeding than sows provided with 13.4 m^2 but had similar feed intakes, implying a faster eating rate. This suggests that where the sow perceives competition, both the frequency and rate of feeding are adjusted to maintain intake.

Feeding sows *ad libitum* simplifies management. More importantly it removes the association between the presence / appearance of the stockperson in the farrowing house and anticipation of a feeding event. Sow activity tends to be particularly high during parturition and around the regular feeding periods with the risk of overlying being correspondingly higher at these times (English, 1969). In some situations adoption of *ad libitum* feeding has been shown to reduce the peaks of sow activity and increase piglet survival (English, 1969). However, in studies in which sows were fed once or twice per day or *ad libitum* no significant effects on piglet survival were found (Stahly *et al.*, 1979; Anderson *et al.*, 1990; NCR-89 Committee on Confinement Management of Swine 1990; Rudd *et al.*, 1994). A range of other management strategies and housing provisions probably make a greater contribution to the reduction of overlaying deaths than differences in the feeding pattern of the sow (English *et al.*, 1982a). These include:

- the use of farrowing crates designed to control the way in which the sow moves from the upright to the prostrate position
- the provision of heated safe areas (creeps) to attract the piglets away from the immediate vicinity of the sow
- the provision of floor surfaces which ensure good mobility of piglets and a good foothold for the sow

A discussion of the wide range of management strategies which can be adopted to improve the survival of the neonatal pig are outside the scope of this review but see reviews by Brooks, 1989; English *et al.*, 1982b; England, 1986.

17.4.2 Imposed feeding strategies and their effects on feed consumption and performance

There is a great diversity in the feeding strategies imposed on lactating sows on commercial units. Many producers are concerned that if sows are fed *ad libitum* in the early stages of lactation the udder will become overstocked with milk and that this in turn will lead to mastitis and agalactia. Consequently, many producers restrict the feed intake of the sow during early lactation, feeding the sow a restricted ration in one or more feeds per day.

Restriction of feed intake at any stage of lactation should be avoided unless there are serious health contraindications, as the feed intake of the lactating sow is often insufficient to meet nutrient requirements for maintenance and milk production (Lynch 1989; Mullan *et al.*, 1990; Dourmad, 1993). Nutrient intakes in lactation affect the overall productivity of the herd by influencing piglet growth rates and the post weaning reproductive performance of the sow (Lynch, 1989; Mullan *et al.*, 1990; Koketsu *et al.*, 1996a; Koketsu *et al.*, 1996b).

The feed intake of normal sows fed *ad libitum* on conventional diets may vary between 2 and 8 kg per day (see review by Whittemore, 1990) and the maximum intake of a sow, at a single feed, is generally between 3 and 4kg. Data collected by Handley *et al.* (1996) (Table 17.4) demonstrate the variation in intake achieved by sows of the same genotype on five different farms.

On *ad libitum* feeding, feed intake normally falls on the day of parturition and then increases progressively after weaning reaching a peak after approximately 7 days (for example see Figure 17.7). However, the pattern can become disrupted with adverse effects on sow and litter performance.

Table 17.4. Mean voluntary feed intakes (kg/d) of lactating sows in five commercial herds. (Handley et al., 1996)

Herd	Primiparous sows	Multiparous sows
A	6.19 ± 0.20	6.66 ± 0.10
B	4.27 ± 0.20	5.53 ± 0.14
C	5.24 ± 0.10	6.36 ± 0.09
D	5.32 ± 0.11	5.84 ± 0.09
E	6.31 ± 0.27	6.52 ± 0.09
Overall	5.46± 0.07	6.19 ± 0.04

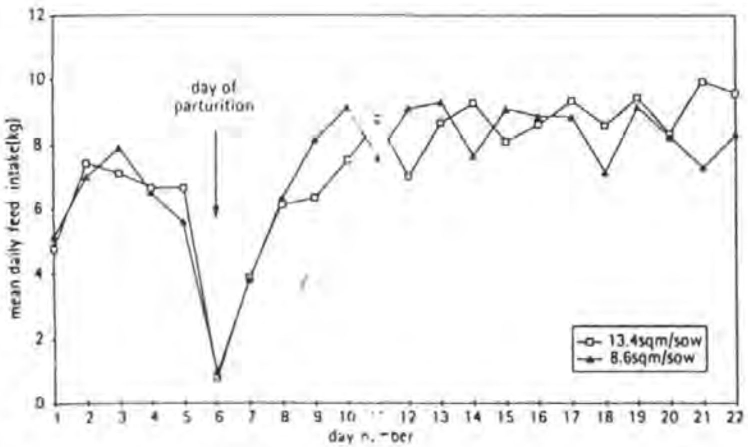

Figure 17.7. Mean daily feed intakes of ad libitum fed, group housed sows in two different space allocations providing 13.4m² and 8.6m² per sow from 5 days before parturition until day 17 of lactation (Burke, unpublished data)

Koketsu *et al.* (1996b) examined the records of 25,040 sows on 30 commercial farms and were able to characterise six distinct patterns of daily feed intake occurring during lactation. Average daily feed intake was 5.2 (SD 1.4) kg/d with the peak intake occurring at 12.6 (SD 4.6) kg/d days of lactation. Their data showed that sows having earlier peak feed intakes have higher average daily feed intakes and that average daily feed intake was highest for sows whose feed intake increased rapidly or gradually after farrowing with no drop in intake (Table 17.5). These sows also had the shortest weaning to conception intervals (Koketsu *et al.*, 1996a).

Although the major determinant of appetite is nutrient need, the wide variation in intakes reported in the literature reflect the moderating influence of a number of other variables.

It is well established that feeding levels in gestation affect sow feed intake during lactation (see review by Whittemore, Chapter 10). Several authors report increased overall lactation feed intakes when sows are fed *ad libitum* (Stahly *et al.*, 1979; Rudd *et al.*, 1994; Neil *et al.*, 1996b; Neil *et al.*, 1996a). The feeding of lactating sows *ad libitum* is also supported by Eastham *et al.* (1988) and Yang *et al.* (1989), who point out that even on this regimen, a degree of backfat loss is inevitable during lactation.

Increased feed intakes during lactation were reported in sows fed wet mash to appetite twice daily compared with those fed dry meal *ad libitum* (O'Grady *et al.*,

Table 17.5. Effect of pattern of feed intake in lactation on average daily feed intake, litter weaning weight and weaning to conception interval (After Koketsu et al., 1996a; Koketsu et al., 1996b)

Pattern of feed intake in lactation	Average daily feed intake (kg)	Litter weaning weight (kg)	Weaning to conception interval (d)
Feed intake increasing rapidly after weaning with no drop	$5.87 \pm .02^{2}$	$53.2 \pm .16^{2}$	6.6 ± 1.06^{2}
A major decrease of ≥ 1.8 kg/d observed relative to the previous peak level; intake remained low for ≥ 2d	$5.12 \pm .02^{2}$	$51.6 \pm .13^{3}$	6.9 ± 1.0^{2}
A minor decrease of < 1.8 kg/d observed relative to the previous peak feeding level	$5.42 \pm .02^{3}$	$53.3 \pm .14^{2}$	6.7 ± 1.01^{2}
Feed intake low throughout the lactation and did not exceed 4.5 kg/d	$3.24 \pm .08^{4}$	$51.3 \pm .66^{34}$	9.2 ± 1.07^{3}
Feed intake increased gradually during lactation with intake in the first week not exceeding 2.7 kg/d	$3.98 \pm .07^{5}$	$50.3 \pm .51^{4}$	7.9 ± 1.06^{3}
Feed intake increasing gradually with no drop. Peak at 10 d or later after farrowing	$5.91 \pm .03^{2}$	$53.6 \pm .20^{2}$	6.6 ± 1.02^{2}

^{234} Means in the same column lacking a common superscript letter differ ($P < 0.05$)

1985; Genest *et al.*, 1995) and in sows allowed to mix feed and water compared with those fed the same diet, dry (Pettigrew *et al.*, 1984). The feeding of high energy diets results in higher energy intake (Lynch, 1989), particularly when the energy is provided by fats or oils, which create less metabolic heat during digestion (Seerley, 1984; Whittemore, 1993).

17.4.3 Effects of Temperature

Increased metabolic heat production resulting from higher feed intake and the metabolic activity of milk production effectively reduces the lower critical temperature (LCT) of the sow. The zone of thermal comfort of the sow includes the range of temperatures between the LCT and the evaporative critical temperature (ECT), between which there are no extra demands for heat production and optimal feed intakes are achieved. The LCT varies widely according to sow body weight and condition and housing conditions and is considerably lower for lactating sows than for other classes of pigs. Lynch (1977) suggested that the LCT of sows in lactation ranged from 20°C to below 10°C depending on feeding levels. A more recent estimate of the lower limit to the zone of thermal comfort for the lactating sow was 12°C (Black *et al.*, 1993b). A number of authors have reported studies in which the relationship between ambient temperature and voluntary feed intake have been investigated. For example, Lynch (1977) demonstrated that for each 1°C increase in temperature between 21°C and 27°C, sows reduced feed intakes by 0.1kg/day. More recently, reductions in lactation feed intake of 0.2 kg/day per 1°C increase in environmental temperature from 18°C to 30°C were described by Stansbury *et al.* (1987). It is estimated that feed intake will be reduced by 1g for every 1°C above the LCT for every 1kg of body weight (Whittemore, 1993). Conversely, when ambient temperatures fall below the LCT homeothermy is maintained by reducing heat loss to the environment and increasing heat production through a rise in feed intake (Sorensen, 1961). Ambient temperatures above the evaporative cooling temperature (ECT) lead to a reduction in food intake, milk yield, reproductive performance and growth rate of piglets (Black *et al.*, 1993a).

17.4.4 Effects of season and photoperiod

The ancestral wild pig is a short daylength seasonal breeder with a period of anoestrous occurring during summer and autumn (Mauget 1982). The domestic pig appears to have remnants of this seasonality which is often manifested as 'summer infertility' (Love *et al.*, 1993). In many confinement management systems the sow is removed from seasonal photoperiod control as daylength is a function of the management regime. However, in less confined housing and 'outdoor' systems of sow management seasonal effects are significant (Love *et al.*, 1993). Summer infertility in pigs has been reviewed extensively by Claus *et al.*, (1985), Seren *et al* , (1987) and Love *et al.* (1993). Seasonal changes have a genetic component and the variability in expression of seasonality even in seasonally infertile sows suggests that local environmental factors such as boar presence (Bassett *et al.*, 1996) and nutrient status (Love *et al* , 1995) may be important modifiers.

For confinement systems a better understanding of the role of photoperiod and temperature on behaviour would enable controlled environments to be adjusted to optimise both sow and piglet performance. Reports on the effects of photoperiod duration on confined sows are equivocal. Both light intensity and light duration are important variables and no studies have considered both parameters in a systematic way. The most notable effect of photoperiod was reported by Stevenson *et al.*, (1983) who compared the lactation performance of sows given either <1 h or 16 h d-1 of supplemental light provided by cool white fluorescent light (32 to 266 lux). The only other light was from piglet heat lamps (<50 lux) which were on 24 hours per day. Sows given supplemental light weaned

significantly heavier litters than controls (56.7 vs 53.4 kg $P<.05$) and significantly ($P<.01$) more treated sows (83%) than controls (68%) were remated by 5 d postweaning. As there were considerable differences in the light intensity at different positions in the farrowing house it was possible to regress litter weight at weaning against light intensity. Overall litter weight increased ($P<.05$) 141± 6 g for each 10 lux increase in light intensity.

Mabry *et al.* (1982b) compared the effects of a 16 h photoperiod with an 8 h photoperiod and found that piglets exposed to 16 h light suckled significantly ($P<.05$) more often than piglets exposed to 8 h light over the 24 h period. This was particularly noticeable during the 4 h periods 1600-2000 and 0800-1200 h. As a result litters exposed to a 16 h light pattern weaned significantly ($P<.05$) more pigs per litter with significantly ($P<.01$) heavier 21 d weights. Similar effects on piglet survival and growth were obtained in a second study (Mabry *et al.*, 1982a). In addition sow milk yield at day 15 of lactation was increased from 5.76 to 7.17 kg in sows subjected to the longer photoperiod. It seems likely that this effect may have resulted from sows having increased milk synthesis due to increased suckling stimulus.

In contrast, other workers have found no beneficial effect on lactation performance of extending the photoperiod (Greenberg *et al.*, 1982; Gooneratne *et al.*, 1990; Prunier *et al.*, 1994).

Few studies have investigated the hormonal status of sows subjected to different photoperiods. Neither prolactin (Cunningham *et al.*, 1981) nor FSH concentration (Prunier *et al.*, 1994) differed significantly in lactating sows subjected to an 8 or 16 h photoperiod. The latter workers found higher ($P<.001$) oestradiol -17β levels in sows on 8 h photoperiods in January but not in July.

Unfortunately, none of these studies reported on aspects of sow feeding behaviour or activity levels. Changes in either or both sow feeding behaviour and piglet suckling behaviour may be implicated in those studies where improved weaning weights were achieved. Similarly, studies of sow activity levels under different lighting conditions might provide some explanation for the reported differences in the survival rate of their piglets.

17.5 Drinking behaviour

Despite the importance of water intake for the maintenance of feed intake and milk production there is very little information available on the drinking behaviour of the sow. The onset of lactation in sows increases the demand for both water and feed immediately after farrowing (Friend, 1971). Milk contains around 80% water (range 74.2-82.9; Bowland (1966)) so a high yielding sow may need to consume up to 7 litres of water just to satisfy the demand for milk secretion. The factors affecting water demand have been reviewed by Brooks *et al.* (1990). Fraser *et al.* (1990) reviewed 12 studies of voluntary water consumption in sows. The lowest mean intake was 8.1 litres/day and the highest 25.1 litres/day with most of the studies having means in the range 13-19 litres per day. It is hardly surprising that large differences in mean values have been recorded in different experiments given the variability between animals within experiments. For example individual sow intakes ranged from 9.3 to 21.5 litres/day and 6.1 to 21.7 litres/day in the studies of Mahan (1969) and Fraser *et al.* (1989) respectively. Gill (1989) found that total water consumed (i.e. water mixed with the sow's feed plus water taken from drinkers) increased linearly up to farrowing and reached 12.2±1.1 litres on the day before parturition. On the day of farrowing water intake decreased sharply to 9.3±0.84 litres/sow. Thereafter, intake increased curvilinearly to reach a maximum of 24 litres/day 18 days post partum. The average daily water intake in this study was 18.9±0.27 litres/day. A similar pattern of water consumption has been described by Fraser *et al.* (1989).

Reduced water consumption results in increaced faecal dry matter and this in turn could predispose sows to mastitis metritis agalactia syndrome. Therefore, it is important to ensure that sows do not have restricted intakes around farrowing. Klopfenstein *et al.* (1995) investigated whether the time given to sows to adapt to a new environment and a different watering system affected water intake. In their study moving sows to farrowing accommodation 25 or 3 days prior to farrowing had no effect on water intake. However, they found that the average daily water consumption of most sows dropped drastically at farrowing and remained lower than the late gestation level for the first 3-4 days following parturition.

The study of Fraser *et al.* (1989) is interesting in that a very strong positive relationship was found between water intake of sows in the first three days after birth and piglet weight gain over the same period. Another interesting finding in this study was the relationship between the amount of time that the sow was active and water consumption (Table 17.6). This may imply that the time the newly farrowed sow allows for drinking is limited.

Table 17.6. Percentage of time spent active (standing and sitting) and water intake during the 24 h before and the 72 h after the start of farrowing (Fraser et al., 1989)

Time relative to farrowing	Percent time spent active (mean and range)	Water intake (l) (mean and range)	r^2
24 h before	30.5 (22.4-42.8)	12.8 (5.6-24.1)	0.63
1-24 h after	5.1 (1.5-14.9)	4.9 (0.0-15.7)	0.71
25-48 h after	6.5 (1.8-15.3)	8.4 (1.0-21.2)	0.92
49-72 h after	8.2 (2.7-15.3)	10.9 (3.2-20.0)	0.58

17.6 Sexual behaviour

17.6.1 Post partum oestrus

Oestrous cycling and sexual behaviour are normally suppressed in the lactating sow. Studies published in the 1950's indicated that a postpartum oestrus occurred in 50-99% of sows (Warnick *et al.*, 1950; Burger, 1952; Baker *et al.*, 1953; Self *et al.*, 1958) but that this was anovulatory except in the unusual circumstance that the piglets died or were removed at birth (Warnick *et al.*, 1950). However, no recent studies have made reference to the occurrence of postpartum oestrus in sows, even when the sows were group housed during lactation. Therefore, it must be questioned whether the sows reportedly showing postpartum oestrus in the 1950's were isolated cases or whether the tendency to show postpartum oestrus has been lost in modern genotypes.

17.6.2 Lactational oestrus

In theory, sow productivity could be increased if lactational anoestrous could be overcome and the sow successfully mated while still lactating. However, to be a viable alternative management strategy lactational oestrus would have to occur:

- in a high percentage of sows;
- at a predictable time after parturition;
- at an earlier time post partum than the normal post weaning oestrus.

In addition the survival rate and growth of the litter being suckled would have to be maintained and the size and viability of the succeeding litter would not have to be compromised.

As the process of lactation suppresses oestrus (Edwards, 1982) a number of workers have investigated the effect of reducing the suckling stimulus by 'partial weaning', that is removing the piglets from the sow for a portion of the day, and allowing pheromonal stimulation by providing daily contact with a mature boar (Smith, 1961; Cole *et al.*, 1972; Henderson *et al.*, 1984; Stevenson *et al.*, 1984; Newton *et al.*, 1987; Costa *et al.*, 1995) and additionally treatment with exogenous hormones (Crighton, 1970; Guthrie *et al.*, 1978; Hausler *et al.*, 1980; Cox *et al.*, 1982; Costa *et al.*, 1995). Although all these techniques have resulted in a limited number of animals ovulating during lactation they have not produced management practices that are worthy of commercial adoption.

Commercial herds have been observed in which sows did return to oestrus during long lactations (Table 17.7). Although a high incidence of lactational oestrus was recorded the sows that did conceive did so following a longer period post partum than would normally be expected for sows weaned at four weeks of age or less.

Table 17.7. Characteristics of sows showing lactational oestrus on two commercial farms

	(Rowlinson *et al.*, 1974)	(Petchey *et al.*, 1979)
Length of lactation (d)	46.3 ± 0.5	53.3 ± 0.7
Sows showing lactational oestrus (%)	49	100
Conception rate of sows mated during oestrus (%)	78	85
Farrowing to mating interval (d)	40.3 ± 1.81	35.5 ± 0.47

Three features of these farms appeared crucial to their success in stimulating oestrus in lactation. First, the sows were allowed to lactate for longer (45-55 days) than is allowed in most current commercial practice. Secondly, the sows were group housed during lactation with a mature boar present. Thirdly, they were provided with generous feeding which minimised weight loss.

Subsequent studies conducted under experimental conditions have confirmed that high incidences of lactational oestrus are only achieved if all three of these features are present. (Petchey *et al.*, 1980; Rowlinson *et al.*, 1981; Rowlinson *et al.*, 1982; Bryant *et al.*, 1983a). Although these techniques were capable of inducing lactational oestrus, there were a number of reasons why they did not find favour with producers. First, the costs involved and the management problems posed were too great. Secondly, they did not produce any increase in annual sow output compared with conventional management with weaning at 3-4 weeks of age. Thirdly, piglet growth performance was inferior and weaning weight was more variable than that of piglets reared in farrowing crates.

Some interest in lactational oestrus has been rekindled as a result of welfare concerns about restraining sows in farrowing crates for the duration of lactation. A desire to develop more welfare friendly housing systems has again led to sows being housed in more complex social environments with the result that some of the sows demonstrate oestrus (Henderson *et al.*, 1989; Stolba *et al.*, 1990; Hulten *et al.*, 1995a). However, in many cases this may reflect poor mothering and suckling behaviour on the part of the sow which reduces the suckling stimulus that she receives and hence removes the lactational inhibition of oestrus cyclicity.

Grouping sows during lactation seems to have little or no effect on sow feed intake (Bryant *et al.*, 1983b; Bryant *et al.*, 1984).

17.6.3 Interrelationships between suckling behaviour and lactational oestrus.

As indicated in the foregoing section lactational oestrus may be a consequence of reduced suckling stimulus. This may occur in one of three ways

- sows suckling small litters (as a result of post partum losses) may receive insufficient physiological stimulus to maintain lactation
- sows may abandon their piglets leaving other sows in the group to suckle them (in this situation the sow effectively weans herself early) (Boe, 1994)
- sows may reduce suckling stimulus by preventing access to their udders by sternal lying (Gotz, 1991) or by absenting themselves from their piglets (even though not abandoning them) in housing systems where the piglets are retained in nest areas by barriers (Boe, 1993; Hulten *et al.*, 1995b; Rantzer *et al.*, 1995b).

In the first of these situations there is no obvious behavioural component. In the other two the behaviour of the sow is instrumental in producing the effect. In both cases the sow may be motivated to the action as an escape from the constant attentions of her piglets (Jensen, 1988; De Passille *et al.*,1989). This behaviour parallels that of wild pigs where the sow increasingly absents herself from her piglets as lactation progresses (Mauget, 1982).

Grouping sows during lactation does result in some disruption of the normal suckling pattern. Bryant and Rowlinson (1984) found that true nursing was inhibited for a period after grouping ranging from 2.5 to 7.5 h in individual sows but that suckling frequency recovered thereafter to pregrouping levels. The incidence of false nursings increased following grouping and remained higher. In a comparison of group and individually housed sows it was found that nursing frequency was very similar as was the degree of synchronisation of suckling by sows sharing the same environment. However, the incidence of false nursings was much higher in the grouped sows (Bryant *et al.*, 1983b).

Group housing of lactating sows facilitates cross suckling by their piglets (Bryant *et al.*, 1983b; Bryant *et al.*, 1984; Algers, 1991; Wattanakul *et al.*, 1997). Algers (1991) found that about 30% of the piglets in the group housing system nursed sows other than their mother but only about 3% of the piglets totally abandoned their own mother for other sows. However, cross suckling could be seen as a mechanism by which less advantaged piglets could avail themselves of a better milk supply from a sow other than their dam. This would only be the case though, if the receiving sow had a spare teat, and this provided a superior milk supply to the teat abandoned on the natural mother. This is rarely the case. Furthermore, the alien pig still has to gain access to the teat of another sow and the more dominant piglets still outcompete the weaker pigs in the group (Braun *et al.*, 1988). This may help explain why the piglets of group housed sows have significantly poorer daily gain and higher consumption of creep feed prior to weaning (Rantzer *et al.*, 1995a). In addition the piglets of group housed sows in Rantzer's (1995a) study showed a dominance of haemolytic *E.coli* in rectal swabs at weaning indicating that the weaning process may already have begun. Thus although cross suckling may benefit some dominant individuals it may actually reduce the milk supply to the weaker pigs and result in reduced total milk output by the group of sows, as less productive teats are rejected, and atrophy due to the lack of stimulation of being suckled (Hulten *et al.*, 1995b).

Hulten (1997) studied the performance of sows and litters in commercial units where group housing was practised from about two weeks of lactation. Piglet mortality in the litters of multiparous sows was higher (6.5%) in the group housing period than for comparable litters of sows which were individually housed (1.4%). In primiparous sows housing system had no significant effect on mortality. Similarly, preweaning atrophy of mammary glands did not occur in primiparous sows (Hulten *et al.*, 1995b). These results suggest that the relationship between primiparous sows and their litters are not affected by group housing whereas the relationships between multiparous sows and their litters are.

17.7 Conclusions

This review has demonstrated that the success of the sow in rearing her litter to weaning is determined by a complex and interrelated series of behaviours. Many of these act through nutrition. Mothering and suckling behaviour in the perinatal period influence the success of the piglet in obtaining its first suckle, vital for the acquisition of both immunity and nutrients. Subsequently, the suckling behaviour of the sow affects the nutrient supply and thereby the growth of the piglet.

The feeding, drinking and sexual behaviour of lactating sows can have a significant effect on their nutrient intake, which in turn determines the quantity and quality of milk produced and hence the nutrients available to their piglets. The differences in behaviour of individuals and hence rearing success are considerable, even in systems of housing where sows are confined in farrowing crates. When sows are confined in farrowing crates sow temperament and mothering behaviour have less effect on the sow's success in rearing piglets and the interventions of the stockperson in the process assume greater importance. With consumer antagonism to confinement systems mounting, researchers and pig producers are actively seeking alternative forms of housing. There is renewed interest in loose and group housing of lactating sows. In such systems sow temperament and mothering behaviour are important components of success.

Our understanding of the reproductive physiology and nutrition of the sow has increased greatly in recent years and the housing systems that have been adopted have provided opportunities to exploit that knowledge. If, as seems likely, consumer concerns move the pig industry towards less confined systems of housing for lactating sows it will be essential to gain further insights into the contribution that different behaviours make to rearing success. Unless we can understand how lactation behaviour is, and can be influenced by the sow's environment, we will be unable to design housing systems and identify genetic selection criteria which will enable us to capitalise on our understanding of the sow's physiology and biochemistry. Future advances in sow management may depend less on the physiologist and the biochemist and more upon the research of the ethologist studying the sow and the psychologist studying the stockperson.

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Proceedings of the British Society of Animal Science 1998

Published by
British Society of Animal Science

The Proceedings of the British Society of Animal Science constitute summaries of papers presented at the Society's Annual Meeting in Scarborough in March 1998.

The summaries have not been edited and the Society can accept no responsibility for their accuracy. Views expressed in all contributions are those of the authors and not those of the British Society of Animal Science.

ISBN 0 906562 25 2

Suckling frequency of group housed sows in two different space allocations

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Introduction The more frequent the opportunities for piglets to suckle, the higher their milk intake and subsequen liveweight gain during lactation (Newberry and Wood-Gush 1984). Studies of sows in communal farrowing system revealed that suckling frequency decreased from week 2 of lactation onwards (Houwers, Buré and Koomans 1992; Bo 1993). The objective of this study was to investigate the effect of two different space allocations on the sucklin frequency of group housed sows and on litter performance to day 17 of lactation.

Material and methods Four groups of four multiparous sows were allocated to one of two pen areas, in a loos house farrowing system from 5 days before the expected farrowing date until the oldest litter was 21 days of age. Th two pen areas provided 13.4m^2 (L) and 8.6m^2 (S) per sow respectively. A row of four farrowing enclosures, fitte with heated piglet creep areas and deeply bedded with straw, were provided, within an otherwise unbedded pen. Sow were marked for individual identification and observed using continuous time lapse video recordings (Panasonic AG-6730; Matsushita Electric Industrial Co. Ltd., Osaka, Japan). Piglets were weighed and identified with numbere ear tags on day 1 following birth, then weighed again at the end of the study. Data were analysed by oneway analysi of variance and general linear model to determine whether there was a significant effect of pen size and day of lactatio on suckling frequency.

Results The mean daily number of suckling bouts for sows in each treatment group are presented in Figure 1 Suckling frequency was greater for S than for L sows from day 1 until day 17 of lactation ($P<0.001$). The effect o day of lactation, during week 1 postpartum, was statistically significant ($P<0.05$), reflected in a gradual increase i the number of daily suckling bouts in both treatment groups. From day 8 to day 17 there was no further influence o day of lactation on mean daily suckling frequencies which were 38.3±0.66 and 52.7±0.75 for L and S pen area respectively. Piglet performance data are presented in Table 1. Numerical data suggest that S piglets had higher dail weight gains, compared with L piglets, however the difference was not statistically significant.

Figure 1 Mean daily number of suckling bouts for sows in two different pen areas (error bars denote SE_M)

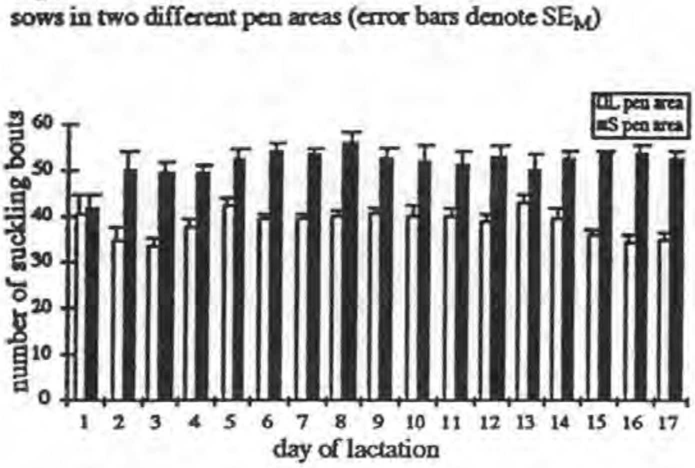

Table 1 Mean birth weight, mean numbe reared, mean end weight and mean daily weigh gain (DWG) $\pm SE_M$ for litters in two pen areas

	13.4m^2/sow(L)	8.6m^2/sow(S)
birth weight(kg)	1.5±0.08	1.4±0.13
number reared	9.8±0.62	7.9±0.99
end weight(kg)	5.9±0.26	6.3±0.48
DWG(g)	219±9	240±14

Conclusions The mean daily suckling frequencies of 38.4±0.53 and 51.6±0.61 over lactation, for L and S spac allowances, respectively, were considerably higher than the 26 to 30 per day reported by other workers (Houwers *et al* 1992; Boe 1993). The increased number of sucklings per day in S pen area may have been an effect of the lack o suitable resting places outside the farrowing enclosures, resulting in these sows remaining in closer contact with thei piglets. The increased suckling frequency had beneficial effects on nutrient intake of piglets, which resulted in highe daily weight gain for piglets in S pen area. The results indicate that in the reduced space allowance, sows remained in more regular contact with their litters and maintained high suckling frequencies, with ensuing benefits to piglet liveweight gains.

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Learning, motivation and cognition: are current models good enough?

and

Improving animal welfare through understanding behaviour

ISAE UK/EIRE Winter Meeting
3rd December 1997
The Royal Veterinary College, London

Feeding strategies and daily feed intakes of group housed sows fed *ad libitum* from 5 days before parturition until day 17 of lactation

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Introduction

Legislation in the UK, banning the use of sow stalls and tethers, has led to the development of group loose housing systems for gestating sows. Consumer concern about food animal production methods brought about the introduction of quality assurance schemes for fresh meat by most major food retail chains. A key element of the widely adopted RSPCA Freedom Foods scheme is that the farrowing crate be phased out as soon as a practicable alternative becomes available (RSPCA 1997). The animal welfare lobby is campaigning to prevent the confinement of sows in the farrowing crate during parturition and lactation (Anon. 1997). Loose house farrowing accommodation requires an increased space allowance per sow, particularly in group farrowing systems (Burke 1996). In commercial pig production, space is expensive, so there is pressure to keep the allowance per sow to a minimum. The objective of this study was to investigate the effect of two space allocations per sow, on feeding strategies and feed intakes of group housed sows over parturition and during lactation.

Method

Four groups of four multiparous sows were allocated to one of two pen areas, in a loose house farrowing system from 5 days before the expected farrowing date until the oldest litter was 21 days of age. The two pen areas provided 13.4m^2(L) and 8.6m^2 (S)/sow respectively. A row of four farrowing nest enclosures, fitted with heated creep areas and deeply bedded with straw, were provided, within an otherwise unbedded, concrete floored pen (Figure 1a,b). Sows were marked for individual identification and observed using continuous time lapse video recordings (Panasonic, AG-6730; Matsushita Electric Industrial Co. Ltd., Osaka, Japan). A lactation diet (J.Bibby Agriculture Ltd, Peterborough) providing 14MJ/kg DE and 18% CP, was supplied *ad libitum* via a sow operated star wheel feeder (Quality Equipment, Bury St Edmunds, UK), adapted to facilitate the calculation of individual feed intakes. The observations were divided into three time blocks: days -5 to onset of parturition (day -1), days 1 to 7 of lactation and days 8 to 17 of lactation, for which the daily number of feeding visits, daily feed intakes and total time spent feeding per day/sow, were recorded. Data were analysed using oneway analysis of variance.

Results

The mean daily feed intakes, mean number of feeder visits/day and mean time spent feeding/day for sows in each treatment, during each time block, are presented in Table 1. Feed intake/visit was greater for S than for L sows during each of the three time blocks studied. This difference between treatments was statistically significant ($P<0.001$). The duration of each feeder visit was significantly longer for S sows from day -5 to parturition onset ($P<0.05$), however, for subsequent time periods this difference was not apparent. S sows had a significantly increased feeding rate, compared with L sows, from day -5 to parturition onset ($P<0.001$) and days 1 to 7 of lactation ($P<0.01$). Numerical data suggest that feeding rate continued to be higher in S sows, compared to L sows, during days 8 to 17 of lactation, however, this difference was not statistically significant.

Conclusions

Daily feed intakes of no more than 5 to 6kg are frequently reported for lactating sows (National Research Council 1987; Mullan, Close and Cole 1990). In contrast, sows in this study achieved considerably higher feed intakes during lactation of 7.69±0.31kg and 7.72±0.35kg for L and S sows respectively. This was accomplished by sows taking a series of small feeds throughout the day. Sows in S pen area made fewer visits to the feeder/day and spent less time/day engaged in feeding, compared with L sows. During each visit, more feed was consumed by S sows, achieved by an increased feeding rate, which resulted in similar daily feed intakes in both treatment groups. The results indicate that sows in the reduced pen area adapted their feeding behaviour, perhaps, in order to minimise the occurrence of potentially aggressive encounters and maintained feed intakes in line with nutrient requirements during lactation.

Figure 1 Layout of pen area in the loose house farrowing system
a) providing 13.4m^2/sow (L) b) providing 8.6m^2/sow (S)

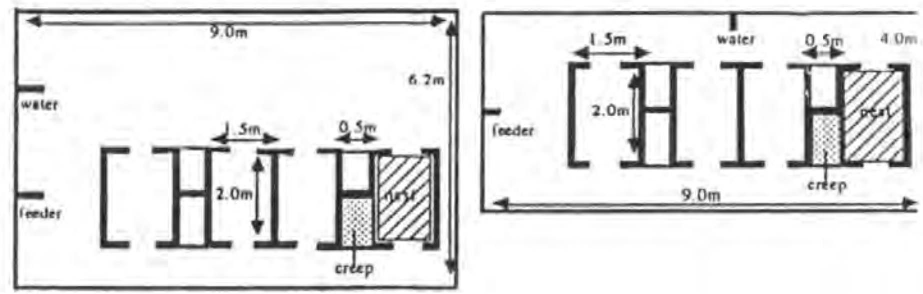

Table 1 The mean ±SE_M daily feed intake, number of visits to the feeder per day and time spent feeding per day by farrowing and lactating sows in two different pen areas

Area/sow	*13.4m^2/sow(L)*			*8.6m^2/sow(S)*		
Time period(days)	*-5 to -1*	*1 to 7*	*8 to 17*	*5 to -1*	*1 to 7*	*8 to 17*
intake/day(kg)	6.9 ± 0.42	5.8 ±0.46	9.0 ±0.35	6.8 ±0.54	6.8 ±0.58	8.4 ±0.40
visits/day	8.3^a ±0.68	7.4^b ±0.60	9.5^c ±0.45	5.5^a ±0.45	5.6^b ±0.45	8.0^c ±0.46
time/day(hrs)	2.6^d ±0.16	1.5 ±0.11	2.0^e ±0.07	2.1^d ±0.17	1.3 ±0.11	1.7^e ±0.05

pairs of means with the same following letter in the same row differ at ^{a}=P<0.001; ^{b}=P<0.05; ^{c}=P<0.05; ^{d}=P<0.05; ^{e}=P<0.001

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EASTER SCHOOL IN AGRICULTURAL SCIENCE

PROGRESS IN PIG SCIENCE

7–11 April 1997

Daily feed intakes of group housed sows fed ad libitum from 5 days before parturition until day 17 of lactation

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Increased heat production from higher feed intake and milk production reduces the lower critical temperature of the lactating sow. Four multiparous sows were housed in a group farrowing system from five days before parturition until the oldest litter was twenty one days of age. A lactation ration (digestible energy 14 MJ/kg; crude protein 18%) was provided via a sow operated feeder. Ambient temperatures were recorded by data logger. The mean daily ambient temperature was 8.07^{o}C (s.e. 0.29) to day 8 of lactation. It then fell to 3.22^{o}C (s.e. 0.28) for the remainder of the study. Temperature and daily feed intakes were not correlated. Sows obtained their food from a mean of 7 (s.e. 0.38) small meals /24hrs. The mean intake to farrowing was 6.94kg (s.e. 0.75). This fell to 0.85kg (s.e. 0.85) at parturition. Intakes then rose steadily to 10.81kg (s.e. 2.04) by day 6 of lactation, followed by a slight fall to 7.07kg (s.e. 1.02) on day 7. The mean daily intakes of individual sows, from day 8 to day 17 of lactation, of 11.03kg (s.e. 0.45), 5.57kg (s.e. 0.62), 13.88kg (s.e. 0.95) and 9.37kg (s.e. 0.56) were significantly different ($P<0.001$) and positively correlated to litter size ($r_4 = 0.893$, $P<0.05$). Ad libitum feeding of sows in a group farrowing system encourages feeding strategies more suited to individual needs. Given freedom and control of their environment sows manage excess thermogenesis and sustain feed intakes.

PIG FARMING

Volume 45 No 4 April 1997

The sow pool idea from Sweden was recently lauded as a possible alternative to stalls and tethers in the UK. However, following their recent study tours Dr Jeremy Marchant, from the University of Cambridge, and Jean Burke, from the Seale-Hayne Faculty, University of Plymouth, offer an alternative viewpoint.

It's a hard life for sows in these POOLS OF DISCONTENT

It is important to look at the reasoning behind the sow pool concept, and its development. The first pool was established in 1988 and the system has become increasingly popular with the traditional small-herd farmers. Now, about 10 per cent of Sweden's breeding herd is in sow pools.

In 1988, legislation was passed which banned stalls and tethers for dry sows, gave a minimum weaning age of four weeks and permitted the use of farrowing crates for only one week. To comply with the rules, farrowing accommodation had to be reorganised to provide an increased space allowance per sow and litter.

Many farms were unable to make these changes due to lack of space for all categories of pigs and therefore faced the prospect of large capital investment in a rebuilding programme or going out of business.

Abattoir concern

Abattoirs were concerned that if farmers reduced stock or ceased to rear pigs there would be a shortage of slaughter pigs. The result was the establishment of large central sow pools, where the sows could be housed in service and gestation.

This enabled the smaller farms to become satellite units, with the space normally occupied by dry sows to be used for farrowing and lactating accommodation.

The sows became the property of slaughterers, and were hired to farmers on annual contracts. The pools vary from 260-2200 sows with between three and 34 satellite herds.

At face value, the concept seems to be attractive, and it could appear that a similar arrangement in the UK might benefit producers facing difficulties in converting their dry sow accommodation, as Colin Baldwin, pigmeat strategy manager, MLC, suggested in the September '96 issue of Pig Farming. However, he visited a satellite unit and not a sow pool. The sow pool system was described by Swedish researchers as a hard system for sows, and visiting one of the central sow pool farms it was obvious why.

Management

The pool handles a total herd of 1200 sows with 800 sows at the central unit and the rest out on satellite farms at any one time. Sows return to the central pool at weaning and are housed in groups of four, in pens with free access stalls, for both natural service and artificial insemination. Most services, are Duroc boars and semen.

After four weeks they are moved across the service house into partially-slatted pens in groups of 10-12. When diagnosed pregnant they are moved to a different building with similar pens, in groups of 10-14.

Group size depends on the extent of re-grouping needed because of returns to service. Sows remain here until three weeks before expected farrowing dates, when they are transported to the satellite farms in batches of 15-72.

The satellite units operate an all-in, all-out system and order enough sows in a single batch to fill their entire farrowing accommodation. The sows are weaned at a minimum of four weeks after farrowing and return to the pool. The satellite unit rears the piglets either up to point of sale, or transfers them to a finishing unit at 12 weeks of age.

This company-operated a contract scheme which guaranteed the satellite unit a minimum of 10 piglets born a litter.

Condition of sows. Although farmers are supposedly checked two weeks post-farrowing to ensure that sow feed levels are adequate and body condition is being maintained, sows are returned from farms in very variable condition.

A study carried out by Dr Anne-Charlotte Olsson and coworkers of the Swedish University of Agricultural Sciences on five sow pools revealed that up to 16 per cent of all sows were classed as thin and up to 44 per cent classed as fat.

Many also had injuries, particularly ulcerations to the point of the shoulder. They also found up to 40 per cent of sows had abscesses and up to 16 per cent had locomotor problems.

Frequent regrouping

Lack of stability. The size of the operation means there can be no stability in the life of the sows in the system. They are subject to frequent re-grouping and accommodation changes within the central pool and are most likely be sent to a different farm and management system, with different companions, for each farrowing.

On their return to the pool, they are placed in a succession of newly-formed groups as they move through the system, and so are continually subjected to aggression in the re-establishment of a social hierarchy.

The poor body condition of sows results in a high level of unsuccessful services. This in turn leads to more mixing and yet more aggression and injuries. Not surprisingly, the culling rate is high.

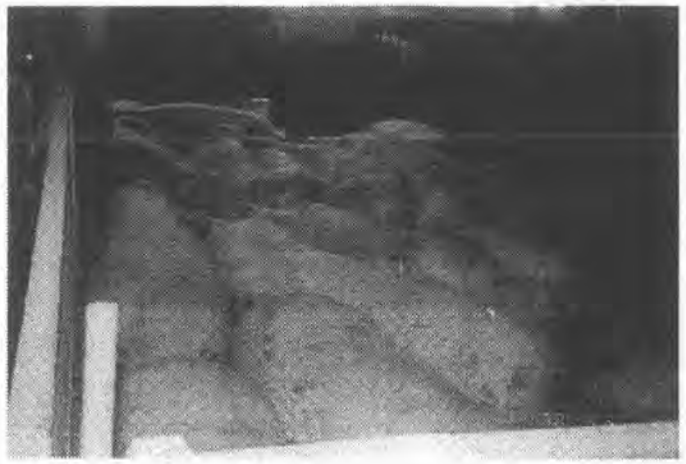
No bedding

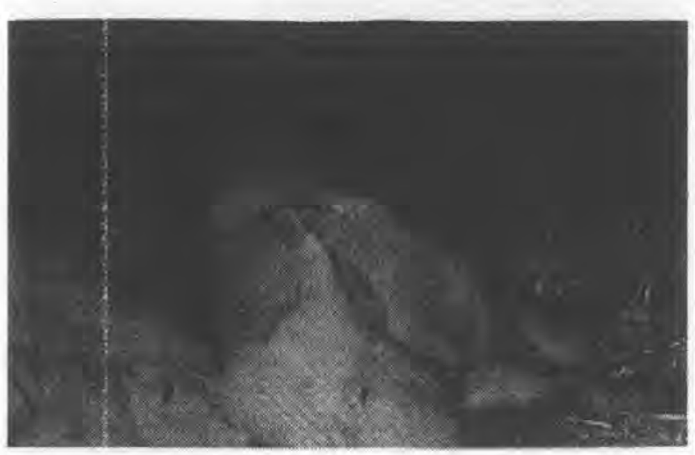
Pen shape. Optimisation of rules means sows have little or no free space and no straw bedding. The law requires the provision of 45 cm of feed trough a sow and a minimum lying area of 1.3 sq m a sow, but it omits any size requirement for dunging. To use as little space as possible, long narrow pens were designed, with a small, raised slatted area at one end.

When under-stocked, there is sufficient free space. But when stocked at the correct rate, there is very little free space with nowhere for sows to escape from attack.

Movement around the pen cannot be carried out without stepping on or knocking into pen mates, again resulting in aggression which tends to escalate as the attacked sow tries to get away. The dunging area is difficult to reach and hence, pen cleanliness becomes poor, with between 30-50 per cent of the lying area becoming fouled.

When stocked at the correct rate, there is very little free space with nowhere for individual sows to escape from aggressive encounters.





Injury is common, particularly ulcerations to the point of the shoulder. A study found up to 40 per cent had abscesses and up to 16 per cent had locomotor problems.

The law stipulates that straw must be provided daily but gives no guidance on quantity. The amount of bedding given to sows in these systems varies from 0.3-0.7 kg a sow a day, but where only 0.3 kg is used, it is rapidly eaten, leaving the pen floors completely bare.

Feeding regime. Sows were not sorted according to condition on their return to the pool farm, and so as the feeding system favoured the larger, fitter animals, the variation in body condition became greater.

Twin delivery

Liquid feed for the sows was delivered into the long troughs in each pen through two delivery pipes. It had been found that aggression among sows was high at feeding and so it was only carried out once a day, in the belief that this kept the number of aggressive interactions to a minimum.

However, Dr Olsson found that the distribution of the feed in the trough depended greatly on its consistency and even when properly fluid, it could take as long as 45 seconds after delivery for the feed to distribute along the whole length of the trough.

Therefore, the higher ranked sows would monopolise the feed release point and guard a large section of the trough, leaving the lower ranked sows to compete for the available space. This resulted in a large amount of place-changing and up to 26 per cent of sows leaving the trough completely after only three minutes following feed delivery.

Conclusions

Introduction of the sow pool system appears to have been a retrograde step in sow welfare in one part of the production cycle, brought about by legislation to improve their welfare in another. The fact that this occurred in Sweden, where welfare standards are generally considered to be high, is all the more disturbing.

The system could be improved considerably by:

The introduction of strict controls on sow condition at weaning and return to the pool. Careful selection of sows according to body condition and parity when forming new groups. Increased individual space allowance within pens. A less competitive feed system.

Even with these changes it would be difficult, if not impossible, to eliminate the frequent mixing of unacquainted sows and the unacceptably high levels of aggression in such a system. It is questionable whether regularly transporting heavily pregnant sows, close to parturition and again immediately on weaning, so while still lactating should be acceptable.

In its present form the sow pool should not be recommended as an alternative system to stalls and tethers.

Our visit to the sow pool was a very depressing introduction to pig production in Sweden - a disappointment. But it must be stressed that we saw many fine examples of commercial pig production systems.

❑ *The tour was sponsored by the Braude Travel Scholarship, Royal Bath and West of England Agricultural Society, Cornwall Education and Research Trust, and Churchill Fellowship.*

PIG FARMING

Volume 45 No 2 February 1997

Can crateless farrowing ever prove to work successfully . . ?

The final part of an article by Jean Burke, University of Plymouth, and Dr Jeremy Marchant, University of Cambridge, investigating alternatives to the traditional farrowing crate. Here they look at the formation of multi-suckling groups. Part 1 was in January.

DENMARK:

Research at the Danish Institute of Animal Science (DIAS) focused on evaluating the effects of mixing methods on the level of aggression observed among piglets, subsequent mortality and the weight–spread when weaned at five weeks.

Four strategies were used:

1. Sows and piglets moved simultaneously, on day 11 after farrowing
2. Sows and piglets moved simultaneously, on day 14 after farrowing
3. Sows moved together, and than two hours later; all piglets moved together, on day 11 after farrowing
4. Each sow and her litter moved separately at three-hour intervals on day 11 after farrowing.

When each sow and her litter were introduced singly at intervals to the multi-suckling pen, the amount of disturbance was reduced. In a more recent study, sows farrowed in groups of three in pens with three straw-filled nest boxes. At about two weeks of age the piglets of one group were closed out of the nests and forced to stay in the unfamiliar communal area with the sows.

Piglets of a second group had their nest enclosures removed from the pen so that mixing occurred more gradually and, although they had access to a strange part of the pen, piglets could choose to remain on familiar ground. The results of this study await analysis.

SWEDEN:

Previous work at the Swedish University of Agricultural Sciences (SLU) looked at piglet aggression during mixing in a semi-natural enclosure.

They determined that on first encountering piglets from other litters there were a lot of interactions but that the proportion involving aggression was low. Over the next few weeks the number of interactions decreased but the proportion involving aggression increased. The sow is present throughout this time, and it could be that her presence decreases the amount of aggression occurring when piglets are first mixed.

To test this two different ways of introducing sows and litters to multi-suckling pens were compared. In the first, all sows and litters were moved and mixed at the same time; and in the second, the litters were moved first and the sows one hour later.

The preliminary findings are that there is less fighting among piglets when sows are present, there is more aggression in groups of piglets with low variation in weight than those with high variation in weight and that big piglets fight more than small piglets.

After 24 hours, the level of aggression among groups of piglets in each mixing method equalises over time. The presence of the sows appears only to delay the onset of aggressive encounters. Little or no aggression occurred among the sows.

Conclusions

Good maternal characteristics and the degree of aggression and activity tolerable in sows may be identified by a range of behaviours against production parameters.

Selection of those most suited to loose farrowing systems may then be possible. Once the required maternal attributes of sows have been recognised, housing design may be adjusted to encourage good characteristics. This would help sows to achieve a high level of piglet care without disrupting normal behaviours and interactions - and so remove the need to crate the sow at any time over farrowing.

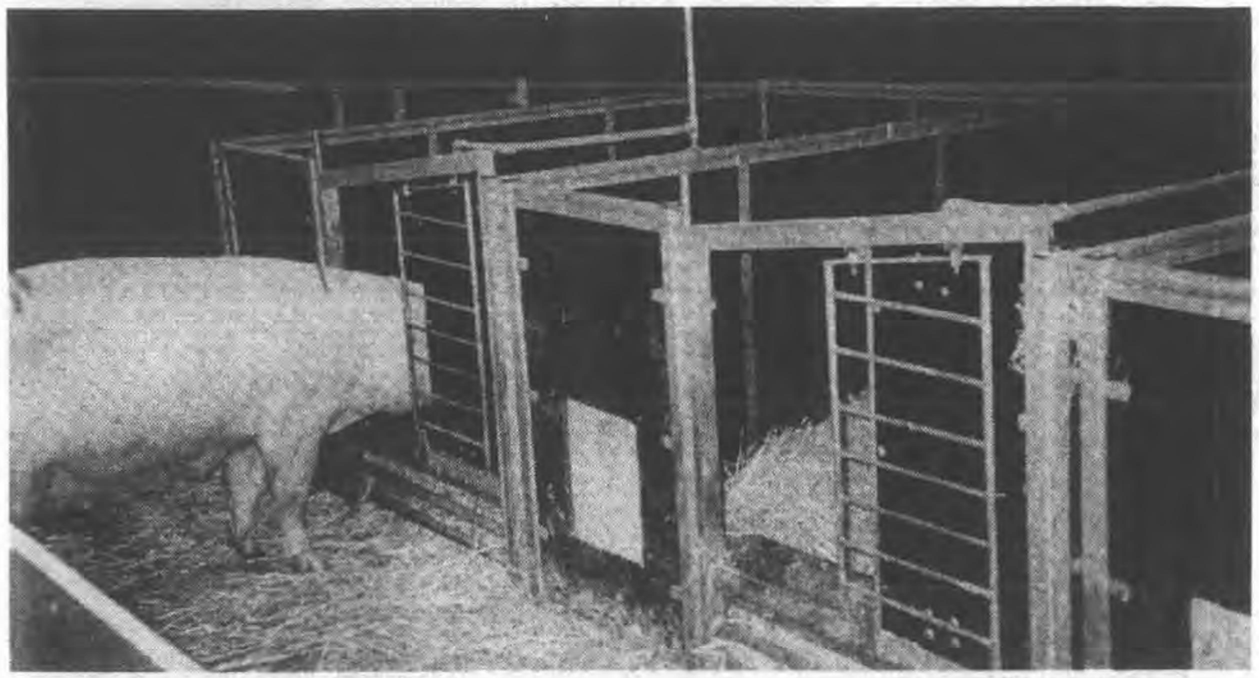
The studies on the formation of multi-suckling groups demonstrates how observation of the behaviour of sows and litters can be used to help in the development of a management system to the mutual advantage of the animals and stockpeople.

The behavioural approach to system design focuses on the needs of the sow and litter, giving them control over their environment instead of using constraint and force to make them conform in what are often inappropriate conditions.

PIG

Volume 45 No 1 January 1997

The traditional farrowing house is under increasing pressure from the UK welfare lobby. Are the Scandinavians any closer to solving problems associated with alternative systems? Jean Burke, University of Plymouth, and Dr Jeremy Marchant,University of Cambridge, undertook study tours to find out.



CRATELESS FARROWING will it ever work?

Changes in public opinion on animal welfare are influencing the way many farmers keep their stock. Some changes are voluntary; others are through imposed legislation. Legislation in the UK will see an end to pig confinement in gestation from January 1999.

The Danes are evaluating less restrictive forms of housing for sows in gestation and over lactation. Pressure from consumers is one reason, but perhaps more important is the potential loss of export business if UK supermarkets refuse to take pigmeat from producers using stalls and tethers from 1999.

Higher mortality

Sweden has gone further and already has legislation in place which guarantees sows more freedom of movement at all stages of the productive cycle, although sows may be kept in crates for up to seven days over farrowing.

Group farrowing would appear to be the natural extrapolation of group housing of gestating sows. But commercial experience in Sweden and trials in Denmark found the familiar problems associated with these farrowing systems re-emerged with, in general, higher piglet mortality.

Freedom problems

A large proportion of piglet deaths in any farrowing system can be accounted for by lack of vigour due to starvation and injury from sow movements. But it becomes increasingly difficult to safeguard piglets in their early, most vulnerable days of life when sows have increased freedom of movement and a choice of environments.

Success in rearing piglets becomes much more dependent on the sow's actions and the amount of time she is prepared to invest in her young. Group farrowing has brought greater risk of crushing and uneven growth rates. Some litters confined to the farrowing boxes have been abandoned and weaned early by sows not returning to nurse them.

For these systems to be successful, piglets must be able to follow the sow away from the farrowing site, as they would in a natural setting a week or so after birth.

For these reasons, most of Sweden's commercial sows are housed individually in pens for farrowing and for at least the first two weeks of lactation. The nest-leaving and integration phase of lactation is stimulated on some units by moving sows and litters in groups to multi-suckling accommodation for the final weeks of lactation.

The production levels achieved by these units may be variable but can be competitive (see Table 1). The application in a national pig industry with larger and historically more intensive units would need to be tested.

Second peak

Although most deaths occur in the first few days after farrowing, the disruption that the move causes to suckling patterns and the aggression displayed among the piglets can bring another peak of deaths in the multi-suckling phase.

Researchers in Denmark and Sweden are focusing on two important areas of work related to piglet mortality in loose-housed farrowing and lactation systems:

❑ Identification of sow behavioural and physiological characteristics which will aid management and protect piglets

❑ The effects of different ways of mixing sows and litters on piglet mortality on introduction to multi-suckling pens

Characteristics of sows

DENMARK:

Researchers lead by Dr Karin Hjelholt Jensen at the Danish Institute of Animal Science (DIAS) have made detailed observations of the activities of individually-penned sows over farrowing and early lactation, to pinpoint exactly when and how piglets died.

The study has revealed a wide variation in the amount of care taken by individual sows, particularly when lying down and when changing lying position in the presence of piglets. In addition, there were differences in the time taken to establish a regular suckling pattern within individual litters.

The researchers have defined five characteristics which are important in maternal success and devised tests to assess these traits in individual sows:

1 Responsiveness to piglets - researchers scored individual reactions to sounds of a distressed piglet played close to the udder as the sow lowered herself to a lying position.

2 Protective behaviour - sows with five-day-old piglets were confronted with a life-sized dummy of a stockperson against a background of sounds from angry sows, and their protective and aggressive tendencies were scored.

3 High milk production - assessed by weighing piglets before and after suckling over several suckling events.

4 High nursing motivation - suckling motivation was evaluated by first isolating sows from their piglets so that a suckling bout was missed. On reuniting the sow with her litter she was offered food. The strength of suckling motivation was scored according to the choice made by the sow between feeding and suckling and length of time she took to nurse the piglets.

5 Strong bonding with the litter - the drive of the sow to seek and find her piglets once they were removed from view was assessed.

The scores of each sow were then compared with piglet mortality and cause of death, as a first step towards identifying ways to predict good and bad sow mothering characteristics.

Present work is focusing on identifying behavioural tests which can be used on pre-pubertal gilts and which will give an indication of how well those gilts will subsequently perform as mothers - an extremely useful management tool!

SWEDEN:

Researchers lead by Professors Bo Algers and Per Jensen at the Swedish University of Agricultural Sciences (SLU) have also acknowledged the existence of good and bad mothers, both within and between different breeds of sows.

The quality of mothering had always been judged after the event, in terms of the number of pigs weaned by each sow, but now they are investigating the possibility to predict mothering qualities of sows by physiological profiling.

The release of the hormone oxytocin may be an important influence on an individual female's mothering ability. High peaks of oxytocin, released in parturition, were associated with short-duration farrowings, and low peaks with long farrowings.

Prolonged farrowings are already known to be associated with higher numbers of stillborn piglets.

It was also found that sows with the higher peaks in oxytocin had higher baseline levels of the circulating hormone and were more likely to be aggressive towards intruders and very protective of their litters.

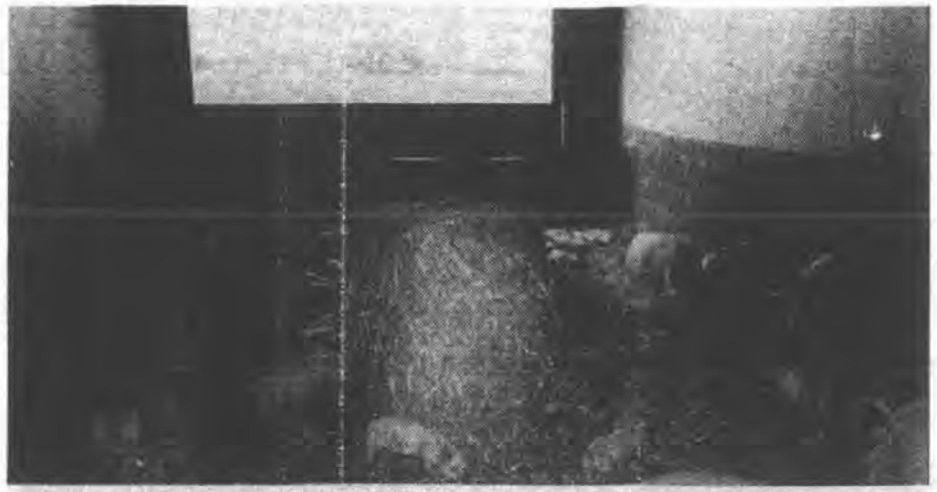
Difficulties

Although a degree of aggression can be a sign of strong mothering motivation, sows which are extremely aggressive create management difficulties in loose housing systems.

Their rapid movements are often a danger to their piglets, as they react vigorously to any perceived danger.

These sows are usually culled, which means there is a danger of selectively culling out sows with high oxytocin levels - which could lead to problems at farrowing becoming more widespread over the long term.

❑ *NEXT ISSUE: We look at the formation of multi-suckling groups.*



Far left: Experimental group farrowing system at DIAS, Bygholm, Denmark.

Left: A multisuckling pen for eight sows and litters at Farm 2, Sweden.

TABLE 1
Productivity of three Swedish farms practising individual farrowing with group lactating from two weeks.

	Herd size (sows)	Pre-weaning mortality	Weaning age (weeks)	Production (pigs/sow/year)
Farm 1	55	12-20	6-7	21-22
Farm 2	64	19	5	19
Farm 3 (Crate 7 days)	250	5-10	5	22.3

An investigation of experimental and commercial non-confinement and group farrowing systems in the Netherlands, Germany, Denmark, Sweden and Norway

A report for
The British Society of Animal Science
The Royal Bath and West of England Society
The Cornwall Education and Research Trust
3rd to 29th June 1996

Jean Burke

Summary

Twelve European research centres and seven commercial pig production units were visited during a study of research on the development of unrestricted and group farrowing systems for sows. The journey through the Netherlands, Germany, Denmark, Sweden and Norway was undertaken in June 1996. Consumer concern regarding farm animal welfare was evident in all the countries visited. All had some research interest in alternative farrowing accommodation which would remove the need to confine the sow during parturition and lactation. The types of farrowing accommodation in commercial use included the traditional farrowing pen, the crateless farrowing pen, the combination farrowing pen, the communal farrowing system and the fully integrated production system. All alternative systems required higher space allowances per sow and litter than systems using farrowing pens with crates. Piglet mortality ranged from 5% to 19% across the systems, with the better results being achieved in the combination pen and the crateless farrowing pen. The study found that alternatives to the farrowing crate are in existence and in commercial use within the EU, indicating that pressure to improve the welfare of the farrowing sow and prevent her confinement in the crate may eventually come from outside the UK as well as from the major retailers and the UK welfare lobby.